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September 9, 2005

By Messenger

The Honorable Vernon A. Williams
Secretary
Surface Transportation Board
1925 K Street, N.W.
Washington, DC 20423-0001

RE: Finance Docket No. 34421, *HolRail LLC-Petition for Exemption from 49 U.S.C. 10901 to Construct and Operate a Rail Line in Orangeburg and Dorchester Counties, South Carolina*; Finance Docket No. 34421 (Sub No. 1), *HolRail LLC-Petition for Crossing Authority Under 49 U.S.C. § 10901(d).*

Dear Secretary Williams:

Please find enclosed for filing the original and ten (10) copies of HolRail LLC's "Petition for Crossing Authority and Supplemental Evidence in Support of Petition for Exemption." Also enclosed are three (3) compact disks containing the electronic version of the written text and exhibits. In addition, enclosed is a check to cover the $200 filing fee for the crossing petition. An extra copy of this filing is enclosed for stamping and returning to our offices.

Please note that Exhibit D to the Verified Statement of Gene A. Davis is an over-sized document that has been submitted separate from the main pleading. Also some of the exhibits are in color. All color and over-sized pages have been separately identified in the original document for easy reference by the Board.

Should you have any questions regarding the foregoing, please do not hesitate to contact me.

Sincerely,

FILED
SEP 09 2005

Jeffrey O. Moreno

Enclosures

Cc (w/enclosure): Louis E. Gitomer, Counsel for CSX Transportation, Inc.

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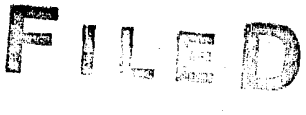
BEFORE THE
SURFACE TRANSPORTATION BOARD

STB FINANCE DOCKET NOS. 34421 AND 34421 (Sub-No. 1)

HOLRAIL LLC PETITION FOR EXEMPTION FROM 49 U.S.C. § 10901 TO CONSTRUCT AND OPERATE A RAIL LINE IN ORANGEBURG AND DORCHESTER COUNTIES, SOUTH CAROLINA

HOLRAIL LLC—
PETITION FOR CROSSING AUTHORITY UNDER 49 U.S.C. § 10901(d)

HOLRAIL LLC PETITION FOR CROSSING AUTHORITY AND SUPPLEMENTAL EVIDENCE IN SUPPORT OF PETITION FOR EXEMPTION



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September 9, 2005

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BEFORE THE
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HOLRAIL LLC PETITION FOR EXEMPTION FROM 49 U.S.C. § 10901 TO CONSTRUCT AND OPERATE A RAIL LINE IN ORANGEBURG AND DORCHESTER COUNTIES, SOUTH CAROLINA

HOLRAIL LLC—
PETITION FOR CROSSING AUTHORITY UNDER 49 U.S.C. § 10901(D)

HOLRAIL LLC'S PETITION FOR CROSSING AUTHORITY AND SUPPLEMENTAL EVIDENCE IN SUPPORT OF PETITION FOR EXEMPTION

In response to the October 20, 2004 decision of the Surface Transportation Board ("STB" or "Board") in this proceeding ("*October 20th Decision*"), HolRail LLC ("HolRail") hereby submits its "Petition for Crossing Authority and Supplemental Evidence in Support of Petition for Exemption."

This is a pro-competitive rail construction case that requires the Board to balance its responsibilities under the national rail transportation policy with the unique environmental considerations presented by this project. The evidence presented herein demonstrates that the Board can achieve an optimal balance between the national rail transportation and environmental protection policies by granting HolRail's Petition for Exemption and Petition for Crossing Authority.

On November 13, 2003, HolRail filed a Petition for Exemption to construct approximately 2.3 miles of new rail over one of two alternative routes for the purpose of bringing competitive rail service to a cement production facility in Holly Hill, South Carolina

(the "Holly Hill Facility") operated by HolRail's corporate parent, Holcim (US) Inc. ("Holcim"). Rather than construct the new rail line through an environmentally sensitive wetlands area, known as "Four Hole Swamp," on property owned by Holcim, HolRail identified a "Preferred Route" that could be constructed within a previously developed transportation corridor shared by CSX Transportation, Inc. ("CSX") and South Carolina Highway 453. In order to minimize potential harm to the environment, HolRail would construct the Preferred Route mostly within CSX's right-of-way for approximately 1.7 miles, running parallel and adjacent to the CSX line that currently serves the Holly Hill Facility. HolRail's Petition for Crossing Authority, which is contained in this pleading, requests authority from the Board for HolRail to cross CSX's property with its Preferred Route.

Only if the Board denies HolRail's request for authority to construct the Preferred Route does HolRail request authority to construct an "Alternate Route" that also would parallel the CSX line, but instead of being adjacent to it, would be approximately 105 feet further east on property owned by Holcim. Crossing authority is not necessary to construct the Alternate Route, which would remain on Holcim property.

HolRail's Petition for Exemption, as extensively supplemented herein, fully satisfies the exemption standards set forth at 49 U.S.C. § 10502(a) and, in the alternative, the public convenience and necessity standard set forth at 49 U.S.C. § 10901(c). Controlling STB precedent establishes that rail construction projects advance numerous elements of the rail transportation policy at 49 U.S.C. § 10101. Moreover, by building and operating within CSX's existing corridor, HolRail's "Preferred Route" strongly advances 49 U.S.C. § 10101(7) by mitigating the ability of environmental factors to act as a barrier to entry. Indeed, the unique environmental considerations surrounding this project militate strongly in favor of the Preferred

Route, which will be far less disruptive to surrounding wetlands than the Alternate Route. HolRail's supplemental evidence also plainly shows that the build-out is of limited scope and that regulation is not needed to protect shippers from the abuse of market power. *See* 49 U.S.C. § 10502(a)(2)(A) and (B). Accordingly, the Board should not hesitate to grant an exemption giving HolRail authority to construct its Preferred Route.

Once the Board has granted HolRail's Petition for Exemption to construct the Preferred Route, CSX may not block that construction because HolRail has satisfied the standards of 49 U.S.C. § 10901(d). HolRail's Petition for Crossing Authority establishes conclusively that construction and operation of the Preferred Route satisfies those standards because it will not unreasonably or materially interfere with CSX's operation of the crossed line. *See* 49 U.S.C. § 10901(d)(1)(A) and (B). In addition, HolRail is prepared to fairly compensate CSX, as required by 49 U.S.C. § 10901(d)(1)(C).

The Board's consideration of both HolRail's Petition for Exemption and Petition for Crossing Authority should be guided by two basic sets of facts. These facts are the special environmental considerations surrounding this project and the absence of any unreasonable or material interfere with CSX's existing rail operations.

First, the special environmental considerations surrounding this rail construction project play an important role in the Board's evaluation of the national rail transportation policy under § 10502(a)(1) and upon its determination of the public convenience and necessity under § 10901(c). In performing its environmental review of rail construction projects, the Board must balance the rail transportation policies with federal environmental policies. In this case, the Board can achieve an optimal balance by approving the least environmentally detrimental route, which means authorizing HolRail to construct its Preferred Route across CSX's right-of-way.

Second, the impact of HolRail's construction and operation of the Preferred Route upon CSX's existing rail line plays a dual role in this proceeding. Under 49 U.S.C. § 10901(d)(1)(A) and (B), the Board must grant HolRail's Petition for Crossing Authority unless the crossing will unreasonably or materially interfere with CSX's operations. In this case, CSX also has based its opposition to HolRail's Petition for Exemption upon allegations that construction of HolRail's Preferred Route would undermine the stability of CSX's roadbed and thereby interfere with its operations. Thus, if the Board rejects CSX's interference claims in opposition to the Petition for Exemption, there is no factual basis for the Board to deny the Petition for Crossing Authority.

At least one member of the Board has publicly expressed concern over HolRail's proposed construction of the Preferred Route across CSX's property. Commenting separately in the *October 20th Decision* at 5, Commissioner Buttrey stated:

> HolRail will have a heavy burden to convince me that this is a proper use of the construction and crossing provisions of the statute. Instead, HolRail's proposal appears to be tantamount to a confiscation that is beyond anything contemplated by section 10901.

HolRail understands this initial reticence, given the limited information that HolRail was able to present in its original Petition for Exemption. Now that it has developed additional information from discovery ordered by the *October 20th Decision*, HolRail has tackled this burden by presenting substantial evidence herein to justify its petitions based on the limited scope of the proposed project, the extraordinary environmental issues presented, and the national rail transportation policy.

HolRail presents its evidence and argument in six parts, which are supported by four verified statements. These parts are summarized as follows:

EVIDENCE AND ARGUMENT

I. Procedural Background: In this section, HolRail summarizes the procedural history of this proceeding and its relevance to this submission.

II. Identity and Interest of HolRail: In this section, HolRail describes itself and its parent company, Holcim (US) Inc., and summarizes the reasons for constructing a new rail line.

III. Description of Proposed Construction: In this section, HolRail provides the alignment and operating plan for both its Preferred and Alternate Routes, as requested by the Board's *October 20th Decision*. In addition, HolRail explains why a third route, on the west side of State Highway 453, was not pursued.

IV. Supplemental Evidence in Support of Petition for Exemption: In this section, HolRail addresses the standards, in 49 U.S.C. §§ 10502(a) and 10901(c), for approving construction of both the "Preferred" and "Alternate" Routes. HolRail explains how the Preferred Route is less detrimental to the environment than the Alternate Route, and why this fact, in combination with other relevant considerations, should persuade the Board to grant HolRail authority to construct the Preferred Route across CSX's property.

V. Petition for Crossing Authority: In this section, HolRail addresses the standards, in 49 U.S.C. § 10901(d), for obtaining authority to cross the property of CSX with the "Preferred Route." HolRail also responds to CSX's contention that the Board lacks the statutory authority to grant HolRail's crossing petition.

VI. Summary and Request for Relief: In this section, HolRail summarizes the evidence in support of its Petitions for Exemption and Crossing Authority and requests that the Board grant both petitions.

VERIFIED STATEMENTS

Verified Statement of Looman Stingo ("Stingo V.S."): Mr. Stingo describes the identity and interest of the petitioner, HolRail, and its parent company, Holcim (US) Inc. He also explains the reasons for pursuing the proposed construction, the rail routes considered, and the reasons for selecting the Preferred Route, which parallels CSX's existing track across CSX property, over two alternative routes.

Verified Statement of Gene A. Davis ("Davis V.S."): Mr. Davis is Director, Transportation Engineering, for R.L. Banks & Associates, Inc. He describes the track alignment for both the Preferred and Alternate Routes. In addition, he evaluates the

condition of the existing CSX line and explains why HolRail's construction of the Preferred Route, across the existing CSX right-of-way, will not unreasonably interfere with CSX's rail operations, and in fact, will stabilize CSX's existing embankment.

Verified Statement of Walter H. Schuchmann ("Schuchmann V.S."): Mr. Schuchmann is Director, Rail Operations for R.L. Banks & Associates, Inc. He describes the operating plan for the proposed new rail construction and reviews CSX operations over its existing line. Mr. Schuchmann explains why HolRail's construction and operation of its Preferred Route, across the existing CSX right-of-way, will not unreasonably or materially interfere with CSX's rail operations.

Verified Statement of Mark Taylor ("Taylor V.S."): Mr. Taylor is Vice President of Fletcher Group, Inc. He has performed environmental analyses of the project area and explains why the Preferred Route, across the CSX right-of-way, has significantly fewer environmental consequences than the Alternate Route.

I. PROCEDURAL BACKGROUND.

By petition filed on November 13, 2003, HolRail requested an exemption under 49 U.S.C. § 10502(a) from the prior approval requirements of 49 U.S.C. § 10901 to construct and operate approximately 2.3 miles of rail line in Orangeburg and Dorchester Counties, South Carolina. The proposed construction would extend north from a connection with the Norfolk Southern Railway Company ("NSR"), near Giant, South Carolina, across Four Hole Swamp, to a cement production facility at Holly Hill, South Carolina that is owned by HolRail's parent company, Holcim.

HolRail proposed two routes for this new construction. HolRail's "Preferred Route" would parallel an existing CSX line and would be constructed, in significant part, within the existing CSX right-of-way and adjacent to the existing CSX track. The "Alternate Route" also would parallel the existing CSX line, but it would be constructed almost entirely on property already owned by Holcim, approximately 105 feet further east. HolRail provides a detailed description of both routes in Part III., *infra*, and in the attached Verified Statement of Gene A. Davis. HolRail selected the Preferred Route because it poses significantly fewer environmental consequences to Four Hole Swamp than the Alternate Route. HolRail describes those consequences in greater detail in Part IV.A.1, *infra*, and in the attached Verified Statement of Mark Taylor.

On December 3, 2003, CSX filed both a "Response" and a "Motion to Dismiss" HolRail's Petition for Exemption. CSX argued that, as to the Preferred Route, HolRail's Petition was deficient and it speculated that construction of the Preferred Route within CSX's right-of-way would cause substantial physical damage to CSX's track. CSX did not present any objections to the Alternate Route. HolRail replied to CSX's arguments on December 23, 2003.

Both parties subsequently served discovery requests upon each other. Several discovery disputes arose, which prompted both parties to file motions to compel with the Board. The disputes, in significant part, were caused by CSX's refusal to grant HolRail access to its property in order to gather information to address the very deficiencies in the Petition for Exemption that CSX had alleged in its Motion to Dismiss. The parties also disputed the relevance of various other discovery requests.

In its *October 20th Decision*, the Board denied CSX's Motion to Dismiss, granted both of HolRail's motions to compel in their entirety, and granted portions of CSX's motion to compel. Although the Board noted that HolRail had not provided many details about its proposed construction, it acknowledged that HolRail was unable to do so because CSX had refused HolRail access to CSX's property. *October 20th Decision* at 2. Since the Board could not assess CSX's opposition to HolRail's Petition, or evaluate the environmental impacts, without such information, the Board denied CSX's Motion to Dismiss and granted HolRail's motions to compel so that HolRail could obtain the information necessary to prepare its construction and operating plans. *Id.* at 2-3. The Board also concluded that:

> HolRail's entire case – indeed, even the details of how its construction proposal will look – is inextricably bound up with the crossing issue. Therefore, we will not approach this case in a piecemeal fashion, and we will not rule on the exemption petition until all components of HolRail's proposal, including the anticipated crossing petition, are before us.

Id. at 3. Accordingly, the Board also directed HolRail to submit its crossing petition, along with its construction and operating plans.

Based upon the information that it has gathered and developed from the inspection of CSX's property, HolRail now supplements its Petition for Exemption with its construction and operating plans. In addition, HolRail submits its Petition for Crossing Authority.

II. IDENTITY AND INTEREST OF HOLRAIL.

HolRail is a wholly-owned subsidiary of Holcim (US) Inc., which is one of the largest suppliers of Portland and blended cements and related mineral components in the United States. Holcim has approximately 2500 employees in the United States and annual revenues over $1 billion. Stingo V.S. at 2. It ships more than 20 million tons of cement and related materials annually to and from 14 manufacturing facilities and approximately 70 distribution terminals across the United States. *Id.*

Holcim created HolRail for the purpose of constructing and operating a common carrier rail line, approximately 2.3 miles long, from Holcim's production facility near Holly Hill, South Carolina to a point of connection with the NSR near Giant, South Carolina. *Id.* The Holly Hill Facility produces a variety of cement and masonry products. *Id.* In addition, Holly Hill is a bagging facility for Holcim's specialty colored cement. *Id.* In August 2003, Holcim completed a sizeable expansion of the Holly Hill Facility that doubled its production capacity to approximately 2 million tons of cement per year. *Id.*

Rail transportation is a vital link in the Holly Hill Facility's distribution chain. In 2004, the Facility received over 183,000 short tons of coal (1,836 carloads) in 70-car unit trains. *Id.* That same year, the Facility received 13,872 short tons of white cement (146 carloads), 5384 short tons of lime (57 carloads), and 452 short tons of marble dust (50 carloads). *Id.* at 2-3. In 2004, the Holly Hill Facility shipped approximately 321,062 metric tons of cement (3,716 carloads) outbound by rail. *Id.* at 3. At optimum production levels, the Facility will tender up to 75 rail cars of cement per day in a single block train. *Id.* In 2004, a Holcim subsidiary, Energis LLC, also located at Holly Hill, received approximately 140 tank cars of waste chemicals that were blended and used as fuel in Holcim's cement making operations. *Id.* The Holly Hill Facility consumed some of this fuel and the remainder was shipped to other

facilities. Rail transportation is the most efficient mode for transporting bulk quantities of coal, sand and cement; the safest and most efficient mode for transporting bulk quantities of hazardous waste; and the most economic mode for transporting cement over 100 miles. *Id.*

Presently, the Holly Hill Facility is captive to CSX for all of its rail transportation needs. Holcim has concluded that CSX either is unable or unwilling to satisfy those needs and that rail competition is necessary to achieve the full benefits of the recent plant expansion at Holly Hill. For example, by limiting Holcim's use of private rail cars at Holly Hill, CSX frequently is unable to fulfill the Facility's rail car requirements with its own cars. *Id.* In addition, CSX's cars frequently are bad-ordered or unusable, which interferes with the operations of the Facility and imposes additional costs upon Holcim. *Id.* Because CSX has denied Holly Hill the service and rates that it provides to Holcim's competitors who have competitive rail options (including two located within just 5 miles of the Holly Hill Facility), those competitors have a significant economic advantage over the Holly Hill Facility. *Id.* at 4.

HolRail's proposed construction will create competition between CSX and NSR at Holly Hill, which will result in more responsive, more reliable, and better rail service. Improved rail service, in turn, will support Holly Hill's increased production by enabling Holcim to supply distant markets and to compete in new markets. In addition, rail competition will reduce rates and make the Holly Hill Facility more competitive with other cement producers.

III. DESCRIPTION OF THE PROPOSED CONSTRUCTION.

HolRail has proposed two alternative routes for the rail construction project. In addition, HolRail considered and rejected a third alternative. The Preferred Route and the Alternate Route parallel the existing CSX line at varying distances to the east. The rejected third alternative would parallel the CSX line to the west of State Highway 453, which itself parallels the CSX line over the entire length of the proposed construction. In the following sections, HolRail describes the alignment and operating plans of the Preferred and Alternate Routes and explains why it rejected the third alternative.

HolRail presents both routes in two different formats. First, in Exhibit D to the Davis V.S., HolRail presents engineering drawings and track profiles that show the Preferred Route in relation to the Alternate Route, the CSX track and property line, Highway 453, and various rail-related facilities of Giant and Holcim. Second, in Exhibit A to the Taylor V.S., HolRail presents a U.S. Geological Survey topographic map that shows the alignment of both the Preferred and Alternate Routes, the CSX alignment, Highway 453, nearby utilities, property boundaries, various Giant and Holcim facilities, and wetlands and waters of the United States.

A. The Preferred Route.

1. Alignment.

HolRail Witness Davis describes the Preferred Route in detail at pages 3-5 of his Verified Statement. In addition, he has attached a scaled design plan and track profile that shows the alignment of the Preferred Route relative to the Alternate Route, to the existing CSX track alignment and right-of-way, and to other structures in the immediate vicinity. Davis V.S., Exhibit D; *see also* Taylor V.S., Exhibit A (USGS map of Preferred and Alternate Routes, CSX track, surrounding structures, and wetland areas).

The alignment of the Preferred Route begins at its south end in the rail yard of Giant Cement. The Giant yard contains five tracks. NS owns two storage tracks on the east side of the center track and CSX owns two storage tracks on the west side. The center track is a run-through track over which CSX currently operates its trains to serve Holcim from the South, pursuant to a non-exclusive easement over the track.[1] HolRail and Giant currently are in negotiations over the acquisition of an easement to construct track across the northeastern portion of the Giant yard to a point of connection with the center yard track, over which HolRail also would operate to connect with the NSR. If an agreement cannot be reached, HolRail intends to pursue access through other options available to it under South Carolina law.

HolRail's new construction would begin at the connection point with the center track in the Giant yard, which is designated as Sta. 0+00 on the track profile map. Davis V.S., Exhibit D, Sheet 2. The HolRail track would proceed in a northeasterly direction across Giant property, encroach a few feet onto CSX property by cutting diagonally across the southeast corner for no more than 250 feet, and then move onto Holcim property. *Id.* at 4. Just short of Sta. 4+00, the track would fan out into four yard tracks for the storage, staging and interchange of rail cars. Three of the yard tracks would have a capacity of 27 cars and the fourth track could hold 26 cars. *Id.* at 3. This portion of the construction would occur in upland areas on the southern edge of Four Hole Swamp. *See* Taylor V.S., Exhibit A (USGS map with wetland areas delineated).

At the north end of the HolRail yard, the mainline would turn north/northwest toward the CSX main line and cross onto the CSX right-of-way at approximately Sta. 25+50. Davis V.S. at 4. Just south of Sta. 29+00, the HolRail mainline would curve ten degrees until it comes parallel with the CSX mainline and abuts the CSX embankment, with approximately 30 feet between the

[1] HolRail work paper HOL-00305.

track centers. The two tracks would remain in this configuration until approximately Sta. 98+00. *Id.*, Exhibit D, Sheets 3-5. Mr. Davis has attached, as Exhibit E to his Verified Statement, a typical cross section to illustrate the relationship between the HolRail and CSX tracks. For detailed cross-sections at each Station along the Preferred Route, see Davis V.S., Exhibit D, Sheets 10-14.

The Holrail track will cross three bridge structures, which will be equal or greater in length than the existing CSX bridge structures, along this stretch of rail line. Davis V.S. at 3, 13. Mr. Davis has attached the bridge plans at Exhibit D, Sheets S1-S7, of his Verified Statement.

North of Sta. 98+00, the HolRail mainline would continue in a northerly direction, along the western edge of the Holly Hill Facility, but still within the CSX right-of-way until approximately Sta. 118+54, where it would cross back onto Holcim property and terminate at a tie-in with existing track #7403, a Holcim industry track. *Id.* at 4-5 and Exhibit D, Sheet 5. This would be the northern end point of the HolRail line along the Preferred Route.

Various industry track at the Holly Hill Facility (including track used to serve Energis) would be repositioned so that they could interconnect with the new HolRail track. These relocations are shown on Davis V.S., Exhibit D, Sheets 5-8. In addition, HolRail would install a cross-over to the existing CSX track at Sta. 97+61 that would replace the existing CSX turnout into the Holly Hill Facility. Davis V.S. at 4. This is necessary to enable CSX to serve the repositioned Holly Hill industry track via the same lead track as HolRail.

2. Operations.

In his Verified Statement, HolRail Witness Schuchmann establishes that HolRail's operating plan is feasible and practical. First, Mr. Schuchmann describes CSX's existing operations for serving the Holly Hill Facility. Schuchmann V.S. at 4-7. Second, he describes the construction project and explains why it will have only a minimal impact, at most, upon CSX

operations. *Id.* at 7-9. Finally, Mr. Schuchmann describes how HolRail will operate over the new rail line to serve the Holly Hill Facility and how those operations will be in harmony with continuing CSX rail service. *Id.* at 9-14. Indeed, Mr. Schuchmann concludes that CSX's post-construction operations will be simplified to the extent they change at all.

3. Service under the *Carolinas Plan*.

CSX presently serves the Holly Hill Facility under rights it obtained in Finance Docket No. 32299, *Norfolk Southern Ry. Co. – Consolidation of Operations – CSX Transportation, Inc.*, 1993 ICC Lexis 241 (served Nov. 26, 1993) (the "*Carolinas Plan*"). The *Carolinas Plan* consolidated certain CSX and NSR operations in South Carolina through a collection of trackage rights, lease, operating and switching agreements. As pertinent to the Holly Hill Facility, NSR granted CSX overhead trackage rights on NSR's line between Columbia and Charleston, allowing CSX to operate over that line with its own trains and crews. CSX also gained the right to exit the NSR's Columbia-Charleston line at Pregnall. In addition, CSX leased the NSR line from Pregnall to Giant under an agreement that places the track under the control of CSX. Pursuant to a related agreement, CSX agreed to switch traffic between Pregnall and Giant for all CSX and NSR customers, and those customers shall remain in the respective railroad's account.

Although CSX's own track reaches the Holly Hill Facility from the north, CSX has chosen to provide most of its service from the south, over the NSR-owned track, pursuant to the *Carolinas Plan*. The principal exception is coal traffic, which CSX delivers to the Holly Hill Facility over its own track from the north. Holcim's non-coal traffic currently moves by CSX over the NSR's Charleston-Columbia line to Pregnall, then over NSR track for approximately 6.3 miles from Pregnall north to Giant, then over the center run-through track in the Giant yard for approximately 2593 feet, and finally over CSX's own track for approximately two miles from Giant to the Holly Hill Facility.

The *Carolinas Plan* also will govern NSR's access to the Holly Hill Facility upon completion of HolRail's new line. The Interstate Commerce Commission ("ICC") decision to approve the *Carolinas Plan* mandates the preservation of existing competitive options for shippers:

> Applicants emphasize that, following the consolidation, the current customers of CSXT will continue to be CSXT customers, and the current NS customers will continue to be NS customers. There will be no change in the status of those customers that are jointly served by CSXT and NS, and *no prospective customers will be denied service* by either CSXT or NS as a result of the consolidation.
>
> * * *
>
> In these premises, it is clear that there will be *no change in the competitive balance* between NS and CSXT in South Carolina as a result of the consolidation of operation. Neither the applicants' direct point-to-point competition nor their source competition at common origins or destinations will be affected. *Options currently available to shippers will neither increase nor decrease.*

1993 ICC Lexis 241, at *5-6 [emphasis added]. Because the Holly Hill Facility clearly had a build-out option to NSR at Giant prior to the ICC's approval of the *Carolinas Plan* and because the ICC approved the plan on the grounds that it would not diminish shippers' competitive options, the Holly Hill Facility clearly has the right to access NSR via the new HolRail line and NSR has the right – indeed, a common carrier obligation – to serve the Facility by interchanging traffic with HolRail.

Thus, under the *Carolinas Plan*, NSR most likely will set out and pick up all cars to and from the Holly Hill Facility at Pregnall. CSX would switch those cars, which will remain in the account of NSR, from Pregnall to the HolRail yard at Giant for interchange with HolRail, which will deliver the cars to the Holly Hill Facility. Mr. Schuchmann describes this interchange operation at pages 10 to 12 of his Verified Statement.

B. The Alternate Route.

1. Alignment.

Mr. Davis describes the Alternate Route at pages 5-6 of his Verified Statement and presents the alignment on Sheets 3-9 of his Exhibit D.[2] The Alternate Route alignment also appears on the map attached as Exhibit A to Mr. Taylor's Verified Statement. The principle distinction between the Preferred and the Alternate Routes is that the Alternate Route is situated further east in order to avoid crossing CSX property.

As illustrated on Exhibit D, Sheet 9, the Alternate Route begins at the same point of interconnection with the Giant center yard track as the Preferred Route. However, the Alternate Route then curves more sharply toward the northeast in order to avoid encroaching upon a small corner of CSX property that the Preferred Route must cross. This sharper angle is less desirable from an operating perspective, but remains within the parameters for safe rail operations.

The HolRail yard is situated slightly further east compared with the Preferred Route and it requires five, rather than four, tracks to handle approximately the same number of rail cars as the Preferred Route. Davis V.S. at 5. North of the rail yard, at approximately Sta. 24+00, the Alternate Route takes a more northerly direction than the Preferred Route, still running parallel to the CSX line but remaining outside of the CSX right-of-way by approximately 35 feet. *Id.*, Exhibit D, Sheet 3. At Sta. 79+00, where the CSX right-of-way narrows to 50 feet, the HolRail mainline curves to the northwest in order to more closely parallel the CSX line, while continuing to stay on Holcim property. *Id.*, Exhibit D, Sheet 4. At Sta. 97+00, the HolRail main line curves northeast, further into the Holcim property, as it approaches the Holly Hill Facility and as the CSX right-of-way once again widens. *Id.*, Exhibit D, Sheet 5. The Alternate Route ultimately

[2] Sheets 3-8 of Davis Exhibit D show both the Preferred and Alternate Routes extending north from Sta. 26+50. From Sta. 0+00 to 26+50, however, Sheet 9 replaces Sheet 2 for the Alternate Route.

terminates at the same point as the Preferred Route, Sta. 118+54, which provides access to Holcim's existing industry track #7403. *Id.*

All connections to existing industry tracks at the Holly Hill Facility are made on Holcim property. Although they have similar curvatures to the Preferred Route, the various industry track and turnouts are at different locations due to the more easterly alignment of the Alternate Route. In addition, the cross-over track between CSX and HolRail must be located further south of the Preferred Route location. *Id.*

2. Operations.

Mr. Schuchmann's description of HolRail operations along the Preferred Route also applies to the Alternate Route. The potential to interfere with CSX operations, however, would be even less than with the Preferred Route, since the construction would not occur in the CSX right-of-way. Schuchmann V.S. at 9.

C. The Rejected Route.

In its effort to design a rail construction project with the least impact upon the environment, Holcim considered, and ultimately rejected, a third route. This third route contemplated construction within an existing utility right-of-way on the west side of Highway 453, parallel to the highway and the CSX line. However, after a preliminary review indicated that this route was impractical for operational and economic reasons and otherwise failed to offer significant environmental advantages over the Preferred Route, Holcim rejected this alternative and focused its planning on the Preferred and Alternate Routes. Stingo V.S. at 4-7.

A March 7, 2005 letter from Skeen Railroad Engineering to Holcim summarizes the engineering and operating problems associated with this third route. Stingo V.S., Exhibit A. For example, this alternative would require two highway crossings within just a two-mile stretch of

Highway 453 in order to connect the Holly Hill Facility with the NSR. *Id.* at 6. Both crossings would be longer than is typical because they would have to cross the highway at very acute angles of less than 25 degrees. This would render them less safe and more difficult to maintain. Moreover, these two HolRail crossings would be in addition to an existing nearby CSX crossing, bringing the total number of highway crossings within a three mile stretch of Highway 453 to three. *Id.* There also is significantly more standing water on the west side of the highway due in part to the highway's damming effect, which means that rail construction over this area would require substantially more fill dirt than the Preferred Route. *Id.*

The alignment of the third alternative would require a rigid crossing of the CSX mainline track at the Holly Hill Facility. *Id.* The Preferred and Alternate Routes avoid this operational and maintenance liability.

In addition, construction of this third alternative would require HolRail to locate its rail yard on the west side of Highway 453. As a consequence, all switching of cars between the yard and the Holly Hill Facility would have to cross the highway, frequently blocking it for extended periods of time. *Id.* Thus, in addition to two highway crossings in such a short distance, the frequency and duration of highway blockings undoubtedly would generate strong public safety and convenience objections.

Finally, the utility right-of-way that the third alternative would occupy is not sufficient to accommodate a rail line in addition to the existing utilities. That right-of-way already is occupied by high voltage electric transmission lines and an underground natural gas pipeline, which are shown on the map attached as Exhibit A to the Taylor V.S. Because the gas pipeline occupies the area where the rail line would be constructed, it would have to be relocated. Stingo V.S. at 6. Furthermore, it also could be necessary to relocate the power lines and to clear

additional vegetation outside of the utility right-of-way. *Id.* Thus, even if a rail line could be physically squeezed into the utility right-of-way, the relocation of the existing utilities, if possible, would cause additional environmental impacts.

According to HolRail's environmental witness, Mark Taylor, the rejected route and the Preferred Route have comparable impacts upon the environment. Taylor V.S. at 2-3. Thus, there is no substantial environmental advantage to constructing the rejected route. Since the rejected route also poses significant operating and economic concerns, it was clear early in the review process that a rail route on the west side of Highway 453 was not a practical alternative to either the Preferred or Alternate Route. Stingo V.S. at 6-7.

IV. HOLRAIL'S PROPOSED CONSTRUCTION SATISFIES THE STATUTORY STANDARDS FOR APPROVAL.

The Board *shall* authorize new rail construction *unless* it determines that the proposed construction is "inconsistent with the public convenience and necessity."[3] 49 U.S.C. § 10901(c). Prior to passage of the ICC Termination Act ("ICCTA"), the statute *permitted* the ICC to authorize new rail construction if the project was *consistent* with the public convenience and necessity. *See* 49 U.S.C. §10901(a) and (c)(1) (1995). In ICCTA, Congress intentionally eased the statutory standard by *requiring* the STB to authorize new rail construction unless it was *inconsistent* with the public convenience and necessity.[4] In recognition of this fact, the Board recently declared:

> This permissive licensing policy establishes a clear presumption in favor of rail construction proposals and conforms to the broader congressional policies to promote "effective competition among rail carriers" and to "reduce regulatory barriers to entry into...the industry." 49 U.S.C. 10101(4), (7).

STB Finance Docket No. 34079, *San Jacinto Rail Limited Construction Exemption and The Burlington Northern and Santa Fe Ry. Co. Operation Exemption—Build-out to the Bayport Loop Near Houston, Harris County, TX*, slip op. at 6, n. 12 (served Aug. 28, 2002) ("*San Jacinto*").

Congress went even further by providing that the STB *shall* exempt a transaction from regulation under the statute, if it finds that (1) continued application of the statute is not

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[3] The "public convenience and necessity" historically has been defined by a three-part test of (1) financial fitness, (2) public demand or need, and (3) the public interest. This "standard has become less restrictive over the years as a result of the pro-competitive policies embodied in the [Staggers Act and ICCTA]." STB Finance Docket No. 33740, *The Burlington Northern and Santa Fe Railway Co.—Petition for Declaration or Prescription of Crossing, Trackage, or Joint Use Rights*, slip op. at 6, n. 18 (Served May 13, 2003). *See also, Louisville & Jefferson County Riverport Authority et al.—Construction and Operation Exemption—In Jefferson County, KY*, 4 I.C.C. 2d 749, 754 (1988) ("The Staggers Act changed the wording of § 10901 to make it easier for a proposal to be found to be in the public interest.").

[4] *Id.* at 7, n. 20.

necessary to carry out the rail transportation policy codified at 49 U.S.C. § 10101, and (2) *either* the transaction is of limited scope, *or* regulation under the statute is not needed to protect shippers from abuse of market power. 49 U.S.C. § 10502(a).

HolRail's proposed construction of either its Preferred or Alternate Route is *not* inconsistent with the public convenience and necessity, and in fact, the Preferred Route will enhance the public convenience and necessity by fostering rail competition with the least potential environmental harm. The transaction also will promote the national rail transportation policy, will be of limited scope, and will not subject shippers to an abuse of market power. Therefore, the Board should authorize construction of HolRail's Preferred Route, and at the very least, its Alternate Route.

A. Regulation is not Necessary to Carry Out the Rail Transportation Policy at 49 U.S.C. § 10101.

Regulation of HolRail's proposed construction and operation of a rail line along either the Preferred or Alternate Routes is not necessary to carry out the national rail transportation policy. Indeed, the proposed construction would enhance many of these policies. This satisfies the first of two standards required for obtaining an exemption under 49 U.S.C. § 10502(a) and it also demonstrates that the proposed construction is *not* inconsistent with the public convenience and necessity, as required by 49 U.S.C. § 10901(c).

1. Both the Preferred and Alternate Routes promote competition, which underlies the rail transportation policies at 49 U.S.C. § 10101(1), (2), (4), (5) and (7).

The Board, in numerous decisions, has determined that new rail construction that creates competition is consistent with the rail transportation policies at 49 U.S.C. § 10101(1), (2), (4),

(5) and (7).[5] These objectives are: (a) to allow, to the maximum extent possible, competition and the demand for services to establish reasonable rates for rail transportation; (b) to minimize the need for Federal regulatory control over the rail transportation system; (c) to ensure effective competition among rail carriers to meet the needs of the public; (d) to ensure effective competition and coordination between rail carriers and other modes; and (e) to reduce regulatory barriers to entry into and exit from the industry. By providing alternative rail service to shippers currently served by CSX, HolRail's construction of either the Preferred or Alternate Route will provide the same competitive benefits as these other projects approved by the Board. Thus, an exemption would further these rail transportation policies.

By granting HolRail authority to construct its Preferred Route, the Board would take a particularly significant step in furtherance of the policy "to reduce regulatory barriers to entry into and exit from the industry." *See* 49 U.S.C. § 10101(7). The Board recently declared that this specific rail transportation policy conforms directly with the "permissive licensing policy" of § 10901(c), which requires the Board to authorize rail line construction projects "unless...such activities are inconsistent with the public convenience and necessity." *San Jacinto* at 6, n. 12. In this case, the Board would mitigate the ability of the environmental laws to act as a regulatory

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[5] *See* STB Finance Docket 34210, *Sunflower Rail Company, LLC—Construction and Operation Exemption, Finney County KS,* (Served March 21, 2003); STB Finance Docket No. 34079, *San Jacinto Rail Limited Construction Exemption and The Burlington Northern and Santa Fe Ry. Co. Operation Exemption—Build-out to the Bayport Loop Near Houston, Harris County, TX,* (served Aug. 28, 2002); STB Finance Docket No. 34060, *Midwest Generation, LLC—Exemption from 49 U.S.C. § 10901—For Construction in Will County, IL* (Served March 21, 2002); STB Finance Docket 34002, *Alamo North Texas Railroad Corp.—Construction and Operation Exemption—Wise County, TX* (Served Sept. 3, 2002); STB Finance Docket No. 33782, *Entergy Arkansas and Entergy Rail—Construction & Operation Exemption—White Bluff to Pine Bluff, AR,* (Served May 4, 2000); ICC Finance Docket No. 32630, *Omaha Public Power District—Construction Exemption in Otoe County, NE* (Served May 2, 1995); and ICC Finance Docket 32607, *WFEC Railroad—Construction & Operation Exemption—Choctaw & McCurtain Counties, OK,* (Served Feb 27, 1996).

barrier to entry into the railroad industry, by allowing the least environmentally detrimental route to be constructed, thus achieving an optimal balance between rail transportation and environmental protection policies.

Although HolRail could avoid the necessity of crossing CSX's property by constructing the Alternate Route, which stays on Holcim property, the Alternate Route would produce greater environmental impacts that could be substantially mitigated by constructing the Preferred Route immediately adjacent to the existing CSX line. These environmental impacts pose a substantial barrier to entry into and exit from the railroad industry. Sound public policy dictates that the Board consider the Preferred Route as a superior alternative that would cause significantly less environmental harm, while promoting the pro-competitive national rail transportation policies.

HolRail Witness Taylor compares the environmental impacts of the Preferred and Alternate Routes in his Verified Statement. He describes the importance of wetlands to our environment both for their ability to naturally cleanse the water that flows through them and as a "nursery" to many species. Taylor V.S. at 3. Four Hole Swamp, which covers 375 square miles upstream of the proposed crossing, is unique among wetland environments in South Carolina, with numerous braided channels but no well-defined river. *Id.* The major effects of constructing a transportation system across wetlands are on plant life and habitat, wildlife and habitat, hydrology, and water quality. *Id.* at 4. By designing and constructing multiple transportation systems within the same corridor, however, these impacts can be substantially mitigated.

An existing transportation corridor already crosses Four Hole Swamp along the route of HolRail's proposed rail construction project. This corridor includes, from west to east, above ground power lines, a buried gas line, South Carolina Highway 453, and the CSX rail line. The Preferred Route would widen this existing corridor by constructing the proposed roadbed

immediately adjacent to the CSX roadbed, which would impact approximately 7 acres of wetland. *Id.* at 5. In stark contrast, the Alternate Route would create an entirely separate transportation corridor, to the east of the existing corridor, through approximately *27 acres* of undisturbed wetlands. *Id.* In addition to these 27 acres of wetland that the Alternate Route would displace, the entire area between the two corridors, which currently is undisturbed, would be adversely affected by isolation from Four Hole Swamp on both the east and west sides. *Id.* Mr. Taylor illustrates this "island effect" in Exhibit B of his Verified Statement.

A variety of wetland plant species likely would be eliminated from the developed and cleared portions of the rail project. However, the fewer acres impacted by the Preferred Route means it will have a smaller impact upon wetland plant species than the Alternate Route. In addition to its greater direct impact upon plant species, the Alternate Route will create a median, or "island," between itself and the CSX roadbed, in what is now an undisturbed wetland area, that will significantly change the quality of the wetland flora post-construction. For example, the clearings required for two transportation corridors will introduce more sunlight into the forest, changing the current conditions that favor native plants. *Id.* at 7. This also will create favorable conditions for invasive exotic plant species. *Id.* at 7-8.

There will be a similar impact upon wildlife habitat. The separate transportation corridor created by the Alternate Route would create an "island effect" for wildlife that is every bit as damaging as for plant species. It would bisect the land and lead to habitat fragmentation for many species due to barriers that would block their movement, resulting in the formation of subpopulations. *Id.* at 8-9. For terrestrial predator species, the Alternate Route would become a prime pathway where none currently exists, giving them an unnatural advantage over their prey. *Id.* The "island" areas also are more likely to be taken over by exotic species. *Id.* at 9. Research

confirms that species diversity, species density and breeding densities decrease with increased proximity to roadways. *Id.* The Alternate Route would greatly increase the roadway exposure compared with the Preferred Route.

The Alternate Route also will have a much more severe impact upon the hydrology of Four Hole Swamp than the Preferred Route. Wetlands purify surface water by removing both sediment load and trace elements, and they recharge groundwater resources. *Id.* For example, sediment is removed during flooding and is assimilated into organic-rich soil by the abundant vegetation and plant debris on the swamp floor. *Id.* at 10. In addition, various wetland plants remove trace pollutants, such as arsenic and zinc, from solution in surface water. *Id.* A transportation corridor that involves significant fill and a limited number of trestles constricts and inhibits the water flow that provide these wetland benefits. *Id.*

Mr. Taylor has determined that the existing transportation corridor created by Highway 453 and the CSX line already dams the flow of water through Four Hole Swamp. *Id.* The Preferred Route, which would simply widen that corridor, would not materially alter this existing condition for better or worse. *Id.* On the other hand, the Alternate Route would be expected to exacerbate the existing problem by creating a second dam approximately 130 feet further downstream. *Id.* The area between the two corridors could become a lake or stagnant backwater. *Id.* at 10-11.

The Preferred Route would eliminate wetland conditions on one-quarter as much acreage as the Alternate Route. *Id.* at 8. Stated differently, the Preferred Route would enlarge the total impact area of the existing transportation corridor by less than 20%, compared with 60% for the Alternate Route. *Id.* Because the Alternate Route would be a new transportation corridor, rather

than a widening of the existing corridor, and because it would reach deeper into Four Hole Swamp, it will have significantly greater impacts on the environment than the Preferred Route.

CSX is attempting to use the greater environmental impact of the Alternate Route as a barrier to entry for HolRail. In its recent comments concerning the Board's proposed scope of the environmental impact study for this project, CSX expresses concern:

> that the alignment proposed for the alternate route, that is not on CSXT's property, be the most efficient and environmentally friendly route available that does not require construction to be within CSXT's right-of-way....CSXT requests that from an environmental viewpoint, the no-build alternative be given equal consideration as the preferred and alternate routes.

CSX Comments on Scope of EIS, p. 4 (filed Aug. 31, 2005). CSX's statement summarily rejects the substantially less detrimental Preferred Route and then uses the greater environmental impact of the Alternate Route to push the "no-build" alternative, thus creating a barrier to entry. This elevates environmental policy over the rail transportation policy. Congress, however, intended that the Board balance those policies, which inevitably will be in conflict for most, if not all, rail construction projects. The Preferred Route offers the best alternative for balancing those policies, by substantially mitigating any environmental harm while still allowing HolRail to construct its new line.

In this case, because HolRail's proposed construction would cross an environmentally sensitive area, the Board should grant HolRail authority to construct its Preferred Route, which has substantially fewer environmental impacts than the Alternate Route. By authorizing construction of the Preferred Route, the Board will foster the multiple pro-competitive rail transportation policies along with the policy of reducing regulatory barriers to entry.

2. HolRail's shared use of the CSX right-of-way for a short distance will not impact any CSX plans to use this property for rail purposes.

HolRail has determined that CSX has no plans to use its existing right-of-way between Giant and the Holly Hill Facility, which ranges from 50-100 feet wide, for additional railroad purposes. Therefore, CSX has no basis to object to the Preferred Route on such grounds.

In STB Finance Docket No. 34376, *City of Creede, CO—Petition for Declaratory Order*, slip op. at 6 (served May 3, 2005), the Board recognized that the "extra width on the sides of the track allows room to maintain or upgrade the track, to provide access to the line, to serve as a safety buffer, and to ensure that sufficient space is left available for more tracks and other rail facilities to be added, as needed, as rail traffic changes and grows, among other uses." In an attempt to ascertain whether CSX has any plans of its own for using its entire right-of-way across Four Hole Swamp, HolRail posed Document Request No. 13, which asked CSX to produce "all documents prepared by or for CSX since January 1, 1999 that refer or relate to any plans to add to, or improve upon the rail infrastructure between Pregnall and Vance, SC." CSX did not produce any documents in response to this request. Furthermore, it is highly improbable that CSX would double-track this line in the future, since current operations average only one train per day in each direction. Moreover, since the right-of-way beyond the roadbed is entirely swampland, it is even less likely that CSX would use that property for *any* other rail purpose.

According to the Board, "the burden is on the party seeking to take property away from the national transportation system to show that the entire ROW is not and will not be needed for rail purposes." *Id., citing City of Lincoln—Pet. for Declaratory Order,* STB Finance Docket No. 34425 (served Aug. 11, 2004). HolRail has made this showing. Furthermore, in this proceeding, HolRail does not seek to take property away from the national transportation system, but rather, it seeks to add to the national rail infrastructure. Thus, it is clear that HolRail's Preferred Route

would not deny CSX the use of its right-of-way for rail purposes, whereas HolRail would make immediate use of that property for rail purposes.

3. CSX's speculative assertions regarding physical harm to its rail line from construction of HolRail's Preferred Route do not adversely implicate any rail transportation policies.

In its December 3, 2003 Response to HolRail's Petition for Exemption, CSX contends that construction of HolRail's Preferred Route would contravene several rail transportation policies. The sole argument underlying CSX's contention is an unsupported assertion that the proposed construction of HolRail's Preferred Route immediately adjacent to the existing CSX embankment will cause physical damage to CSX's rail line. CSX Response at 5-6. According to CSX, such damage would contravene 49 U.S.C. § 10101(1), (2), (3), (4), (5), (8), (9) and (11). But, as HolRail demonstrates through the Verified Statement of Gene A. Davis, construction of the Preferred Route will not adversely affect the CSX line, and in fact will improve and stabilize CSX's embankment.

Mr. Davis has over 20 years of Transportation experience as a professional civil engineer. Davis V.S., Exhibit A. He spent 18 of those years in the Engineering Department of NSR, where he was involved in the management and engineering of railroad track structures, bridge and building inspections, condition assessment, maintenance, rehabilitation, design and construction, and rail operations. Of particular relevance to the HolRail project, while with NSR, Mr. Davis supervised numerous construction projects in areas similar to Four Hole Swamp and monitored one such track construction in low lying marshland immediately adjacent to a main track. Davis V.S. at 13-14. According to Mr. Davis, construction projects similar to the HolRail Preferred Route are not uncommon and the use of proven engineering methods during construction can eliminate or negate any potential for damage to the existing CSX track. *Id.*

Mr. Davis directly refutes CSX's speculative and trumped up assertions regarding potential damage to its embankment and trestles. First, CSX feigns concern that, "If the foundation of HolRail's Line is allowed to abut or occupy the same space as CSXT's foundation in Four Hole Swamp, it will destabilize CSXT's line that was built in an environment that challenges the ability to engineer a stable and safe rail line." CSX Response at 5. But, rail construction across a swamp is not the eighth wonder of the world that CSX attempts to portray. Through the proper employment of established engineering techniques, HolRail can construct its Preferred Route without harming the existing CSX line.

During construction, HolRail will take appropriate safeguards to ensure the stability of the existing CSX roadbed where construction work is being performed. These safeguards, which are discussed at pages 11-12 and in Exhibits C and E of the Davis V.S., include saw cutting into the toe-slope of the CSX roadbed and daily inspection of the work area.

Despite CSX's dire warnings about the instability of the surrounding soil, established engineering techniques will permit HolRail to build its roadbed adjacent to the CSX roadbed without destabilizing it. Davis V.S. at 7, 10-12. Davis Exhibit C describes how to stabilize the sub-grade (roadbed) area utilizing riprap (one or two man stones) or larger rock to a height of two feet above water level, and then using smaller rock to fill voids in the road bed. A combination of vibratory rollers, "Geo-Grids," and sub-grade materials would be used in one foot lifts to achieve the desired top elevation of the sub-grade. After that, a six inch layer of sub-ballast would be installed and compacted and track construction would begin.

Once the HolRail roadbed is completed along the Preferred Route, the CSX roadbed actually will be *more stable* than it is today. This conclusion is based on both the experience of

Mr. Davis and upon the "Report of Geotechnical Exploration" prepared by Carolina Consulting Engineers, Inc. after conducting 56 soil test borings along the proposed alignment. *Id.*, Exhibit B.

South Carolina Highway 453 currently provides a buffer against standing water seeping into the west side of the CSX roadbed. The HolRail roadbed would give CSX a similar buffer on the east side. Since HolRail's roadbed would abut the east side of the CSX roadbed, the Preferred Route actually would protect the CSX roadbed from water seepage, especially during high water periods, which would enhance its stability. *Id.* at 11.

The Alternate Route has greater potential to destabilize the CSX roadbed than the Preferred Route. Both Mr. Davis and Carolina Consulting have observed corrective maintenance measures taken by CSX to stabilize, protect, and rebuild the east slope of its embankment. *Id.* at 10-12, Exhibit B at 1, and Exhibit G. The Alternate Route could act as a dam that leaves standing water between the CSX and HolRail lines, allowing that water to back up onto the east side of the CSX embankment, which could require CSX to take additional corrective measures. In contrast, the Preferred Route would protect the east side of the CSX embankment, which would greatly reduce, if not eliminate, the need for CSX to undertake further corrective efforts to stabilize its roadbed. *Id.* at 11. Thus, CSX's lack of opposition to the Alternate Route on operational grounds betrays the insincerity of its arguments in opposition to the Preferred Route.

CSX also grossly exaggerates its second principle concern, that the construction of new bridges by HolRail would destabilize CSX's wooden trestles. The existing CSX trestles are on timber driven piles with some helper bents installed. They show signs of wear that is typical of their age, but no immediate repairs are necessary. *Id.* at 12. If nearby bridge construction were to present any damage risk to the CSX trestles, it would be the shifting of helper bents caused by the pile driving process. The moist soil conditions in the area, however, will minimize even the

remote potential for vibration transfer during pile driving. *Id.* Furthermore, if any damage should occur, it could easily be remedied by shimming the caps in order to maintain elevation. *Id.* at 13. This situation would be monitored by conducting a daily walking inspection of the CSX bridges during HolRail's pile driving operation and by performing a thorough bridge inspection upon completion of the pile driving operation. *Id.*

Since the Preferred Route is likely to improve rather than harm CSX's line, its construction cannot contravene the rail transportation policies identified by CSX. The risk of any damage occurring to CSX's line is remote, and regular inspections will identify any damage that might occur before it can affect CSX's rail operations, so that the damage can be immediately repaired. CSX has not alleged any other harm from construction of either the Preferred or Alternate Route that would contravene, or be inconsistent with, the national rail transportation policies.

B. Regulation is not Necessary Because the Project is Limited in Scope.

HolRail's Preferred and Alternate Routes satisfy the second part of the exemption standard because they are limited in scope. The routes will be approximately 2.3 miles long and will parallel CSX's existing rail line. The Board has found much larger projects to be of limited scope. *See* ICC Finance Docket 32607, *WFEC Railroad—Construction & Operation Exemption—Choctaw & McCurtain Counties, OK,* (Served Feb 27, 1996) (14 mile line); ICC Finance Docket No. 32630, *Omaha Public Power District—Construction Exemption in Otoe County, NE* (Served May 2, 1995) (5 mile line), and ICC Finance Docket No. 31989, *The Elk River Railroad, Inc.,—Construction and Operation Exemption—Clay and Kanawha Counties, WV,* (Served May 28, 1992) (30-mile line). Therefore, precedent dictates that both of HolRail's proposed routes are limited in scope within the meaning of 49 U.S.C. § 10502(a)(2)(A).

Although CSX has not challenged HolRail's contention regarding the limited scope of its project in any of its pleadings to date, it has made numerous statements about the allegedly unprecedented nature of HolRail's Preferred Route. However, even accepting that allegation as true, the very limited scope of the project should mitigate any such concern. The portion of the project within CSX's right-of-way is only 1.7 miles long and it would be constructed across CSX property that passes through environmentally sensitive wetland on which there is little, or no, likelihood that CSX ever would conduct expanded rail operations. Furthermore, the Alternate Route entirely across Holcim property is less desirable because of its greater environmental consequences. Therefore, the limited scope (*i.e.* length) of this project and the special environmental facts surrounding it allow the Board to authorize construction of the Preferred Route without implicating concerns that might arise in a similar project involving a crossing of much broader scope.

C. Regulation is not Necessary to Protect Shippers from Abuse of Market Power.

Even if the Board were to conclude that HolRail's proposed transaction is not limited in scope, the Board should easily make the alternative finding, at 49 U.S.C. § 10502(a)(2)(B), that regulation is not needed to protect shippers from the abuse of market power. *See* STB Finance Docket No. 34060, *Midwest Generation, LLC—Exemption from 49 U.S.C. § 10901—for Construction in Will County, IL* (served March 20, 2002). Similar to the Board's conclusion in *San Jacinto* at 7, this transaction would dilute CSX's existing market power in the area by providing another transportation option.

In a rather specious argument, CSX contends that HolRail's proposed construction would open the door for abuse of market power by HolRail. CSX Response at 7. CSX claims that, if the traffic along the route cannot support two railroads, HolRail could end up being the sole

carrier to other cement facilities, which would be competitors of HolRail's parent company, Holcim. This statement simply is untrue.

The only other cement facility that HolRail could physically access directly as a result of its proposed construction is Giant Cement, at the southern end of the proposed line. Giant currently receives dual rail service from both CSX and NSR. Therefore, even if HolRail displaces CSX, Giant would continue to receive dual service through NSR. Furthermore, Giant still would have access to CSX even if CSX ripped up its track across Four Hole Swamp today, because CSX also operates over the NSR track that serves Giant from the south and it has the right to serve Giant over that track under the *Carolinas Plan*. *See* Part III.A.3, *supra*. Indeed, under the *Carolinas Plan*, CSX operates the NSR line exclusively as the agent of NSR. That fact would not change if CSX abandoned its own track to the north across Four Hole Swamp.

D. At a Minimum, the Board Should Authorize Holrail to Construct the Alternate Route.

The basic point of contention between HolRail and CSX in this proceeding is over construction of the Preferred Route, not the Alternate Route. CSX has not raised any concerns over the Alternate Route in its pleadings and, in fact, has disavowed any such concern. *See* CSX Response at 4 ("The proposed 'route' that concerns CSXT is the one that HolRail claims would 'share' the CSXT right-of-way with CSXT's existing rail line....."). Because the Alternate Route does not share the CSX right-of-way, CSX has not presented any basis to deny HolRail's Petition for Exemption, as it applies to the Alternate Route.

V. PETITION FOR CROSSING AUTHORITY.

HolRail submits this crossing petition in support of its request to construct the Preferred Route across CSX's rail corridor for approximately 1.7 miles. In this section, HolRail demonstrates that its proposed crossing is within the Board's statutory authority to grant and that its crossing satisfies the statutory requirements.

A. Description of Proposed Crossing.

The entire length of HolRail's Preferred Route is 2.3 miles long, of which HolRail intends to construct approximately 1.7 miles across CSX's property. HolRail Witness Davis describes the crossing in detail at pages 3 to 5 of his Verified Statement.

The crossing would occur between Stations 25+50 and 115+00 on the drawings attached to the Davis V.S. as Exhibit D. An additional crossing of less than 250 feet would occur between approximately Sta. 4+00 and 6+00, where the track that connects HolRail's yard to the run-through track in the Giant Yard encroaches upon a small corner of CSX property by a few feet. The remainder of the project, including the rail yard, would be constructed on property owned either by Holcim or Giant.

Mr. Davis has attached a typical cross section of the Preferred Route, as Exhibit E to his Verified Statement, that illustrates the relationship between the proposed HolRail track and the existing CSX track. Davis Exhibit D, Sheets 10-14, provides detailed cross sections at each Station along the Preferred Route. As these drawings illustrate, the crossing would be similar to double-tracking the existing CSX line. It would involve the construction of roadbed and track immediately adjacent to, and abutting, the existing CSX roadbed. The track centers would be constructed 30 feet apart. In addition, HolRail would construct three trestle bridges, of equal or greater length, adjacent to the existing CSX trestles.

B. HolRail has Satisfied the Statutory Standards for Crossing.

The crossing statute at 49 U.S.C. § 10901(d)(1) states that:

> When a certificate has been issued by the Board under this section authorizing the construction...of a railroad line, no other rail carrier may block any construction...authorized by such certificate by refusing to permit the carrier to cross its property if—
>
> (A) the construction does not unreasonably interfere with the operation of the crossed line;
>
> (B) the operation does not materially interfere with the operation of the crossed line; and
>
> (C) the owner of the crossing line compensates the owner of the crossed line.

Thus, once the Board concludes that a proposed construction is *not* inconsistent with the public convenience and necessity under § 10901(c), or otherwise exempts the transaction under § 10502(a), no carrier may block the construction by refusing access to its property, if the three statutory standards are satisfied.[6] *See* STB Finance Docket No. 33740, *The Burlington Northern and Santa Fe Railway Co.—Petition for Declaration or Prescription of Crossing, Trackage, or Joint Use Rights*, slip op. at 6 (Served May 13, 2003) ("*BNSF*").

In this proceeding, CSX has based its opposition to HolRail's Petition for Exemption upon the very same allegations of fact that are relevant to the § 10901(d)(1) standards for obtaining crossing authority. For example, CSX's entire objection to HolRail's construction of the Preferred Route within CSX's right-of-way, pursuant to §§ 10901(c) and 10502(a), is based on allegations that this construction would unreasonably interfere with CSX's own operations and therefore would be contrary to the national rail transportation policy. *See* Part IV.A.3, *supra*. This is precisely the same factual showing that is required by the standards for crossing petitions

[6] The Board will set the compensation required by the third factor if the parties cannot agree upon proper compensation after the Board has granted the Crossing Petition.

at § 10901(d). Therefore, if the Board grants HolRail authority to construct its Preferred Route, it also should grant HolRail's crossing petition under § 10901(d)(1), since the relevant facts are the same for both petitions.

1. Construction of the Preferred Route does not unreasonably interfere with the operation of CSX's line.

CSX's principle argument that construction of the Preferred Route will unreasonably interfere with its operations is its allegation that construction will physically harm the CSX line. This is the same argument that CSX has raised in opposition to the Petition for Exemption. Thus, HolRail already has refuted CSX's speculation of possible physical harm to its track and trestles at Part IV.A.3, *supra*. As HolRail noted in that section, this type of rail construction project is not unique or unusual and, upon completion, the HolRail roadbed actually will improve the stability of CSX's roadbed. Mr. Davis, who has supervised similar projects in wetland areas for the NSR, reached this conclusion after carefully scrutinizing the engineering drawings (Exhibit D) and construction procedures (Exhibit C); reviewing the Report on Geotechnical Exploration (Exhibit C); visiting the construction site; and inspecting the existing CSX track and roadbed. Davis V.S. at 2, 13-14. HolRail refers the Board to Part IV.A.3 of this filing, rather than repeat those arguments here.

HolRail Witness Schuchmann describes CSX's operations at pages 4-7 of his Verified Statement. He concludes that it should be quite simple to coordinate HolRail's construction activity to avoid interference with CSX train movements, since there is only one round trip train per day, 5 days per week, between Giant and Holly Hill and the train speeds on this track are only 10 MPH. Schuchmann V.S. at 8-9. Furthermore, Holcim is the only major shipper served by CSX over this line segment, with only one other shipper even receiving daily switching

service. *Id.* at 8. Thus, even if there were any service impacts, they would be felt almost exclusively by Holcim.

HolRail Witness Davis has provided details on the construction procedures and the potential interference with CSX operations at pages 6-8 and 10-14 of his Verified Statement. Since virtually all of the construction south of Sta. 25+50, including the rail yard, will be on Holcim or Giant property, that portion of the project should have no impact upon CSX. Once the Preferred Route crosses onto CSX property, its construction can readily be coordinated with CSX to minimize any effects upon CSX's operations.

Mr. Davis includes a step-by-step outline of construction procedures in Exhibit C to his Verified Statement. Since many of the job functions on CSX property can occur simultaneously, the overall duration of the project can be limited to approximately 14 months. Davis V.S., Exhibit C. For example, roadbed construction could occur at both project ends while bridge construction could occur simultaneously (except for the middle bridge). Davis V.S. at 6-7.

All bridge, switch and track construction can be accomplished without prolonged fouling of the CSX line. *Id.* at 6. When it becomes necessary to foul the CSX line, the construction crews and equipment could clear the line quickly when alerted by a flagman of an approaching train. Schuchmann V.S. at 8. The only project that would directly affect CSX's operations would be a 4-6 hour outage for installation of the cross-over track and switches at each end of the HolRail construction. Davis V.S. at 6; Schuchmann V.S. at 9. Since CSX operates only one train per day, 5 days per week, over its line, any adverse effects can be substantially mitigated, if not eliminated altogether, through careful coordination between HolRail and CSX and by performing some work on weekends. Davis V.S. at 6.

Because construction of HolRail's Preferred Route will not unreasonably interfere with the operation of CSX's rail line, CSX may not block that construction once the Board has authorized it pursuant to 49 U.S.C. §§ 10901(c) and 10502(a).

2. Operation of the Preferred Route does not materially interfere with the operation of CSX's line.

The operation of HolRail's Preferred Route presents even less concern than its construction for interference with CSX's line. Since the Preferred Route does not laterally cross CSX track at any point, HolRail trains will not block or otherwise interfere with the one CSX train that operates in each direction five days per week.[7] HolRail Witness Schuchmann describes the post-construction operations of HolRail at pages 9-12 of his Verified Statement.

The HolRail track will be accessed from the Giant yard track by means of a hand throw switch at MP 396.55. Schuchmann V.S. at 10. The normal position of the switch would be aligned and locked for the CSX alignment, which traverses the Giant yard track via trackage rights at this point. *Id.* Thus, CSX trains would be able to operate between Pregnall and Holly Hill, through this switch, without stopping, just as they operate over that line today.

When acting as the agent for NSR to interchange cars with HolRail, CSX would obtain permission to enter HolRail track by radio or telephone before reaching the connection switch. *Id.* Crews would stop at the switch, unlock it, and align it for the HolRail connection. *Id.* Once the train clears the switch, CSX would align the switch for the CSX track, lock it, and advise the CSX dispatcher that the train is clear of the CSX track. *Id.* For a train of up to 100 cars, this procedure typically should take no more than 10 minutes. *Id.*

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[7] *Cf.*, Finance Docket No. 32607 (Sub-No. 1), *WFEC RR Co.—Construction and Operation Exemption—Choctaw and McCurtain Counties, OK—Petition for Issuance of an Order Pursuant to 49 U.S.C. 10901(d)*, 1996 STB Lexis 56, *7 (served Feb. 23, 1996) (No material interference with operations from a fly-over bridge crossing where only two trains daily move in each direction).

CSX then would proceed to place the train in HolRail's yard, disconnect its locomotive, and repeat the above process in reverse to exit the HolRail track. Mr. Schuchmann describes the train operations within the HolRail yard and on the HolRail track north of the yard at pages 11-12 of his Verified Statement.

Mr. Schuchmann also describes two alternative scenarios for CSX's post-construction operations at the Holly Hill Facility at pages 13-14 of his Verified Statement. He concludes that CSX will retain the same post-construction functional access to all tracks within the Facility that it currently enjoys and that CSX's operations either will be simplified, by consolidating car delivery and pickup at the north end of the Facility, or will be unchanged from current operations. Furthermore, CSX's coal deliveries to the Facility will not change, since those trains will continue to arrive and depart from the north just as they do today. *Id.* at 13.

Because operation of HolRail's Preferred Route will not materially interfere with the operation of CSX's rail line, CSX may not block that construction once the Board has authorized it pursuant to 49 U.S.C. §§ 10901(c) and 10502(a).

C. The STB has Statutory Authority to Grant HolRail's Crossing Petition.

CSX's contention that the Board lacks authority to grant HolRail's crossing petition under 49 U.S.C. § 10901(d) ignores the plain language of that statute. Once the Board has issued a certificate under § 10901(c), or granted an exemption under § 10502(a), authorizing HolRail's construction of the Preferred Route within CSX's right-of-way, § 10901(d) expressly prohibits CSX from blocking that construction, except when the construction and operation of the line would unreasonably and materially interfere with CSX's own operations. Thus, once the Board grants HolRail authority to construct its Preferred Route, it has all the authority it needs to also grant the crossing petition.

CSX's real grievance is with any decision by the Board to authorize construction of the Preferred Route in the first place. There is absolutely no claim by CSX, however, that the Board lacks such authority; only that the Board should not grant it. Once the Board grants construction authority, there is no basis for asserting that the Board cannot then enforce its decision through § 10901(d), as Congress clearly intended.

HolRail's request for crossing authority is within the scope of the statute's plain language, its underlying purpose, and historical precedent. In contrast, CSX wrongly contends that § 10901(d) requires a physical crossing of "track," as opposed to a "line." The Board should reject CSX's misreading of the statute, and grant crossing authority to HolRail, as requested herein.

1. The plain meaning of Section 10901(d) gives the Board authority to grant HolRail's proposed crossing.

The plain language of § 10901(d) does *not* require a physical intersection of track, and is *not* limited to a crossing over the width of a right-of-way. Indeed, § 10901(d) does not even contain the word "track," but instead uses the words "property" and "line." The statute reads:

> (d)(1) When a certificate has been issued by the Board under this section authorizing the construction or extension of a railroad line, no other rail carrier may block any construction or extension authorized by such certificate by refusing to permit the carrier to *cross its property* if –
>
> > (A) the construction does not unreasonably interfere with the operation of the *crossed line*;
> >
> > (B) the operation does not materially interfere with the operation of the *crossed line*; and
> >
> > (C) the owner of the crossing line compensates the owner of the *crossed line*.

49 U.S.C. § 10901(d)(1) [emphasis added].

CSX would rewrite the statute by substituting the word "track" for the words "property" and "line." Its only support for this revisionist interpretation is a single passage in the legislative history of ICCTA, which states, "Subsection (d) replaces former Section 10901(d), which empowers the agency to order one railroad whose tracks block the access of another railroad's tracks to provide crossing arrangements." *See* H. Conf. Rep. No. 104-422, *reprinted in* 1995 U.S.C.C.A.N. 793, 864. This statement, however, neither expressly nor implicitly limits the Board's authority to crossings of "track." Rather, it merely explains, by reference to a common example, that ICCTA reenacted the same powers that the ICC held pre-ICCTA. The original enactment of § 10901(d) was in the Staggers Act of 1980, and that legislative history does not use the term "track." *See* H.R. Conf. Rep. No. 96-1430 (1980), *reprinted in* 1980 U.S.C.C.A.N. 4110, 4147. Thus, to adopt CSX's interpretation would be to conclude that Congress intended to narrow the scope of § 10901(d) in ICCTA. Clearly, the legislative history of ICCTA does not manifest any such intent.

More importantly, the Board need not refer to legislative history at all because § 10901(d) is not ambiguous. "The preeminent canon of statutory interpretation requires us to 'presume that [the] legislature says in a statute what it means and means in a statute what it says there.' Thus, our inquiry begins with the statutory text, and ends there as well if the text is unambiguous." *BedRoc Ltd., v. United States*, 541 U.S. 176, 183 (2004) (citation omitted). CSX's self-serving and unduly restrictive use of legislative history is impossible to reconcile with the plain language of the crossing statute because it reads out the words "property" and "line." This narrow rendering differs markedly from the statute that Congress enacted, and thus cannot be sustained.

A proper reading of the operative terms of the statute confirms that it governs more than a physical crossing of "track." The terms "cross," "property," and "line" easily permit HolRail's crossing of CSX's right of way. Since these terms are not defined in the statute, it is appropriate to refer to the definitions given to those terms by the rail industry and in common usage.

According to Webster's Third New International Dictionary (Unabridged) 540-41 (1976), "cross" means, among other things, "to lie or be situated across;" "to extend from one edge or corner of to the other;" "to extend across or over;" or "to go from one side of to the other." All of these meanings encompass both lateral (*i.e.* width) and longitudinal (*i.e.* length-wise) crossings, and thus "cross" applies to HolRail's Preferred Route across the length of CSX's corridor for 1.7 miles. The new line "will lie or be situated across," "extend from one edge or corner of to the other [of]," "extend across or over," and "go from one side to the other [of]" CSX's property from a point at the Holly Hill Facility to a point approximately 1.7 miles to the south. Thus, the statute's use of "cross," bars a rail carrier from blocking any construction of a rail line by refusing to permit another carrier to cross any portion of that carrier's "property."

The term "property" as used in § 10901(d)(1) also applies to HolRail's proposed crossing because CSX's right-of-way falls within the plain meaning of the word. Black's Law Dictionary explains that "property" is "commonly used to denote everything which is the subject of ownership, corporeal or incorporeal, tangible or intangible, visible or invisible, real or personal." Black's Law Dictionary 1382 (Revised 4th ed. 1968). Black's defines "real property," as "[l]and, and generally whatever is erected or growing upon or affixed to land." *Id.* at 1383. Here, HolRail seeks to construct the Preferred Route across CSX's *land* from a point at Holcim's facility to a point approximately 1.7 miles south. Because "property" includes land, tracks,

facilities, etc., singularly or together, HolRail's proposed crossing clearly falls within the scope of § 10901(d)(1) as a request for authority to cross "property" of another carrier.

HolRail's crossing also comports with 49 U.S.C. §§ 10901(d)(1)(A) – (C), which employ the term "crossed line." In the railroading context, the term "line" has a broader definition than "track," such that the term "crossed line" does not require an actual intersection of tracks, but includes a crossing of land that is inherently part of a "line." For example, in describing property encompassed by a rail line in an abandonment proceeding, the Federal Court of Appeals for the Sixth Circuit stated, "it is evident that a rail line embraces *more than just the track* necessary for the provision of rail service." *Railroad Ventures, Inc. v STB*, 299 F.3d 523, 552-553 (6th Cir. 2002) [emphasis added]. The court cited *In re Boston & Maine Corp.*, 596 F.2d 2, 6 (1st Cir. 1979), which noted that "a railroad line is not merely the service being provided, but the physical properties and interests belonging to the debtor that constitute the line." Additionally, in *Iowa Terminal Railroad Co. v. ICC*, 853 F.2d 965, 972 (D.C. Cir. 1988), the court upheld the ICC's decision to require conveyance of a 10 acre parcel of land as part of the sale of a to-be abandoned rail line for continued rail operations. Indeed, construing "line" broadly to include land is consistent with the statute's use of the term "property." Therefore, because "line" encompasses, *inter alia*, land, tracks, and facilities, HolRail's petition, which seeks authority to cross over CSX's land, falls squarely within the scope of §§ 10901(d)(1)(A) – (C).

2. Relevant ICC and STB precedent supports HolRail's proposed crossing.

CSX mistakenly contends that HolRail's construction of 49 U.S.C. § 10901(d) is unprecedented. In fact, both the Board and the ICC have applied the crossing statute in situations that involved one carrier crossing the line of another lengthwise, and one carrier crossing another carrier's property *but not its tracks*.

In STB Finance Docket No. 33740, *The Burlington Northern and Santa Fe Railway Co.—Petition for Declaration or Prescription of Crossing, Trackage, or Joint Use Rights*, 2003 STB Lexis 244 (Served May 13, 2003) ("*BNSF*"), the Board applied the crossing statute to allow BNSF to operate *lengthwise* over a quarter mile section of line owned by the Keokuk Junction Railway Company. The Board stated that "the term 'crossing' must be viewed *pragmatically*" to encompass different scenarios. *Id.* at *32 [emphasis added]. Here, HolRail's proposed crossing, which involves parallel construction and operation, is not nearly as intrusive as the crossing the Board approved in *BNSF*, which invoked § 10901(d) to require one carrier to allow another carrier to operate over its tracks.

Similarly, in Finance Docket No. 32547, *Kansas City Southern Ry.—Construction and Operation—to Exxon Corporation's Plastics Plant*, 1995 ICC Lexis 138 (Served June 12, 1995) ("*KCS*"), the ICC granted an exemption to Kansas City Southern Railway ("KCS") from the requirements of 49 U.S.C. § 10901 to build a 0.375 mile long rail line to industry track facilities of an Exxon plant. The ICC approved KCS's petition despite the fact that the line would cross an easement for rail service held by the Illinois Central Railroad Company ("ICR"), which had not built a track along the easement. The ICC stated:

> If we approve this petition to permit KCS to build this line[,] KCS may avail itself of section 10901(d) to cross ICR's *property*, i.e., *the easement*. ICR's rights are protected by the requirement that any such application meet the standards of section 10901(d) and that ICR be compensated if the crossing is approved."

Id. at *6-7 [emphasis added]. Thus, the ICC concluded that KCS could properly invoke the crossing statute to cross ICR's easement, despite the absence of a physical intersection of track.

That conclusion is entirely consistent with HolRail's invocation of the crossing statute to cross CSX's property, a crossing that also does not involve intersecting CSX's track.[8]

CSX has attempted to distinguish the foregoing decisions on various superficial grounds. The *BNSF* decision supports HolRail's use of § 10901(d) precisely because the Board invoked that statute to permit BNSF to operate over KJRY's tracks in a *lengthwise* crossing that is even more intrusive than the crossing HolRail has proposed. The decision also establishes that the statute is not limited to so-called "widthwise" crossings, as CSX wrongly contends. The *KCS* decision declared that KCS could invoke the crossing statute to cross ICR's property, even in the absence of any track. Although CSX contends that these decisions do not present precisely the same facts as HolRail's crossing petition or that they constitute *dicta*, it cannot cite to any decision that would prohibit HolRail's proposed crossing. The precedent that does exist, therefore, clearly demonstrates that HolRail's interpretation of § 10901(d) is reasonable.

3. The scope of § 10901(d) is properly informed by older state law precedent.

Although not decided under § 10901(d), there are examples of projects very similar to HolRail's proposed crossing, dating back more than a century, that demonstrate that HolRail's proposal is far from unprecedented. These projects were approved under state laws that applied standards nearly identical to § 10901(d) and which, therefore, should inform the Board's construction of that statute.

For example, in *Southern Pacific Railway Co. v. Southern California Railway Co.*, 111 Cal. 221 (Cal. 1896), a court permitted Southern Pacific Railway Co. ("SP") to employ eminent

[8] *See also,* ICC Finance Docket Nos. 32158 and 32158 (Sub-No. 1), *Gateway Western Railway Company—Construction Exemption—St. Claire County, IL,* 1993 ICC Lexis 147 at *1 (served July 28, 1993) ("GWRC also sought authority to cross property it jointly owns with [Southern Pacific Lines] on the north end of the line to be constructed under Finance Docket No. 32158. This assertedly does not involve the crossing of any track, and thus, would not interfere with any existing rail operations.")

domain for the purpose of constructing a parallel rail line within Southern California Railway Co.'s ("SC") existing right-of-way. The court found that SP's appropriation was proper because its construction and use would not interfere with SC's operations and because SC could be compensated for the use. *Id.* at 231-232. These are the same three standards (*e.g.*, construction interference, operation interference, and compensation) that are considered under § 10901(d).

Similarly, in *North Carolina Railroad Co. v. Carolina Central Railway Co.*, 83 N.C. 489 (N.C. 1880), a court denied an injunction sought by the North Carolina Railroad Company ("NCR") to prevent the Carolina Central Railroad Company ("CRC") from acting under its appropriation power to construct a rail line within NCR's existing right-of-way and parallel to its existing tracks, in order to reach a depot. In denying the injunction, the court found that construction and operation of the parallel line would not interfere with the incumbent's operations. *Id.* at *10-11. Once again, these are nearly identical to the standards in § 10901(d).

The fact that these long-established precedents applied the same standards as § 10901(d) to approve projects very similar to HolRail's proposed crossing should carry some weight in the Board's construction of the crossing statute. In both cases, the crossing railroads invoked, and the courts applied, the relevant state law that gave railroads the power to cross property belonging to other railroads. No corresponding federal law existed at the time. Today, ICCTA has superseded those state laws with federal law that applies the same standards. Because of the fundamental similarities between the standards applied in those older state law cases and those adopted in § 10901(d), those state law cases remain relevant and persuasive evidence of the intent behind § 10901(d).

Indeed, the Board itself recently concluded that "One of the reasons that Congress enacted [§ 10901(d)] was to confirm its view of *existing* law—that one carrier could not

unreasonably interfere with another's crossing—and to designate a single forum (the Board) in which the crossing carrier could vindicate its crossing rights."[9] When Congress enacted ICCTA, it preempted all State laws affecting transportation by rail carriers, including state laws of eminent domain such as those applied in the preceding cases. 49 U.S.C. § 10501(b). Congress, however, did not leave a regulatory void. Instead, it substituted the jurisdiction of the STB. In the case of eminent domain, Congress granted the STB comparable authority over all rail carriers through the crossing provisions of § 10901(d). There is no indication in either the plain language of § 10901(d) or its legislative history that Congress intended to grant the STB less authority over crossings than the states themselves previously possessed.

Moreover, when Congress has intended to restrict the STB's authority over certain rail property, it has done so expressly, such as in 49 U.S.C. § 10906, where it declared that the Board "does not have authority...over construction, acquisition, operation, abandonment, or discontinuance of spur, industrial, team, switching, or side tracks." The Board should not merely infer a similar restriction upon its crossing authority.

4. CSX greatly exaggerates the implications of granting HolRail's crossing petition.

In a statement of alarmist hyperbole, CSX warns that HolRail's interpretation of § 10901(d) threatens the very existence of rail transportation in this country because it "would permit the expropriation of every railroad line in the United States for the construction of a parallel line, within the railroad's own right-of-way."[10] In reality, the Board should grant

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[9] *See* STB Finance Docket No. 33740, *The Burlington Northern and Santa Fe Railway Co.—Petition for Declaration or Prescription of Crossing, Trackage, or Joint Use Rights*, slip op. at 11 (served May 13, 2003) [emphasis added], *citing* H.R. Rep. No. 1035, 96th Cong., 2d Sess. 66-67.

[10] *See* CSX Transportation, Inc.'s Response and Opposition to HolRail LLC's First Motion to Compel—Request for Entry Upon Land, pp. 3-4 (filed March 11, 2004).

HolRail's crossing petition precisely because of its limited scope and the collection of distinct facts surrounding this project.

Before the Board may grant crossing authority, it first must have issued a certificate authorizing the line construction under 49 U.S.C. § 10901(c), or granted an exemption under 49 U.S.C. § 10502(a). Thus, the Board must first determine that the proposed project is not inconsistent with the public convenience and necessity. It will be much more difficult for a petitioner to make this showing for a project that would occupy a lengthy portion of the crossed railroad's property; that would adversely affect the crossed railroad's use of its property for present and future rail purposes; and that would not otherwise have substantial environmental consequences. As discussed in Part IV, *supra*, it is this unusual combination of factors that justifies Board authorization of HolRail's Preferred Route under § 10901(c). Once the Board grants that authorization, § 10901(d) is merely the means by which to prevent CSX from blocking construction. Since very few projects are likely to possess all the same traits as HolRail's Preferred Route, CSX's alarmist claim is unfounded.

Furthermore, the crossing statute itself prohibits the Board from issuing crossing authority *unless* the applicant satisfies both the "unreasonable interference" and the "material interference" prongs at 49 U.S.C. § 10901(d)(1)(A) and (B). The potential for such interference is likely to increase in proportion to the length of property to be crossed. Thus, Union Pacific's Sunset Line is not threatened; nor is CSX's I-95 line.

Just because the unique circumstances of this case clearly support HolRail's crossing application, the same result would not necessarily follow in every other lengthwise crossing case that might be filed. Each crossing petition must succeed or fail on its own peculiar facts. Thus, HolRail's application poses no threat to the continued viability of the nation's rail network.

5. HolRail's petition is consistent with the pro-competitive objectives of § 10901(d).

Congress enacted 49 U.S.C. § 10901(d), as part of the Staggers Rail Act of 1980, with the objective of facilitating competition-enhancing build-outs by preventing incumbents from blocking new construction. *See* H.R. Conf. Rep. No. 96-1430 (1980), *reprinted in* 1980 U.S.C.C.A.N. 4110, 4147. The ICC confirmed this fact in ICC Finance Docket Nos. 32630 and 32630 (Sub-No. 1) *Omaha Public Power District—Construction Exemption in Otoe County, NE, etc.*, 1995 ICC Lexis 297 at *4 (Served Nov. 30, 1995) ("*OPPD*"):[11]

> The legislative history of section 10901(d) indicates that the provision is intended to permit easier railroad entry. The purpose of the statute is to provide a way to overcome the ability of existing carriers to block the construction of new rail lines by refusing to allow potential competitors to cross their existing lines.

HolRail's crossing petition is consistent with this pro-competitive purpose. HolRail's objective is to bring the benefits of rail-to-rail competition to Holcim's Holly Hill Facility.

STB Chairman, Roger Nober, has spoken frequently about the benefits of promoting competition through rail build-outs. In *San Jacinto* at 6, Chairman Nober noted that:

> In short, BNSF's new line would result in an additional service option for Bayport Loop shippers and require BNSF and UP to compete for their traffic. These goals are fully consistent with the public interest and the RTP.

An STB News Release on the project quoted Chairman Nober as stating that "Permitting railroads to construct new lines to reach customers is the right way to promote rail-to-rail competition." STB News Release No. 03-21 (May 9, 2003).[12] In a subsequent public statement regarding local opposition to that project, the Chairman stated that:

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[11] *See also Louisville & Jefferson County Riverport Authority and CSX Transportation, Inc.—Construction and Operation Exemption—In Jefferson County, KY*, 4 I.C.C.2d 749, 755 (1988).

[12] HolRail work paper HOL-00295.

> (the STB's) interest is not in the San Jacinto project per se, but the viability of build-ins as a competitive option. If (municipalities) make it harder to construct build-ins, it's less likely people will be willing to see them as viable and be willing to spend the money on applying for them. STB sees build-ins as a market based means of competition to single served areas.

John Gallagher, *Shippers' Eminent Rivals; Fight for lines in Houston comes down to BNSF's ability to win eminent domain rights for tracks*, Traffic World, Sept. 20, 2004, p. 25. *See also*, John Gallagher, *Undone Deals; Shippers find themselves sidelined by local opposition to rail projects*, Traffic World, Oct. 20, 2003), p. 29 ("But obviously we want to be sure that the authority to build and provide competitive service is still a viable option.").[13]

After court rulings delayed both the San Jacinto project and another rail construction project by the Dakota, Minnesota & Eastern Railroad, Chairman Nober, in a speech before the National Industrial Transportation League, stated:

> I am concerned about the larger implications that these rulings may have on the decisions of railroads and shippers to try to improve their competitive positions by building-in. Since these types of projects are privately-funded, I worry that companies may decide that it is too risky to tie up capital on a build-in project and no longer look to these as private-sector solutions to railroad competition.

Will court rulings discourage rail investment; industry outlook, Railway Age, May 1, 2004, p. 6.[14]

A crossing petition is necessary in this case to address environmental concerns that otherwise could be a barrier to HolRail's entry. As explained more fully in Part IV.A.1., *supra*, § 10901(d) allows the Board to achieve an optimal balance between the pro-competitive rail transportation policies and federal environmental protection policies. This application of § 10901(d) is consistent with its overarching purpose, as explained in its legislative history and

[13] *Id.* at HOL-00298 and HOL-00302.
[14] *Id.* at HOL-00300.

in the *Midwest* and *OPPD* decisions. Moreover, it responds directly to Chairman Nober's own concerns about the viability of new rail projects as private-sector solutions to rail competition by mitigating environmental impacts that otherwise could constitute an insurmountable barrier to entry.

VI. SUMMARY AND REQUEST FOR RELIEF.

HolRail's Supplemental Evidence, as presented herein, fully demonstrates that its pro-competitive rail construction project at Holly Hill meets the exemption standards set forth at 49 U.S.C. § 10502(a), and, in the alternative, the public convenience and necessity standard set forth at 49 U.S.C. § 10901(c). Furthermore, once the Board grants HolRail authority to construct its Preferred Route, it should also grant HolRail's crossing petition because HolRail's evidence satisfies the standards for crossings at 49 U.S.C. § 10901(d).

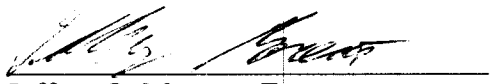
First, controlling STB precedent establishes that this project advances numerous elements of the rail transportation policy at 49 U.S.C. § 10101. Moreover, by building and operating within CSX's existing corridor, and thereby preserving a pristine wetland, HolRail's Preferred Route specifically advances 49 U.S.C. § 10101(7) by minimizing barriers to entry arising from environmental laws and regulations. Indeed, HolRail's evidence clearly demonstrates that the Preferred Route greatly mitigates environmental contingencies arising from construction in Four Hole Swamp.

Second, HolRail's supplemental evidence plainly shows that its build-out is of limited scope and that regulation is not needed to protect shippers from the abuse of market power. Accordingly, with the benefit of supplemental information provided herein by HolRail, the Board should not hesitate to grant an exemption giving HolRail authority to build its Preferred Route or, in the alternative, to issue construction authority under 49 U.S.C. § 10901(c).

Because HolRail's crossing petition presents evidence that satisfies the standards set forth at 49 U.S.C. § 10901(d), the Board should grant additional authority to HolRail, allowing it to construct its Preferred Route across CSX's right-of-way for a distance of 1.7 miles. HolRail's detailed expert testimony establishes conclusively that HolRail's construction will not unreasonably interfere with CSX's operation of the crossed line, and that HolRail's operation will not materially interfere with CSX's operation of the crossed line. Indeed, HolRail's construction will strengthen and protect CSX's roadbed and its operations will simplify CSX's operations. Additionally, HolRail's legal argument regarding the intent and the ambit of the crossing statute resolves any doubt that HolRail has invoked it properly. In fact, the crossing statute expressly contemplates limited takings—like this one—in order to foster competition in the rail industry and provides for an adequate remedy by requiring the crossing carrier to pay compensation to the crossed carrier.

Accordingly, HolRail respectfully requests that the Board grant authority for its construction of the Preferred Route and crossing authority, as necessary for construction and operation of that Route. In the alternative, in the event that either construction or crossing authority are not approved, HolRail requests that the Board grant construction authority for the Alternate Route.

Respectfully submitted,



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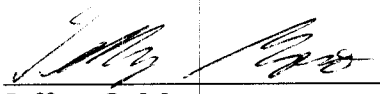
September 9, 2005

Attorney for HolRail LLC

CERTIFICATE OF SERVICE

I hereby certify that this 9th day of September, 2005, I served a copy of the foregoing "Petition for Crossing Authority and Supplemental Evidence in Support of Petition for Exemption" by hand delivery upon counsel for CSX Transportation, Inc., at the following address:

Louis E. Gitomer, Esq.
BALL JANIK LLP
1455 F Street, N.W.
Suite 225
Washington, D.C. 20005



Jeffrey O. Moreno

Stingo V.S.

BEFORE THE
SURFACE TRANSPORTATION BOARD

STB FINANCE DOCKET NOS. 34421 AND 34421 (Sub-No. 1)

HOLRAIL LLC PETITION FOR EXEMPTION FROM 49 U.S.C. § 10901 TO CONSTRUCT AND OPERATE A RAIL LINE IN ORANGEBURG AND DORCHESTER COUNTIES, SOUTH CAROLINA

HOLRAIL LLC—
PETITION FOR CROSSING AUTHORITY UNDER 49 U.S.C. § 10901(d)

VERIFIED STATEMENT OF LOOMAN F. STINGO

A. IDENTITY OF WITNESS AND SUMMARY OF CREDENTIALS

My name is Looman F. Stingo. I am Senior Vice President, Logistics for Holcim (US) Inc. ("Holcim") and I am General Manager of HolRail LLC ("HolRail"). My business address is 1100 Victory Way, Suite 50, Ann Arbor, Michigan 48108. I have served as Holcim's Senior Vice President, Logistics for eight years. My primary responsibilities are planning, implementing, and managing Holcim's transportation and logistics operations on a company-wide basis. As part of that responsibility, I have supervised the planning and implementation of the rail construction project that is the subject of this proceeding before the Surface Transportation Board ("STB" or "Board").

I have prepared this Verified Statement in support of HolRail's petition for STB authorization to construct a new rail line to connect Holcim's Holly Hill Facility with the Norfolk Southern Railroad ("NSR") approximately 2.5 miles away. My purpose is to provide information about (i) Holcim; (ii) Holcim's operations at Holly Hill; (iii) Holcim's reasons for constructing a new line of rail to provide competition at Holly Hill; and (iv) the various routes

that Holcim has considered for the new rail line. In order to prepare this Verified Statement, I reviewed material prepared by Skeen Railroad Engineering, Inc. ("Skeen") and Fletcher Group Inc. ("Fletcher"). Skeen was retained to design HolRail's proposed new rail line and Fletcher was retained to address the environmental issues associated with the construction.

B. IDENTITY OF HOLCIM (US) INC.

Holcim is a wholly-owned subsidiary of Holcim Ltd., of Switzerland, one of the largest Portland cement companies in the world. With 14 manufacturing facilities and more than 70 distribution terminals, Holcim is one of the largest cement manufacturers in the United States. It ships over 20 million tons of Portland cement and related materials each year. Holcim has approximately 2,500 employees in the United States, and its annual revenue is approximately $1.1 billion.

HolRail is a wholly owned subsidiary of Holcim. Holcim created HolRail for the purpose of constructing, owning, and operating a new common carrier rail line that would connect Holcim's Holly Hill, South Carolina facility with the NSR.

C. HOLCIM'S OPERATIONS AT HOLLY HILL

Holcim's Holly Hill cement manufacturing facility (the "Facility") is located in Orangeburg County, South Carolina. It produces a range of cement and masonry products and it serves as a bagging facility for Holcim's specialty colored cement. In August of 2003, Holcim completed an expansion project that increased the size of the Facility and doubled its production capacity. The Facility currently has the ability to produce approximately 2 million tons of cement per year.

Holcim relies extensively on inbound and outbound rail transportation to support its operations at Holly Hill. In 2004, the Facility received over 183,000 short tons of coal (1,836

carloads) in 70-car unit trains in order to fuel its kiln. In the same year, the Facility received 13,872 short tons of white cement (146 carloads), 5,384 short tons of lime (57 carloads), and 452 short tons of marble dust (5 carloads). In 2004, the Facility shipped outbound approximately 321,716 metric tons of cement (3,716 carloads) by rail. At optimum production levels, the Facility will tender up to 75 rail cars of cement per day in a single block train.

In 2004, a Holcim subsidiary, Energis LLC, also located at Holly Hill, received 140 tank cars of waste chemicals that were blended for use as fuel. The Facility consumed some of this fuel and Energis LLC shipped the remainder to other Holcim facilities.

Rail transportation is the most efficient transportation mode for shipping bulk quantities of coal, sand , and cement. In addition, it is the safest mode for transporting hazardous waste. Furthermore, it is the most economic mode for moving cement over distances greater than 100 miles. Accordingly, Holly Hill must have rail service that meets all of its operational requirements.

D. HOLCIM'S RAIL SERVICE AT HOLLY HILL AND REASONS FOR CONSTRUCTING A NEW RAIL LINE TO ESTABLISH COMPETITIVE ACCESS

Presently, the Holly Hill facility is captive to CSX Transportation, Inc. ("CSX") for all of its rail transportation requirements. Based on its past experience with CSX, Holcim has concluded that CSX's rail service does not and cannot meet the needs of the Facility. For example, restrictions that CSX has placed on Holcim's use of private railcars have harmed the Facility because CSX frequently cannot meet the Facility's railcar requests with its own cars within required times. Moreover, CSX's cars are frequently in an unusable condition. Rejection of such cars interferes with operations and imposes costs on the Facility. Generally speaking, CSX's track record at Holly Hill is weak; its service is unreliable and inadequate; and, its customer representatives have been indifferent to requests for improvements. Thus, Holcim

strongly desires to establish a competitive rail alternative for the Facility that will meet its requirements. Holcim created HolRail in order to accomplish this objective.

Once completed, HolRail's new rail line will create competition between CSX and NSR. Holcim believes that competition will result in more responsive, more reliable, and better rail service. Improved rail service, in turn, will support Holly Hill's increased production by enabling the Facility to supply distant markets and to compete in new markets. In addition, rail competition will reduce rates and make the Holly Hill facility more competitive with other cement producers, including two other large production plants within five miles that have competitive rail service. Thus, competitive rail access will allow the Facility to achieve the full benefits of the recently completed plant expansion.

E. ROUTES THAT HOLRAIL CONSIDERED FOR ITS NEW RAIL LINE.

Holcim considered three routes for construction of its new line of rail from the Holly Hill facility to a connection with NSR. I refer to these routes as the "Preferred Route," the "Alternate Route," and the "Rejected Route." All of these construction routes generally would extend south from the Holly Hill facility for approximately 2.3 miles and tie into an existing track located on the property of Giant Cement Company, Holly Hill's southern neighbor. In the following paragraphs, I will describe the foregoing routes and explain why Holcim chose to pursue the Preferred Route.

Holcim initially sought to avoid the environmental consequences of new rail construction altogether by first asking CSX to allow NSR to access the Holly Hill Facility over CSX track. Under the "Carolinas Plan," CSX currently switches all shippers located between Pregnall and Giant, South Carolina for both itself and NSR. In order to serve Holly Hill, CSX and NSR

would need only to extend the scope of the "Carolinas Plan" by approximately two miles to reach Holly Hill. CSX, however, refused to consider this option.

Faced with the need to construct a separate rail line from Holly Hill to the NSR, Holcim initially focused its attention upon the Alternate Route because it could be constructed on property Holcim already owned over most of its length. That route would run parallel to the existing CSX line approximately 130 feet to the east. Construction was determined to be both practical and feasible.

However, in the early planning stages, it was immediately clear that the Alternate Route would pose significant environmental concerns because it would cross undisturbed areas of Four Hole Swamp, an environmentally sensitive wetland. The Alternate Route would disturb approximately 27 acres of wetland and it would create an "island" between it and the CSX roadbed that would adversely impact native plant and animal species. These concerns are discussed in detail in the Verified Statement of Mark Taylor.

Because of the environmental consequences posed by constructing a rail line on Holcim-owned property, Holcim sought to explore other routes that would have fewer consequences. The best option was to widen the existing transportation corridor across Four Hole Swamp, which consisted of South Carolina Highway 453 and the CSX rail line, since that would impact fewer acres of wetland and would not create the "island" effect that two separate transportation corridors over 100 feet apart would create. This would entail constructing the rail line immediately adjacent to either Highway 453 on the west or the CSX line on the east.

Because of the anticipated objections of CSX, Holcim first explored the feasibility of constructing its rail line over the Rejected Route, within a utility easement on the west side of Highway 453. However, Skeen quickly identified numerous problems that rendered that route

both impractical and highly undesirable. Skeen summarized its concerns in a March 7, 2005 letter to Holcim, which I have attached as Exhibit A.

First, the Rejected Route would have required two at grade crossings of Highway 453 within less than two miles, the first near the northern terminus at Holly Hill and second near the southern terminus at Giant. Both of these highway crossings would have occurred at fairly sharp angles, making them more dangerous, more expensive, and more difficult to maintain. In addition to an existing CSX grade crossing, these crossings would have been the second and third such crossings in as many miles, which would raise objections from the State based on public safety and convenience.

In order to be operationally feasible, the Rejected Route also necessitated construction of a marshalling yard for Holly Hill on the opposite side of Highway 453 from the Facility. Switching cars to and from the Facility frequently would block the highway for extended periods of time. And, the line from the yard into Holly Hill would require a crossing of CSX's existing track, raising additional contingencies for construction and operations.

Moreover, construction of the Rejected Route would be incompatible with presently existing utilities. The right-of-way, which is only about 35 feet wide, would be too narrow to accommodate a rail line and the existing utilities. The project would have required relocation of the underground natural gas line and perhaps the overhead power lines. Also, large pools of standing water would have required substantial amounts of fill. Finally, the Rejected Route did not achieve significant environmental benefits over the Preferred Route.

Due to the significant problems associated with the Rejected Route, HolRail turned its attention to the Preferred Route, which would abut the CSX line on the east side of the existing transportation corridor across Four Hole Swamp. HolRail's environmental consultant, Fletcher,

concluded that the Preferred Route would create the fewest problems for the ecology of Four Hole Swamp. For example, construction of the new line immediately adjacent to the existing CSX line eliminates the potential for the "island" effect created by the Alternate Route and the consequences arising therefrom. The Preferred Route also would impact only 8 acres of wetland, compared to 27 acres for the Alternate Route, which significantly diminishes displacement of plants and animals.

Additionally, HolRail's engineers, Skeen, determined that construction and operation of the Preferred Route would be the most practical and feasible alternative, and that it could be constructed without significant interference to CSX's operations. Indeed, I subsequently learned that HolRail's roadbed actually would reinforce the stability of CSX's roadbed. The Preferred Route also avoids any highway crossing and the associated public safety and operating concerns.

Based upon the environmental and operating factors discussed above, Holcim decided to pursue the Preferred Route as the best option for both itself and the overall public interest. Although HolRail has preserved the Alternate Route as a fall back option, it very much wants to pursue this project in the form that is best for the overall environment in which HolRail, Holcim, and their employees live and work.

VERIFICATION

I, Looman Stingo, hereby verify under the penalty of perjury that I am qualified and authorized to submit this Verified Statement on behalf of Holrail, LLC and that all of the facts set forth in the foregoing Verified Statement are true and correct to the best of my knowledge. I know that willful misstatements or omissions of material facts constitute federal criminal violations punishable under 18 U.S.C. § 1001 by imprisonment up to five years and fines up to $10,000 for each offense.

Looman Stingo

August 3, 2005

TAB A

SKEEN RAILROAD ENGINEERING

RAILROAD DESIGN AND CONSULTING
SITE PLANNING, INSPECTIONS

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J. GARY SKEEN, P.E.
B. PATRICK SKEEN, P.E.
45 YEARS EXPERIENCE

March 7,2005

Mr. Pat Roesler
Terminal Operations Manager
Holcim U.S.A., Inc.
1100 Victors Way
Suite 50
Ann Arbor, MI 48108

RE: ALTERNATE RAIL ALIGNMENT (WEST SIDE OF HIGHWAY 453) FOR PROPOSED HOLRAIL TRACK AT HOLLY HILL, S.C.

Dear Mr. Roesler:

Pursuant to your requests, Skeen Railroad Engineering (SRE) will outline below the many problems associated with locating the new Holrail trackage on west side of State Route 453. These problems are as outlined below.

1. An alignment on west side of State Route 453 will require two at grade crossings of existing highway. These two crossings would be very long since they would cross highway at very acute angles (25° or less). Railroad crossings at acute angles are typically less safe than perpendicular crossings. Since these crossings would most definitely require protection for vehicular traffic (lights, gates, and bells), the acute angles would make crossings more expensive than normal, unsafe and more difficult to maintain.

2. The alignment will require at least one rigid rail crossing of CSX main track, which would be an operational and maintenance liability. Any rigid rail crossing of CSX main track will require their approval and STB approval. This could prove to be as difficult a process as the encroachment approval on east side of highway.

3. The crossings will present major operational problems, especially on north end of project. All switching in and out of marshalling yard would have to cross highway frequently, blocking it for extended periods of time.

4. There does not appear to be enough right-of-way along power line to allow for construction of rail system. Assuming the power company would agree to such an encroachment, they most certainly are going to require assurances that their system is not jeopardized by rail system and its operation.

5. The liability of operating across these crossings will be great. All engineers operating Holcim locomotives or trackmobiles across these crossings would have to be FRA certified and licensed. All switching of cars across these crossings will require air on train line, which greatly increases operating time.

6. The construction costs for this system will be higher than that of system on east side of CSX main track. Primarily, this is due to more required trackage, long road crossings, and less upland area for roadbed construction.

I would strongly recommend against the construction of a rail system on the west side of State Route 453 for the above reasons. Before considering an alignment on west side of State Route 453, all other alternatives should be thoroughly explored.

Sincerely,

J. Gary Skeen, P.E

Davis V.S.

Before The Surface Transportation Board

STB Finance Docket Nos. 34421 And 34421 (Sub-No. 1)

HolRail LLC - Petition For Crossing Authority

Verified Statement

of

Gene A. Davis, P.E.

Before The Surface Transportation Board
STB Finance Docket No. 34421 And 34421 (Sub-No. 1)
HolRail LLC - Petition For Crossing Authority

Verified Statement
of
Gene A. Davis, P.E.

Qualifications

I am Gene A. Davis, P.E., a consultant with the firm of R.L. Banks & Associates, Inc. (RLBA), a railroad transportation consulting firm comprised of engineers, economists and planners, located at 1717 K Street, NW, Washington, DC 20036. My title is Director, Transportation Engineering and my qualifications are detailed in Exhibit A. I appear in this proceeding on behalf of HolRail LLC.

Scope of Testimony

CSX Transportation (CSX) owns a rail line, portions of which are in Orangeburg and Dorchester Counties, SC between Pregnall and Vance, which is the subject of this proceeding. At Holly Hill, SC, CSX currently provides rail service to the Holcim (US) Inc. (Holcim) cement plant. HolRail LLC, (HolRail) seeks to construct and operate new main and industry tracks providing additional rail access between Holcim's facilities southward to the rail yard adjacent to a plant owned by Giant Cement (Giant) about two miles south of Holcim.

The "Preferred Route" alignment of HolRail's proposed construction is mostly parallel to the existing CSX main track and portions are contained within the CSX right-of-way (ROW). HolRail also has proposed an "Alternate Route" alignment to provide similar access to the Holcim cement plant that could be entirely constructed within

Holcim property with the possible exception of track tie-in points at the Giant yard and Holcim plant area. My contribution to this proceeding is to provide an opinion based on my analysis of which alignment option poses the least environmental impact, provides the most track stability and makes the most economic sense while causing minimal disruption to current CSX operations.

Information Sources

In addition to conducting an on-site physical inspection of the subject property on December 13, 2004, I have reviewed documents produced by CSX in response to HolRail information requests concerning the area of interest. I also have reviewed the following material created by or on behalf of HolRail: an April 28, 2005 report by Carolina Consulting Engineers, Inc. (CCE), which is attached as Exhibit B; a Skeen Railroad Engineering (Skeen) letter to Holcim detailing proposed construction procedures, dated March 7, 2005, attached as Exhibit C; Skeen Drawing No. 05-0530, containing the HolRail track layout, cross-sections, and bridge drawings, attached as Exhibit D; and another Skeen drawing (undated) illustrating a typical cross section of the proposed construction, attached as Exhibit E.

Description of Construction Project

HolRail proposes to construct a new line of rail between the yard adjacent to the Giant facility and the existing Holcim cement plant. All switch and track construction would be completed utilizing American Railway Engineering and Maintenance-of-Way Association (AREMA) and Federal Railroad Administration (FRA) standards and will be sufficient to handle at least 286,000-pound capacity rail cars. All switches will be hand operated and either of #8 or #10 angularity. Typical track roadbed construction is illustrated on Skeen Sheet 8 (Exhibit D) with its track components most likely consisting of:

- 100 pound per yard or greater rail (new or #1 relay);
- minimum 6 inch by 8 inch (cross section) by 8 foot 6 inch (length) new, treated timber ties;

- new or relay tie plates on each tie (double shoulder preferred);
- four or six-hole rail joint bars with sufficient bolts, washers and nutlocks;
- sufficient rail anchors given class of track;
- standard cut track spikes and
- ballast, sub-ballast and sub-grade materials sufficient to comply with AREMA standards.

Exhibit C contains construction procedures proposed to govern the HolRail track system and supplements the drawings, providing an overview of the project. Bridges will be ballast deck with pre-cast concrete span components, have a walkway on the east side of each and either be as long as or slightly longer than the existing CSX wooden trestles. Bridge pilings will be of fourteen inch H-pile, with the configuration based on bent type and location in the bridge. Exhibit D, Sheets S1-S7, contains preliminary detailed bridge plans along with typical member components and construction materials. Following is a brief description of each route being considered by HolRail.

Preferred Route

HolRail proposes to construct the Preferred Route entrance/exit via a #10 right-hand (RH) turnout at the north end of the existing Giant yard between the Norfolk Southern (NS) In switch and the CSX Out switch at STA. 0+00 as illustrated in Sheet 2 of the Skeen drawings (Exhibit D). The Preferred Route would then proceed northeast traversing an existing gravel road crossing having a 48 inch reinforced concrete pipe (RCP) underneath, which would require extending as illustrated in Sheet 2 of Exhibit D. The proposed new switch and track construction would proceed northeast until approaching the south end of the new HolRail yard, (sometimes referred to in other documents as a marshalling yard), consisting of three tracks capable of handling about 27 cars each and one track with capacity being 26 car lengths, used to receive and store loaded and empty cars. Those four tracks would be considered the new HolRail main and three additional storage tracks. Switches on the south end of the HolRail yard

would consist of one RH and two left-hand (LH), #8 switches. Track construction at the south end of the HolRail yard may encroach a few feet on the east side of CSX ROW for about 150 to 250 feet and then construction would continue entirely on Holcim property to the north end of the yard. Switches on the north end of the HolRail yard consist of three #8 RH, hand throw mechanisms. All curves in the HolRail yard area are twelve degrees or less.

The new HolRail main track then proceeds north/northwest toward the CSX main track, crossing onto CSX ROW at about STA. 25+50. Just south of STA. 29+00, the HolRail main negotiates a ten degree RH curve and parallels the CSX main track about 100 feet before it crosses the first of three proposed new bridge structures. Track centers between the HolRail main and CSX tracks are proposed to be typically 30 feet and continue to approximately STA. 98+00 as seen on Sheets 3, 4 and 5 of the Skeen drawings (Exhibit D). A typical cross section illustrating the relationship between the proposed HolRail main and existing CSX main track can be seen in Exhibit E. Two additional new bridge structures and one 36 inch RCP will be traversed in this area. Proposed bridge construction will be discussed later in my statement and will be of better, modern materials which are currently utilized on most, if not all, Class I carriers. HolRail proposes to tie into and extend the existing 36 inch RCP under the CSX track about 33 feet at approximately STA. 79+00 to provide unobstructed flow.

At STA. 97+61, HolRail proposes to install a new crossover constructed of two #10 RH hand throw switches to connect the existing CSX track to the proposed HolRail main track south of all current Holcim operations. A 24 inch RCP in this area would have to be lengthened about 40 feet to accommodate the construction of the new crossover and HolRail main. Sheet 5 of the Skeen drawings (Exhibit D) illustrates the new switch placements and track alignments necessary to connect the proposed HolRail main track with all existing tracks serving the Energis facility, coal unloading shed and the plant. The maximum track curvature of new construction in this area is twelve degrees. All new switch and some track construction associated with the crossover and providing access to the Energis facility, coal unloading shed and plant will be on CSX ROW. The proposed HolRail main proceeds north to just beyond STA. 112+00 where it curves to the northeast and crosses the CSX ROW at about STA.

115+00. A proposed #8 RH switch at STA. 118+54 connects the existing track #7403 with the new HolRail main track. Switch construction of this connect will be on Holcim property with some track construction on both Holcim and CSX properties. Additional switch and track construction to facilitate more efficient rail operations within the plant continue north as illustrated on Skeen sheets 5 and 6 and is contained entirely on Holcim property.

Alternate Route

The Alternate Route proposed by HolRail exits the Giant yard at the same location and varies somewhat from the Preferred Route in that the Alternate Route utilizes a twelve degree curve just beyond the entrance switch versus a ten degree curve for the Preferred Route. The Alternate Route then proceeds northeast, traversing the same existing gravel road crossing and 48 inch RCP, which would not require extending under this alignment; however it would require a proposed retaining wall as illustrated in Sheet 9 of Exhibit D. The south end of the proposed HolRail yard utilizing the Alternate Route alignment contains four LH #8 switches providing access to five tracks. The HolRail yard under this route alignment has track capacities of 21, 23, 25 and two tracks capable of holding sixteen cars each. Similar to the Preferred Route, the body of the HolRail yard tracks is all contained on Holcim property. At the north end of the HolRail yard, the five body tracks go through a ladder system consisting of three RH and one LH #8 switches, becoming the HolRail main at approximately STA. 24+00. From the north end of the HolRail yard, Skeen drawing Sheets 2, 3 and 4 (Exhibit D) illustrate the new HolRail main paralleling the CSX main, 35 feet off CSX ROW until it reaches just south of the existing RCP at STA. 79+00. This location coincides with a narrowing of the CSX ROW. Two proposed new bridges would be located within this area. The Alternate Route then turns northwest for about 300 feet and after a slight LH and RH curve, again parallels the CSX ROW until about STA. 95+61, with a third proposed bridge being in this segment. Skeen drawing Sheet 5 shows the proposed crossover from the existing CSX main to the Alternate Route HolRail main track at the south end of all Holcim operations. The obvious difference between the two routes concerning the proposed crossover is that by choosing the Alternate Route, the switch

on the CSX main providing access to the crossover is located farther south than on the Preferred Route. Connections to existing tracks, under the Alternate Route, at Energis and the coal unloading shed, are made entirely on Holcim property and have similar curvature but different connection locations than that of the Preferred Route. The new HolRail main continues generally north until it reaches the proposed switch, approximate STA. 118+54, which provides access into existing track # 7403. From this switch north, both routes follow the same alignment and are entirely on Holcim property.

Route Construction and Timing

Construction methods and timing can affect the attractiveness of each respective route option and are discussed next. Beginning at Giant yard, the new switch would be assembled in an open area adjacent to (just east of) where the proposed switch is to be installed. After coordination with Giant and CSX, a four to six hour outage could be set up to install the switch on the existing main track without interfering with any rail movements. Due to the light amount of rail traffic on this line, most (if not all) construction can be accomplished in connection with this project with little or no delay to CSX movements. Since rail service in this area is a five day a week operation, outages for track construction to existing CSX main track could be accomplished on Saturday, if necessary. CSX may require a flagman to be present (as is common practice) during construction activities along side its track or while on its ROW. One flagman likely would be assigned to cover the entire project even though it covers over two miles. Adjacent road access allows for quick movement between many work locations.

Since both alternatives utilize basically the same configuration until reaching the north end of the HolRail yard and almost all of the new construction in that area is to be performed on Holcim property, no expected delays to CSX rail traffic should occur during construction of the HolRail yard. The HolRail yard location is in one of the drier portions of the Four Hole swamp and likely will result in quicker roadbed preparation.

Exhibit C provides construction procedures proposed by Skeen in connection with the track system and a step-by-step overall outline. As stated by Mr. J. Gary Skeen, P.E., many of the work activities in the subject corridor can occur simultaneously, thus reducing the overall project duration. All bridge, switch and track

construction north of the HolRail yard can be accomplished without long outages or service disruptions to CSX. Periods of time fouling the CSX main likely would be accomplished utilizing a flagman and would require little time to clear to accommodate train movements. Roadbed construction could occur at both project ends while, after a pile drivability analysis and more detailed bridge plans were finalized, construction of the bridges at MP 395.90 and 394.80 could occur simultaneously or in stages. Staff size, equipment availability and construction capabilities of the selected bridge contractor will affect the ability to construct more than one bridge at a time. Construction of the middle bridge at MP 395.10 likely would require roadbed to be built to either abutment before any bridge work could begin.

The Preferred Route would require less clearing of wetland vegetation and as such is considered more environmentally friendly. While no formal calculations of the amount of fill required in connection with either route has been done, it is readily apparent that less fill would be required utilizing the Preferred Route due to the fact that building next to the CSX track as shown in Exhibit E would require about ten to fifteen percent less roadbed. Building track north of the HolRail yard, utilizing either route, will require soil stabilization in wetland areas.

Mr. Skeen offers a description in Exhibit C of how to stabilize the sub-grade (roadbed) area utilizing riprap (stones small enough to be capable of being handled by one or two people) or larger rock. After achieving a height of two feet above water level, smaller rock would be utilized to fill voids in the roadbed. From this point forward, a combination of vibratory rollers, placements of "Geo-Grids" and sub-grade materials would be utilized in one foot lifts to achieve the desired top elevation of the sub-grade. After achieving the desired roadbed height and width, a six inch layer of sub-ballast would be installed and compacted. Track construction could then begin and ballast applied after completion to achieve the desired amount of ballast under the tie, allowing for adequate drainage. This type roadbed construction would be occurring at both ends of the project simultaneously.

Switch and track construction on the northern end of the project would be accomplished similar to that in the Giant yard area. Switches and connection tracks would be constructed near final locations and after coordination with both CSX and

Holcim, track outages for installation would be set up to minimize delays (if any) to CSX or Holcim operations. Typical outages would be in the four to six hour range, depending on complexity of the configuration. All preliminary track construction can be accomplished near existing CSX and Holcim operations, and with good communication, little or no delay should result. Most of the construction on the north end of the project is on natural ground area and would require less roadbed preparation to achieve stability.

Description of Existing CSX Track Conditions

Existing CSX main track in the Holly Hill area is typical of Class 1 railroad secondary main line and on the day of inspection demonstrated good alignment and surface conditions. Track is constructed of 100 pound per yard continuous welded rail (CWR), timber ties, double shoulder tie plates, spikes and rail anchors. According to the CSX-supplied track chart seen in Exhibit F and other information gained through discovery, alignment shows as mostly tangent with the exceptions being slight curves at milepost (MP) 394.5 (one degree) and 394.7 (four degrees), gradient in the subject area is less than 0.14 percent, speed is limited to ten (10) miles per hour (MPH), rail was placed in track in 1988 as fit (relay) rail and was last surfaced in 2001, 2002 or 2003 (depending on location). (CSX Response to First Discovery Request, pp. 6-30). Also contained within the subject area are three wooden trestles at MP 394.80, 395.10 and 395.90. Bridge related information furnished by CSX demonstrated that:

- Bridge at MP 395.90 is a four pile, 19 span, 190 foot timber open deck constructed in 1940, last inspected on June 29, 2004 and receiving a Last Inspection Class of C3 – "Structural member is functional with signs of deterioration. No maintenance is expected between inspection intervals."
- Bridge at MP 395.10 is a four pile, 57 span, 570 foot timber open deck constructed in 1940, last inspected on June 29, 2004 and receiving a Last Inspection Class of C1 – Structural member is in poor condition and

requires monitoring at each inspection. "Structural members noted with this coding should be considered for maintenance program."

- Bridge at MP 394.80 is a four pile, 22 span, 220 foot timber open deck constructed in 1940, last inspected on June 29, 2004 and receiving a Last Inspection Class of C3 – Same as above.

Two switches providing access to Holcim facilities are located at approximately MP 394.5 and 394.7 (*Ibid.*). According to CSX, there have been no known washouts in the area since January, 2000 to present, however there have been five locations where the east shoulder has sloughed off and been replaced with fresh stone, which CSX surfaces about two times per year as seen in Exhibit G, Photo One. The subject area had brush removed about four years ago and is sprayed annually. There has been no soil condition analysis done in the area and no outside contractors have performed any stabilization work on the roadbed. Regular track inspection reports from CSX revealed no surface irregularities in the sample area between January to December, 2004. CSX reportedly installed about 1,911 ties in the two and one-half miles between MP 394.0 and 396.5 in May 2001. The most recent track geometry car test of March 23, 2004 showed no surface or alignment defects in the subject area. (*Ibid.*) The CSX track traverses portions of the Four Hole swamp and exhibits characteristics of track built in low lying areas with swampy areas at the toe of the fill and more defined waterways near the bridge areas. On the day of my inspection, the wooden trestles appeared in good alignment and profile, consistent with the CSX inspection reports supplied to me.

Impact of Construction on CSX Operations

Construction of the Holrail Preferred Route would not interfere with existing CSX operations because, as stated earlier, all bridge, switch and track construction will be performed near existing tracks but would only foul or disturb the CSX main track under the protection of a flagman or during a planned outage over a short time period. Due to the light volume of rail traffic on this line (one train up and back, five days a week), no train delays should occur. Track speed through the corridor is ten MPH and sight distance is good. Under protection of a flagman, construction on CSX ROW would be accomplished with work equipment and/or employees clearing the CSX main or any Holcim industry track as trains approached. The only time periods CSX main track will be affected directly is during the switch installation at the Giant yard and at the proposed new crossover. All other construction will be on joint industry tracks or on Holcim property. Industry track construction also will be accomplished nearby and after communication with all affected parties, connections made and work completed.

CSX claims that new track construction near its existing main track would destabilize its roadbed and seriously interfere with regular rail service. To the contrary, Messrs. Sewell W. Crisman, IV, P.E. and John J. Perryman, P.E. address the destabilization issue by stating in their CCE report (Exhibit B, p. 1) that

> [W]e understand from speaking with CSX representatives that they continually stabilize this embankment. From a geotechnical perspective, construction of an embankment adjacent to the existing slope will assist in stabilizing the existing slopes.

Based in Charleston, SC, Messrs. Crisman and Perryman are extremely familiar with local conditions and after an extensive number of soil borings (56) reached their determination. CCE conducted sub-surface exploration utilizing American Society for Testing and Materials (ASTM) and Standard Penetration Testing (SPT) methods with locations selected based on the proposed railroad layout (Exhibit B, p.2-17). Selected split-barrel samples were collected, labeled and sent for testing. (*Ibid.*) Surface conditions during the soil testing varied from sand ridges to organic muck flats. (*Ibid.*) For a complete description of ASTM testing methods utilized along with soil boring results, please refer to Exhibit B.

In the area of more defined waterways of the Four Hole swamp, typically at the three current bridge locations, water levels were estimated to vary by season, most likely not exceeding ten feet during wet periods of the year. (*Ibid.*) At all other locations along the roadbed, during periods of high water, the presence of another roadbed on the east side of the CSX main track, such as that proposed as part of the Preferred Route, actually would help to stabilize the CSX main by keeping water that could seep (or migrate) through the CSX roadbed farther away. Water that would be forced into the side of the embankment would have to seep through the new HolRail main roadbed before it could actually reach the existing CSX main roadbed. The same conditions would be true during periods of low water, though not as much hydraulic pressure would likely be forcing the seepage.

With State Route 453 on the west side of the CSX main, the road acts to help stabilize the CSX roadbed and prevent standing water near the toe of the fill on the west side. A drainage ditch provides water runoff between the road and the CSX main track. CSX likely would experience a similar stabilizing effect were the HolRail main to be built utilizing the Preferred Route alignment due to water not being able to stand near the toe of the east side fill (as it does at present). Selection of the Alternative Route alignment would allow standing water between the two mains and eliminate the advantages gained by having the two tracks in close proximity. Due to the low lying topography, the Alternate Route alignment likely will allow water to migrate close to the east side of the CSX main line whereas, if the Preferred Route were chosen, the CSX track likely would experience standing water only near the bridge openings.

During construction of the corridor, appropriate safeguards would be taken to ensure the stability of existing CSX roadbed. Such safeguards would likely include:

- saw cutting (tie-in) into the toe/slope of the existing CSX roadbed, as seen where the CSX and HolRail sub-grades would potentially meet, illustrated in Exhibit E. These saw-cuts would be undertaken progressively as HolRail roadbed work is being performed that day so as not to destabilize other areas of existing CSX roadbed and

- a daily walking inspection at the end of the work day of the area where work was performed that day.

Construction of the Preferred Route alignment potentially could eliminate the need for future CSX corrective maintenance measures such as driving rail or piling (as seen in Exhibit G, Photo Two) to act as a slope stabilizer or dumping loads of riprap to protect or rebuild the slope (as seen in Exhibit G, Photo One), which CSX already has performed on the east side of its line. Riprap use is likely to have occurred within the last five years, while slope stabilization pile driving appears to have been performed many years ago and is verified by CSX response to interrogatory item # 6 in that To the best of CSXT's knowledge and belief, there have been no washouts since January 1, 2000 to the present.

CSX further claims that new bridge construction could destabilize its existing wooden trestles. Although CSX does not clearly state the basis for its concern, the most likely concern that it might have during adjacent bridge construction would be that performed during pile driving. Pile driving during nearby bridge construction, however, should have little to no effect on current CSX bridge stability. Given the moist soil conditions of the area, vibration transfer during pile driving to the existing bridge area will be minimal, if any.

CSX's existing wooden trestles are on timber driven piles with some helper bents installed, for example at MP 395.90 Bent # 5 plus helper bent, as seen in Exhibit G, Photo Three. During discovery, CSX furnished the latest bridge inspection reports of the subject bridges dated June 29, 2004 demonstrating that it regularly inspects its bridges, most likely annually. The 2004 inspection showed that the timber trestles contained within the limits of study are showing signs of wear (typical of their age) but no immediate repairs were deemed necessary, specifically for the bridges at MP 395.90 and 394.80. The bridge at MP 395.10 was considered overall to be in the worst condition of the three and was classified as C1 which means, Structural member is in poor condition and requires monitoring at each inspection. Structural members noted with this coding should be considered for maintenance program.

Pile driving for the new bridges, regardless whether the Preferred or Alternate Route is chosen, would be followed by a thorough bridge inspection of each CSX trestle after completion of the pile driving process. The presence of a CSX flagman with a daily walking inspection of work performed in that area will assure that no helper bents have shifted during the pile driving operation at each location.

Since helper bents are traditionally placed on mud sills resting on either blocking or the ground, occasional shimming of the caps is the most likely remedy that might be required to maintain elevation. This occasional shimming, if required, could be monitored by the CSX flagman. Viewing the existing CSX bridge inspection reports, it should be noted that some shimming of helper and driven bents is required now but is not sufficient to warrant immediate repairs. For example, in Photo Three (Exhibit G), note that the helper bent currently is not flush with the bottom of the stringers.

New bridge construction will have span lengths ranging between 20 and 24 feet, depending on location in bridge, which is two or more times greater than the existing span lengths of current CSX wooden trestles (nominal span length of ten feet). This additional span length will allow for more free water flow and less chance of any drift collecting on the east side of the bridges. Twenty and 24 foot pre-stressed concrete span lengths are common in railroad new bridge construction.

During my eighteen years of track and bridge experience with NS, I personally supervised the construction of numerous bridges, culverts and tracks in areas quite similar to those exhibited in this docket. While in Georgia, my territory had similar soil and water characteristics to that of the Holly Hill area. I have seen a three-quarter mile side track constructed in a low lying, marshy area near Millen, GA utilizing the same techniques and flagman protection listed above with no negative impacts on the main track and no train delays other than when the switches allowing access to the siding were installed. I also have performed repairs to tracks damaged during flooding in Georgia, Virginia and West Virginia and am quite familiar with track work in wet areas.

During my time in Georgia, I supervised the construction of eighteen to twenty new bridges and installation of 70 to 75 new culverts or extensions of existing culverts. Almost all of the bridge replacements that I supervised (many of which also had helper bents) were conversion of wooden trestles to pre-cast concrete, ballast deck bridges

utilizing H-pile similar to what is proposed in this project. At no time during the pile driving process of any bridge location (single or double track) was the existing bridge weakened to the point of needing repair. Monitoring the nearby CSX wooden trestles at Holly Hill during the pile driving operation will ensure that if any displacement of helper bents occurs, necessary, immediate repairs can be made to negate any delays to rail traffic.

Conclusion

If the proposed crossing authority is granted using the Preferred Route alignment, the impact on CSX operations will be minor and the CSX line will not experience any long lasting negative effects due to the construction of the adjacent HolRail main track on CSX ROW. Use of proven engineering methods during construction of the HolRail main can eliminate or negate any potential for damage to the existing CSX track. Indeed, CSX most likely will enjoy a more stable roadbed if the Preferred Route is chosen over the Alternate Route. Thus, from an engineering perspective, it makes more sense to choose the Preferred Route.

Verification

I, Gene A. Davis, P.E., verify under penalty of perjury that I am the same Gene A. Davis, P.E. whose statement of Qualifications appears in Exhibit A of HolRail LLC's Petition for Crossing Authority in this proceeding; that I am responsible for the portion of HolRail LLC's Petition for Crossing Authority in this proceeding related to the track structure and train operations of CSX Transportation contained in Orangeburg and Dorchester Counties, SC, in particular portions near the cement manufacturing plant owned and operated by Holcim; that I know the contents thereof; and that the same are true and correct. Further, I certify that I am qualified and authorized to file this statement.

Gene A. Davis, P.E.

Subscribed and sworn to before this 16th day of June, 2005.

Notary Public

GWENDOLYN M. PENN
NOTARY PUBLIC, DISTRICT OF COLUMBIA
MY COMMISSION EXPIRES 9-14-2009

EXHIBITS

TAB A

Gene A. Davis, P.E.
Director, Transportation Engineering

Education
MBA, Georgia Southern University, 1997
BS, Civil Engineering, Tennessee Technological University, 1983

Professional Registrations and Affiliations
Registered Professional Civil Engineer
American Railway Engineering and Maintenance-of-Way Association, member since 1996
AREMA Member of Technical Committee 12 (Rail Transit) and 18 (Light Density & Short Line Railways)

Years of Transportation Experience
20

Qualifications
Mr. Davis joined RLBA after 18 years of experience with Norfolk Southern Corporation during which he held positions with increasing responsibility within the Engineering Department spanning management and engineering of railroad track structure, bridge and building inspection, condition assessment, maintenance, rehabilitation, design and construction as well as railroad operations.

Relevant Project Experience

- ***Morehead City Terminal/Carolina Rail Services*** Performed a physical inspection and evaluated track condition of seaport terminal operation in Morehead City, North Carolina and determined cost to upgrade and maintain track structure to support handling of 286,000 pound rail cars.

- ***At-Grade Rail-Highway Crossing Dispute - Expert Witness*** Provided point by point rebuttal information pertaining to an ongoing legal preceding concerning grade crossing upgrades and construction effects on a short line railroad's viability. Provided grade crossing construction costs and projected future maintenance cost to current dollars.

- ***State of Washington Department of Transportation*** Inventoried, physically inspected, assessed condition and valued portions of the Palouse River and Coulee City Railroad between Cheney, WA and Coulee City, WA and between Marshall, WA and Hooper Junction, WA as well as all diverging routes in Idaho and Washington, totaling 347 miles and provided a point-by-point rebuttal to comments made by a review appraiser. Net liquidation values were placed on the physical assets of six, separate sub-segments as well as the whole.

- ***Saratoga Economic Development Corporation*** Assessed the ability of the Canadian Pacific Railway's Adirondack Branch to support potential future passenger and/or freight train operations between Saratoga Springs and Corinth, New York in connection with the prospective purchase of the line by RLBA's client. After physical inspection of the many critical assets, in particular bridges, switches and public, at-grade highway-rail crossings, provided an opinion letter as to the track and bridge structure condition. A review of proposed force account work charges necessary to bring the line up to Class 2 track standards also was conducted. Prioritized additional capital spending in the event additional funding was available.

- ***Philadelphia, Bethlehem and New England Railroad*** Performed an NLV and replacement cost estimate utilizing all new materials via a physical track inspection of approximately 42 miles of this switching carrier.

- ***Santa Fe Trails*** Physically inspected and assessed the condition of about 20-miles of Santa Fe Southern Railway track structure between Santa Fe and Lamy, New Mexico. Particular attention was given to drainage structures (bridges and culverts), switches and public at-grade highway-rail crossings along with general track conditions, after which, cost estimates were provided for up to five years to maintain track in a steady state of repair. Comprehensive component condition assessment and cost estimates were associated with due diligence in connection with a possible sale to the public agency preserving rail access to Santa Fe. Provided potential maintenance costs to right-of-way were track to be abandoned.

- ***Northeastern Vermont Development Association*** Advised the Association of the estimated, initial capital cost to reopen rail a line between St. Johnsbury and Gilman, Vermont. After physical inspection of many critical assets, in particular bridges, switches and public at-grade highway-rail crossings, cost estimates were provided to achieve FRA Class 1 track conditions.

- ***The City of West Sacramento Redevelopment Agency*** Inventoried, physically inspected, assessed condition and estimated the net liquidation value of the track structure in a segment of Yolo Shortline Railroad Company railroad right-of-way between West Sacramento and Clarksburg, CA.

- ***The Transportation Agency of Monterey County*** Inventoried, physically inspected, assessed condition and valued Union Pacific Railroad Monterey Branch Line between Castroville and Pacific Grove, CA. Net liquidation values were placed on the physical assets of six separate sub-segments as well as the entire branch.

- ***Iowa Northern Railway Company*** Inventoried, physically inspected, assessed condition and valued railroad right-of-way between Cedar Rapids and Waterloo, IA and between Cedar Falls and Manly, IA. Net liquidation values were placed on the physical assets of both segments before and after track rehabilitation which were utilized in a FRA RRIF application.

- ***SF&L Railroad*** Inventoried, physically inspected, assessed condition and valued railroad right-of-way between Peoria and La Harpe, IL. A net liquidation value was placed on the track structure.

Areas of Expertise

- ***Track and Structure Planning, Rehabilitation, Engineering and Maintenance*** Planned, scheduled and supervised numerous, large track projects such as tie renewals, rail installation, track resurfacing, shoulder cleaning and undercutting operations, structure upgrading and grade/sub-grade stabilization. Supervised numerous bridge and culvert rehabilitation projects including complete renewals, extensive tunnel repairs and tunnel portal reconfigurations. Was responsible for creating capital and operating budgets and working within them. Managed tasks at all levels of engineering responsibility including third party contract work on many projects. Has extensive experience in emergency response and repair.

- ***Design*** Participated in the redesign of the track layout in Sandusky, Ohio yard to streamline operations and the redesign of existing physical plant trackage owned by railroad customers. Responsible for the concept and design of the "Infopage" computerized asset utilization system implemented on Norfolk Southern to better utilize track and bridge components on-hand or inventoried.

- ***Operations*** Experience with switching and yard operations, train performance, customer service, FRA rules, regulations and labor agreements.

- ***Grade Crossings and Other Safety Issues*** Grade crossing committee member on the divisions while serving as a Track Supervisor. The committees sought to eliminate redundant grade crossings, reducing exposure to collisions. Helped facilitate a training conference for 250 Norfolk Southern Eastern Region engineering supervisors addressing the effect on bridge rail alignments of excessive heat and drastic temperature changes that traditionally occur in the Summer. Presentations then were made to front-line maintenance staff.

Norfolk Southern Corporation Work Experience

- ***Track Supervisor (Lake and Pocahontas Divisions)*** Lake Division territory encompassed trackage in Columbus, Delaware, Bucyrus, Bellevue and Sandusky, OH. Pocahontas Division territory included Welch, WV and Richlands, VA. Performed FRA inspections and accomplished remedial repairs to track structure via routine maintenance and rail, tie/surfacing and surfacing gang work. Coordinated contract services including rail grinding and undercutting. On the Lake Division, responsible for over 110 miles including Sandusky Yard and two smaller yards. Pocahontas Division responsibilities included over 36 miles of double and triple track mainline and 44 miles of single track mainline including Auville Yard.

- ***Assistant Division Engineer-Bridges (Pocahontas Division)*** Territory spanned trackage in Charleston and Bluefield, West Virginia, Norton, Virginia and Columbus and Portsmouth, Ohio. Coordinated and facilitated new construction, inspection, and maintenance of drainage structures including bridges and culverts. Coordinated remedial repairs to tunnel structures including portal upgrades. Solicited bids for repairs by contractors and performed repairs to roadway buildings, using company forces. The 1,300 miles of his territory included over 24 miles of various bridge types, 8,000 culverts of varying construction types, 20 miles of tunnels and 16 miles of slide fences.

- ***Bridge and Building Supervisor (Georgia Division)*** Territorial responsibility covered 500 miles including Savannah, Augusta and Macon, Georgia. Performed inspections, supervised maintenance repairs and new construction by company forces of drainage structures including bridges and culverts.

- ***Assistant Track Supervisor (Pocahontas and Virginia Divisions)*** Territory on the Pocahontas Division encompassed trackage in Bluefield and Welch, West Virginia. Virginia Division responsibilities included trackage in Norfolk, Virginia. Performed FRA inspections and remedial repairs to track structures. Assisted in coordinating program maintenance work and contract service work on the track structure. Mr. Davis was responsible for 34 miles of double and triple track on the mainline as well as Bluefield Yard on the Pocahontas Division. Virginia Division responsibilities included 7 miles of double track mainline and also the company's key export coal terminal at Lamberts Point Yard and Portlock Yard in Norfolk Terminal.

- ***Management Trainee (Virginia Division)*** Territory encompassed trackage in Roanoke and Norfolk, Virginia and Bristol, Tennessee. Learned all aspects of track maintenance across the entire Virginia Division through hands-on experience while receiving basic exposure to the supervision of inspection and repair to the track structure.

Turner Engineering

- ***Resident Engineer*** Mr. Davis was the on-site resident engineer of a railroad bridge reconstruction near Cordova, Alabama. He ensured the plans and specifications of Turner Engineering were adhered to during field operations of the bridge reconstruction. Mr. Davis acted as a liaison between the railroad and the contractor who performed the bridge reconstruction.

TAB B

Carolina
CONSULTING
ENGINEERS
Inc.

REPORT OF GEOTECHNICAL EXPLORATION

PROPOSED RAILROAD
HOLRAIL, LLC
HOLLY HILL, SOUTH CAROLINA

Prepared for:

Holcim, Inc.
P.O. Box 698
Holly Hill, South Carolina 29059

Submitted by:

Carolina Consulting Engineers, Inc.
2398 Clements Ferry Road
Charleston, South Carolina

April 28, 2005

CCE Project Number 01-04-1104

April 28, 2005

Carolina CONSULTING ENGINEERS Inc.

Holcim, Inc.
Post Office Box 698
Holly Hill, South Carolina 29059

Attention: Mr. Robert West

Subject: Geotechnical Exploration
Proposed New Railroad
Holly Hill, South Carolina
CCE Project Number 01-04-1104

Dear Mr. West:

Carolina Consulting Engineers, Inc. (CCE) is pleased to submit this report of Geotechnical Exploration for the referenced project. This exploration was authorized by your acceptance of our proposal 04-1090R, dated November 1, 2004. The purpose of this exploration was to obtain information on subsurface conditions and to provide recommendations for site preparation, fill placement, and bridge pile design. This report describes the work performed and presents the results obtained, along with our geotechnical recommendations. An assessment for either site environmental conditions or for the presence or absence of pollutants in the soil, rock, and surface water of the site were beyond the scope of our exploration.

Along with the undersigned, a significant contributor to this report was Mr. E. Lowry Shuler, P.E.
We appreciate the opportunity to be of service to you on this project.

Sincerely,

CAROLINA CONSULTING ENGINEERS, INC.

SOUTH CAROLINA REGISTERED PROFESSIONAL ENGINEER No. 19796 SEWELL W. CRISMAN

Sewell W. Crisman, IV, P.E.
Principal Engineer
Registered SC 19796

John J. Perryman P.E.
Principal Engineer
Registered SC

SOUTH CAROLINA CAROLINA CONSULTING ENGINEERS, INC. No. C02705 CERTIFICATE OF AUTHORIZATION

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EXECUTIVE SUMMARY

The basis of our recommendations is the information provided for the proposed project scope. We received this information in meetings with the project team and from site plans that were prepared by others. Should any of the following information differ, our recommendations may be subject to change.

Holcim, Inc. (Holcim) plans to construct a new railroad and marshalling yard between Holcim's cement plant and Giant Cement's (Giant) plant south of the existing CSX railroad. Holcim has retained Skeen Engineering to perform railroad layout and design as well as gather topographic information. We are utilizing Skeen's preliminary layout and proposed track elevation to provide our geotechnical recommendations. Based on the provided information we understand that a switch will be installed on giant property to turnout to the new rail. The marshalling yard will be between Giant and the first trestle bridge. The current plans include three trestle bridges located adjacent to the existing bridges on CSX's track. We also understand that the new bridges could be longer than the existing bridges.

The project site consists of highly variable surface conditions. Construction of the proposed railroad will encounter difficulties related to clearing, surface water control, and fill placement. The recommendations contained in this report take these difficulties into account.

We expect the three trestle bridges will be supported on driven displacement piles. Due to the encountered soil conditions, we recommend small crossectional area prestressed concrete piles or steel H piles. Recommendations for pile capacities are provided.

We also recommend that once a pile type and capacity are selected, we be retained to conduct a drivability analysis. A drivability analysis will estimate the pile stresses during driving.

1.0 PROJECT INFORMATION

The proposed project will consist of constructing a new railroad located adjacent to the existing CSX railroad near Holly Hill, South Carolina. Specifically the railroad will traverse between the Giant Cement and Holcim Plants (See Figures 1 and 2 in Appendix). The construction includes one mainline railroad with a marshalling yard and associated switches. Since the proposed project crosses Four Holes Swamp, three trestle bridges are required. The purpose of our services is to conduct a subsurface exploration for the proposed alignment and provide geotechnical recommendations for site preparation, fill placement, and pile design parameters.

The basis of our recommendations is the information provided for the proposed scope project. We received this information in meetings with the project team and from site plans that were prepared by others. Should any of the following information differ, our recommendations may be subject to change.

Holcim has retained Skeen Engineering to perform railroad layout and design, as well as gather topographic information. We are utilizing Skeen's preliminary layout and proposed elevation of the track to provide our recommendations. Based on the provided information, we understand that a switch will be installed on Giant Cement's property to turnout to the new rail. The marshalling yard will be between Giant and the first trestle bridge. The current plans include three trestle bridges located adjacent to the existing bridges on CSX's track. We understand that the new bridges could be longer than the existing bridges. Structural loading for the trestle bridges is not available at this time. Therefore, we have provided a range of pile capacities for pre-stressed concrete and steel H piles in Section 5.1.3.1.

During our project meetings, the topic of how the construction and operation of a new railroad will affect the existing CSX railroad was discussed. During our site walk, we observed several areas of embankment instability. We understand from speaking with CSX representatives that they continually stabilize this embankment. From a geotechnical perspective, construction of an embankment adjacent to the existing slope will assist in stabilizing the existing slopes.

2.0 FIELD EXPLORATION

Our field exploration consisted of conducting 56 soil test borings with Standard Penetration Testing (SPT). The boring locations were selected based on the proposed railroad layout. These locations were then flagged in the field by our engineer. The borings were located horizontally and vertically by Prime Engineering, Inc. The boring locations are presented on the following table in State Plane Coordinates and are represented graphically on Skeen Engineering, Inc.'s *Preliminary Rail Alignment.*

Table1: Boring Locations

Boring Number	X	Y	Elevation (ft)
1	26041486.2	6182245.3	71.5
2	26040707.4	6178736.1	74.6
3	26039906.0	6175082.5	78.4
4	26041509.2	6177364.7	77.9
5	26042581.3	6181985.8	77.4
6	26043591.3	6185884.9	74.3
7	26044636.4	6190222.6	70.4
8	26045901.4	6195288.8	68.3
9	26085126.2	6326519.5	76.0
10	26084725.7	6325525.0	76.3
11	26082413.0	6319779.5	77.7
12	26080721.4	6315389.1	78.2
13	26079411.8	6311900.9	78.8
14	26078455.2	6309466.4	78.6
15	26075892.9	6303789.1	76.1
16	26014275.5	6300245.2	74.3
17	26072019.8	6294717.2	72.1
18	26070997.4	6291906.7	69.7
19	26069559.0	6288027.3	66.3
20	26073759.7	6290616.2	72.5
21	26075829.1	6290530.8	69.9
22	26078731.2	6288926.5	71.9
23	26081814.8	6284057.9	70.2
24	26067099.7	6283764.8	64.4
25	26064037.7	6277107.1	63.3
26	26063626.6	6274694.6	73.5
27	26063378.4	6271985.2	64.4
28	26062803.7	6269887.7	64.2

Boring Number	X	Y	Elevation (ft)
29	26062461.3	6268168.8	64.3
30	26061113.4	6263265.5	64.0
31	26059406.0	6255464.1	63.2
32	26058382.0	6251882.2	63.7
33	26056623.4	6245373.3	64.6
34	26055922.7	6242376.0	63.3
35	26055165.0	6239422.0	63.3
36	26054783.0	6236982.0	62.7
37	26054082.1	6233512.2	64.0
38	26053275.9	6230159.0	63.4
39	26052578.8	6227601.7	63.3
40	26051225.8	6221882.9	63.5
41	26050138.6	6217426.8	63.2
42	26048727.0	6211284.5	63.4
43	26047202.6	6205882.9	63.2
44	26046856.4	6204324.1	63.5
45	26046180.0	6200986.3	63.7
46	26045624.1	6198477.2	65.6
47	26044776.7	6195025.5	69.5
48	26044224.7	6192727.6	67.9
49	26043761.6	6190674.9	68.8
50	26042961.4	6187614.8	71.8
51	26042306.5	6185197.3	72.1
52	26072160.0	6290332.0	70.4
53	26071220.0	6289156.0	67.9
54	26069310.0	6286634.0	67.5
55	26067990.0	6284538.0	68.7
56	26073874.7	6291849.1	71.4

3.0 LABORATORY TESTING

We performed laboratory testing on selected samples to verify our visual classifications. In general, we performed wash 200 sieve tests to determine the percent fines, natural moisture content tests and Atterberg limit tests to determine the liquid limit and plasticity index. We conducted these tests in accordance with the applicable ASTM Standards. The standards and procedures are included in Appendix 4. The following tables include the results of our laboratory testing.

Table 2: Laboratory Test Results

Boring	Sample Identification	Depth (feet)	Moisture Content	Passing No. 200 Sieve
B-1	1-1	1.0	16.8%	35%
B-1	1-2	3.0	25.0%	51%
B-1	1-3	5.0	16.9%	23%
B-1	1-4	9.0	23.0%	22%
B-1	1-5	14.5	35.4%	14%
B-1	1-6	19.5	35.7%	10%
B-9	9-1	2.0	14.6%	34%
B-9	9-3	7.0	21.4%	35%
B-9	9-4	9.5	18.5%	25%
B-9	9-5	14.5	20.8%	9%
B-9	9-6	19.5	22.3%	11%
B-9	9-7	24.5	31.3%	20%
B-10	10-4	14.5	57.1%	-
B-12	12-1	4.5	11.5%	32%
B-12	12-2	7.0	29.0%	59%
B-12	12-3	9.5	18.2%	36%
B-12	12-4	14.5	21.2%	16%
B-12	12-5	19.5	24.5%	21%
B-15	15-1	1.5	15.5%	25%
B-15	15-2	4.5	7.6%	26%
B-15	15-3	7.0	14.5%	38%
B-15	15-4	9.5	37.7%	81%
B-15	15-5	14.5	36.7%	52%
B-15	15-6	19.5	22.6%	25%
B-18	18-1	1.0	21.4%	25%
B-18	18-2	3.0	21.4%	28%
B-18	18-3	5.0	14.3%	20%
B-18	18-4	9.0	16.4%	15%

Table 2: Laboratory Results (continued)

Boring	Sample Identification	Depth (feet)	Moisture Content	Passing No. 200 Sieve
B-18	18-5	14.5	83.8%	40%
B-18	18-6	16.5	35.1%	20%
B-21	21-1	3.0	8.5%	25%
B-21	21-2	5.0	14.7%	32%
B-21	21-3	14.5	38.9%	27%
B-24	24-1	1.0	25.9%	47%
B-24	24-2	3.0	17.2%	25%
B-24	24-3	5.0	19.4%	28%
B-24	24-4	9.0	36.2%	19%
B-24	24-5	14.5	26.4%	24%
B-24	24-6	16.5	26.4%	27%
B-27	27-1	2.0	23.8%	39%
B-27	27-2	4.5	22.2%	8%
B-27	27-3	7.0	21.7%	3%
B-27	27-4	9.5	19.8%	3%
B-27	27-5	14.5	27.6%	24%
B-30	30-1	2.0	37.5%	45%
B-30	30-2	4.5	29.9%	12%
B-30	30-3	7.0	43.7%	3%
B-30	30-4	9.5	35.8%	2%
B-30	30-5	14.5	27.1%	27%
B-30	30-6	19.5	29.4%	23%
B-34	34-1	14.5	27.0%	32%
B-34	34-2	9.5	33.3%	13%
B-34	34-3	14.5	31.9%	22%
B-34	34-4	19.5	31.4%	25%
B-34	34-5	24.5	28.6%	27%
B-34	34-6	29.5	28.1%	32%
B-34	34-7	34.5	28.8%	33%
B-34	34-8	39.5	30.0%	27%
B-34	34-9	44.5	35.4%	28%
B-34	34-10	49.5	31.9%	20%
B-34	34-11	54.5	28.2%	27%
B-34	34-12	59.5	31.2%	28%

Table 2: Laboratory Results (continued)

Boring	Sample Identification	Depth (feet)	Moisture Content	Passing No. 200 Sieve
B-36	36-1	1.0	31.8%	29%
B-36	36-2	3.0	22.4%	21%
B-36	36-3	5.0	35.6%	18%
B-36	36-4	9.0	23.9%	22%
B-39	39-1	2.0	22.7%	9%
B-39	39-2	4.5	20.8%	21%
B-39	39-3	7.0	28.4%	3%
B-39	39-4	9.5	23.8%	2%
B-39	39-5	14.5	21.5%	2%
B-39	39-6	19.5	36.5%	22%
B-42	42-1	1.0	15.8%	43%
B-42	42-2	3.0	14.5%	44%
B-42	42-3	5.0	18.2%	43%
B-42	42-4	9.0	36.6%	16%
B-42	42-5	14.5	31.7%	18%
B-45	45-1	1.0	13.8%	117%
B-45	45-2	0.0	n/a	n/a
B-45	45-3	5.0	16.6%	61%
B-45	45-4	9.0	46.6%	56%
B-45	45-5	14.5	32.2%	56%
B-45	45-6	19.5	31.8%	55%
B-48	48-1	1.0	14.9%	68%
B-48	48-2	3.0	23.0%	75%
B-48	48-3	5.0	19.5%	65%
B-48	48-4	9.0	61.4%	85%
B-48	48-5	14.5	34.4%	48%
B-48	48-6	19.5	31.6%	54%
B-51	51-1	1.0	17.9%	68%
B-51	51-2	3.0	17.4%	64%
B-51	51-3	5.0	15.4%	57%
B-51	51-4	9.0	17.7%	46%
B-51	51-5	14.5	19.1%	47%
B-51	51-6	19.5	46.6%	126%
B-51	51-7	24.5	28.9%	59%

4.0 SITE AND SURFACE CONDITIONS

4.1 Site Conditions

The site consists of an operating cement plant and uplands and wetlands of Four Holes Swamp.

The majority of the proposed construction lies in Four Holes Swamp. The ground surface elevation in this area is variable. Surface conditions vary from sand ridges to organic muck flats. This area is seasonally inundated and groundwater is at or near the ground surface. Four Holes Swamp is heavily wooded with large trees and dense underbrush. There are several large bodies of open water. Near the existing CSX Railroad, these bodies have been channeled into three runs which pass under the trestle bridges. Water depth varies with the seasons. However, based on available topographic information, our site observations, and estimated seasonal fluctuations, water depths should not exceed ten feet during wet periods of the year.

In, the upland areas and areas within the cement plant, surface soils are stable under wheeled traffic. These areas have previously been cleared and surface runoff has been established. The surface soils in these areas are typically clayey sands and sandy clays which extend to the Marl. Groundwater elevations range from six to ten feet below the ground surface.

In the plant, we encountered a very dense surface layer. The surface soils have apparently been cemented over the years to depths of 18 to 24 inches.

4.3 Regional Geology

This site is located in the lower section of the Atlantic Coastal Plain Physiographic Province of South Carolina. The soils in this province are generally interbedded silts, sands, and clays that have been deposited during successive advances and retreats of the ocean over the past several million years. Along rivers the marine deposits have been successively eroded and overlain by alluvial deposits.

Most formations within the Coastal Plain were laid down in the shallow sloping sea bottom, tilting somewhat towards the sea at the rate of a few feet per mile. During periods of relatively low sea level, the old bottom deposits emerged, forming plains tilting towards the sea. These plains were subsequently eroded by coastal streams, which formed shallow troughs in otherwise uniform strata.

During periods of relatively high sea level, the former troughs were inundated and filled with more recent sediments. Consequently, many of the formations in the Coastal Plain exist as fractional erosional remnants sandwiched within more continuous strata.

The site is located in the Wicomico Terrace. In natural areas, the Wicomico Terrace ranges in elevation from about 70 to 100 feet above sea level. Beneath the Wicomico Terrace are soils forming the Pre-Pliocene Tertiary, locally termed Marl. Marl is indicated to be of early Oligocene age, approximately 79 million years old. Marl extends to depths up to several hundred feet below ground surface (bgs).

4.4 Subsurface Conditions

The subsurface conditions encountered in the soil test borings are summarized on the Subsurface Profiles and Soil Test Boring Records included in Appendices 2 and 3. The subsurface stratigraphy indicated on the profiles is for illustrative purposes only. The conditions in areas not explored by a boring may vary from those depicted by the soil profile lines drawn between the borings.

In general, we encountered clayey sand and sandy clay from the surface to the top of the Marl. Marl depths range from eight to twenty feet below the ground surface.

Groundwater in the upland areas was measured after completion of drilling at depths ranging from approximately six to ten feet below the existing ground surface. Fluctuations in the ground water level may occur due to variations in rainfall, evaporation, construction activity, surface runoff, and other site specific factors.

5.0 PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

At this preliminary stage, rail alignment configuration, loading conditions and elevations have not been finalized. Specific recommendations for bridge foundation design, embankment design, and site preparation are dependant on these factors. The following paragraphs are intended to provide sufficient information to complete feasibility evaluations for constructing the proposed project on this site. Our recommendations for bridge foundation design, embankment design, and site preparation will be confirmed when the alignment has been finalized.

5.1 Foundations

The trestle bridges are expected to be supported on driven displacement piles. At the time of this report we have not received estimated pile capacities; therefore, we have provided graphs of pile capacity verses depth. It should be noted that we encountered dense layers that may limit the feasibility of driving piles to certain depths. Also due to the density of the Marl formation, we recommend that a drivability analysis be preformed once the individual pile capacities are finalized. The following paragraphs and tables include our recommendations for driven piles.

5.1.3 Driven Displacement Piles

We have prepared pile capacity graphs for Prestressed precast concrete (PSC) and steel H piles.

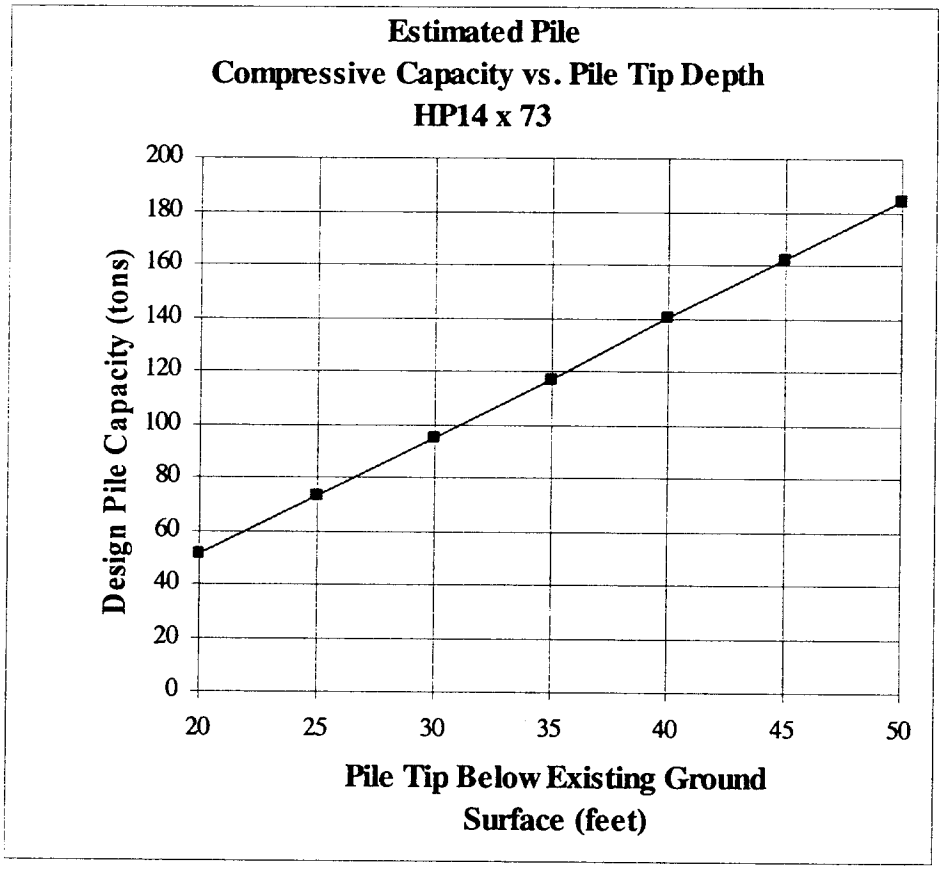
The disadvantages associated with PSC piles are their relatively long lengths (and consequently heavy weight), the necessity for large construction equipment (hammers, cranes, etc.), and the difficulties associated with pile splicing. Also, there has been experience with heaving or lateral displacement of these piles where they have been installed in large pile groups with pile spacing less than three pile widths. Large PSC piles (greater than 18 inches wide) also disturb a significant volume of the Marl as they are driven; reconsolidation of this large volume of disturbed marl may require relatively long lengths of time. Therefore, relatively long lengths of

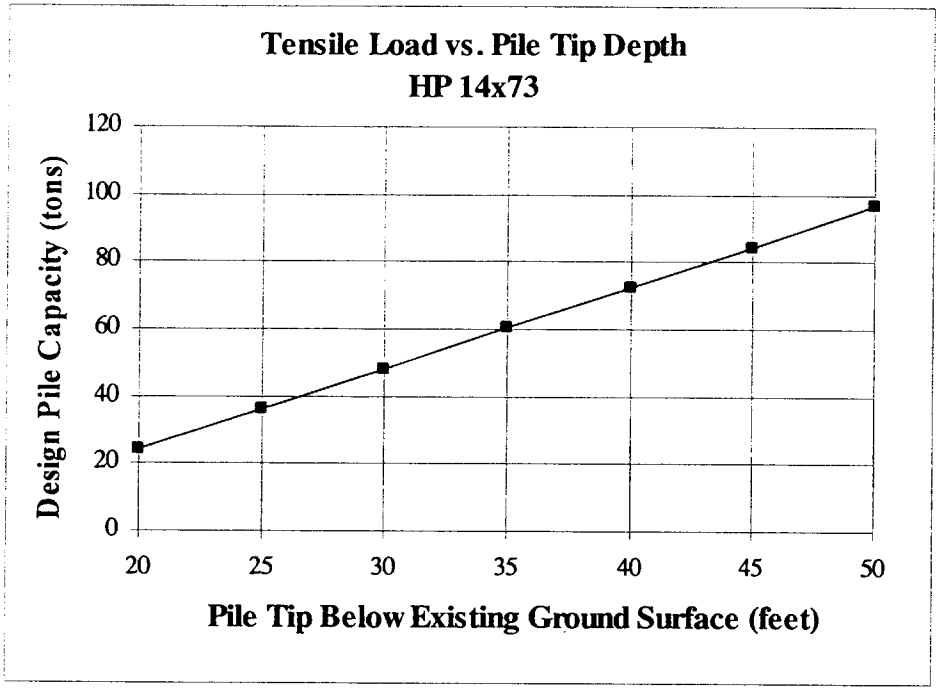
time may be required for piles to achieve their long-term capacity. The problem is accentuated when the piles are grouped.

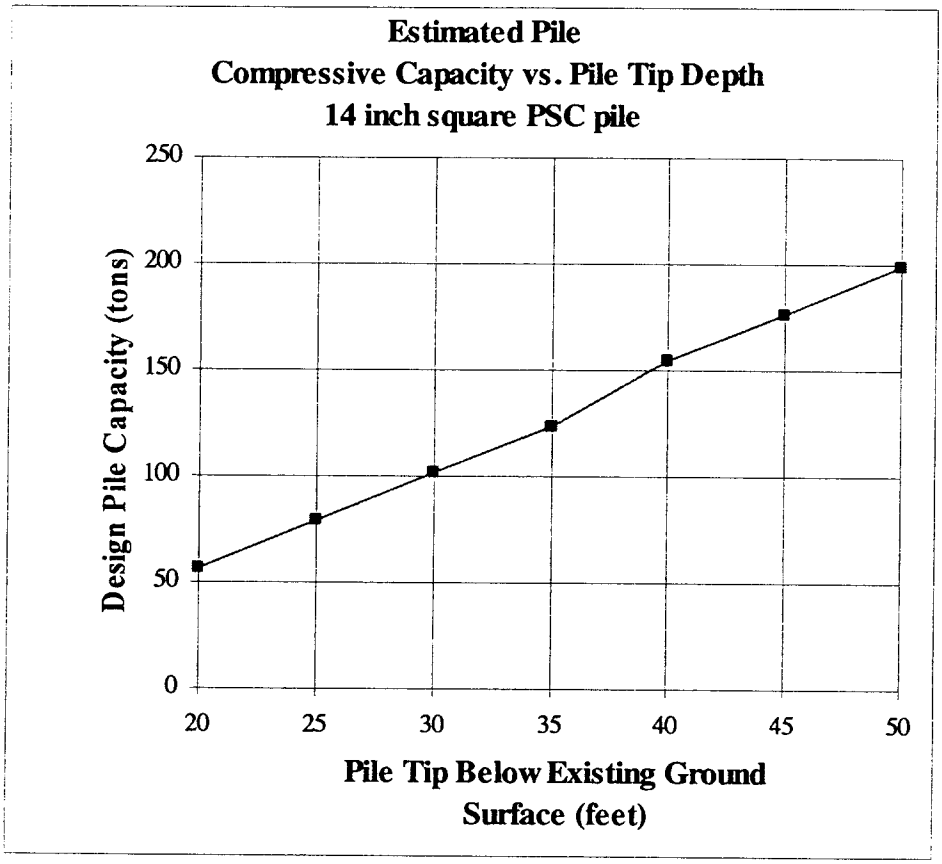
Steel H piles do not displace as much soils as PSC piles; therefore, these piles can be grouped more closely and may drive more efficiently.

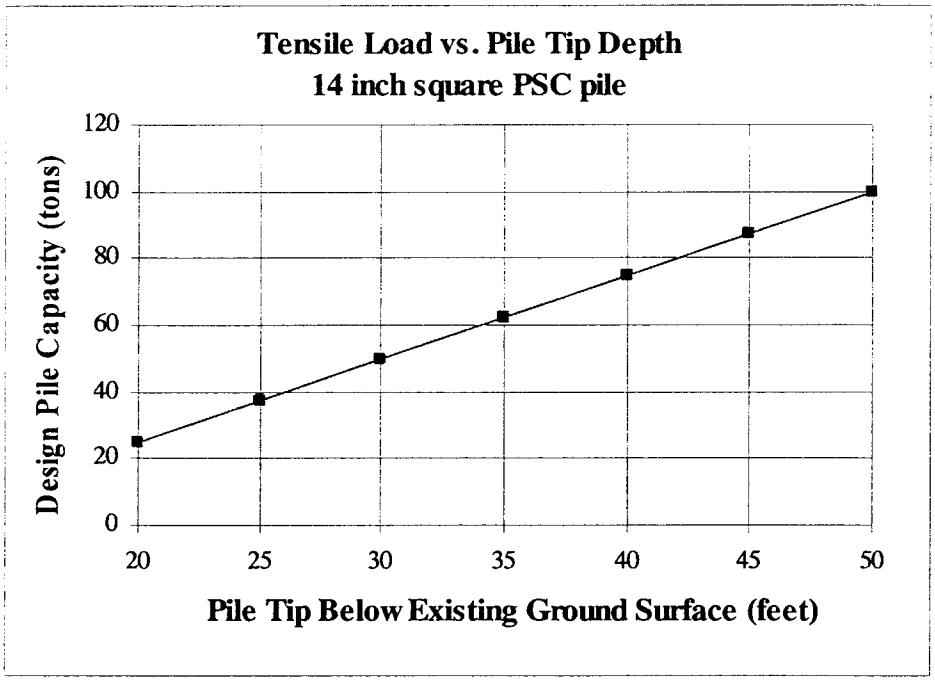
5.1.3.1 Pile Capacity

The preliminary design capacities for PSC piles and steel H piles are indicated in the following graphs:




Tensile Load vs. Pile Tip Depth
HP 14x73
Design Pile Capacity (tons)
120
100
80
60
40
20
0
20
25
30
35
40
45
50
Pile Tip Below Existing Ground Surface (feet)


Estimated Pile
Compressive Capacity vs. Pile Tip Depth
14 inch square PSC pile
Design Pile Capacity (tons)
250
200
150
100
50
0
20
25
30
35
40
45
50
Pile Tip Below Existing Ground Surface (feet)



It should be noted that only geotechnical capacity is considered in the graphs, without regard for stresses during installation or structural capacity of the pile member. Pile drivability analyses for stresses during installation should be performed prior to construction. The structural capacity of the pile members will be determined by structural details including the amount of reinforcement and concrete strength. The majority of the vertical capacity will be developed in the marl. Although nominal contribution to static pile capacity may be available in the upper soils, liquefaction of these soils during a seismic event may result in a temporary loss of support. Additionally, loading may occur as the liquefied upper soils drain and settle around the pile. The soils above the Marl also have the potential for scour. For these reasons we have not included the capacity of these soils in the design pile capacities represented in the above graphs.

Lateral support of the piles is provided in the upper ten pile diameters. Since these soils are susceptible to scour, battering the piles to carry these loads is recommended.

5.2 Ground and Surface Water

As mentioned previously, groundwater was encountered at depths ranging from approximately six to ten feet below the existing ground surface in the upland areas. The water may rise during and following a tropical storm and seasonably during the winter and spring. The shallow marl inhibits vertical drainage of infiltrating rainfall. We do not anticipate groundwater to affect construction in the upland areas.

Surface water in the Four Holes Swamp area will likely make earthwork operations more difficult. Care needs to be taken to prevent erosion of fill materials and maintain positive drainage during embankment construction. Recommendations for site preparation, fill placement and embankment construction are included in the following sections. These recommendations take into account surface water issues.

5.3 Site Preparation

The site preparation consists of two sections, upland areas (including the Cement Plant) and Four Holes Swamp. In the upland areas site preparation will consist of the clearing of vegetation, the stripping of superficial topsoil, and the removal of any asphalt pavement, base, and concrete construction materials. This debris should be removed from the construction area and wasted from the site. The surface soils are considered moisture sensitive and will require proper maintenance in order to prevent soil degradation. During stripping and rough grading, positive surface drainage must be maintained to prevent the accumulation of water on the surface of the subgrade.

In Four Holes Swamp, we recommend the process above for the dry areas. In the low or wet areas we recommend not disturbing the surface soils. We recommend removing vegetation to the ground surface and installing a geogrid (Tensar BX1100 or equivalent). After placing the geogrid, fill placement can begin.

5.4 Fill Placement

When fill is required to achieve finished grades, replace excavated materials, or create embankments, representative samples of the proposed fill materials should be tested to determine the maximum dry density, optimum moisture content, gradation, and plasticity of the soil. The results of these tests will be used to determine whether the proposed fill soils are suitable for use as engineered fill. The tests will also be compared with field density tests to determine whether the required degree of compaction is being achieved during construction.

Compacted fill should be constructed by spreading acceptable soils in loose layers generally not more than eight inches thick. Typical practice in the area is to use sand soils for fill, compacted in thin lifts to at least 95 percent maximum dry density as determined by the Modified Proctor method (ASTM D1557). Fills placed within the upper approximately 24 inches of the sub-grade should be compacted to at least 98 percent of the same specification.

In the wet areas of Four Holes Swamp, it may be necessary to place a bridge lift over the geogrid. This bridge lift should be clean sand (less than 5% fines) and should not exceed two feet. After the bridge lift is placed and compacted, normal fill operations can begin.

6.0 SEISMIC CONSIDERATIONS

Fortunately, the Eastern United States does not experience damaging earthquakes as frequently as Southern California and parts of the western United States. However, when large earthquakes do occur, soils such as those at this site can lose strength and experience significant settlements through liquefaction or lateral spreading. Detailed analysis of earthquake response behavior was beyond the scope of this preliminary assessment. Based on the boring results, the recent fill and natural materials above the marl are subject to liquefaction and settlement due to a seismic event.

Earthquake ground motion parameters at the rock outcrop for this site were obtained from the *U.S. Geological Survey (USGS) Earth Quake Hazards Program - National Seismic Hazard Mapping Project* website database. The values for this site are presented in *Table 3*.

Table 3: Probabilistic Ground Motion Values

Spectral Response Acceleration	***Ground Motion Values for Recurrence Period (g)***
	2% in 50 Years
PGA[1]	0.71
0.2 sec Sa[2]	1.252
1.0 sec Sa	0.331

Notes:
1. PGA is the Peak Ground Acceleration.
2. Sa is the Spectral Response Acceleration at the noted period.

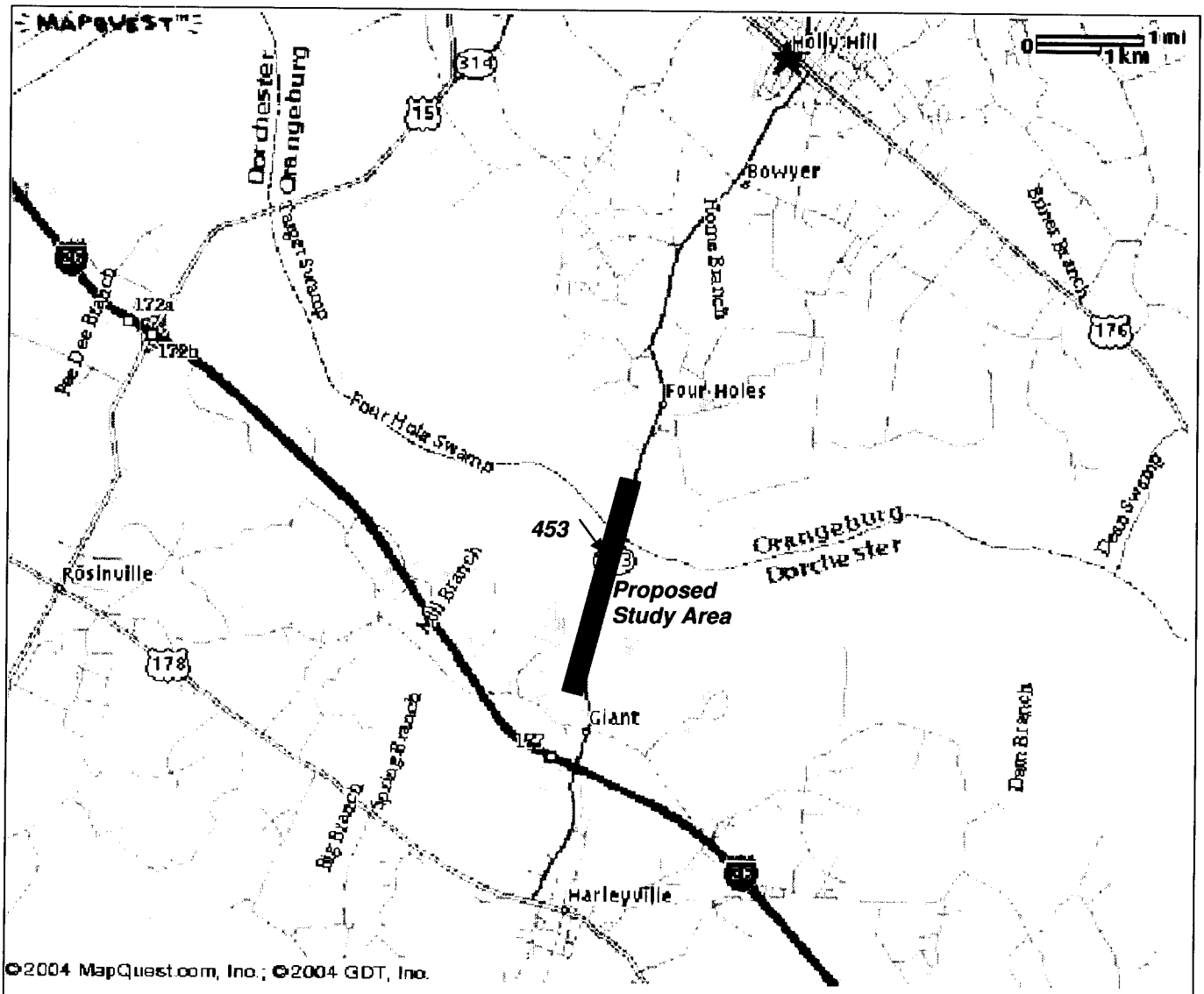
The soil profile type for the encountered soils is a Site Class F in accordance with the IBC 2000. The values for the site coefficients F_a and F_v are listed below:

- $F_a = 1.0$
- $F_v = 1.8$

7.0 RECOMMENDED FURTHER STUDY

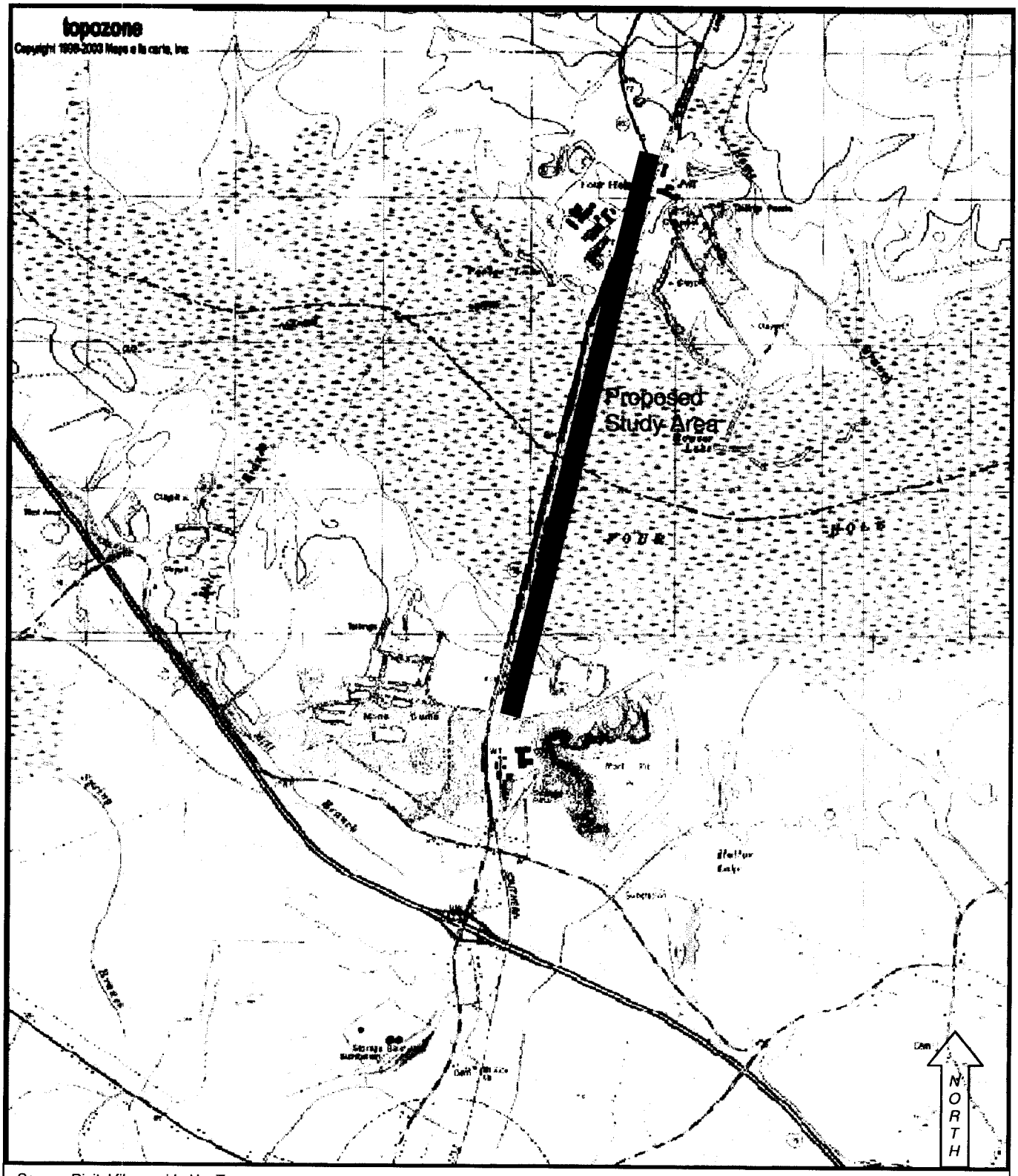
The objective of the preliminary geotechnical exploration is to identify potential major issues to be addressed in the design of the proposed railroad. Further geotechnical exploration of this site may be required if the alignment changes considerably. Once the final alignment is determined, we should be provided the opportunity to review our recommendations.

APPENDIX 1



NORTH

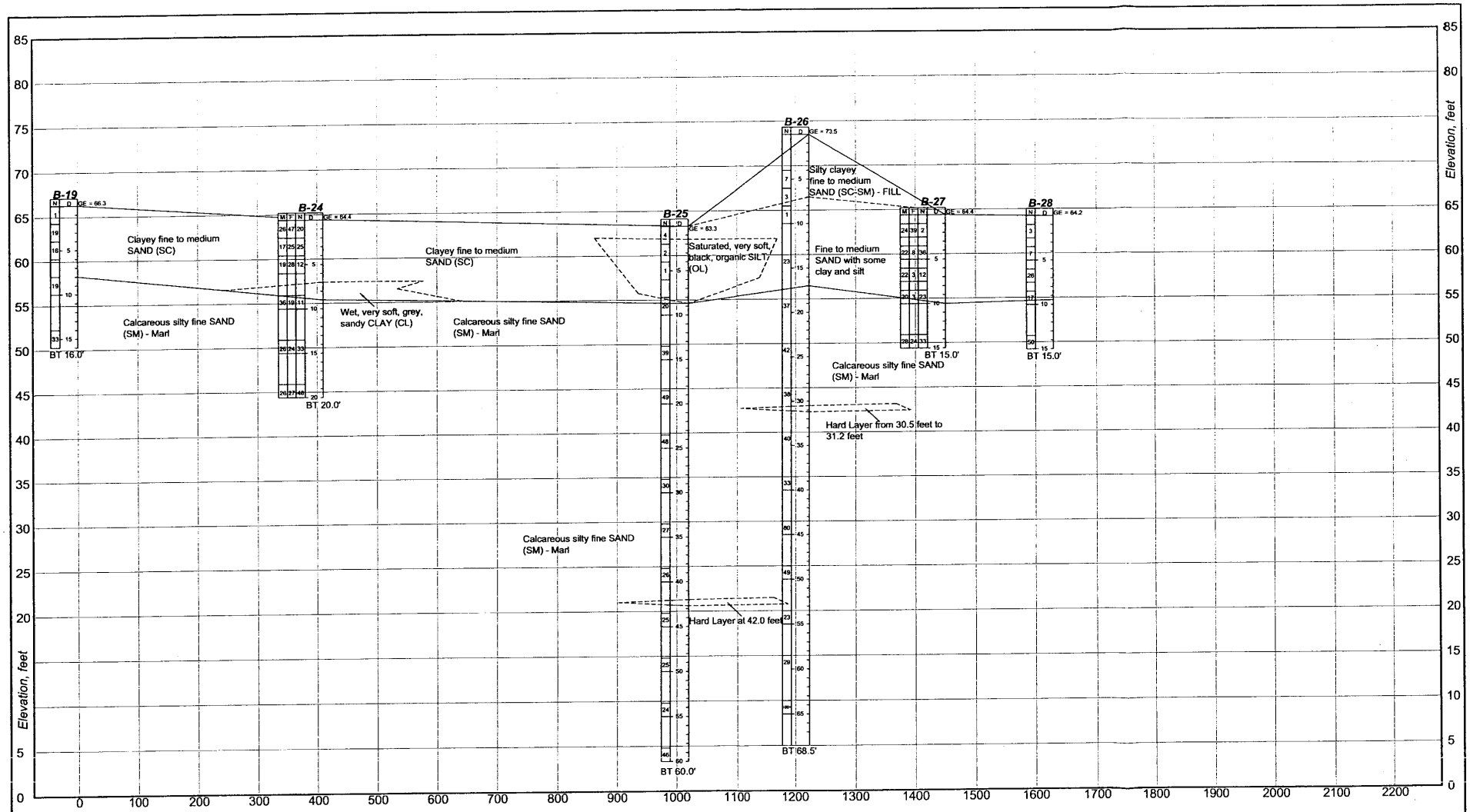
Proposed Railroad Holly Hill, South Carolina	Carolina Consulting Engineers Inc.	Figure 1 Site Location Plan
Prepared By: ARK Date 2/22/05	CCE Project No. 01-04-1104	Checked By: SWC Date 2/22/05



Source: Digital file provided by Topozone.com

Proposed Railroad Holly Hill, South Carolina	Carolina Consulting Engineers Inc.	Figure 2 Topographic Site Map
Prepared By: ARK Date 2/22/05	CCE Project No. 01-04-1104	Checked By: SWC Date 2/22/05

APPENDIX 2

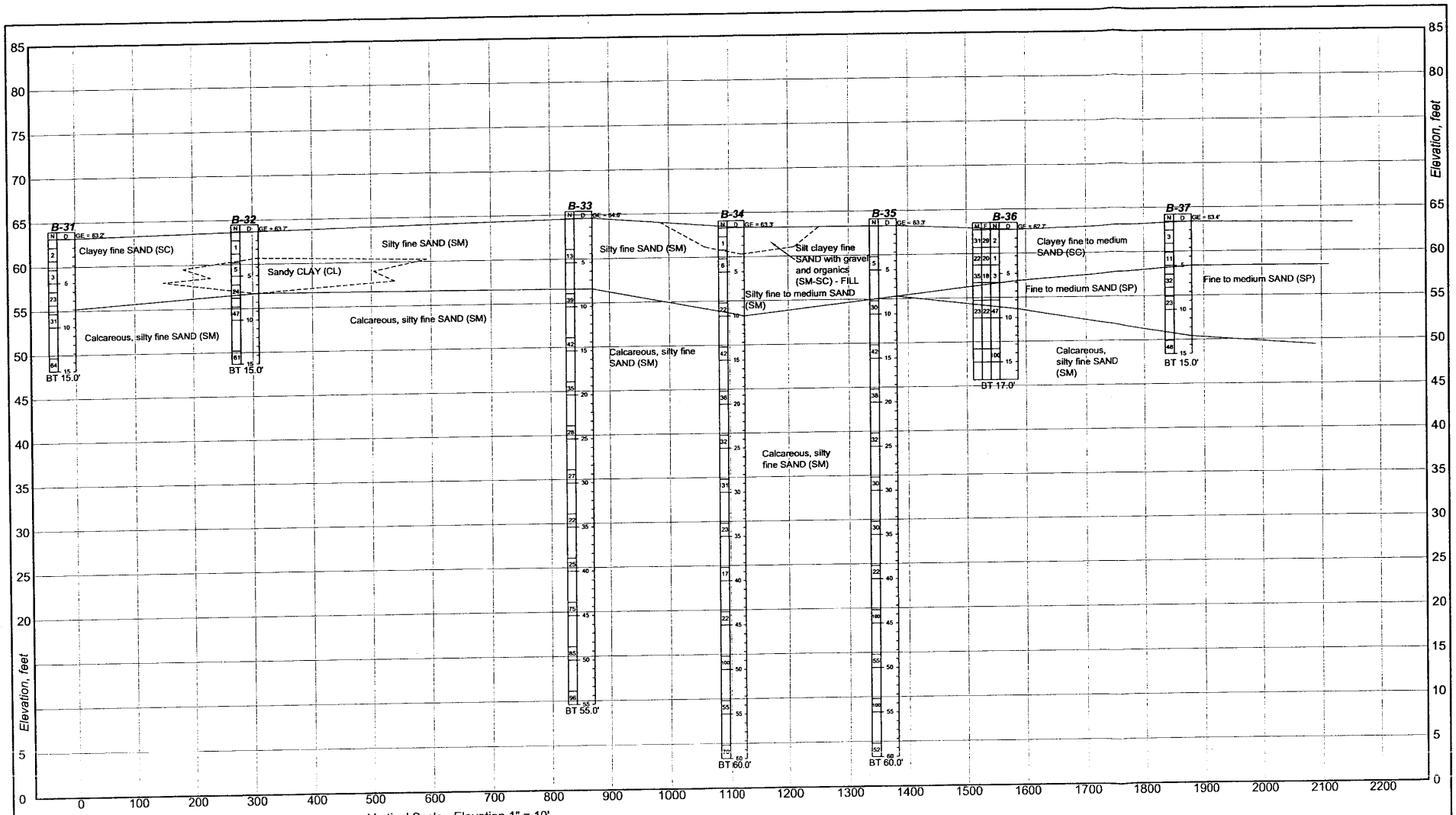


Legend
D = Depth below ground surface, feet
N = Standard Penetration Test N-Value
M = Natural Moisture Content
F = Percent Silt/Clay Fines
BT = Boring Terminated
GE = Ground Elevation

Vertical Scale - Elevation 1" = 10'
Horizontal Scale 1" = 150'

Note: Bridge 1 is closest bridge to Holcim.

Proposed Railroad Holly Hill, South Carolina		Carolina Consulting Engineers Inc.	Figure 3 Soil Profile Section - Bridge 1
Prepared By: JJP	Date: 2/22/05	CCE Project No. 01-04-1104	Checked By: SWC Date: 2/22/05



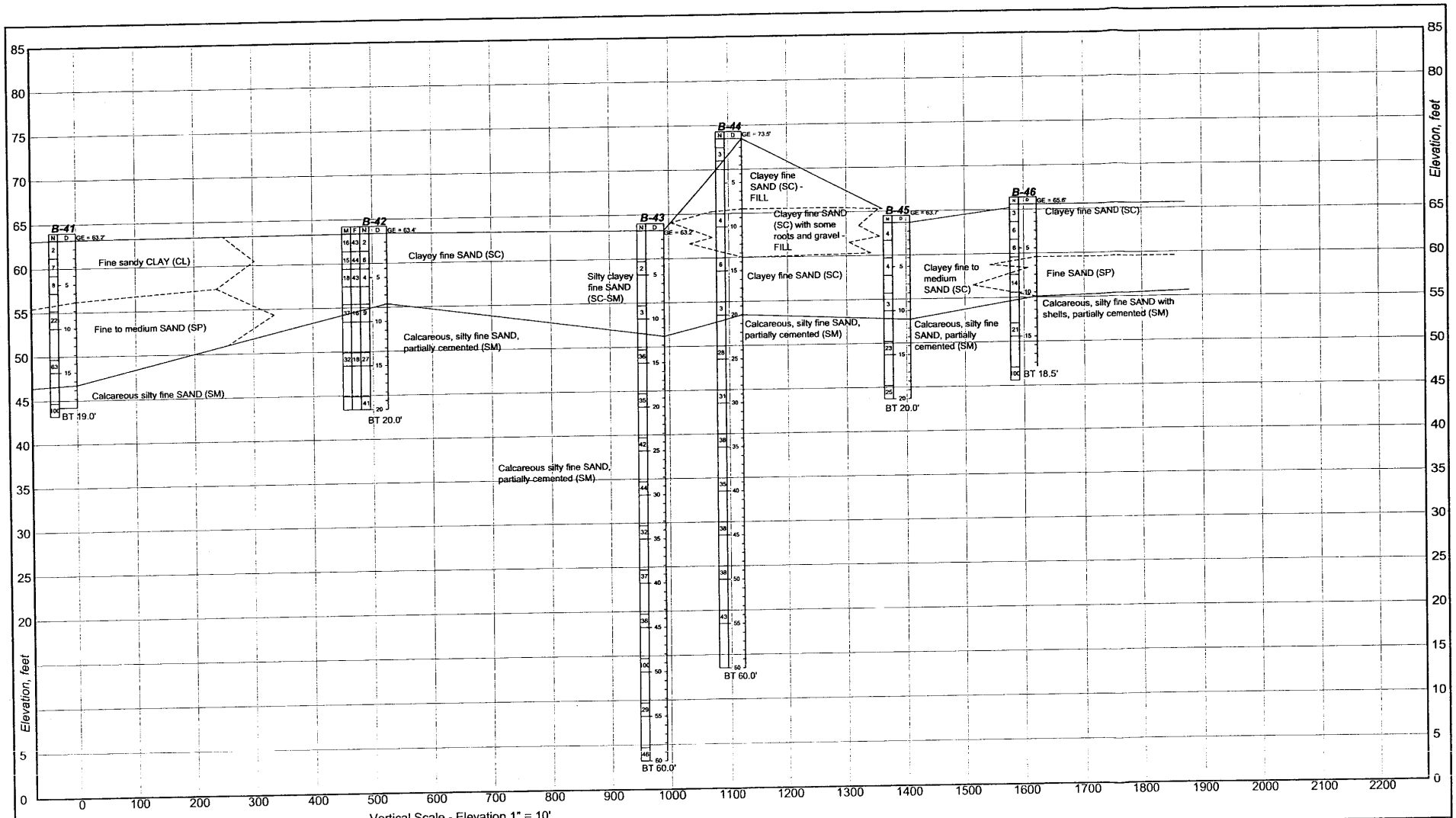
Legend

D = Depth below ground surface, feet
N = Standard Penetration Test N-Value
M% = Natural Moisture Content
F% = Percent Silt/Clay Fines
BT = Boring Terminated
GE = Ground Elevation

Vertical Scale - Elevation 1" = 10'
Horizontal Scale 1" = 150'

Note: Bridge 2 is middle bridge.

Proposed Railroad Holly Hill, South Carolina		Carolina Consulting Engineers Inc.	Figure 4 Soil Profile Section - Bridge 2
Prepared By: JJP	Date: 2/22/05	CCE Project No. 01-04-1104	Checked By: SWC Date: 2/22/05



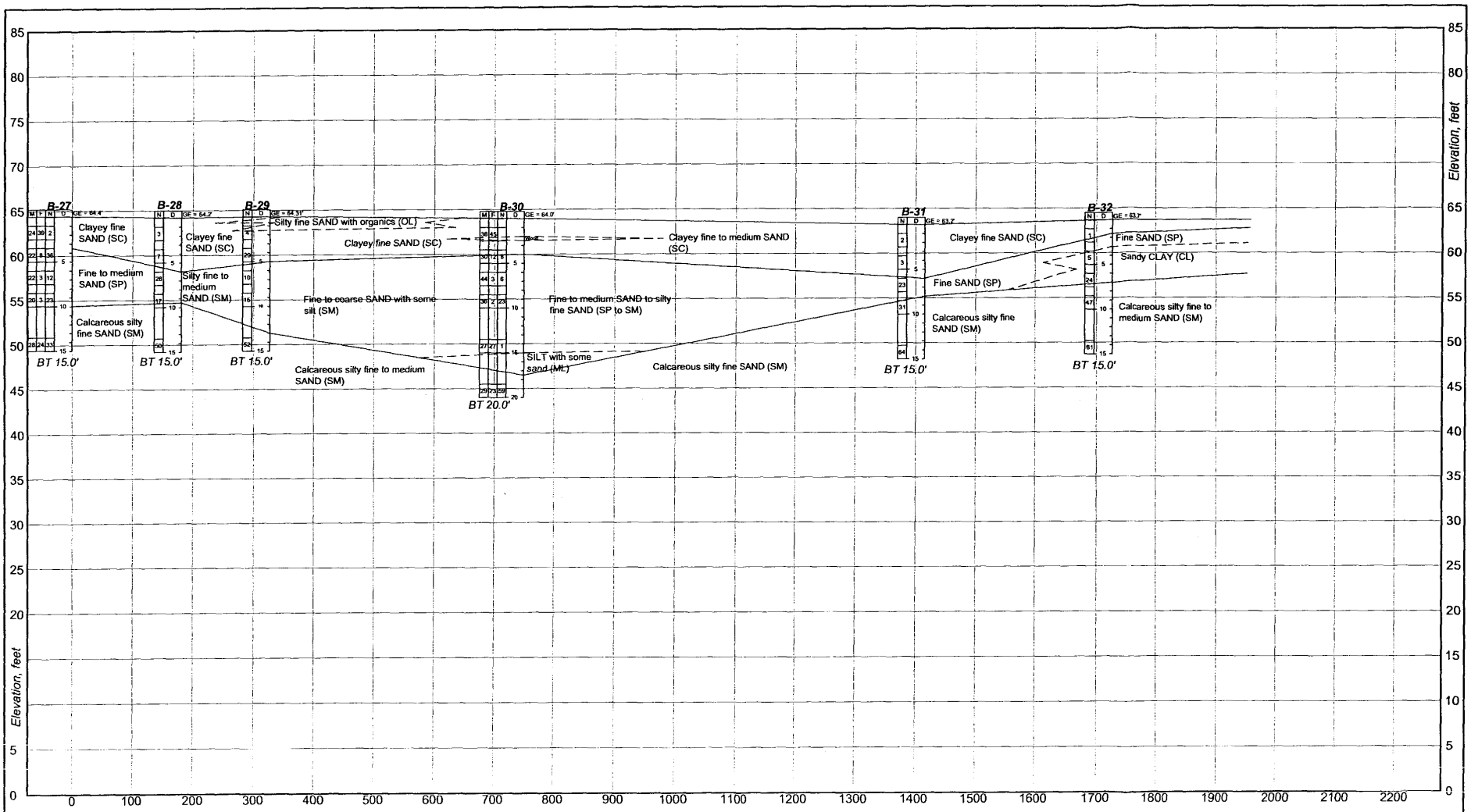
Legend

D = Depth below ground surface, feet
N = Standard Penetration Test N-Value
M = Natural Moisture Content
F = Percent Silt/Clay Fines
BT = Boring Terminated
GE = Ground Elevation

Vertical Scale - Elevation 1" = 10'
Horizontal Scale 1" = 150'

Note: Bridge 3 is closest bridge to Giant.

Proposed Railroad - Holrail Holly Hill, South Carolina		Carolina Consulting Engineers Inc.	Figure 5 Soil Profile Section - Bridge 3
Prepared By: JJP	Date: 2/22/05	CCE Project No. 01-04-1104	Checked By: SWC Date: 2/22/05



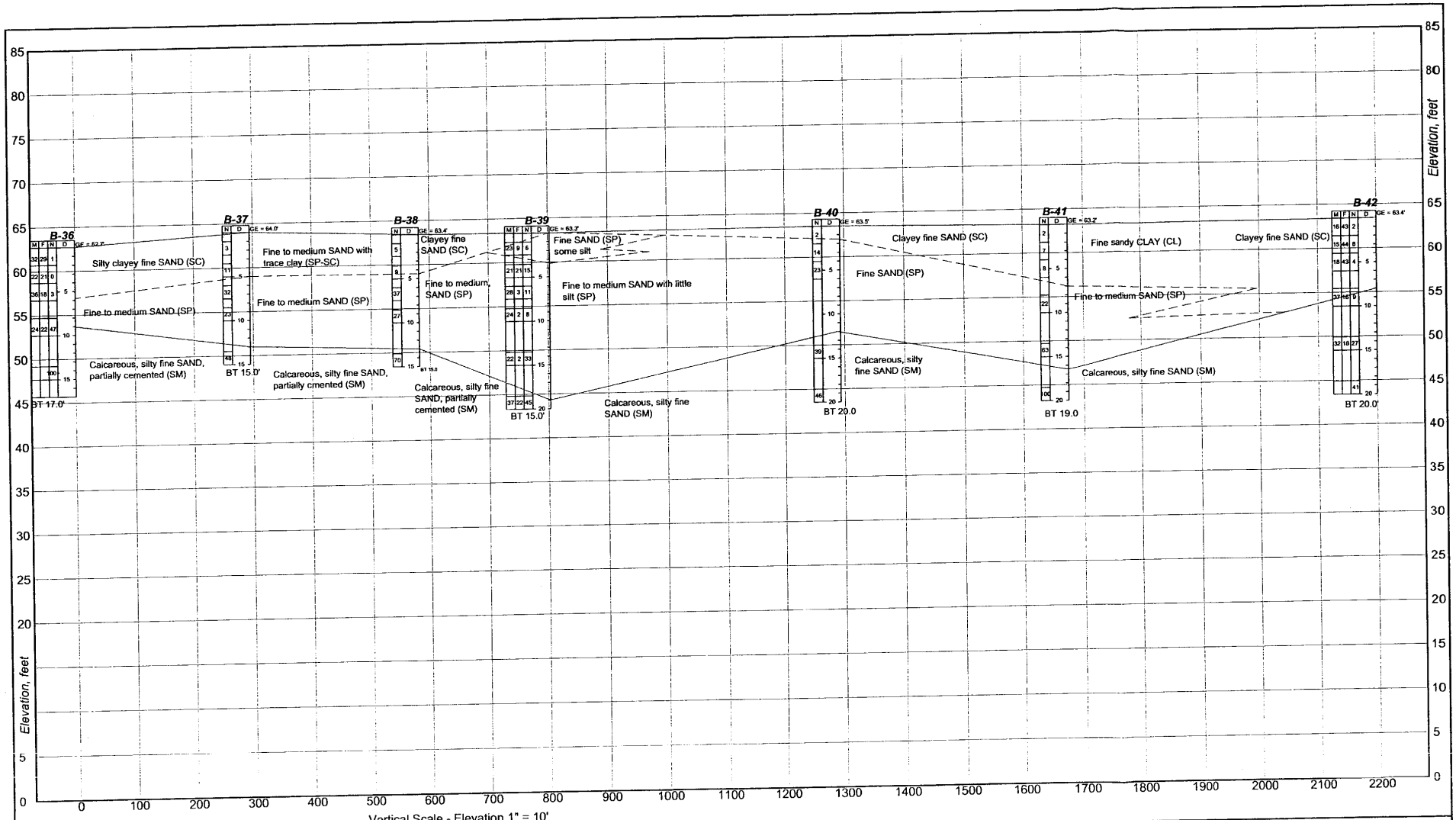
Legend

D = Depth below ground surface, feet
N = Standard Penetration Test N-Value
M = Natural Moisture Content
F = Percent Silt/Clay Fines
BT = Boring Terminated
GE = Ground Elevation

Vertical Scale - Elevation 1" = 10'
Horizontal Scale 1" = 150'

Note: Section A is between Bridge 1 and Bridge 2.

Proposed Railroad Holly Hill, South Carolina		Carolina Consulting Engineers Inc.	Figure 6 Soil Profile Section A
Prepared By: JJP	Date: 2/22/05	CCE Project No. 01-04-1104	Checked By: SWC Date: 2/22/05



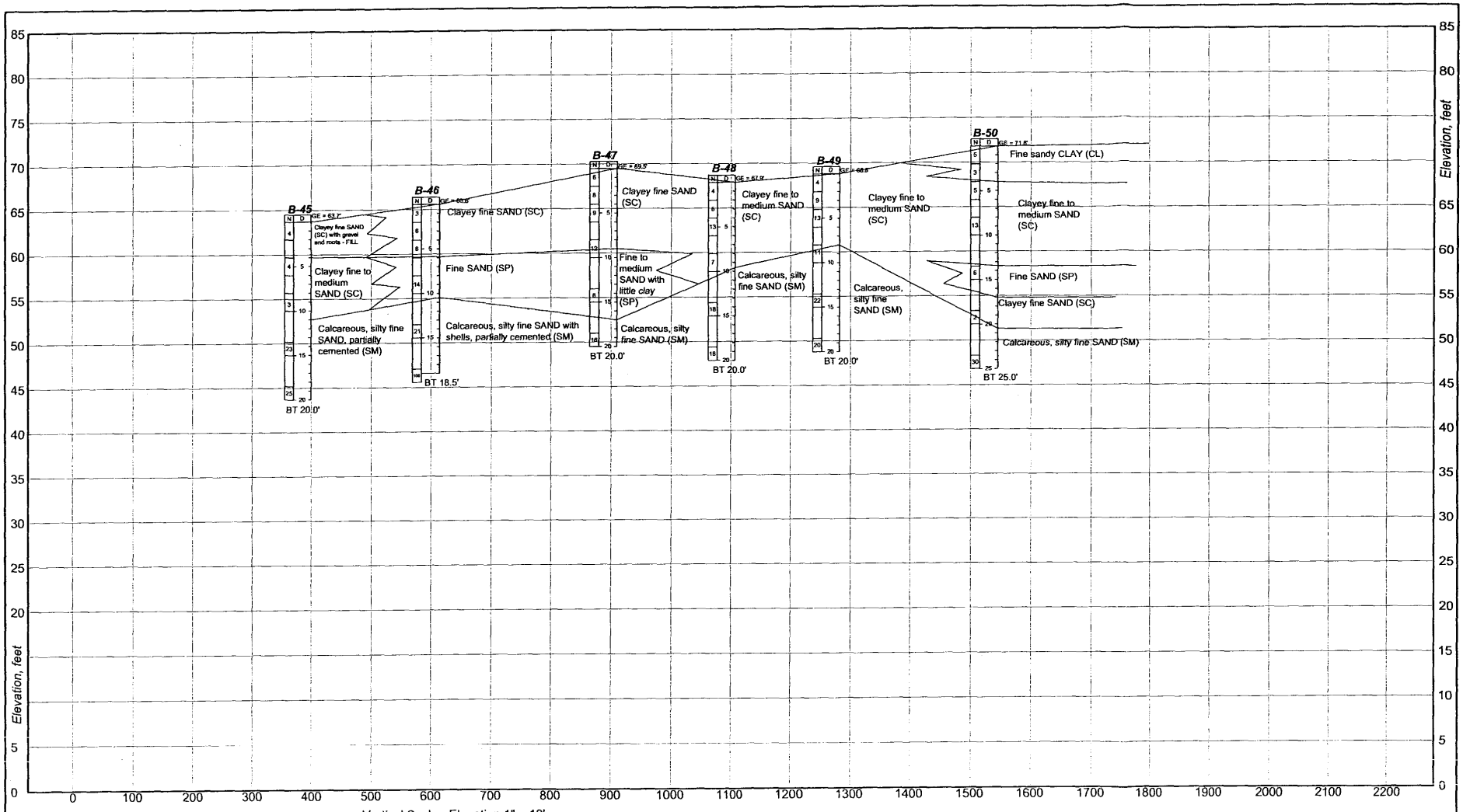
Legend

D = Depth below ground surface, feet
N = Standard Penetration Test N-Value
M = Natural Moisture Content
F = Percent Silt/Clay Fines
BT = Boring Terminated
GE = Ground Elevation

Vertical Scale - Elevation 1" = 10'
Horizontal Scale 1" = 150'

Note: Section B is between Bridge 2 and Bridge 3.

Proposed Railroad Holly Hill, South Carolina		Carolina Consulting Engineers Inc.	Figure 7 Soil Profile Section B
Prepared By: JJP	Date: 2/22/05	CCE Project No. 01-04-1104	Checked By: SWC Date: 2/22/05



Legend

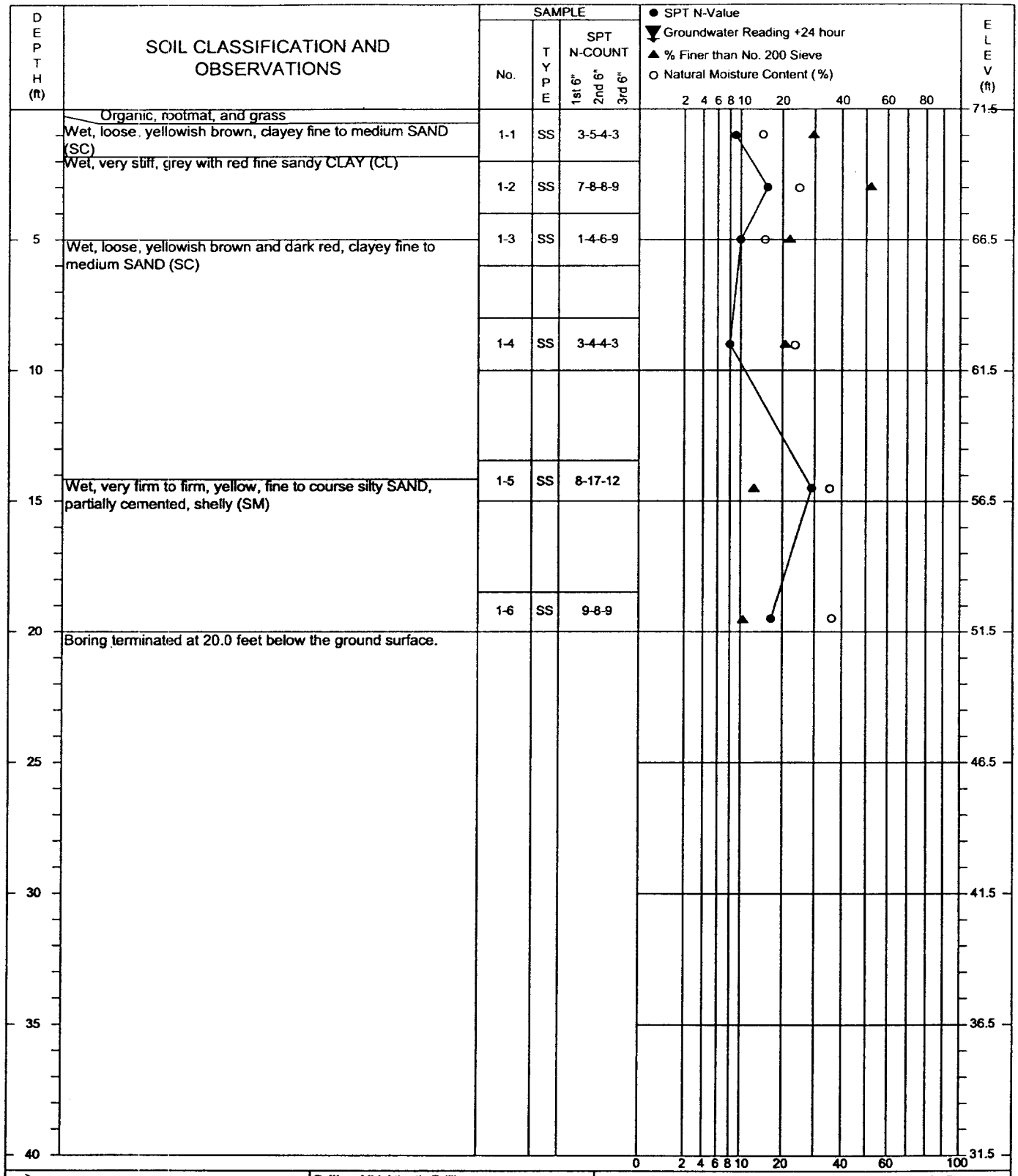
D = Depth below ground surface, feet
N = Standard Penetration Test N-Value
M = Natural Moisture Content
F = Percent Silt/Clay Fines
BT = Boring Terminated
GE = Ground Elevation

Vertical Scale - Elevation 1" = 10'
Horizontal Scale 1" = 150'

Note: Section C is between Bridge 3 and Giant.

Proposed Railroad Holly Hill, South Carolina		Carolina Consulting Engineers Inc.	Figure 8 Soil Profile Section C
Prepared By: JJP	Date: 2/22/05	CCE Project No. 01-04-1104	Checked By: SWC Date: 2/22/05

APPENDIX 3



Carolina CONSULTING ENGINEERS Inc.

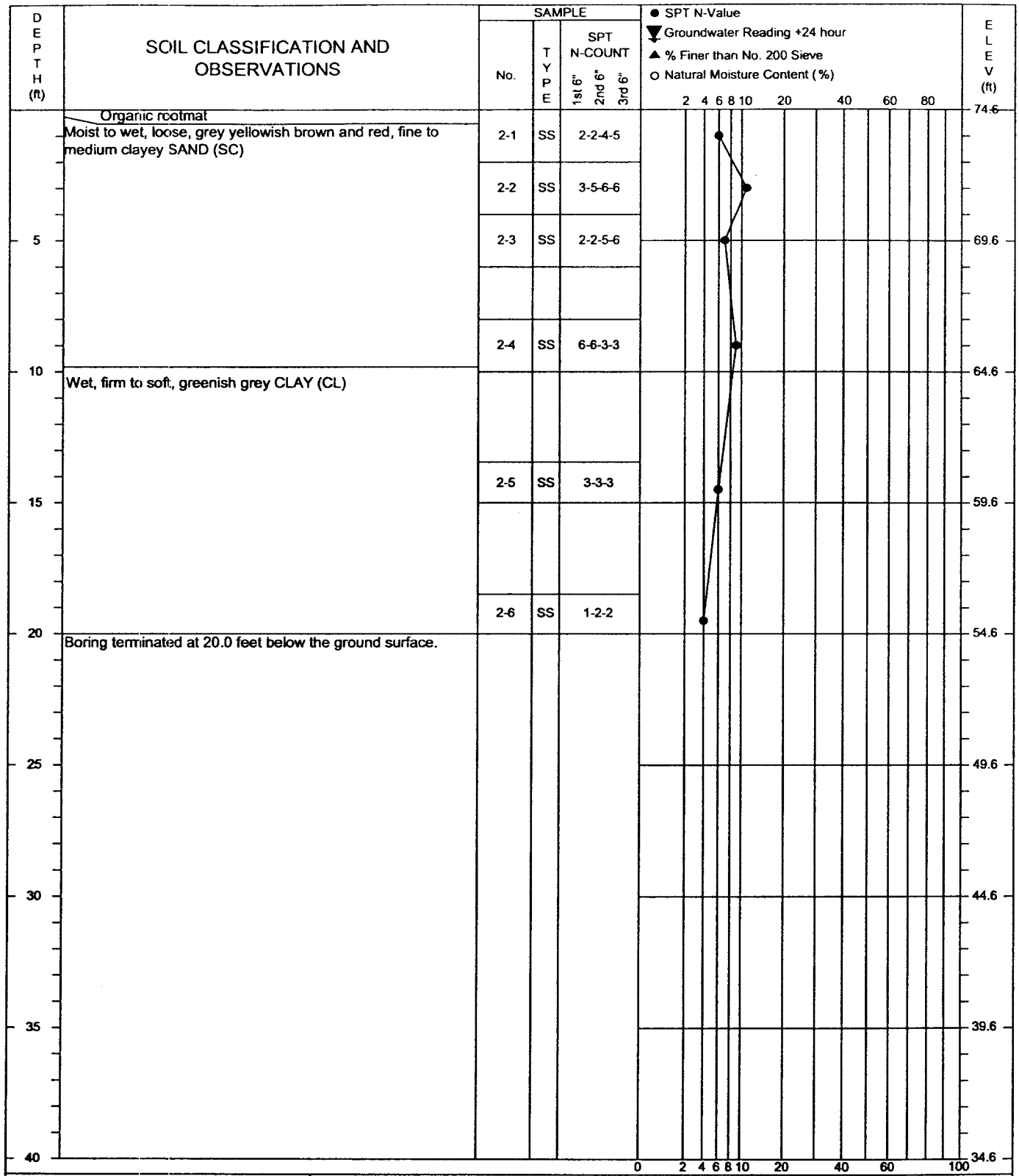
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/7/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-1



Carolina CONSULTING ENGINEERS Inc.

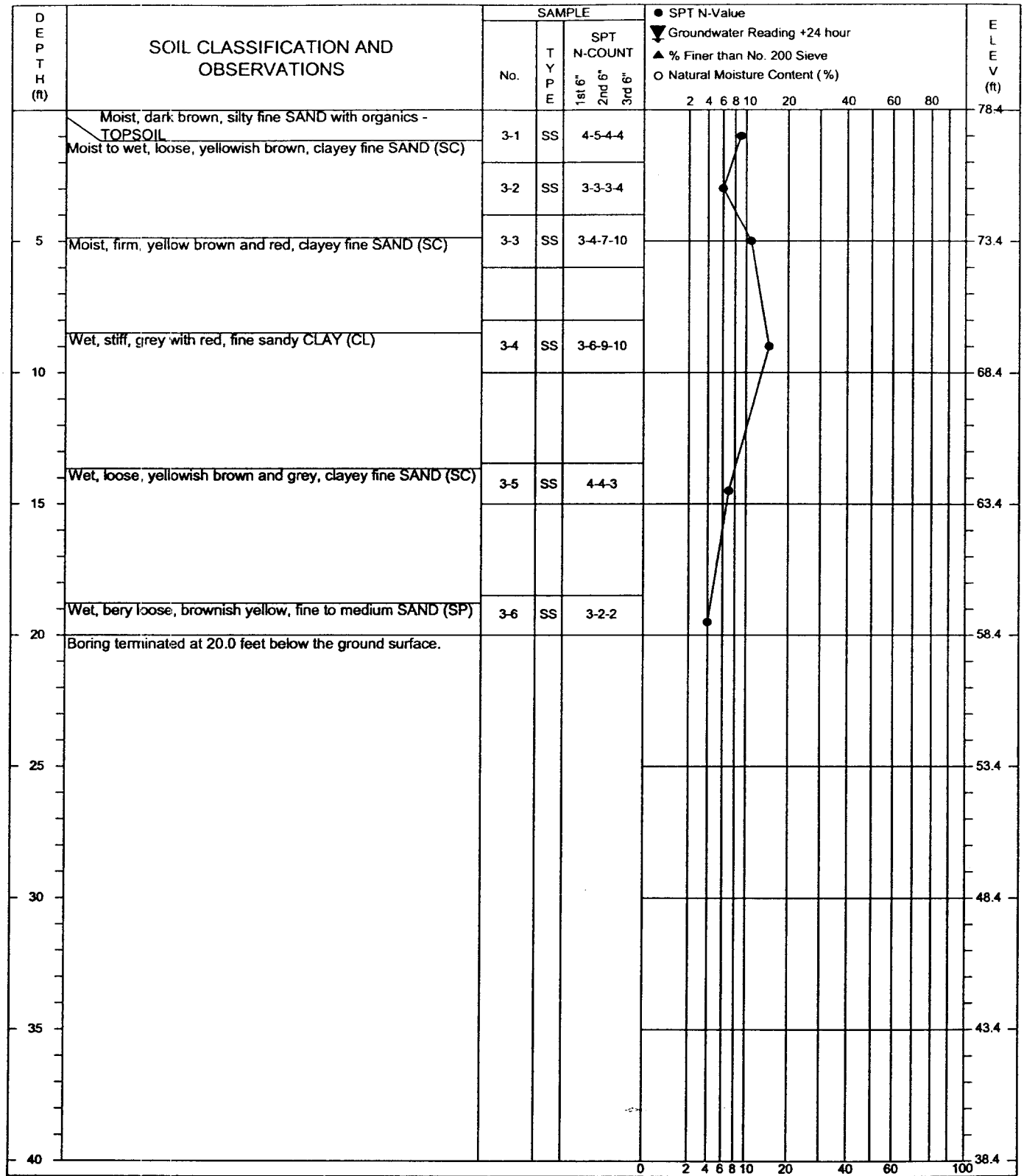
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/7/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-2



Carolina CONSULTING ENGINEERS Inc.

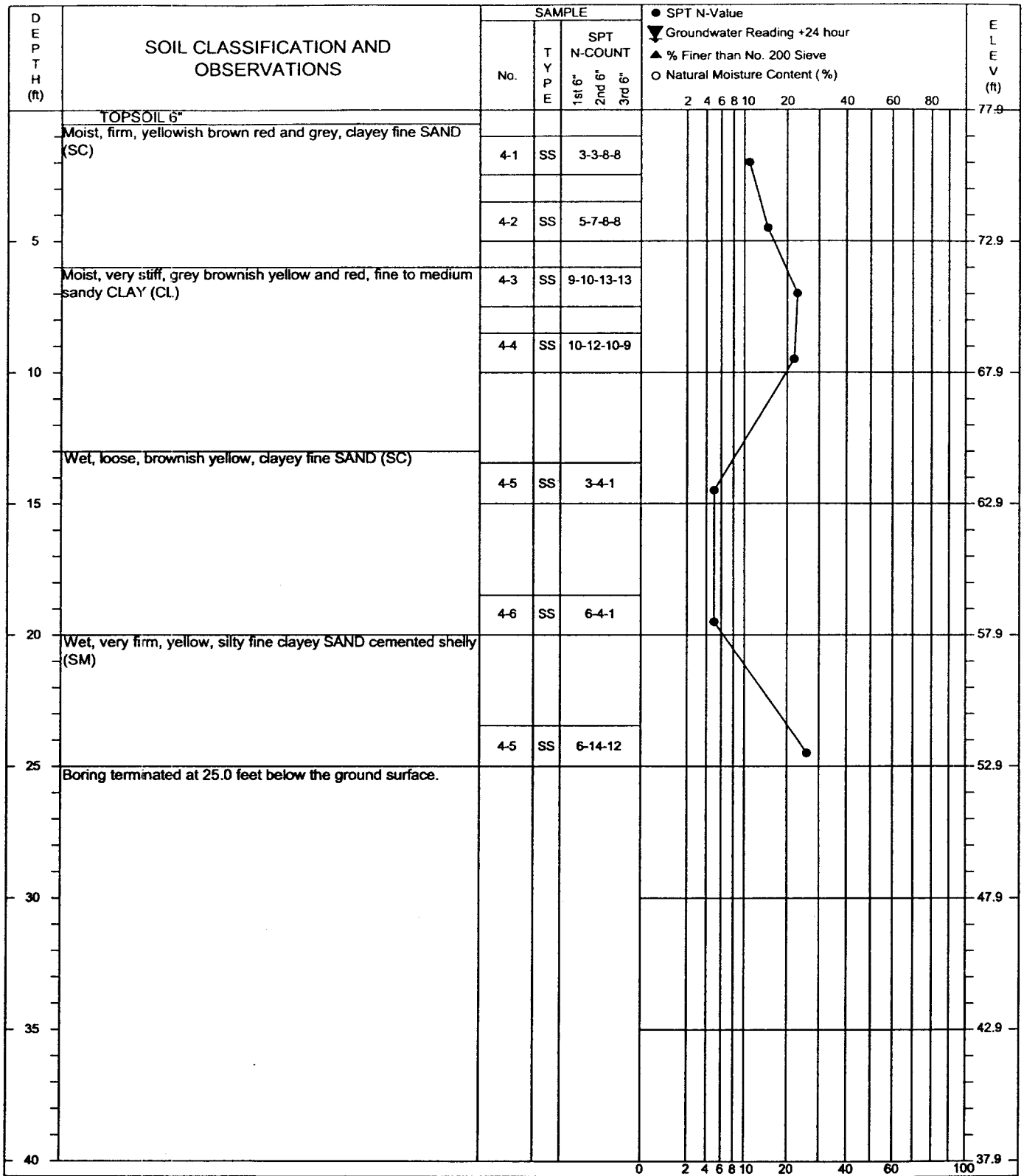
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/7/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-3



Carolina CONSULTING ENGINEERS Inc.

Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/8/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-4

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	SAMPLE TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Dry, dense to very firm, brown grey, silty fine to medium SAND with trace stone (SM) - FILL	5-1	SS	5-15-25-20	77.4
		5-2	SS	8-14-15-12	
	Refusal at 4.0 feet below the ground surface				
5					72.4
10					67.4
15					62.4
20					57.4
25					52.4
30					47.4
35					42.4
40					37.4

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
○ Natural Moisture Content (%)

0 2 4 6 8 10 20 40 60 80 100

Carolina CONSULTING ENGINEERS Inc.

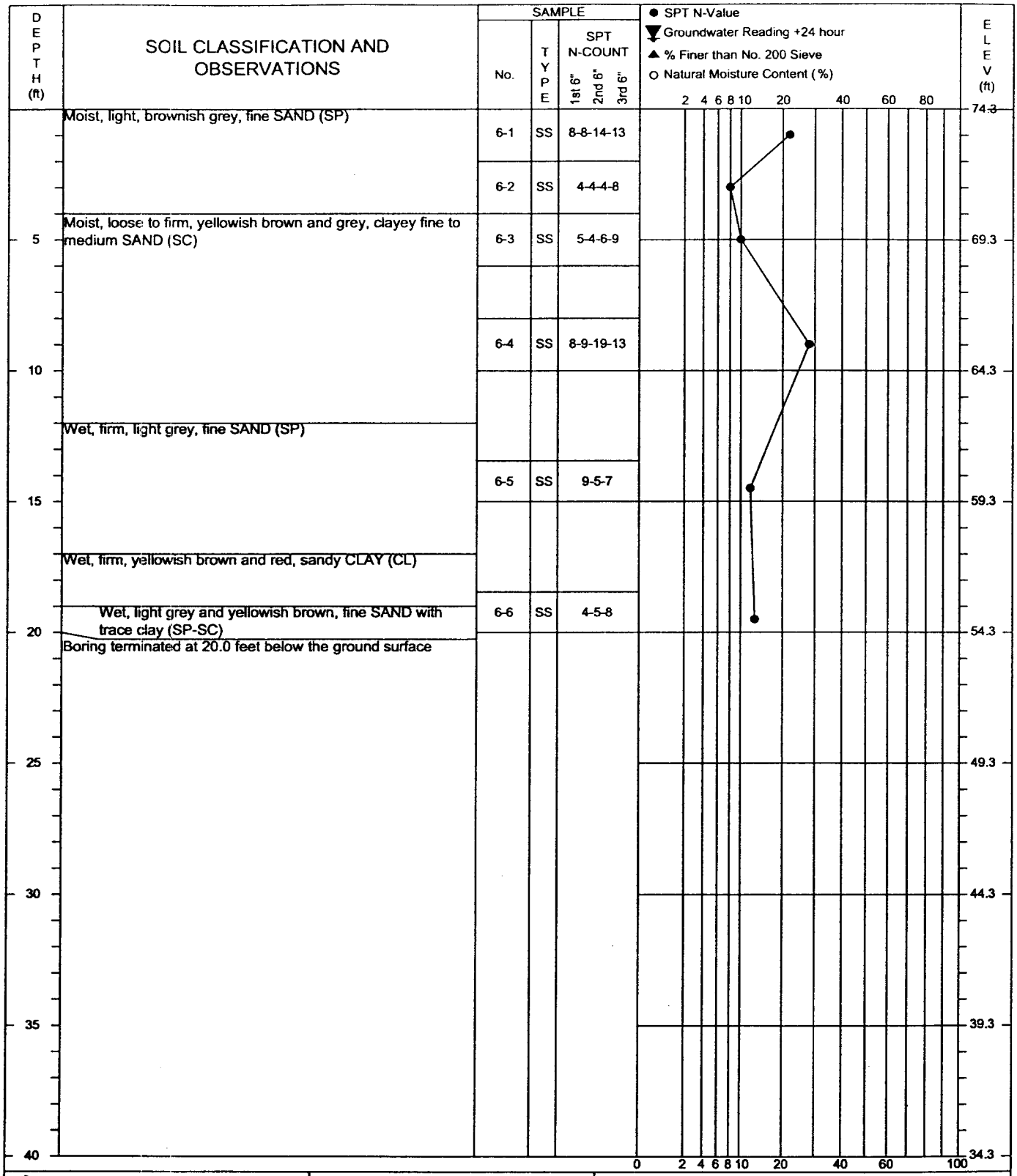
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/1/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-5



Carolina CONSULTING ENGINEERS Inc.

Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/9/04
Project No. 01-04-1104
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BORING: B-6

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Moist, dense, dark brown, silty fine SAND (SM) - FILL	7-1	SS	5-19-22	70.4
	Moist to wet, firm to loose, grey and yellowish brown, clayey fine to medium SAND (SC) - FILL	7-2	SS	3-6-7	
5		7-3	SS	5-6-4	65.4
	Wet, firm, light brownish grey, fine to medium SAND (SP)	7-4	SS	7-7-6	
10					60.4
	Moist, dense to firm, yellow, calcareous silty fine SAND (SM)	7-5	SS	13-17-15	
15					55.4
		7-6	SS	8-6-8	
20					50.4
		7-7	SS	13-13-13	
25	Boring terminated at 25.0 feet below the ground surface.				45.4
30					40.4
35					35.4
40					30.4

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
○ Natural Moisture Content (%)

0 2 4 6 8 10 20 40 60 80 100

Carolina CONSULTING ENGINEERS Inc.

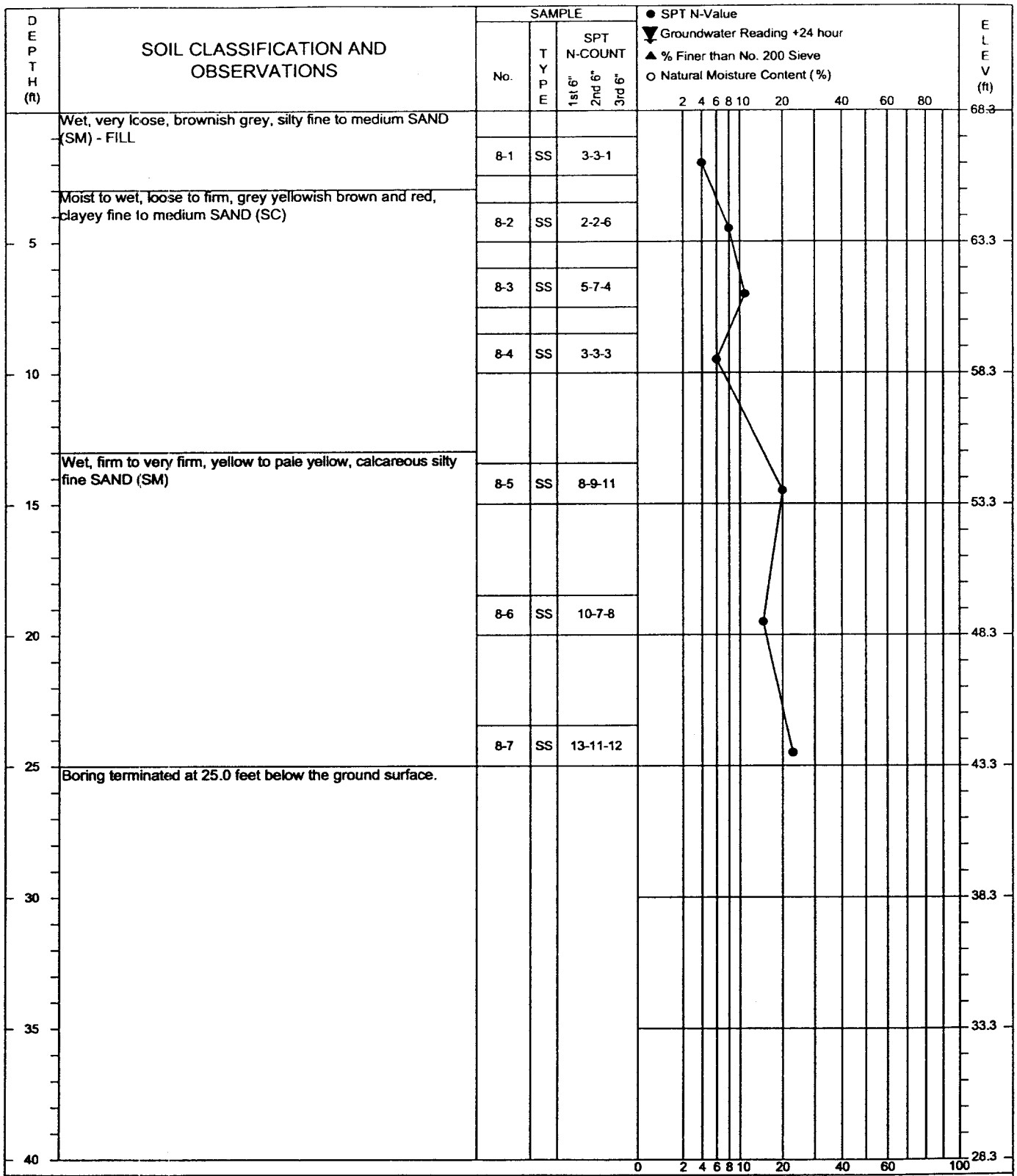
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/13/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-7



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/13/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-8

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Moist, firm to loose, brown grey red, clayey fine to medium SAND (SC)				76.0
		9-1	SS	11-8-7	
		9-2	SS	1-3-4	
5					71
	Moist, firm to loose, light grey, clayey fine SAND (SC)	9-3	SS	4-5-6	
		9-4	SS	3-5-5	
10					66
	Moist to wet, light grey, fine to medium SAND (SP-SM)	9-5	SS	3-3-3	
15					61
		9-6	SS	3-2-1	
20	Moist, very firm, pale yellow, silty fine SAND, partially cemented (SM)				56
		9-7	SS	15-14-15	
25	Boring terminated at 25.0 feet below the ground surface.				51
30					46
35					41
40					36

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
○ Natural Moisture Content (%)

2 4 6 8 10 20 40 60 80

0 2 4 6 8 10 20 40 60 100

Carolina CONSULTING ENGINEERS Inc.

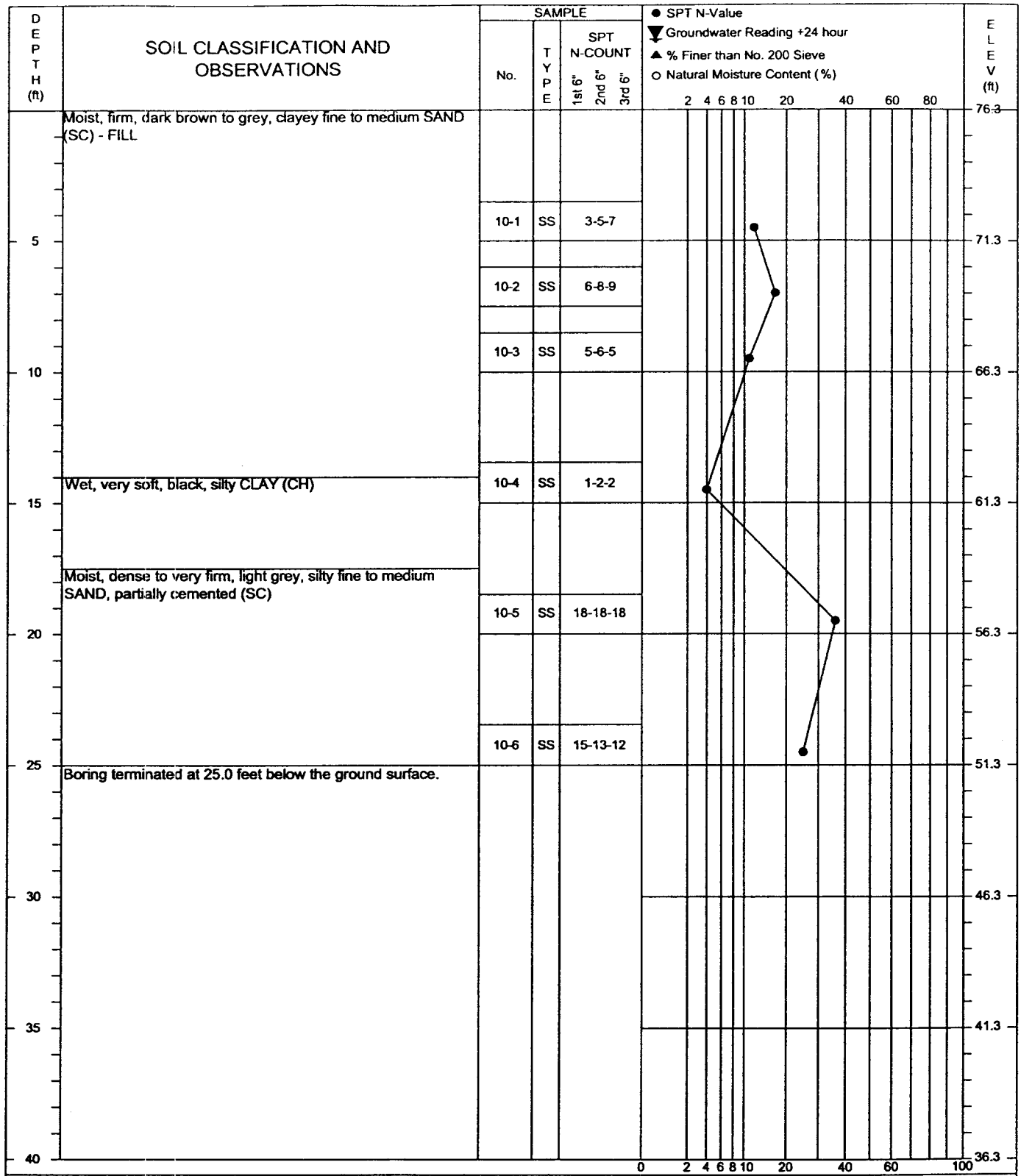
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/9/04
Project No. 01-04-1104
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BORING: B-9



Carolina CONSULTING ENGINEERS Inc.

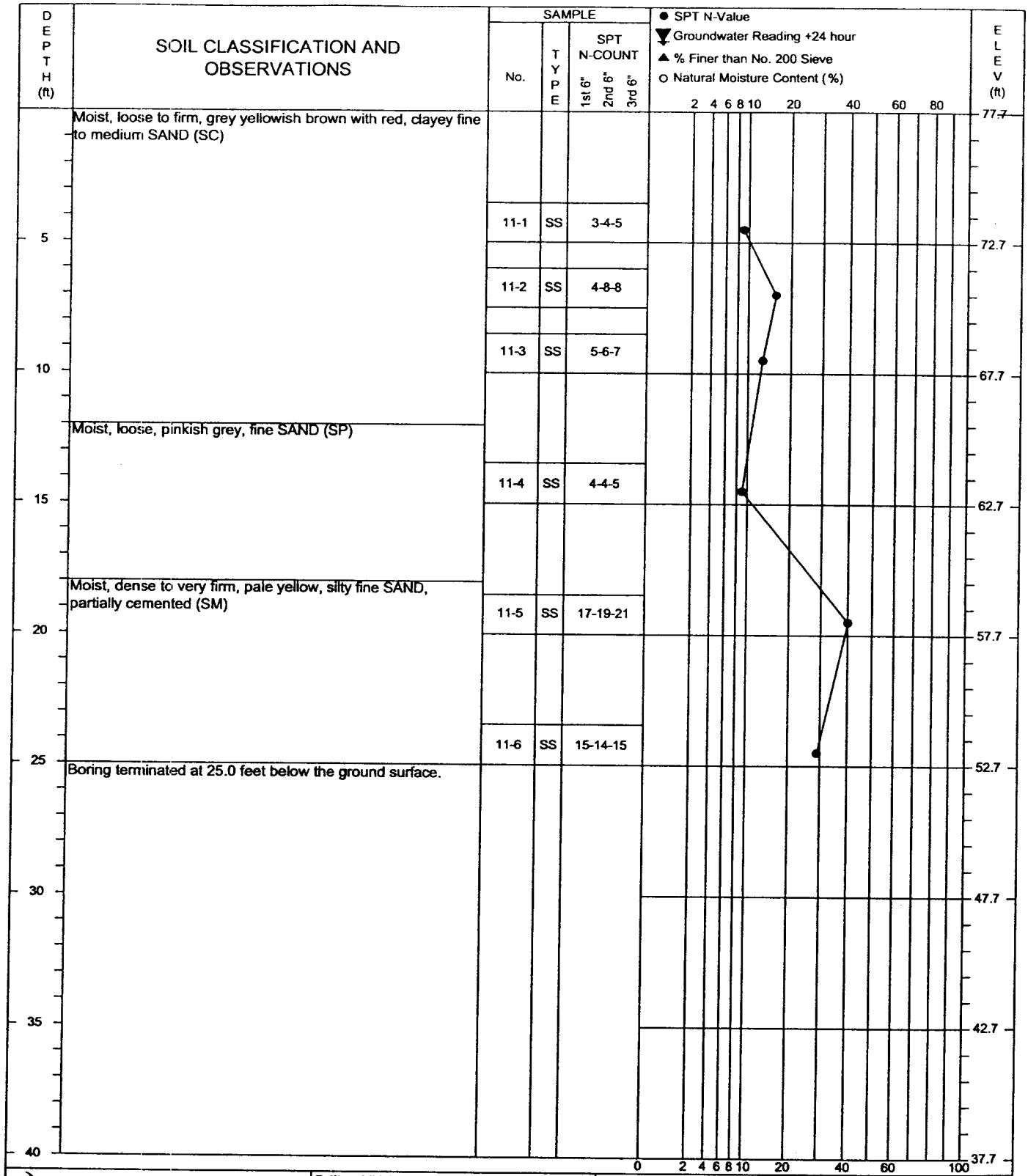
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/9/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-10



Carolina CONSULTING ENGINEERS Inc.

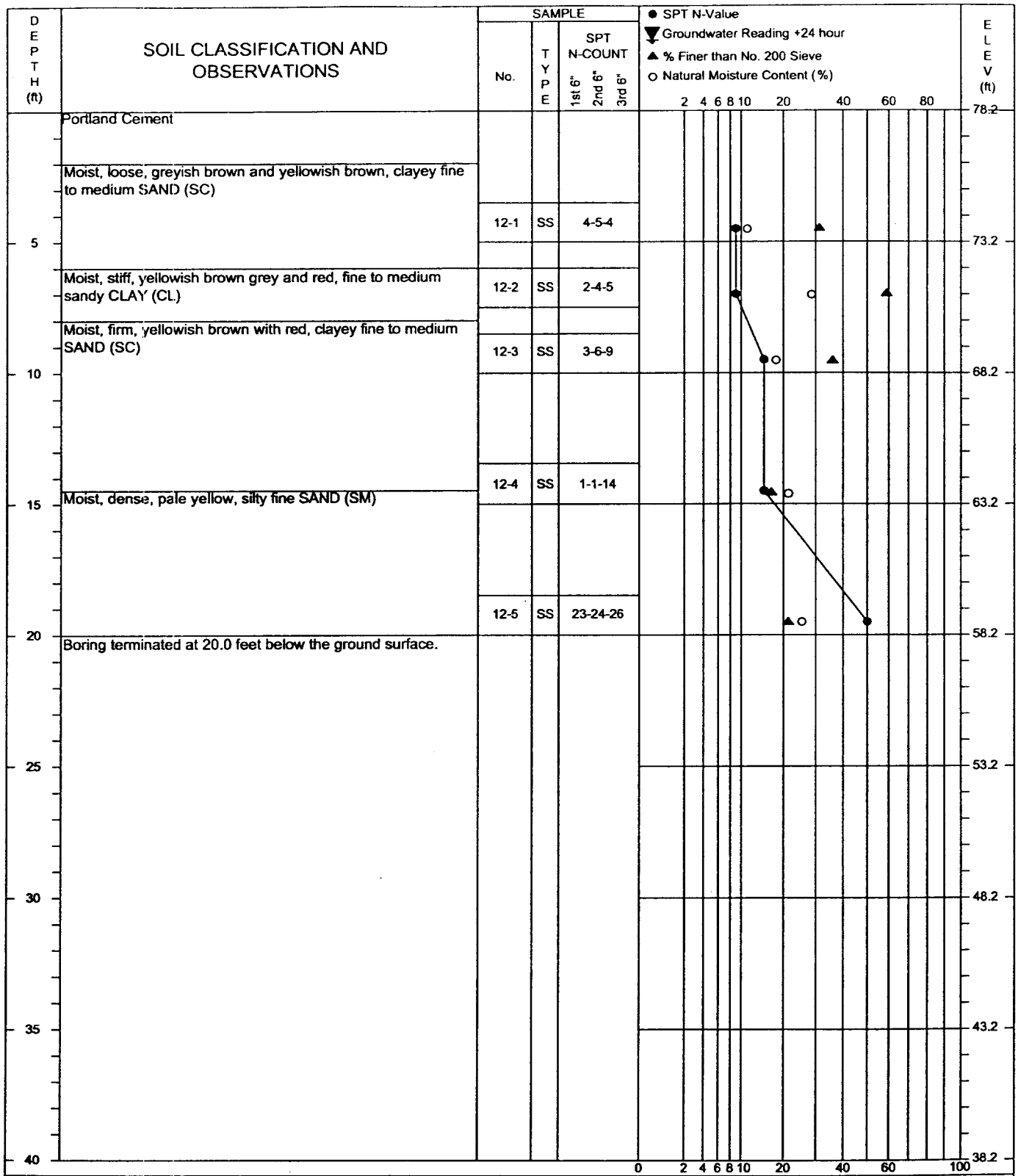
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/9/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-11



Carolina CONSULTING ENGINEERS Inc.

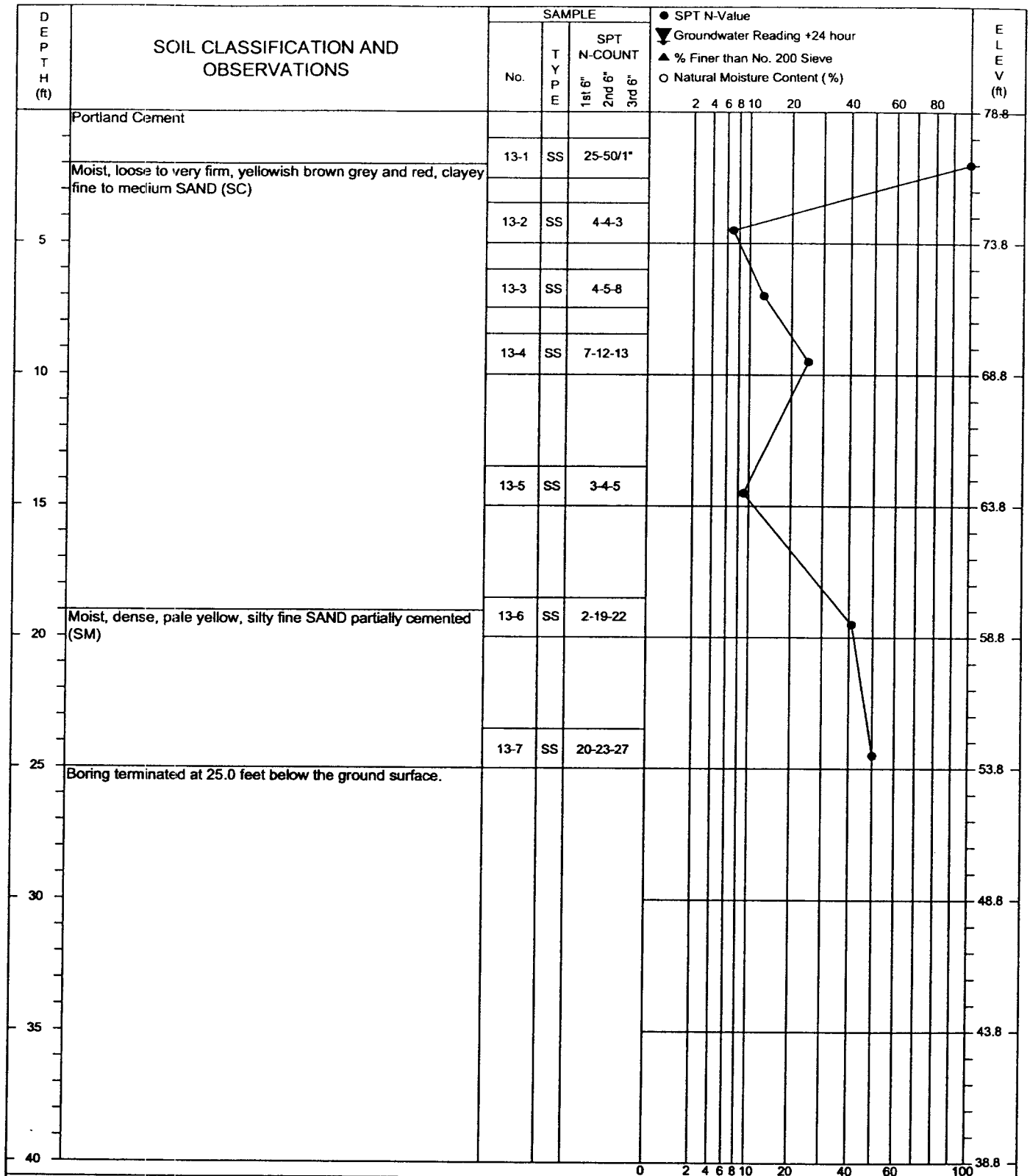
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/9/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-12



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/9/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-13

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Moist, firm, brown, clayey fine to medium SAND (SC) mixed with pale yellow MARL (SM) - FILL				78.6
		14-1	SS	12-7-12	
	Moist, firm, dark brown, clayey fine to medium SANd with trace organics (SC)	14-2	SS	6-5-7	
5					73.6
	Moist, firm, grey with brownish yellow, clayey fine to medium SAND (SC)	14-3	SS	5-5-8	
		14-4	SS	4-4-7	
10					68.6
	Moist to wet, bluish grey with brownish yellow, fine to medium sandy CLAY (CL)				
		14-5	SS	1-3-5	
15					63.6
	Moist, dense, pale yellow to light grey, silty fine SAND, partially cemented (SM)				
		14-6	SS	16-16-22	
20					58.6
		14-7	SS	22-22-23	
25	Boring terminated at 25.0 feet below the ground surface.				53.6
30					48.6
35					43.6
40					38.6

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
○ Natural Moisture Content (%)

0 2 4 6 8 10 20 40 60 80 100

Carolina CONSULTING ENGINEERS Inc.

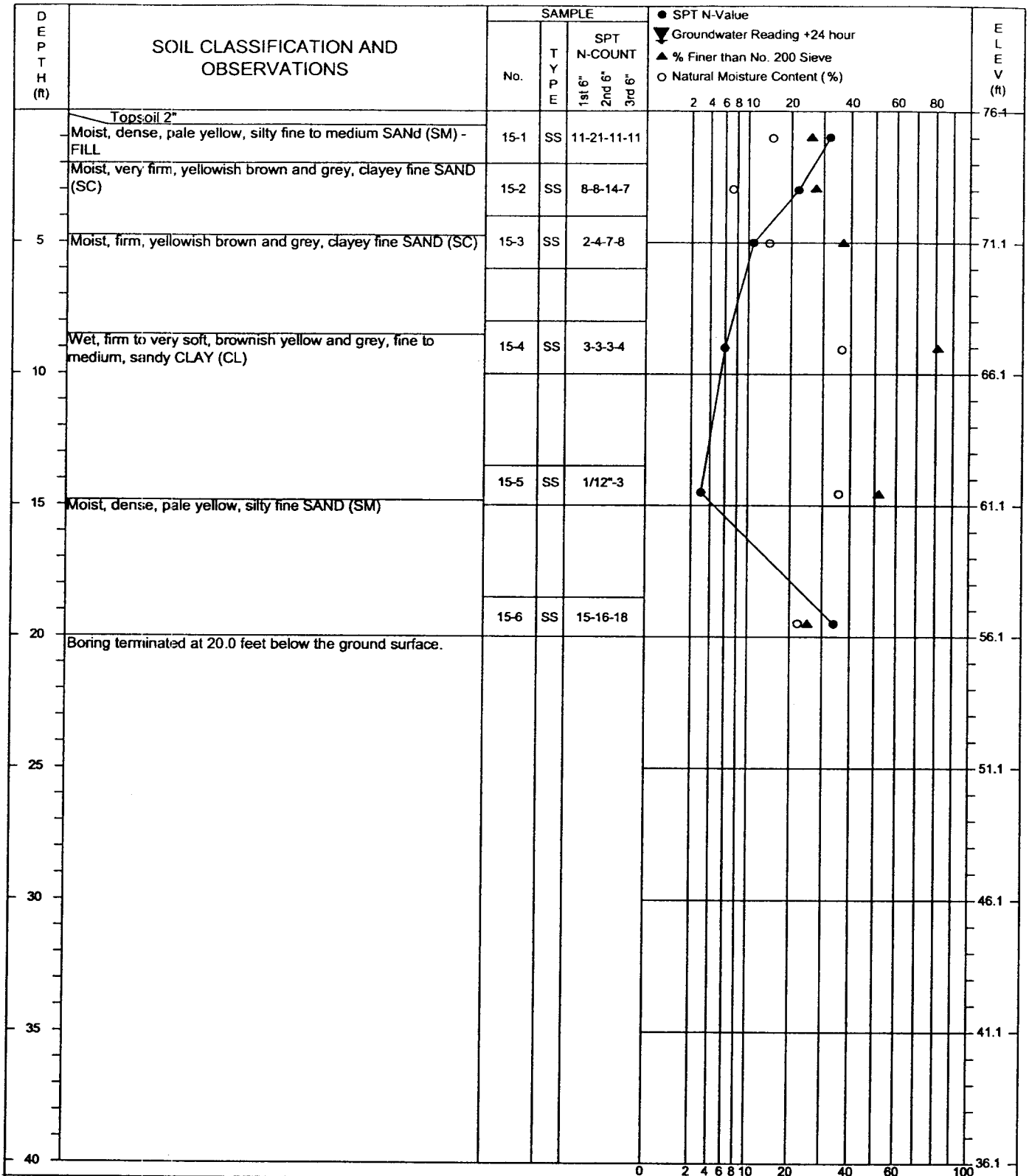
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/9/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-14



Carolina CONSULTING ENGINEERS Inc.

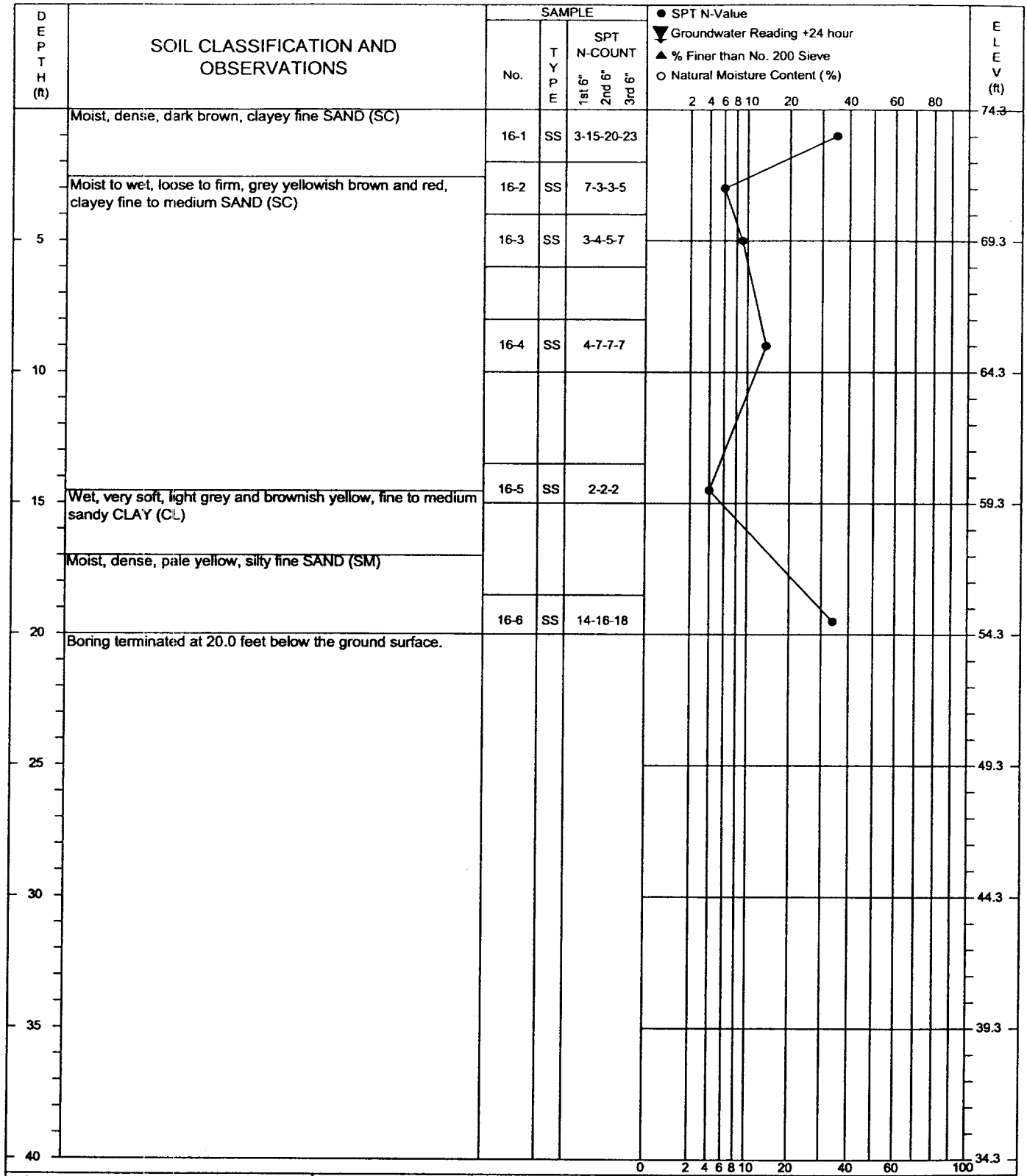
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/2/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-15



Carolina CONSULTING ENGINEERS Inc.

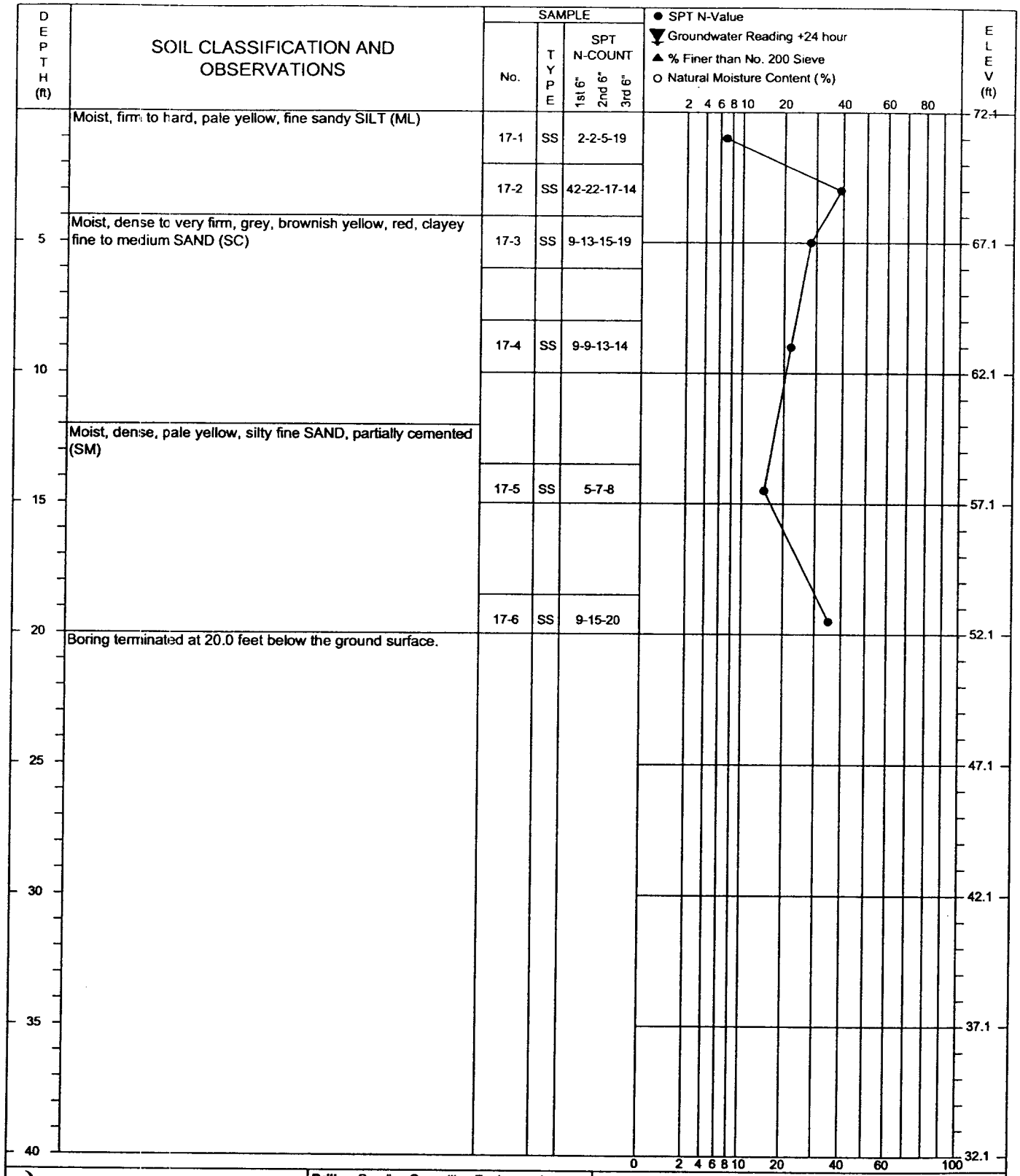
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/2/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-16



Carolina CONSULTING ENGINEERS Inc.

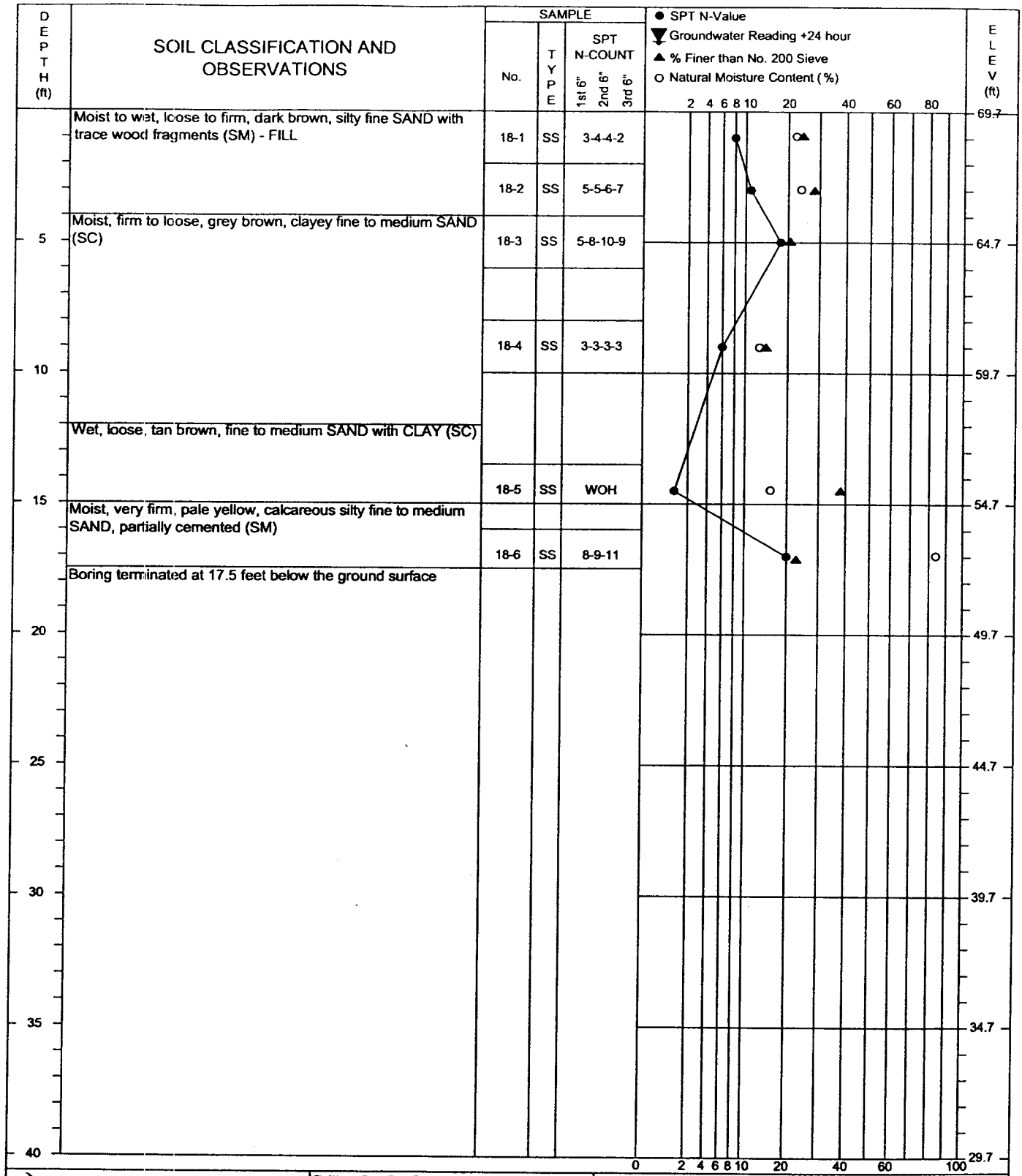
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/2/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-17



Carolina CONSULTING ENGINEERS Inc.

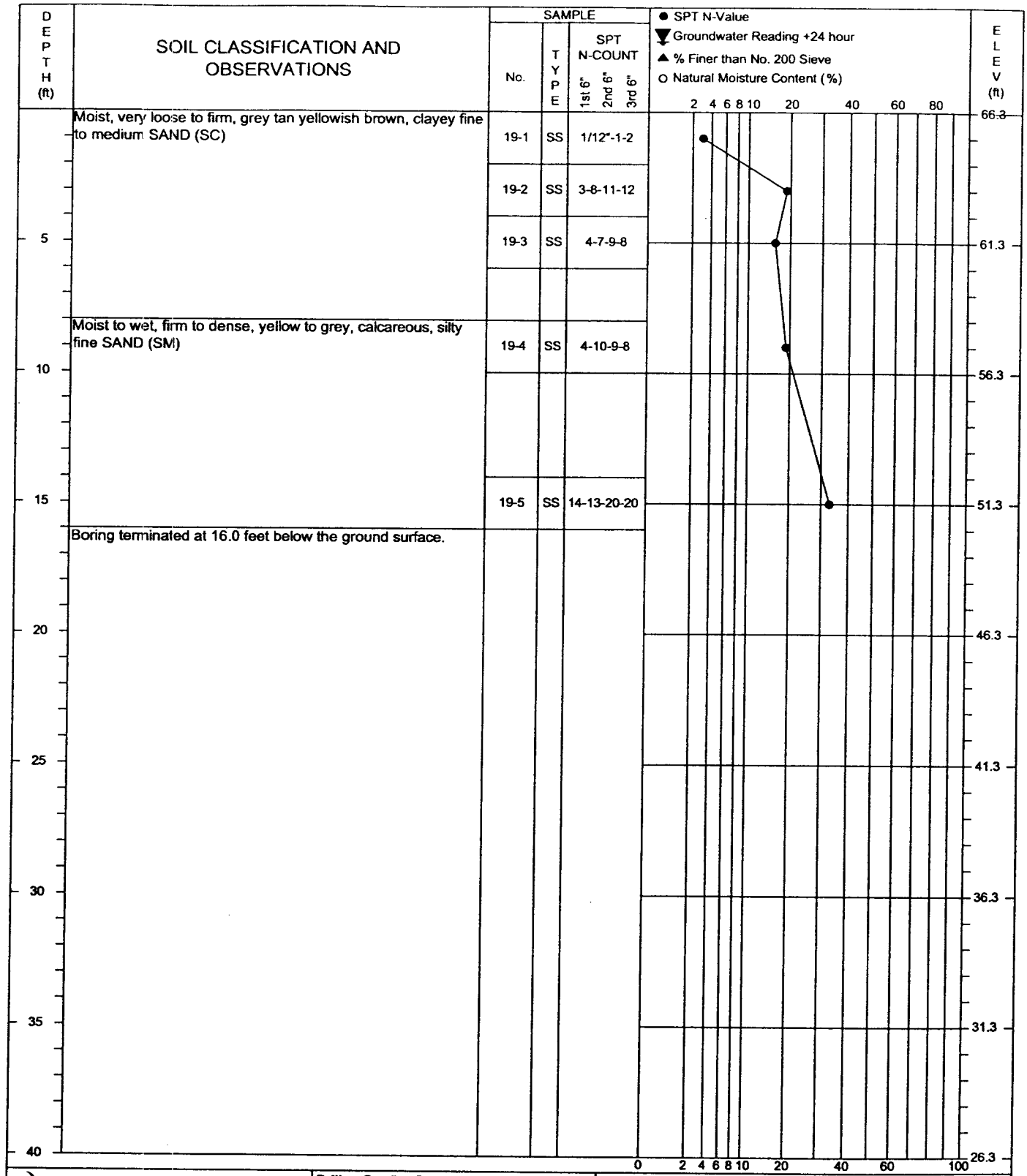
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/1/04
Project No. 01-04-1104
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BORING: B-18



Carolina CONSULTING ENGINEERS Inc.

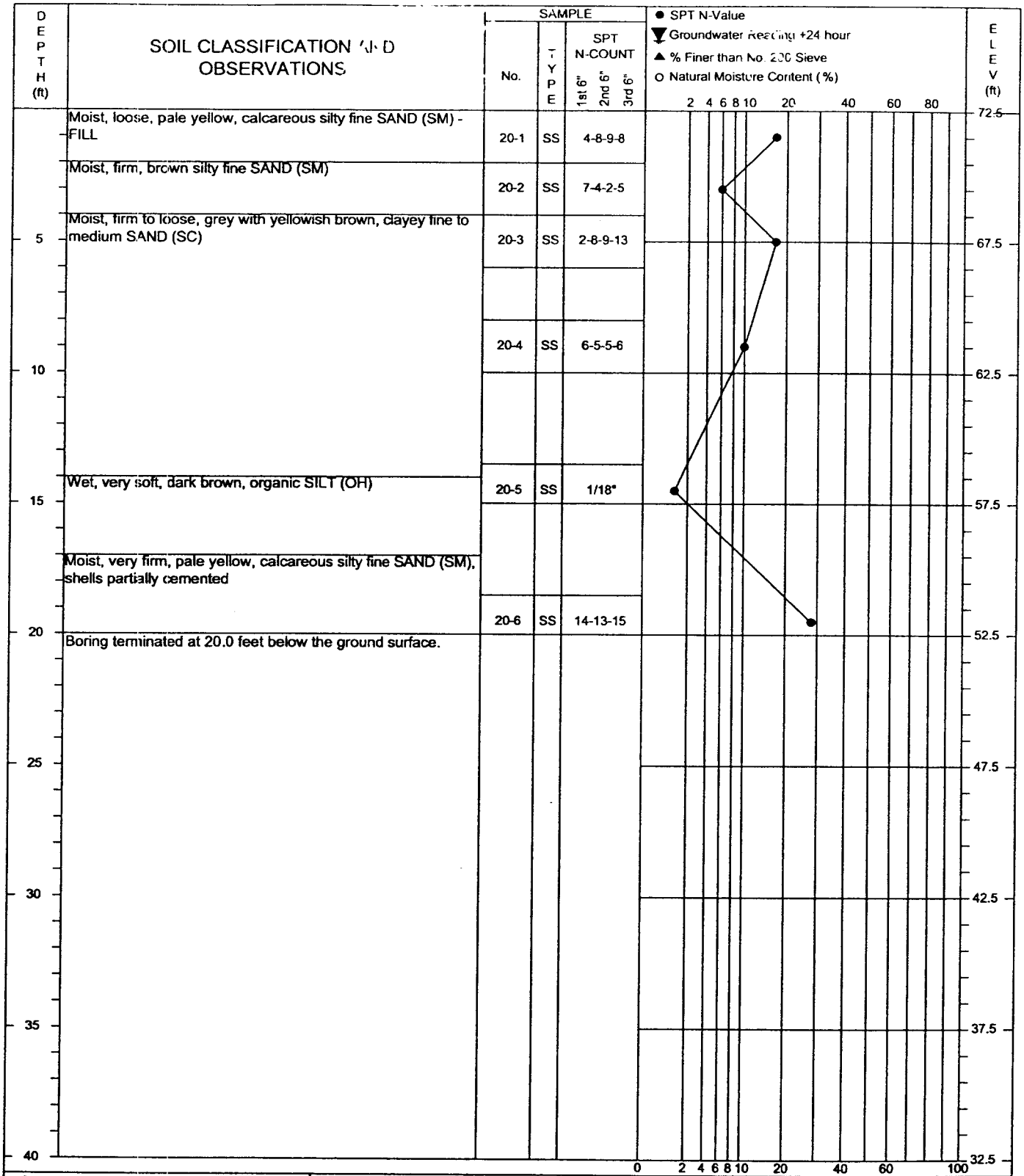
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/2/04
Project No. 01-04-1104
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BORING: B-19



Carolina CONSULTING ENGINEERS Inc.

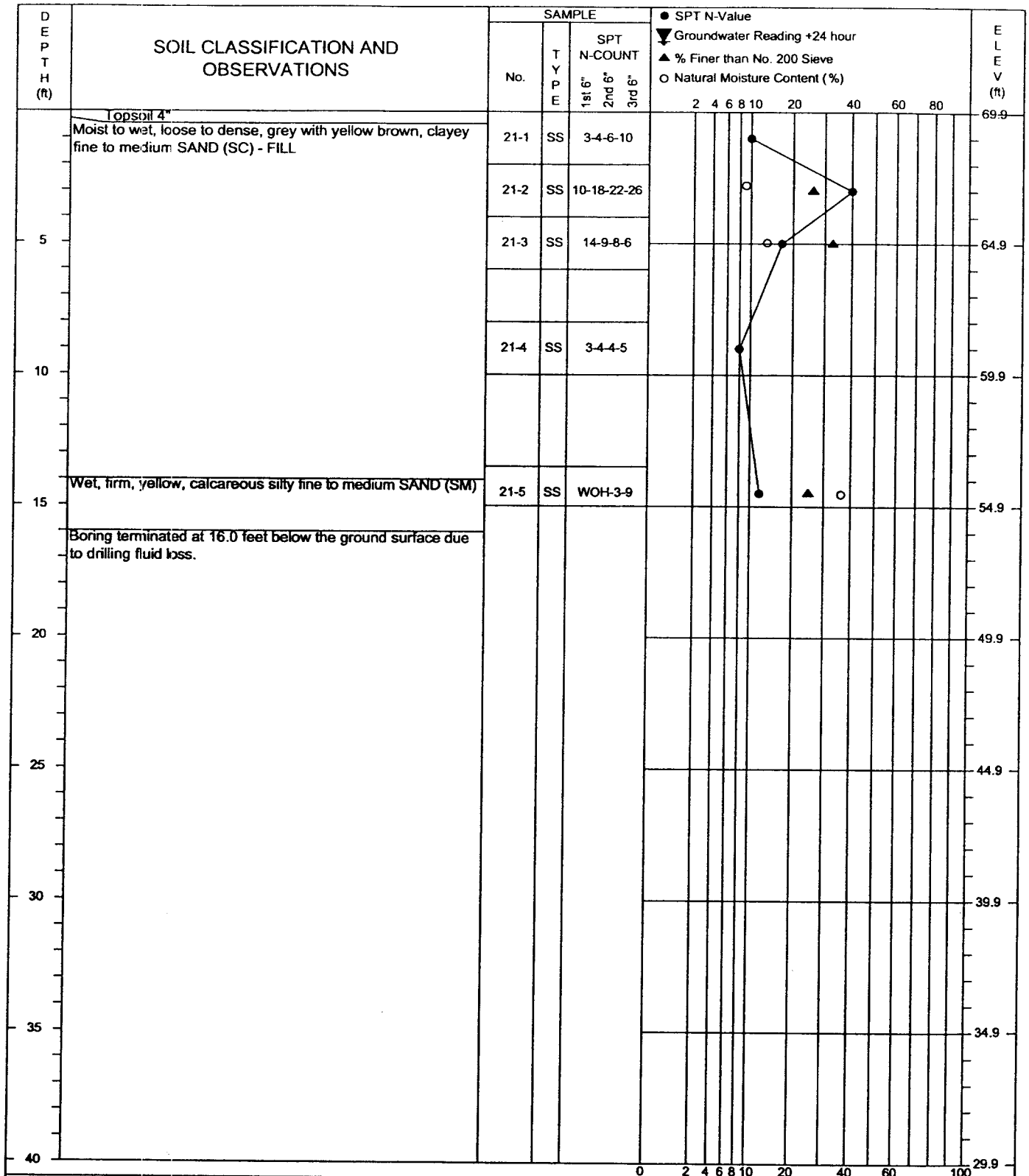
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/1/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-20



Carolina CONSULTING ENGINEERS Inc.

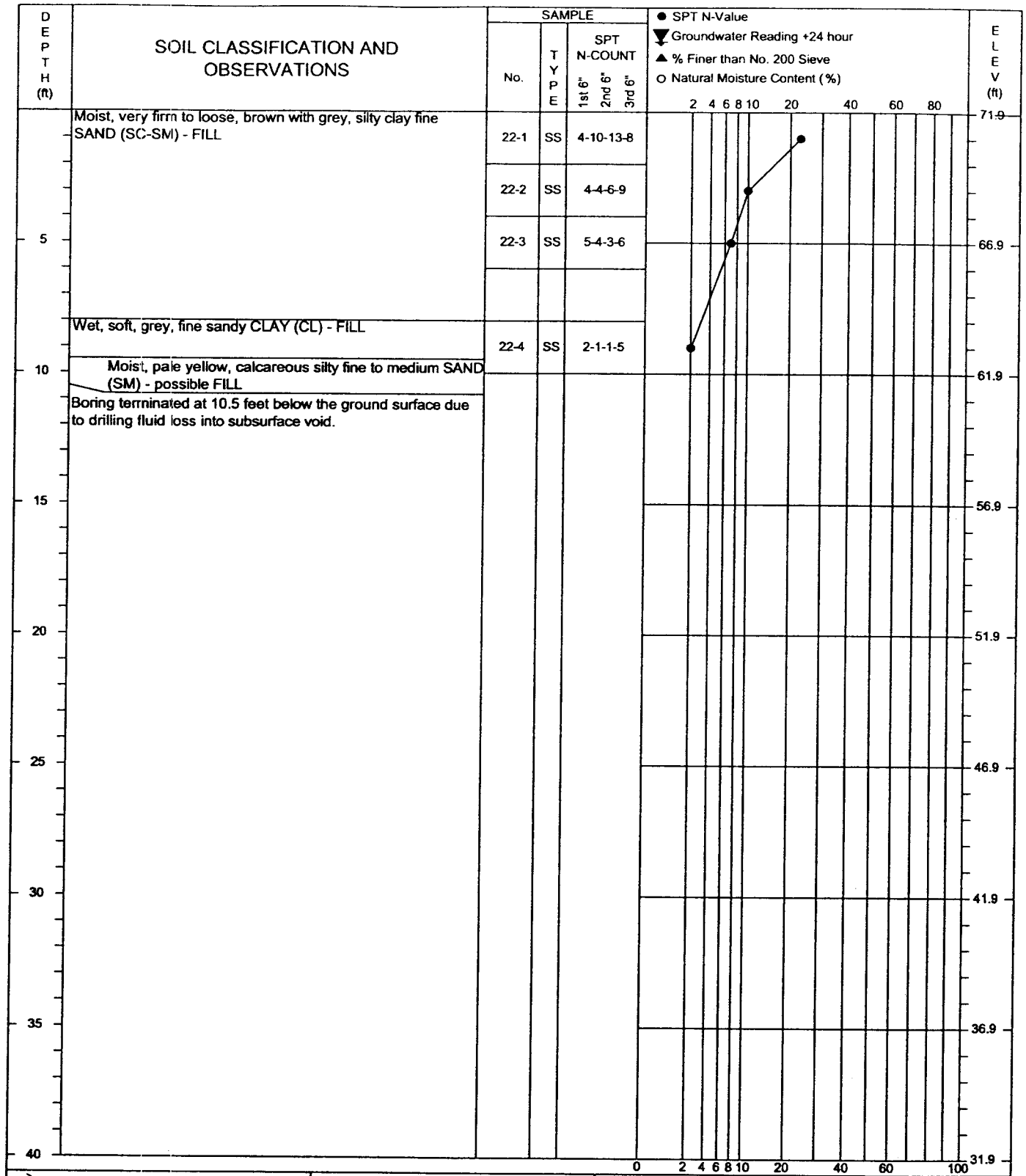
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 11/30/04
Project No. 01-04-1104
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BORING: B-21



Carolina CONSULTING ENGINEERS Inc.

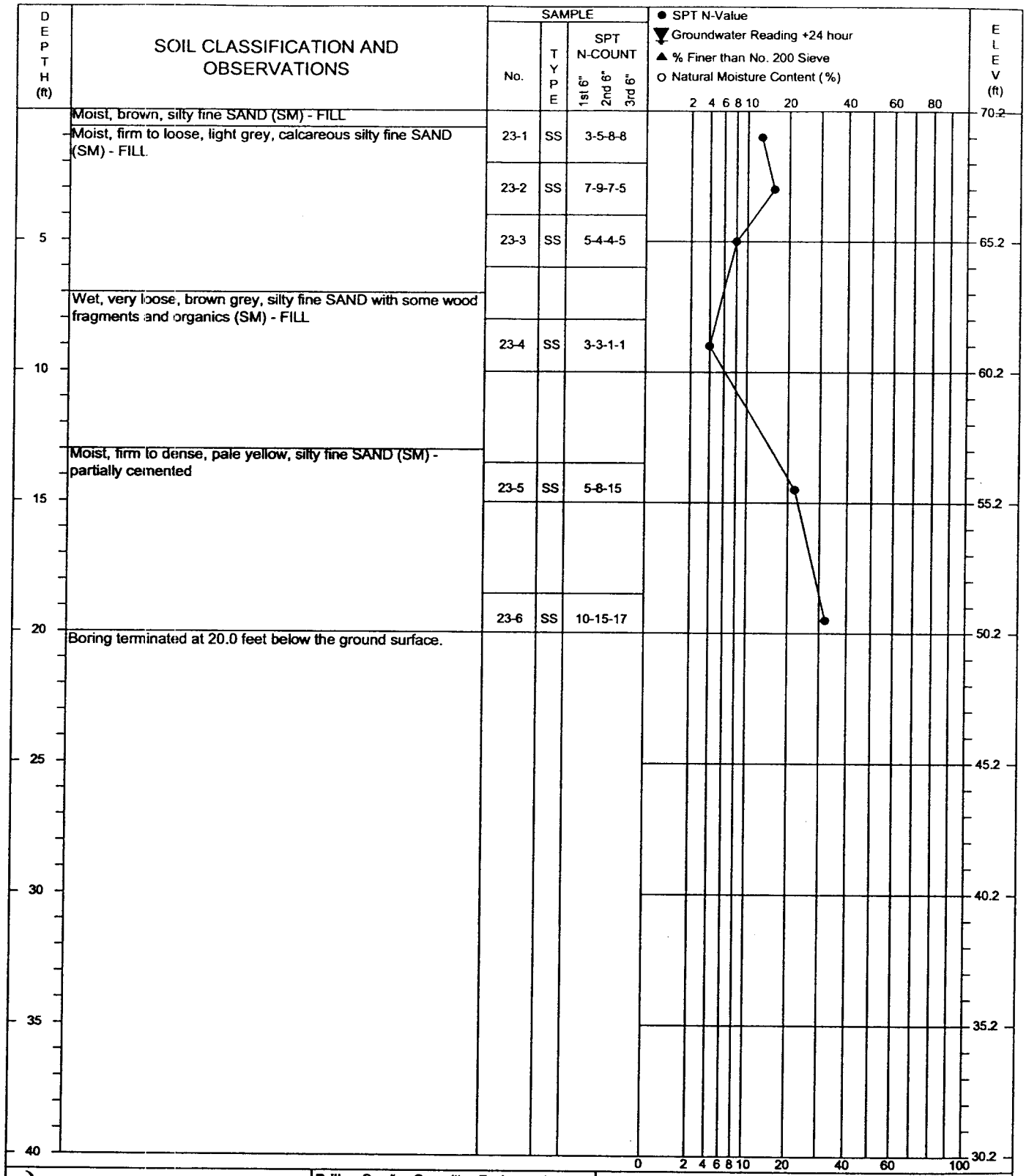
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 11/30/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-22



Carolina CONSULTING ENGINEERS Inc.

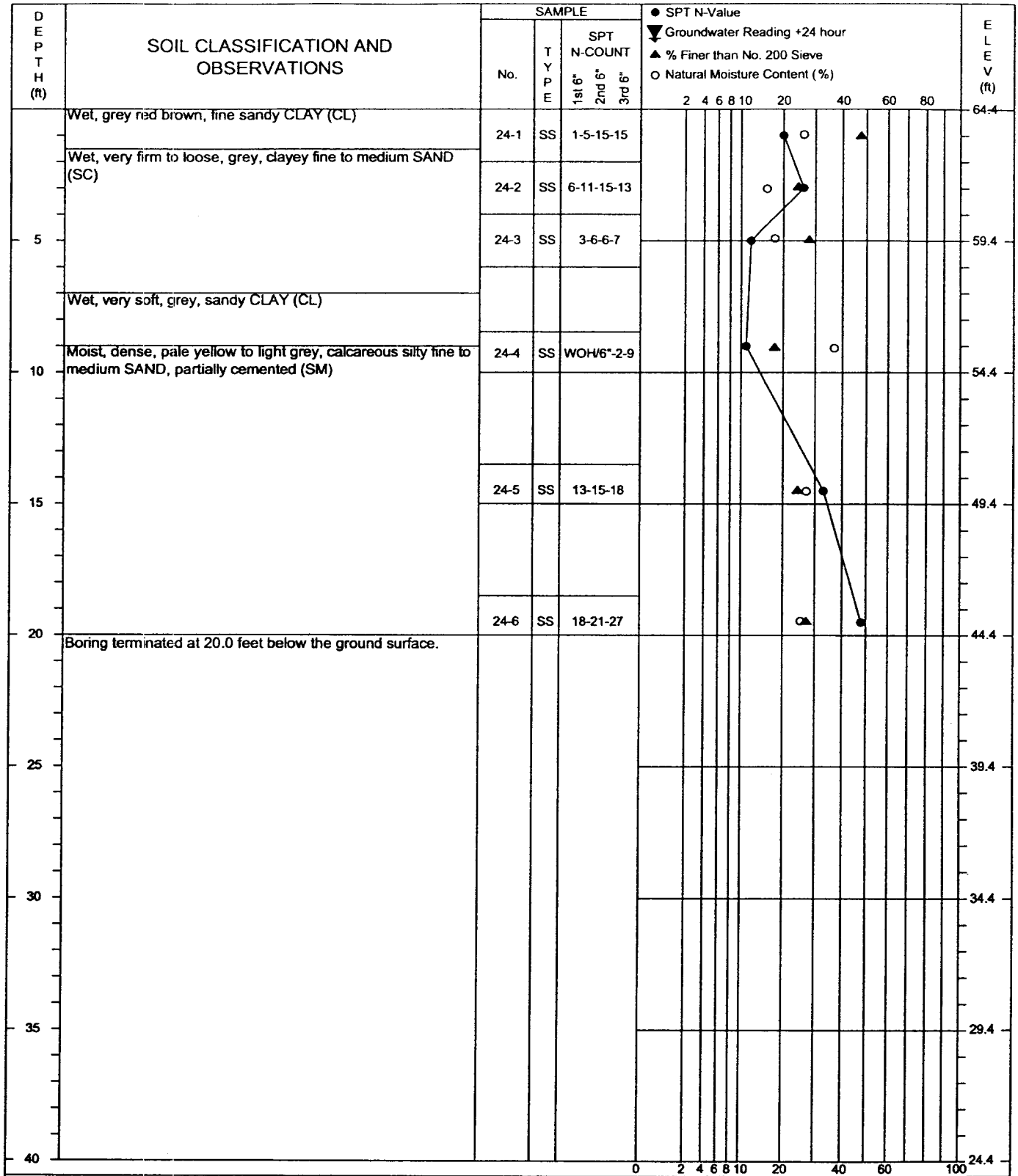
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 11/30/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-23



Carolina CONSULTING ENGINEERS Inc.

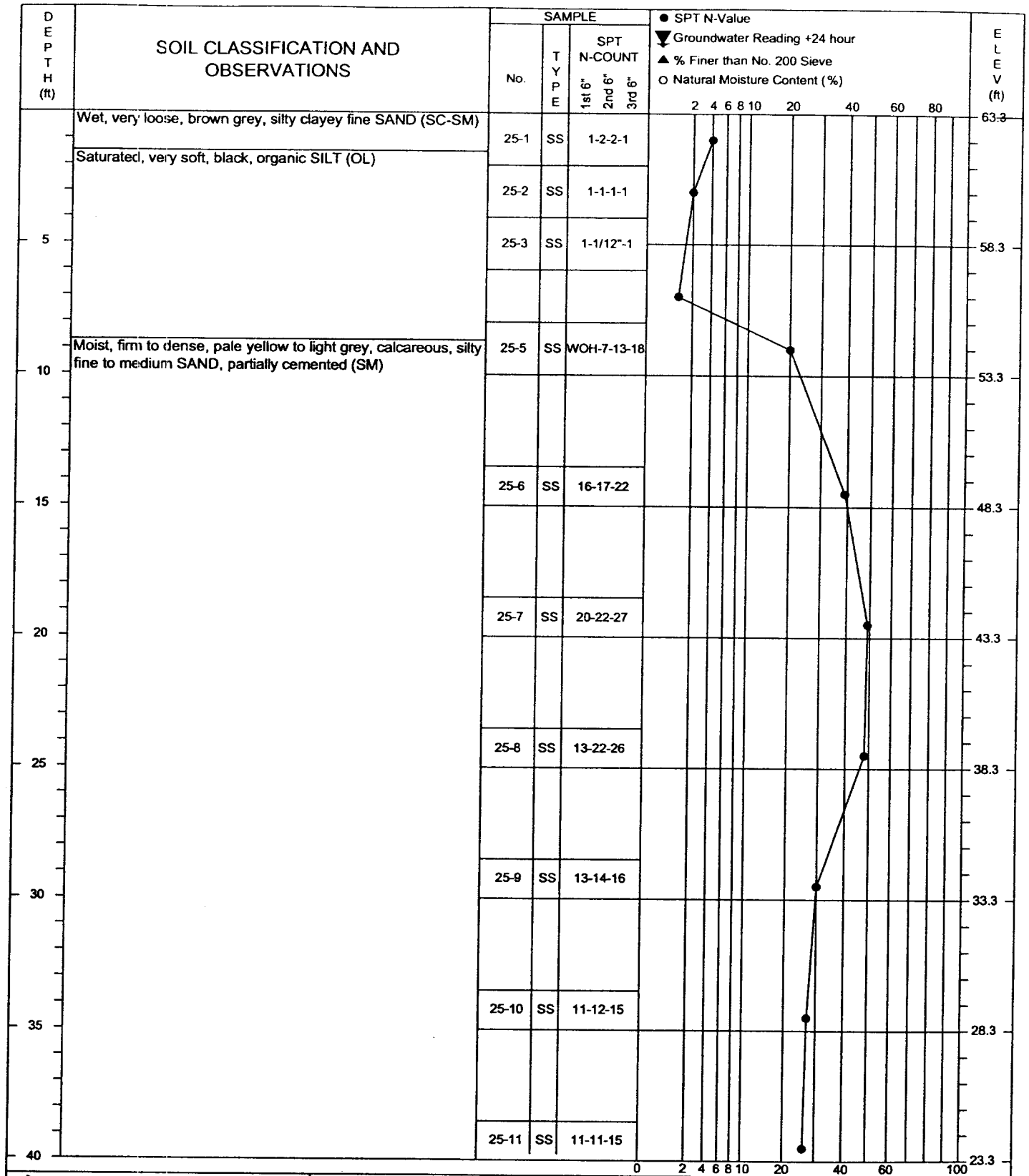
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/6/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-24



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/6/05
Project No. 01-04-1104
Page 1 of 2

Latitude:
Longitude:

BORING: B-25

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	SAMPLE TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Moist, firm to dense, pale yellow to light grey, calcareous, silty fine to medium SAND, partially cemented (SM)				23.3
	Hard Layer at 42.0 feet				
45		25-12	SS	12-14-11	18.3
50		25-13	SS	6-11-14	13.3
55		25-14	SS	9-11-13	8.3
60		25-15	SS	16-21-25	3.3
	Boring terminated at 60.0 feet below the ground surface.				
65					-1.7
70					-6.7
75					-11.7
80					-16.7

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
O Natural Moisture Content (%)

2 4 6 8 10 20 40 60 80

0 2 4 6 8 10 20 40 60 100

Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

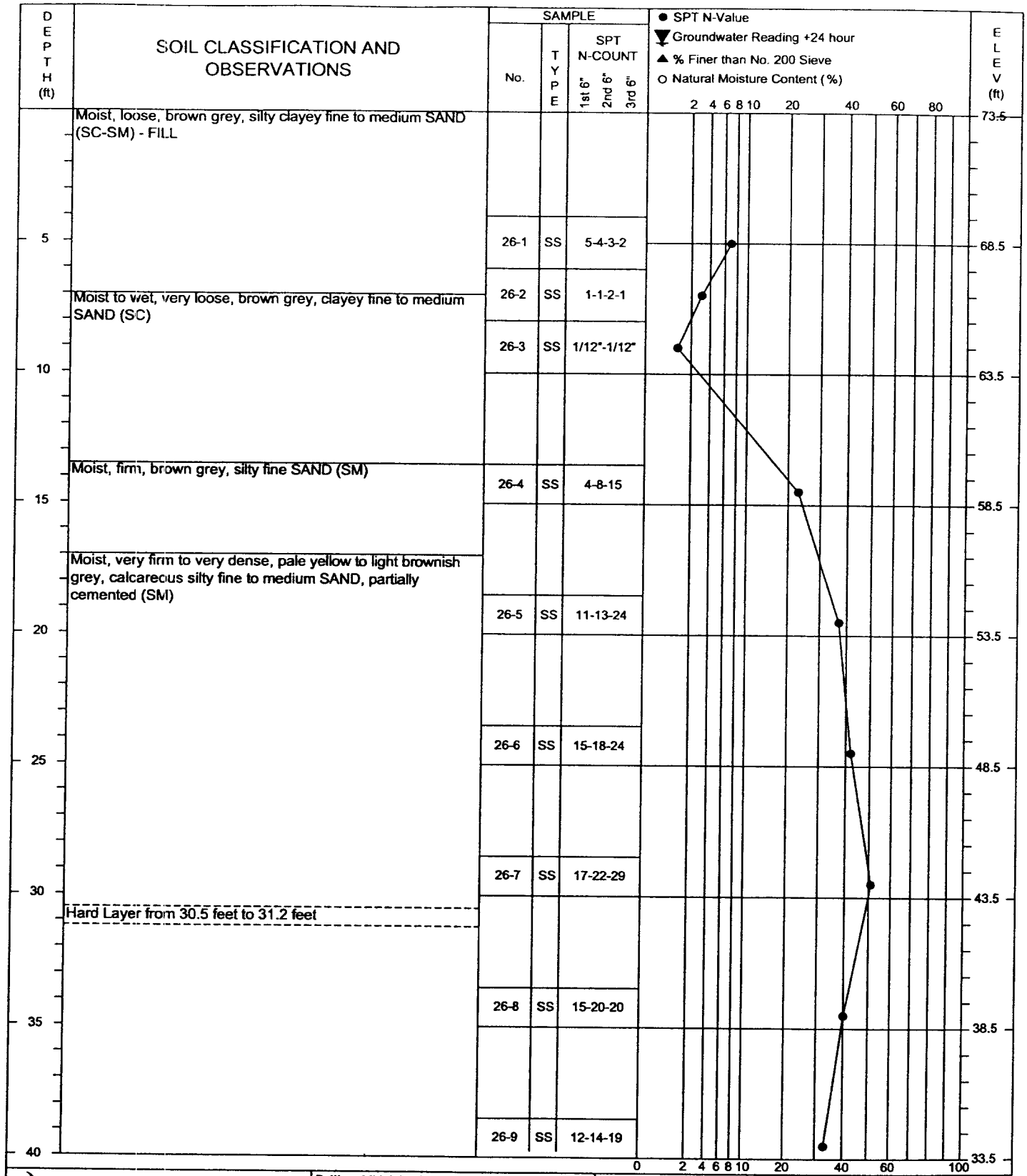
SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/6/05
Project No. 01-04-1104
Page 2 of 2

Latitude:
Longitude:

BORING: B-25



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

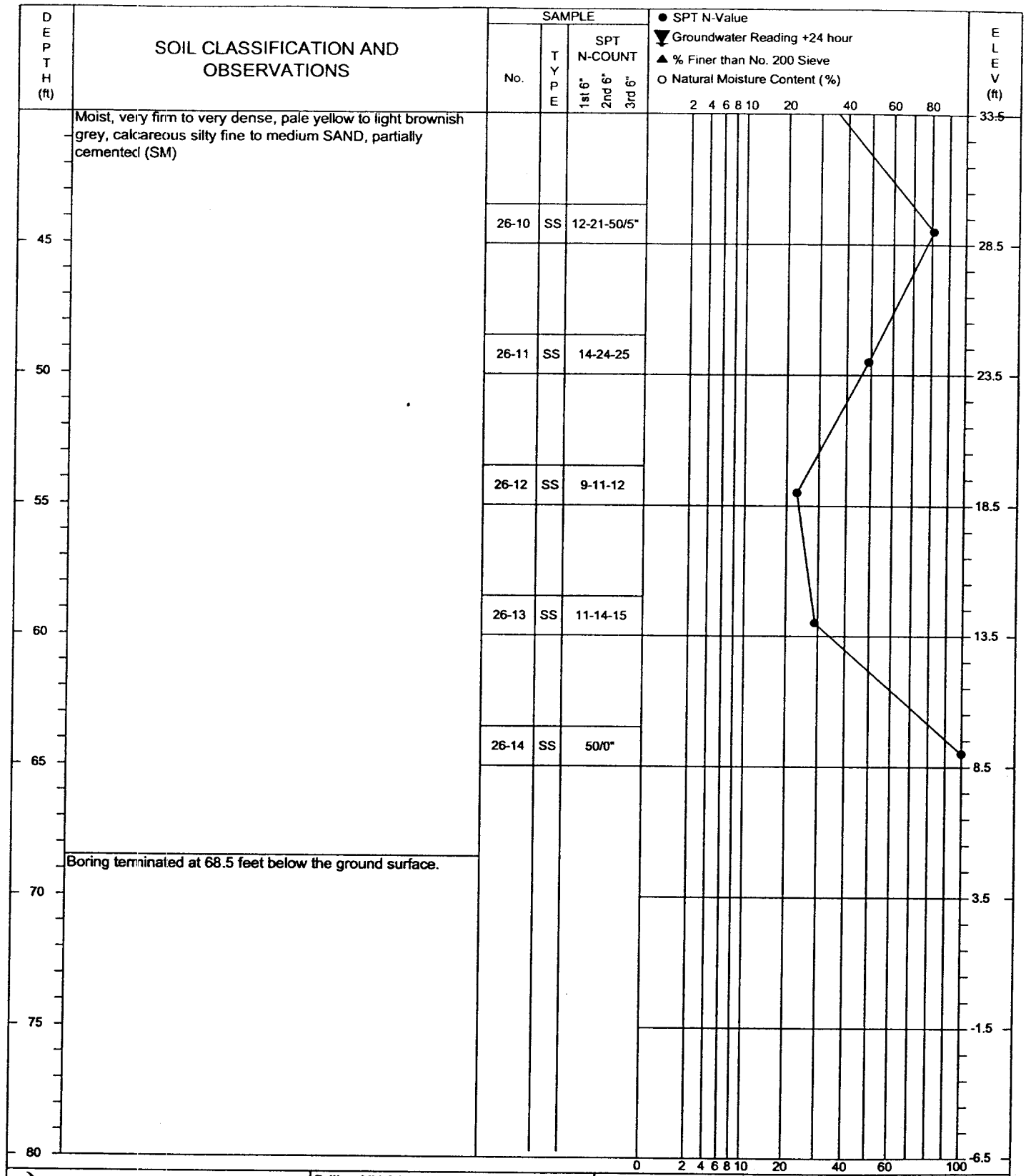
SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/7/04
Project No. 01-04-1104
Page 1 of 2

Latitude:
Longitude:

BORING: B-26



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

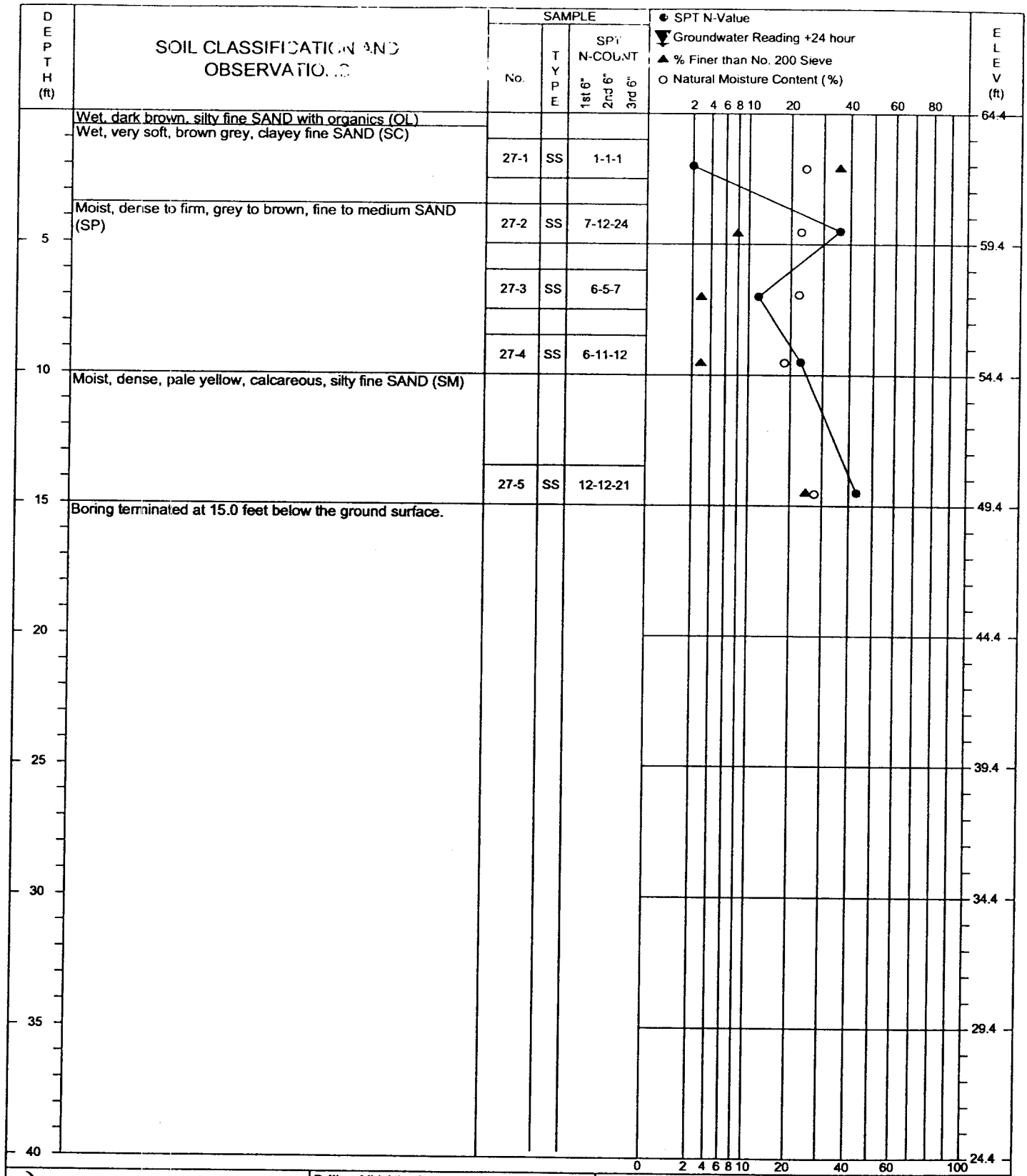
SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/7/04
Project No. 01-04-1104
Page 2 of 2

Latitude:
Longitude:

BORING: B-26



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/14/04
Project No. 01-04-1104
Page 1 of 1

Latitude:
Longitude:

BORING: B-27

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Wet, very loose to loose, grey with brown, clayey fine SAND (SC)				64.2
		28-1	SS	1-1-2	
		28-2	SS	2-3-4	
5					59.2
	Moist, very firm, grey brown, silty fine to medium SAND (SM)	28-3	SS	10-13-13	
	Moist, firm, grey, fine to coarse, SAND (SM)	28-4	SS	4-8-9	
10	Moist, dense, pale yellow to grey, silty fine to medium SAND (SM)				54.2
		28-5	SS	22-24-26	
15	Boring terminated at 15.0 feet below the ground surface.				49.2
20					44.2
25					39.2
30					34.2
35					29.2
40					24.2

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 2000 Sieve
○ Natural Moisture Content (%)

0 2 4 6 8 10 20 40 60 100

Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

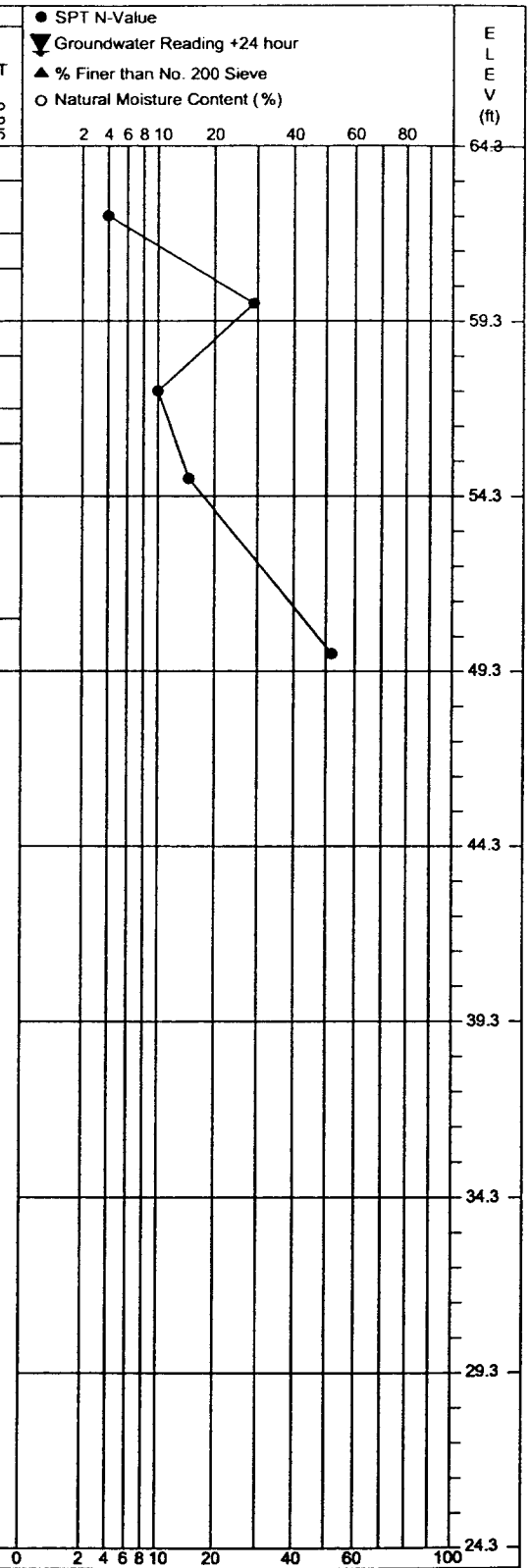
Project: Proposed Railroad

Drilled: 12/14/04
Project No. 01-04-1104
Page 1 of 1

Latitude:
Longitude:

BORING: B-28

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Wet, dark brown, silty fine SAND with organics (OL)				64.3
	Wet, very loose, grey brown, clayey fine SAND (SC)	29-1	SS	1-1-3	
	Moist, very firm, light grey, fine to medium SAND (SP)	29-2	SS	8-12-17	
5	Moist, loose, dark brown, silty fine SAND (SM)	29-3	SS	6-6-4	59.3
	Moist, firm, brown to grey, fine to coarse SAND (SM)	29-4	SS	5-8-7	
10					54.3
	Moist, very dense, light grey, calcareous silty fine to medium SAND (SM)	29-5	SS	17-23-29	
15	Boring terminated at 15.0 feet below the ground surface.				49.3
20					44.3
25					39.3
30					34.3
35					29.3
40					24.3



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/14/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-29

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT (1st 6" / 2nd 6" / 3rd 6")	ELEV (ft)
	Wet, soft, reddish yellow, CLAY (CH)				64.0
	Wood				
	Wet, soft reddish yellow, CLAY (CH)				
5	Wet, loose, dark brown, silty fine SAND with some organics (SM)	30-1	SS	1-2-6	59.0
	Moist, very firm, brownish grey, fine to medium SAND with trace silty (SP-SM)	30-2	SS	2-2-4	
10		30-3	SS	4-8-15	54.0
		30-4	SS	2-1-1	
15	Saturated, very soft, dark brown grey, SILT with some sand (ML)				49.0
	Moist, very dense, light grey, calcareous silty fine SAND (SM)	30-5	SS	15-30-29	
20	Boring terminated at 20.0 feet below the ground surface.				44.0
25					39.0
30					34.0
35					29.0
40					24.0

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
O Natural Moisture Content (%)

0 2 4 6 8 10 20 40 60 80 100

Carolina CONSULTING ENGINEERS Inc.

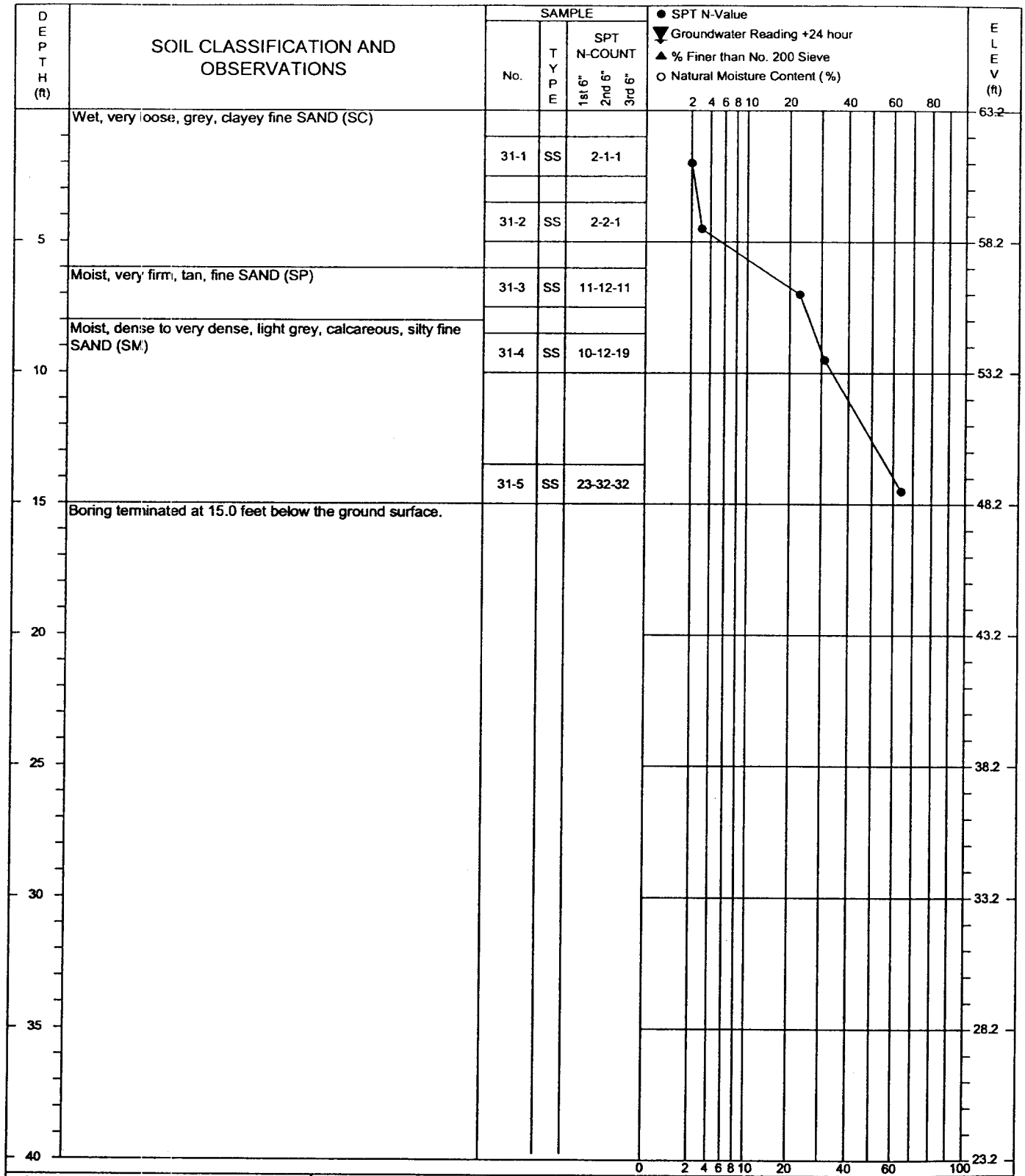
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/14/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-30



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

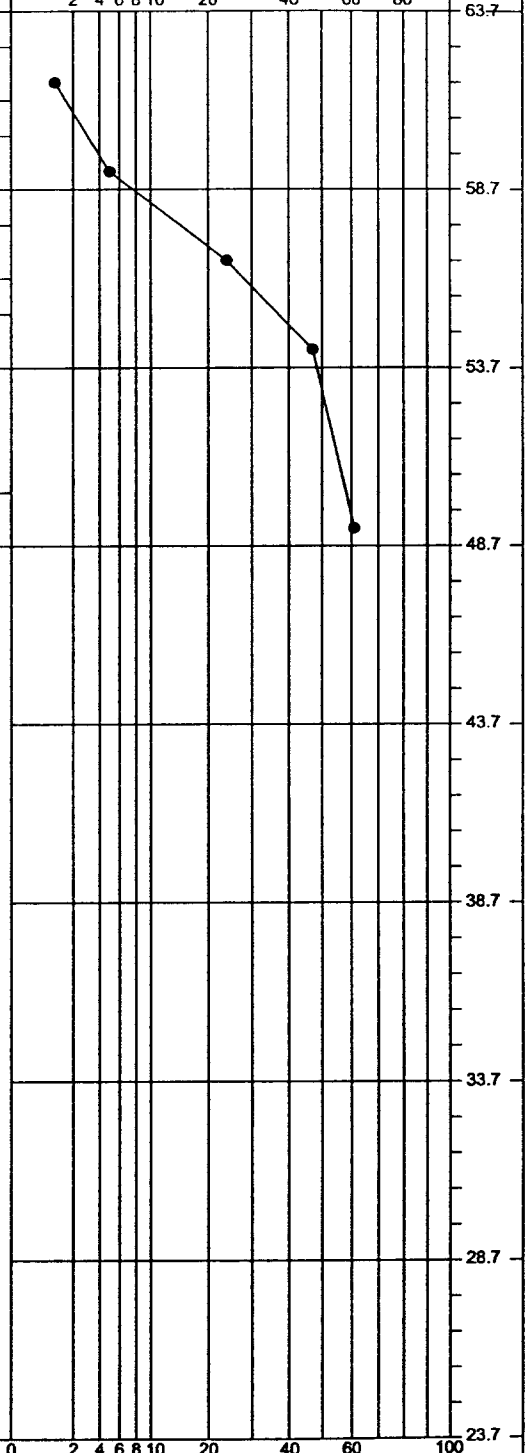
Project: Proposed Railroad

Drilled: 12/14/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-31

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Saturated, very loose, dark brown, silty fine SAND and ORGANICS (OL)				63.7
	Wet, very loose, light grey, fine SAND (SP)	32-1	SS	1-1/12"	
	Wet, firm, grey to bluish grey, sandy CLAY (CL)	32-2	SS	1-2-3	
5					58.7
		32-3	SS	5-5-19	
	Moist, dense to very dense, light grey, calcareous, silty fine to medium SAND (SM)				
10		32-4	SS	10-23-24	53.7
		32-5	SS	21-23-38	
15	Boring terminated at 15.0 feet below the ground surface.				48.7
20					43.7
25					38.7
30					33.7
35					28.7
40					23.7

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
○ Natural Moisture Content (%)



Carolina CONSULTING ENGINEERS Inc.

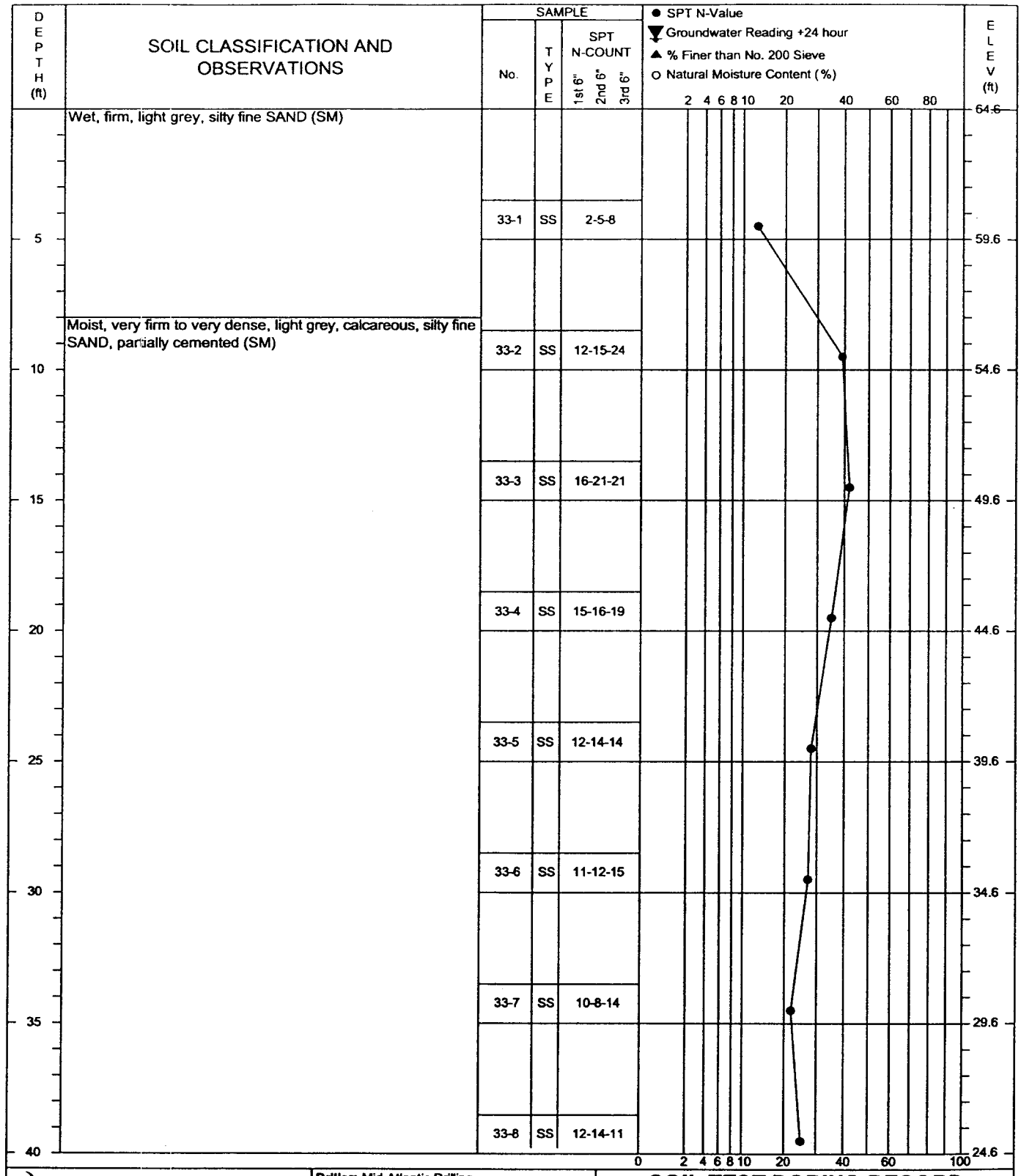
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/14/04
Project No. 01-04-1104
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BORING: B-32



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/6/04
Project No. 01-04-1104
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BORING: B-33

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	SAMPLE TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Moist, very firm to very dense, light grey, calcareous, silty fine SAND, partially cemented (SM)				24.6
45		33-9	SS	15-50/4"	19.6
50		33-10	SS	14-25-50/5"	14.6
		33-11	SS	18-21-50/4"	9.6
55	Boring terminated at 55.0 feet below the ground surface.				
60					4.6
65					-0.4
70					-5.4
75					-10.4
80					-15.4

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
○ Natural Moisture Content (%)

0 2 4 6 8 10 20 40 60 80 100

Carolina CONSULTING ENGINEERS Inc.

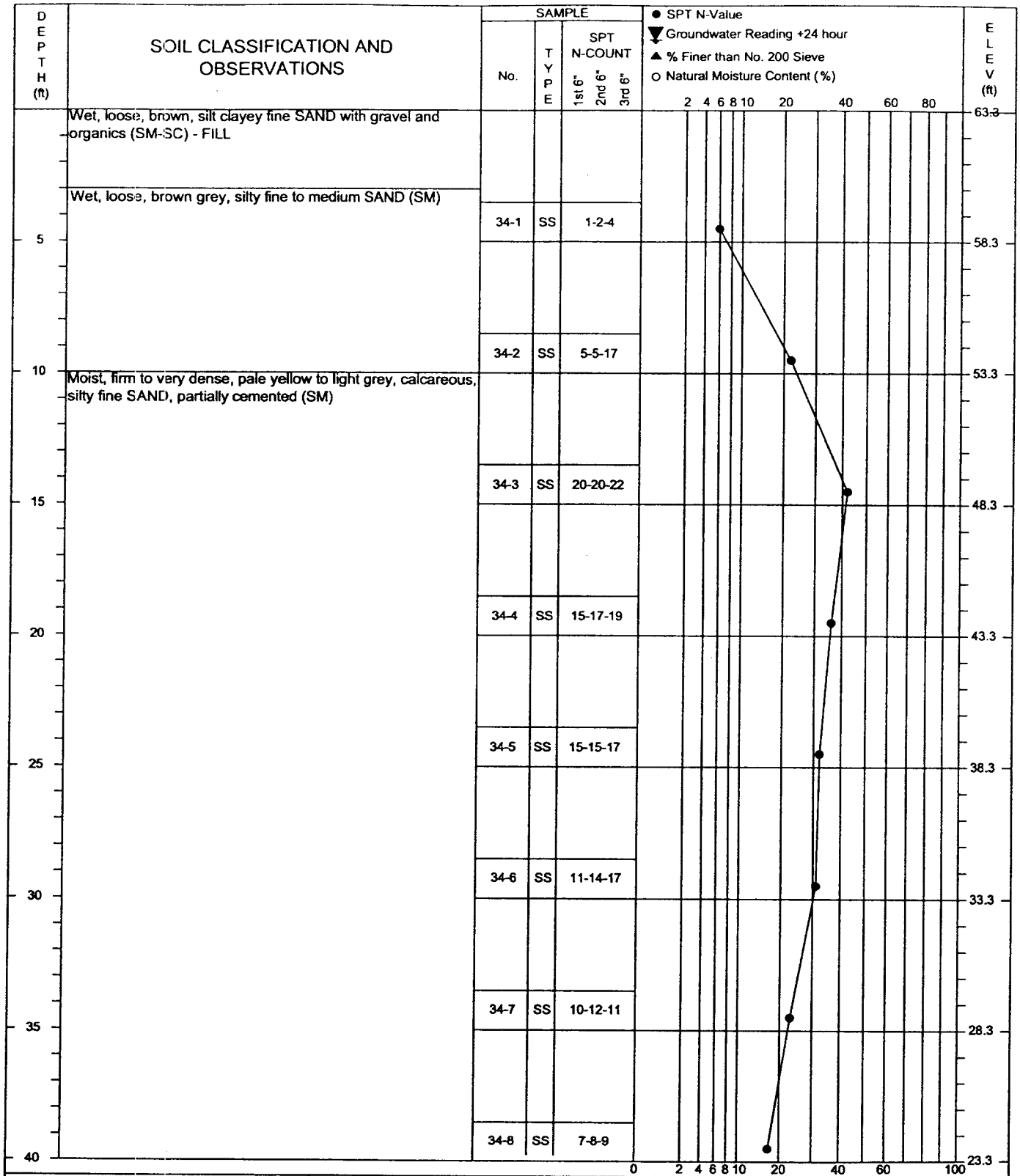
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/6/04
Project No. 01-04-1104
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BORING: B-33



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/7/04
Project No. 01-04-1104
Page 1 of 2

BORING: B-34

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Moist, firm to very dense, pale yellow to light grey, calcareous, silty fine SAND, partially cemented (SM)				23.3
45		34-9	SS	10-10-12	18.3
50		34-10	SS	50/3"	13.3
55		34-11	SS	20-25-30	8.3
60		34-12	SS	17-29-41	3.3
	Boring terminated at 60.0 feet below the ground surface.				
65					-1.7
70					-6.7
75					-11.7
80					-16.7

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
○ Natural Moisture Content (%)

2 4 6 8 10 20 40 60 80

0 2 4 6 8 10 20 40 60 100

Carolina CONSULTING ENGINEERS Inc.

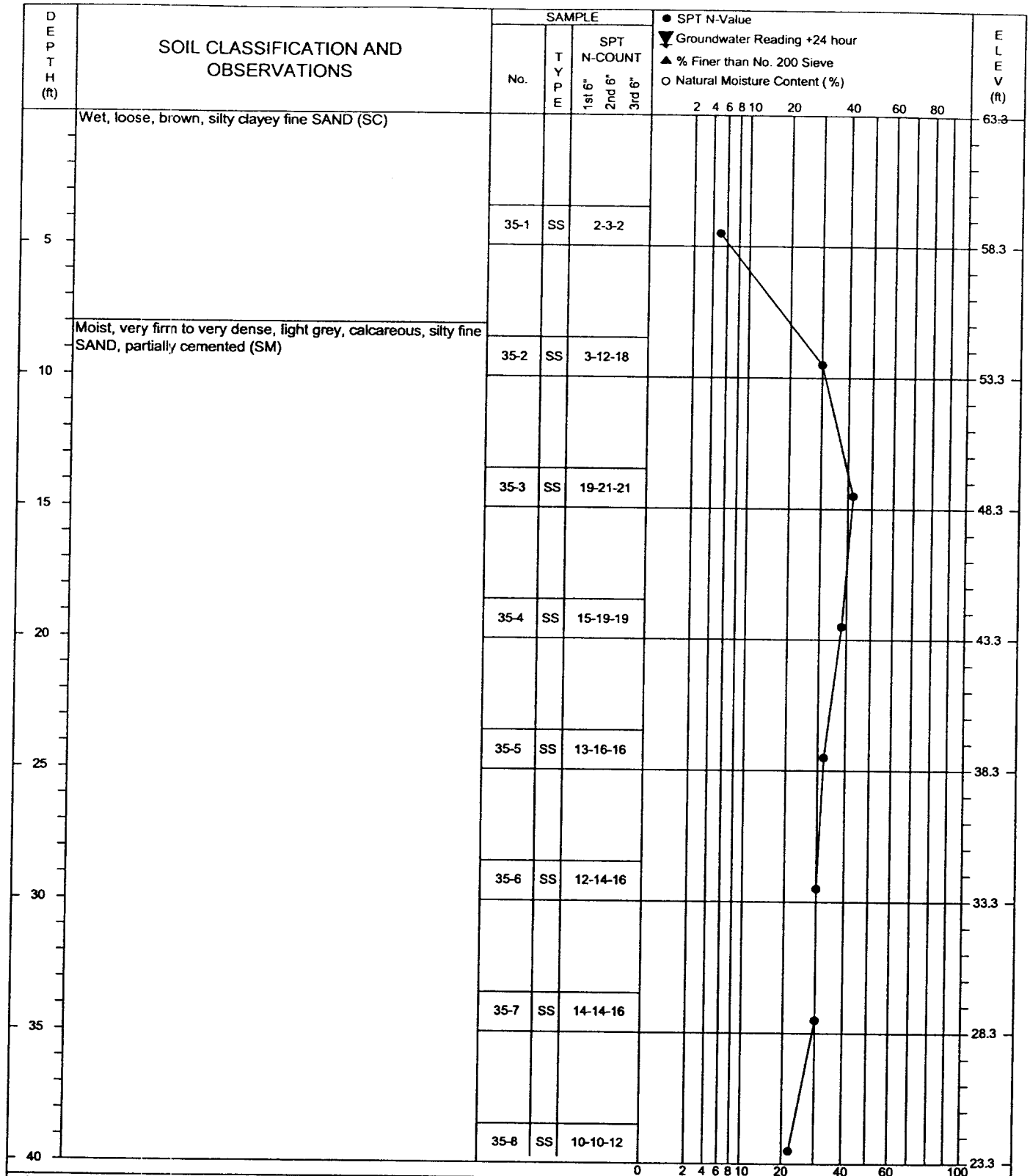
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/7/04
Project No. 01-04-1104
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BORING: B-34



Carolina CONSULTING ENGINEERS Inc.

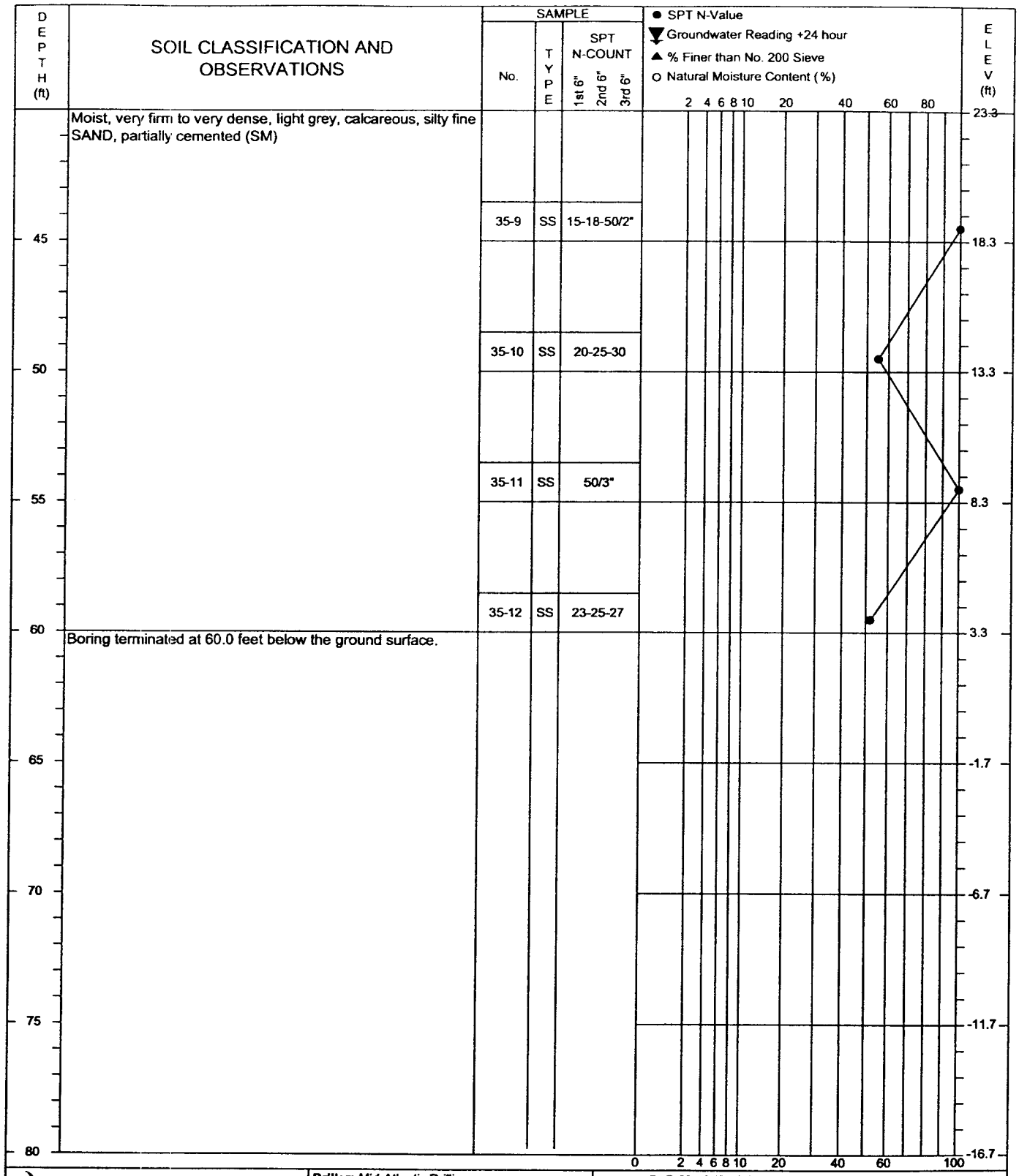
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/7/04
Project No. 01-04-1104
Page 1 of 2

BORING: B-35



Carolina CONSULTING ENGINEERS Inc.

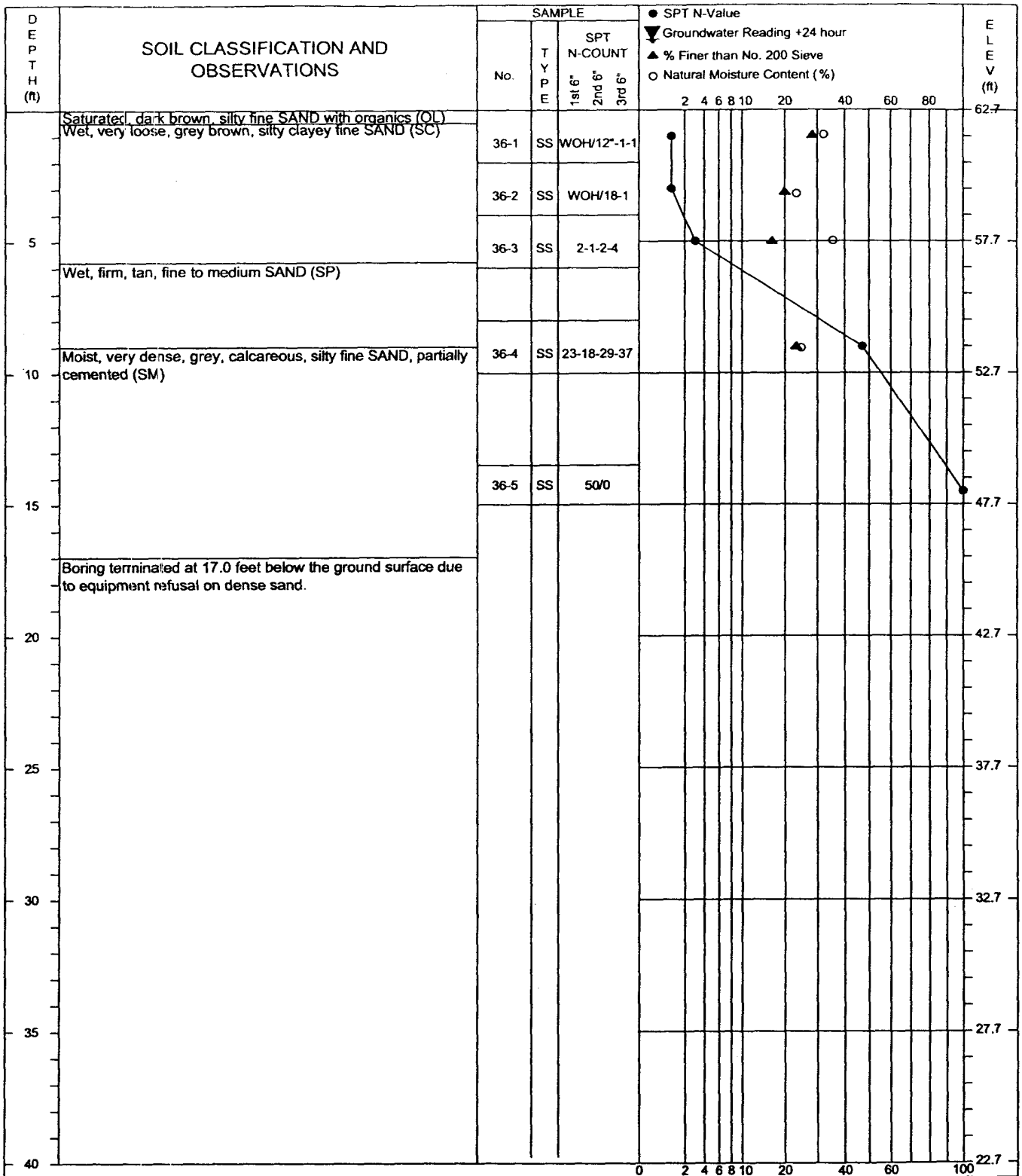
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/7/04
Project No. 01-04-1104
Page 2 of 2

BORING: B-35



Carolina CONSULTING ENGINEERS Inc.

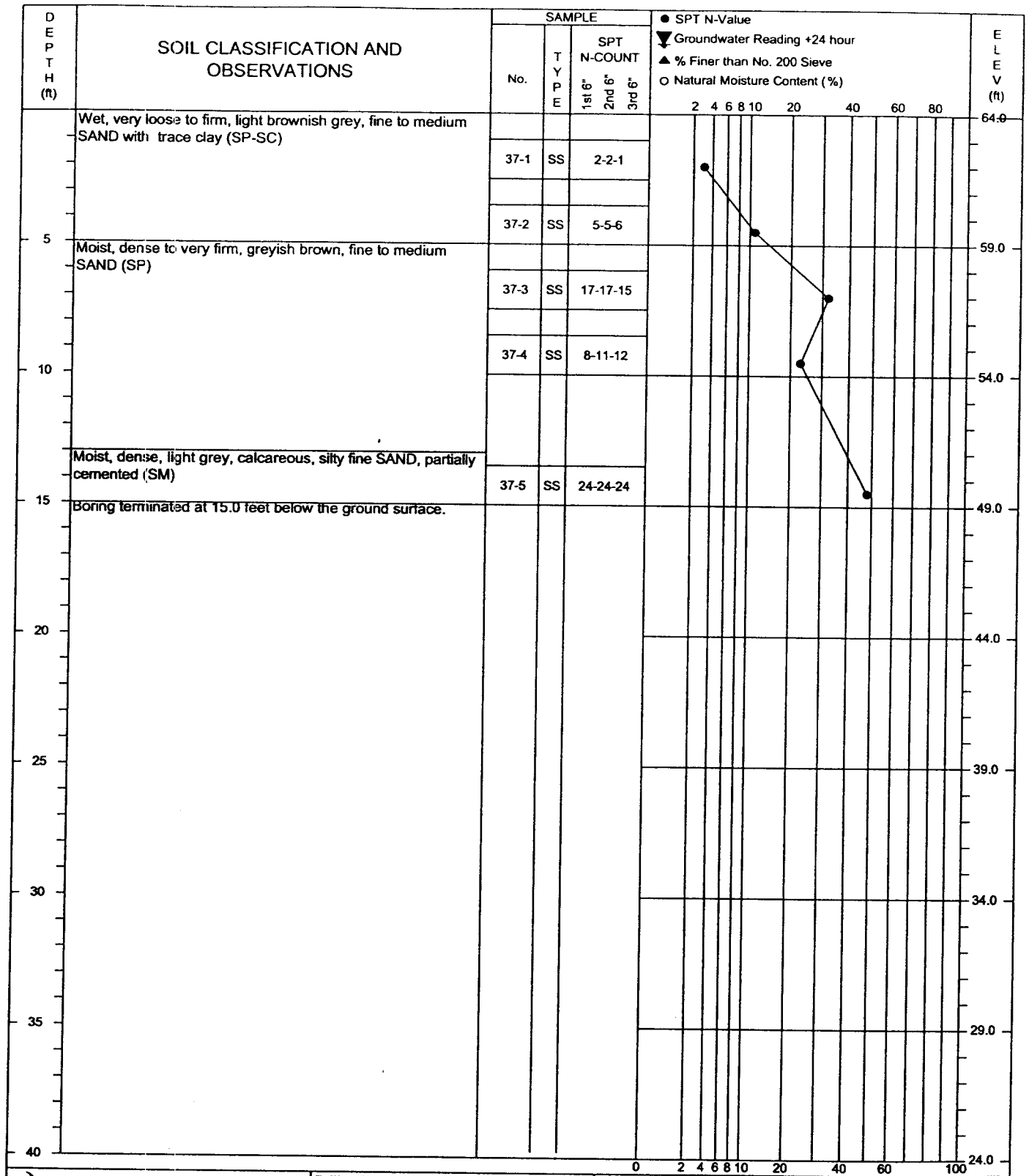
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/15/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-36



Carolina CONSULTING ENGINEERS Inc.

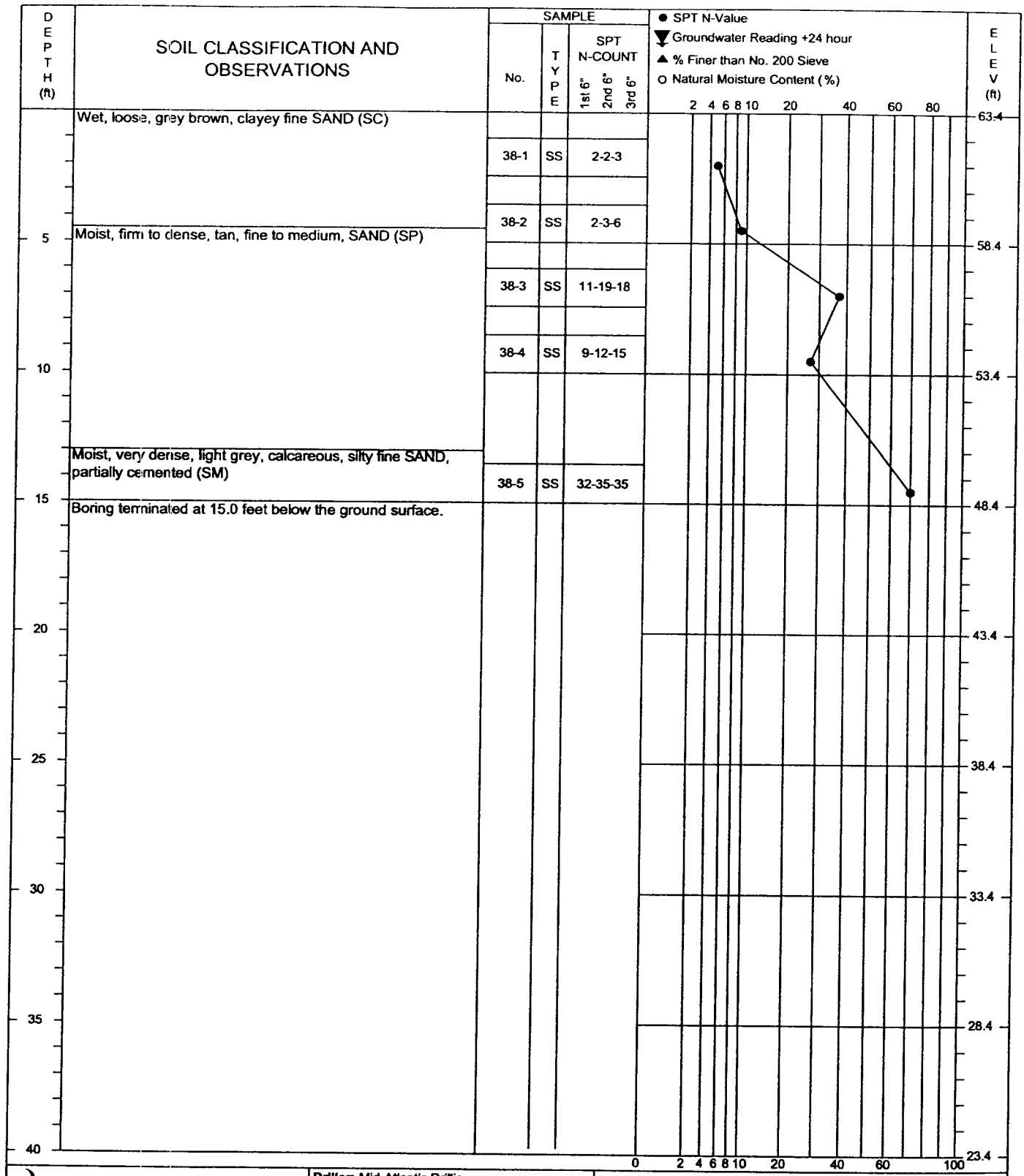
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/15/04
Project No. 01-04-1104
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BORING: B-37



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

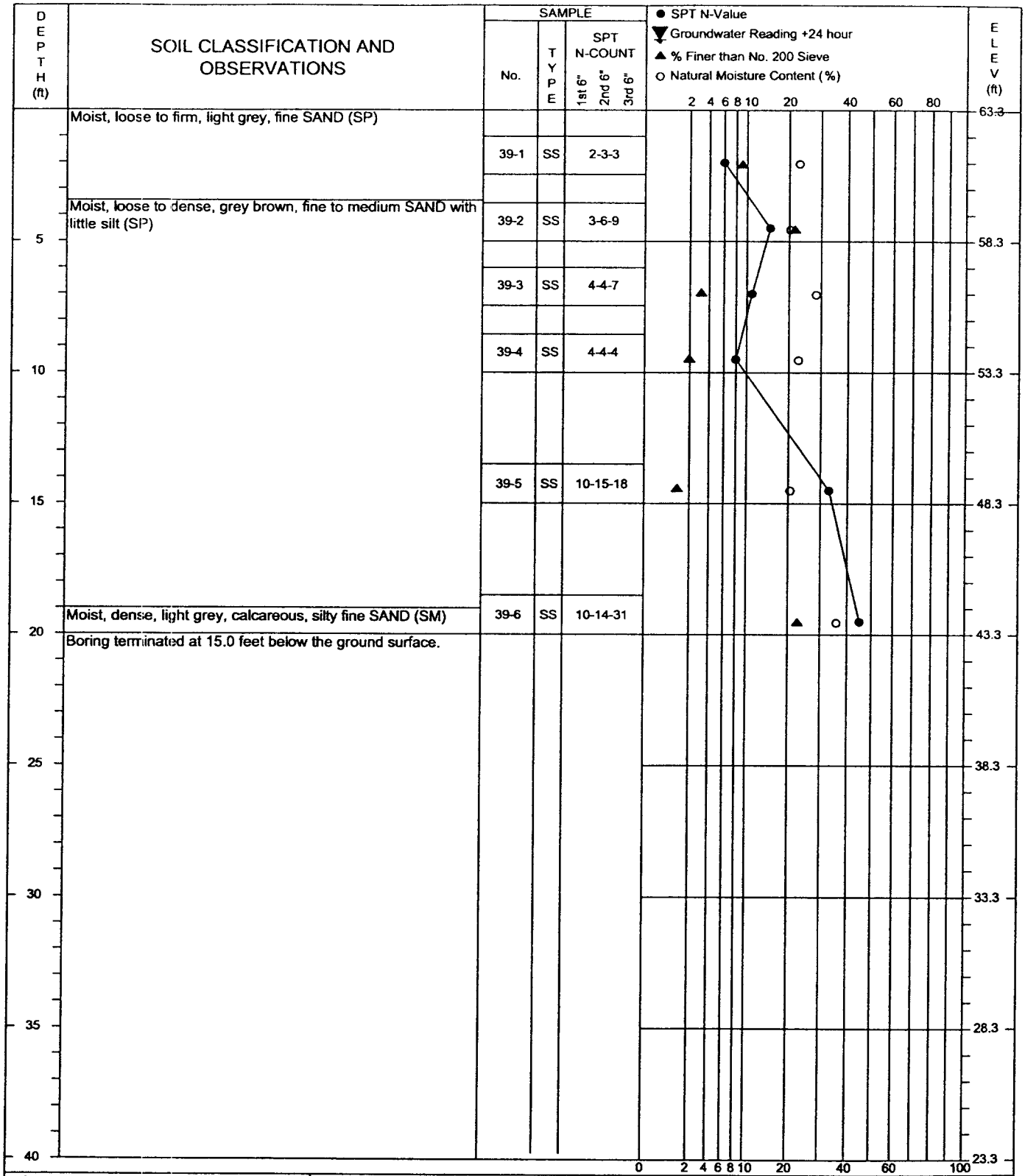
SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/15/04
Project No. 01-04-1104
Page 1 of 1

Latitude:
Longitude:

BORING: B-38



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/15/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-39

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
0	Wet, very loose, yellow brown, clayey fine SAND (SC)	40-1	SS	2-1-1-3	63.5
	Moist, firm to very firm, light grey to light brown, fine SAND (SP)	40-2	SS	6-6-8-9	
5		40-3	SS	6-8-15-11	58.5
10					53.5
	Moist, dense, light grey, calcareous, silty fine SAND (SM)	40-4	SS	15-15-24	
15					48.5
		40-5	SS	17-19-27	
20	Boring terminated at 20.0 feet below the ground surface.				43.5
25					38.5
30					33.5
35					28.5
40					23.5

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
O Natural Moisture Content (%)

2 4 6 8 10 20 40 60 80

0 2 4 6 8 10 20 40 60 100

Carolina CONSULTING ENGINEERS Inc.

Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

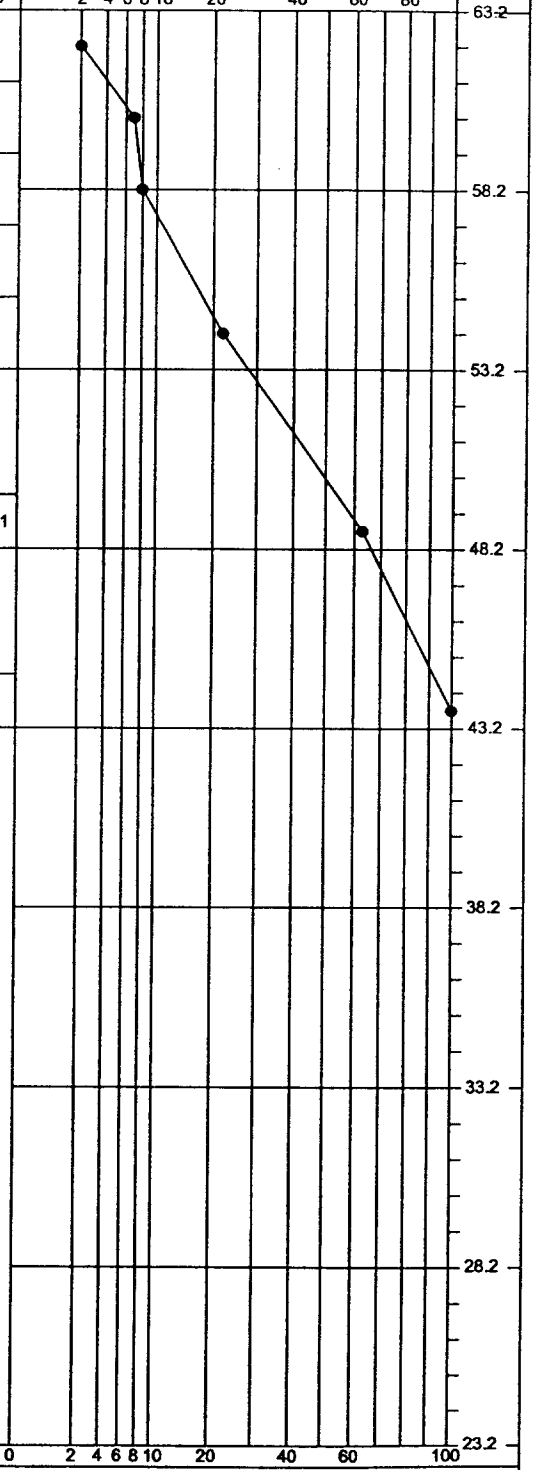
SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/15/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-40

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
0	Wet, very soft to firm, yellow brown and grey, fine sandy CLAY (CL)	41-1	SS	3-1-1-3	63.2
		41-2	SS	3-3-4-5	
5		41-3	SS	2-3-5-6	58.2
	Moist, very firm to dense, light brownish grey, fine to medium SAND (SP)				
		41-4	SS	11-15-7-8	
10					53.2
		41-5	SS	11-23-40-31	
15					48.2
	Moist, dense, light grey, calcareous, silty fine SAND (SM)				
	Boring terminated at 19.0 feet below the ground surface.	41-6	SS	50/6"	
20					43.2
25					38.2
30					33.2
35					28.2
40					23.2



Carolina CONSULTING ENGINEERS Inc.

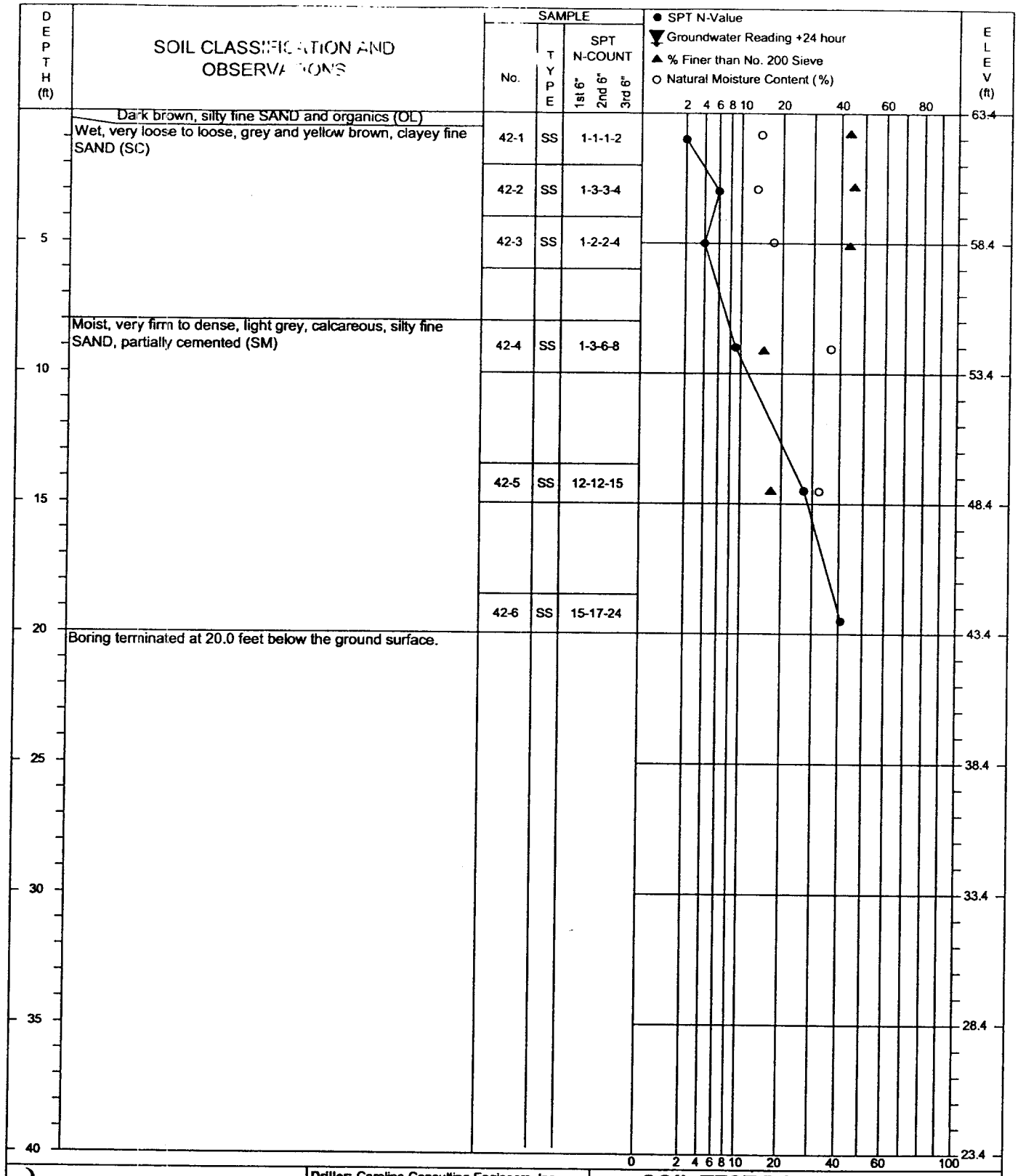
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/14/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-41



Carolina CONSULTING ENGINEERS Inc.

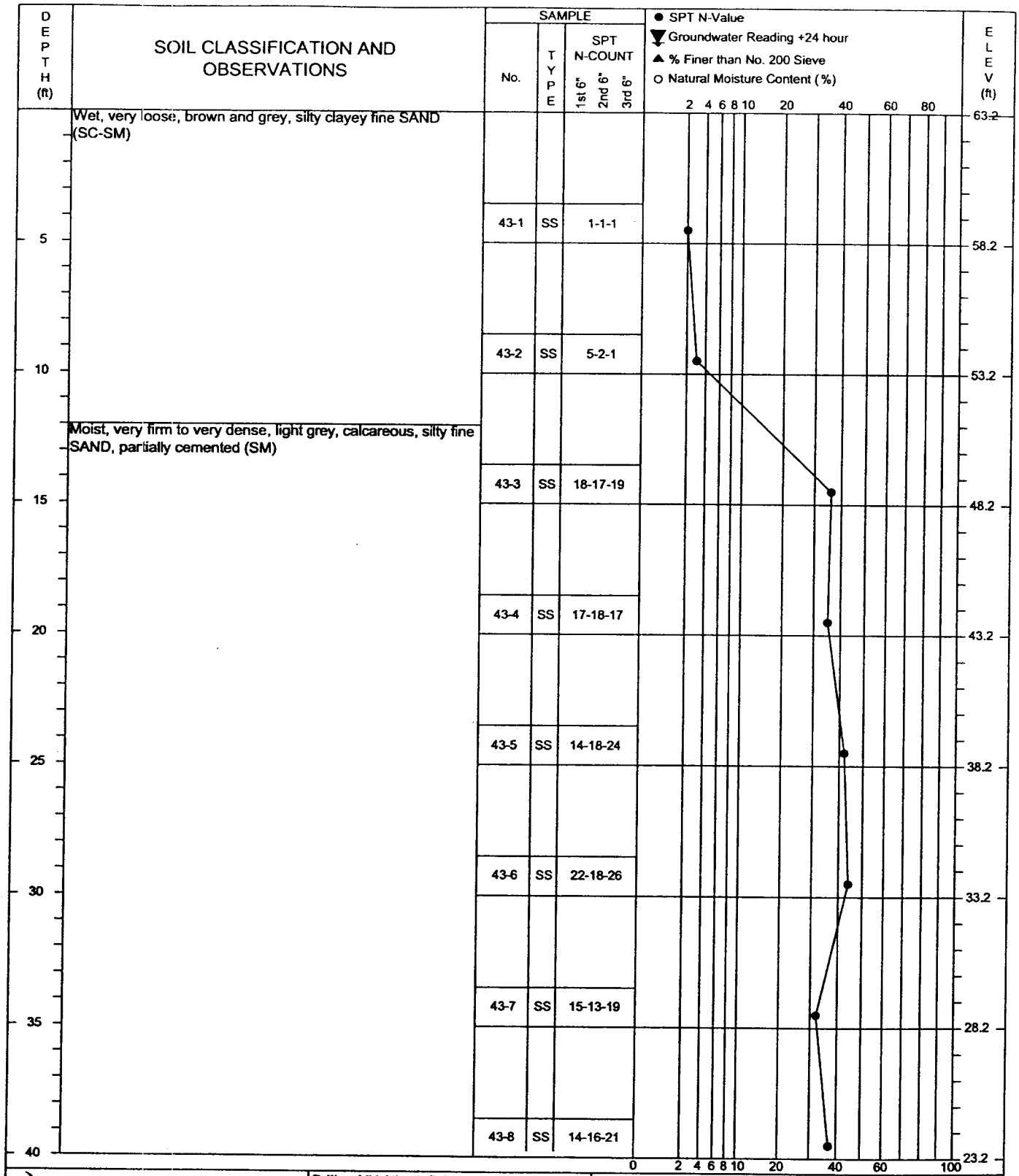
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/13/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-42



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/8/04
Project No. 01-04-1104
Page 1 of 2

BORING: B-43

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Moist, very firm to very dense, light grey, calcareous, silty fine SAND, partially cemented (SM)				23.2
45		43-9	SS	15-17-19	18.2
50		43-10	SS	14-17-50/3"	13.2
55		43-11	SS	17-13-16	8.2
60		43-12	SS	16-26-20	3.2
	Boring terminated at 60.0 feet below the ground surface.				
65					-1.8
70					-6.8
75					-11.8
80					-16.8

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
○ Natural Moisture Content (%)

2 4 6 8 10 20 40 60 80

0 2 4 6 8 10 20 40 60 100

Carolina CONSULTING ENGINEERS Inc.

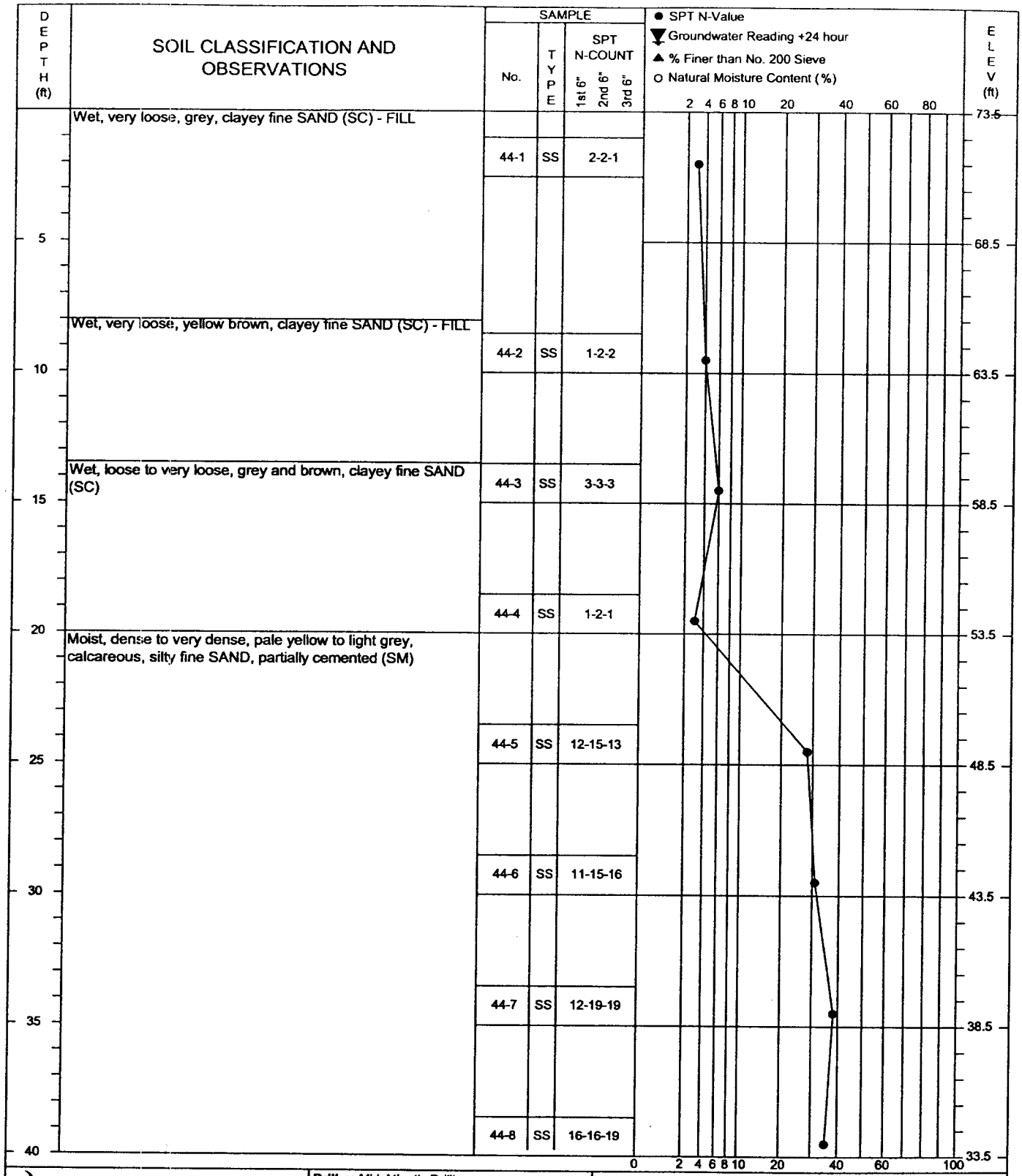
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/8/04
Project No. 01-04-1104
Page 2 of 2

BORING: B-43



Carolina CONSULTING ENGINEERS Inc.

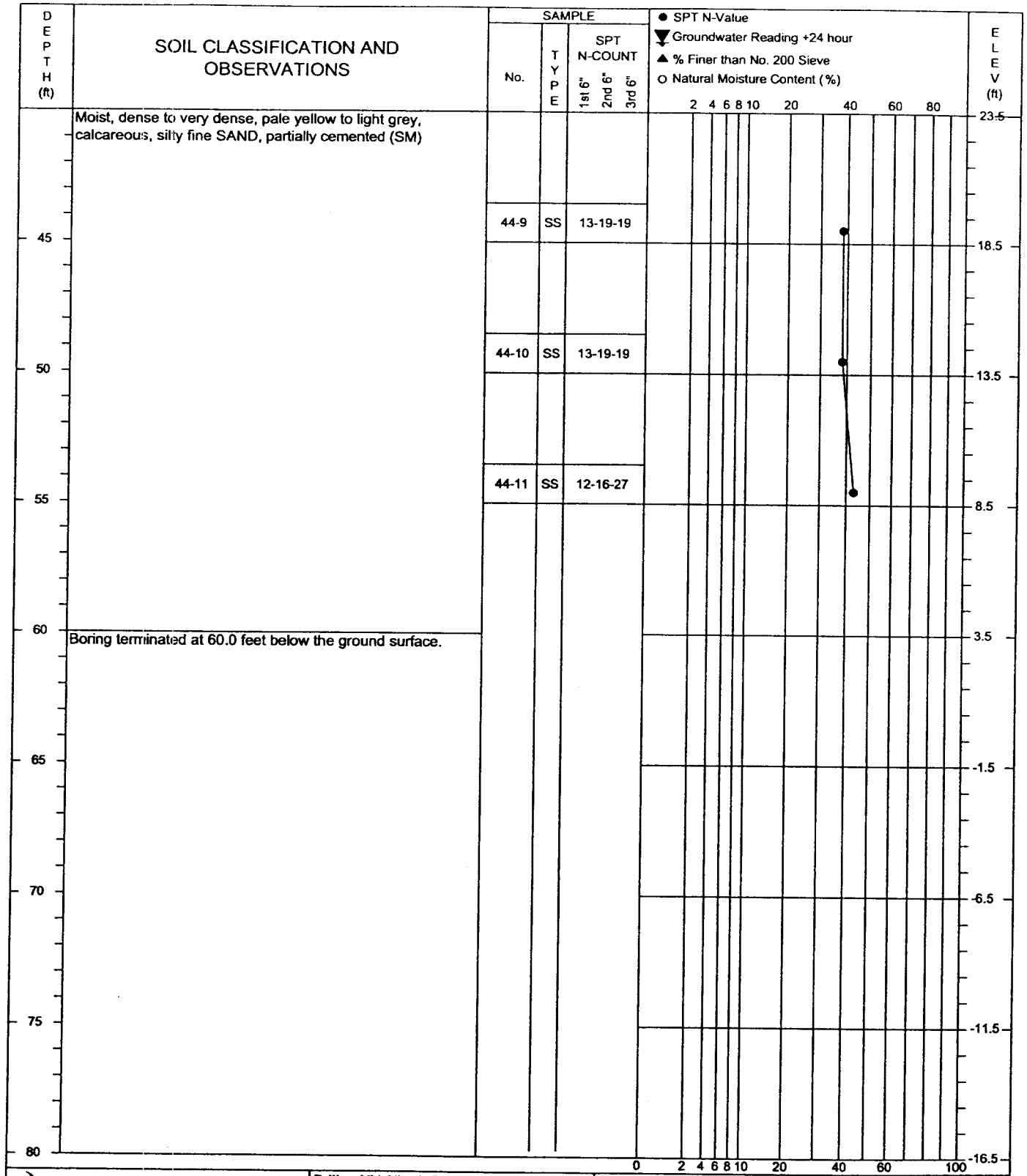
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/8/04
Project No. 01-04-1104
Page 1 of 2

BORING: B-44



Carolina CONSULTING ENGINEERS Inc.

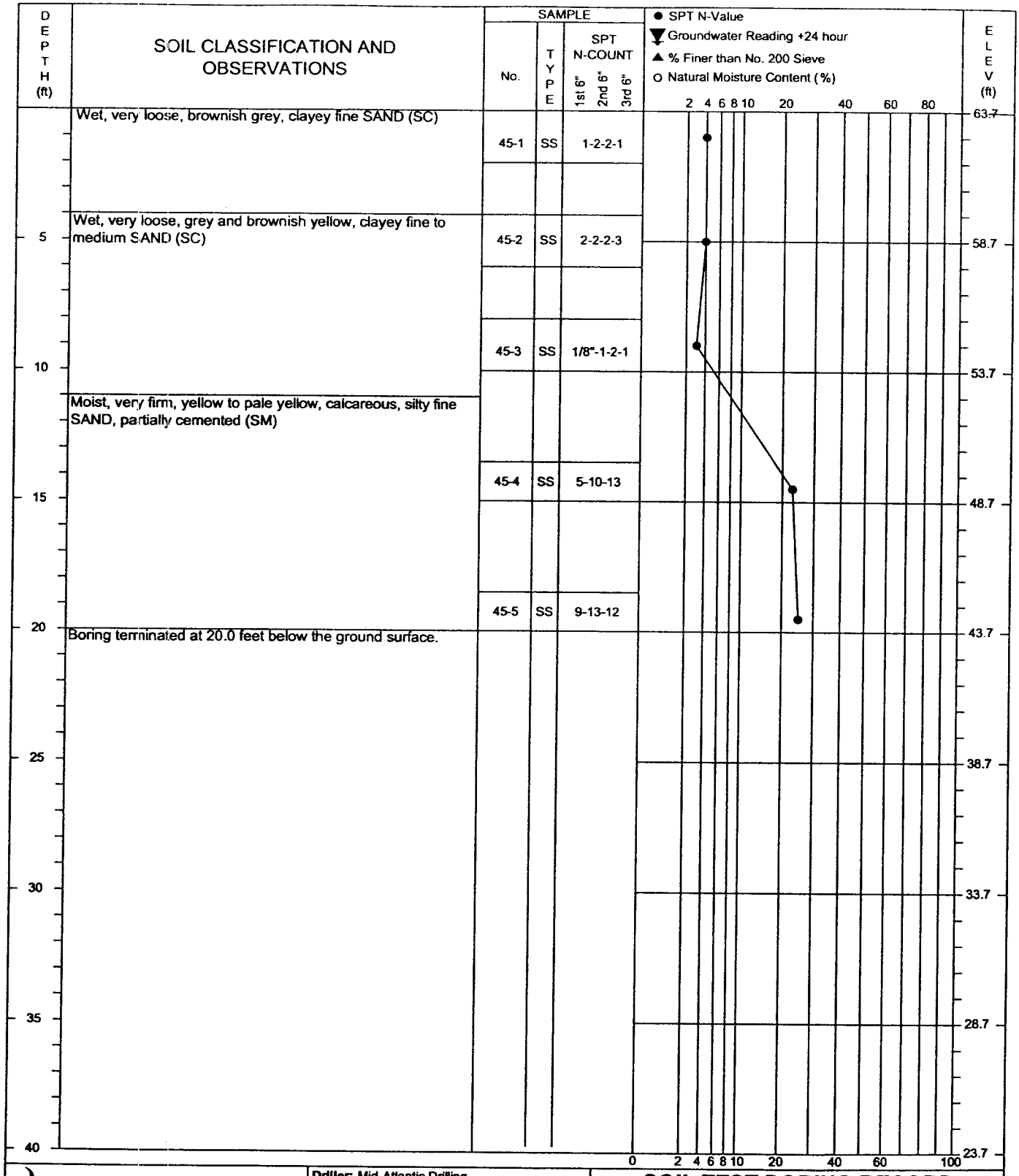
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/8/04
Project No. 01-04-1104
Page 2 of 2

BORING: B-44



Carolina CONSULTING ENGINEERS Inc.

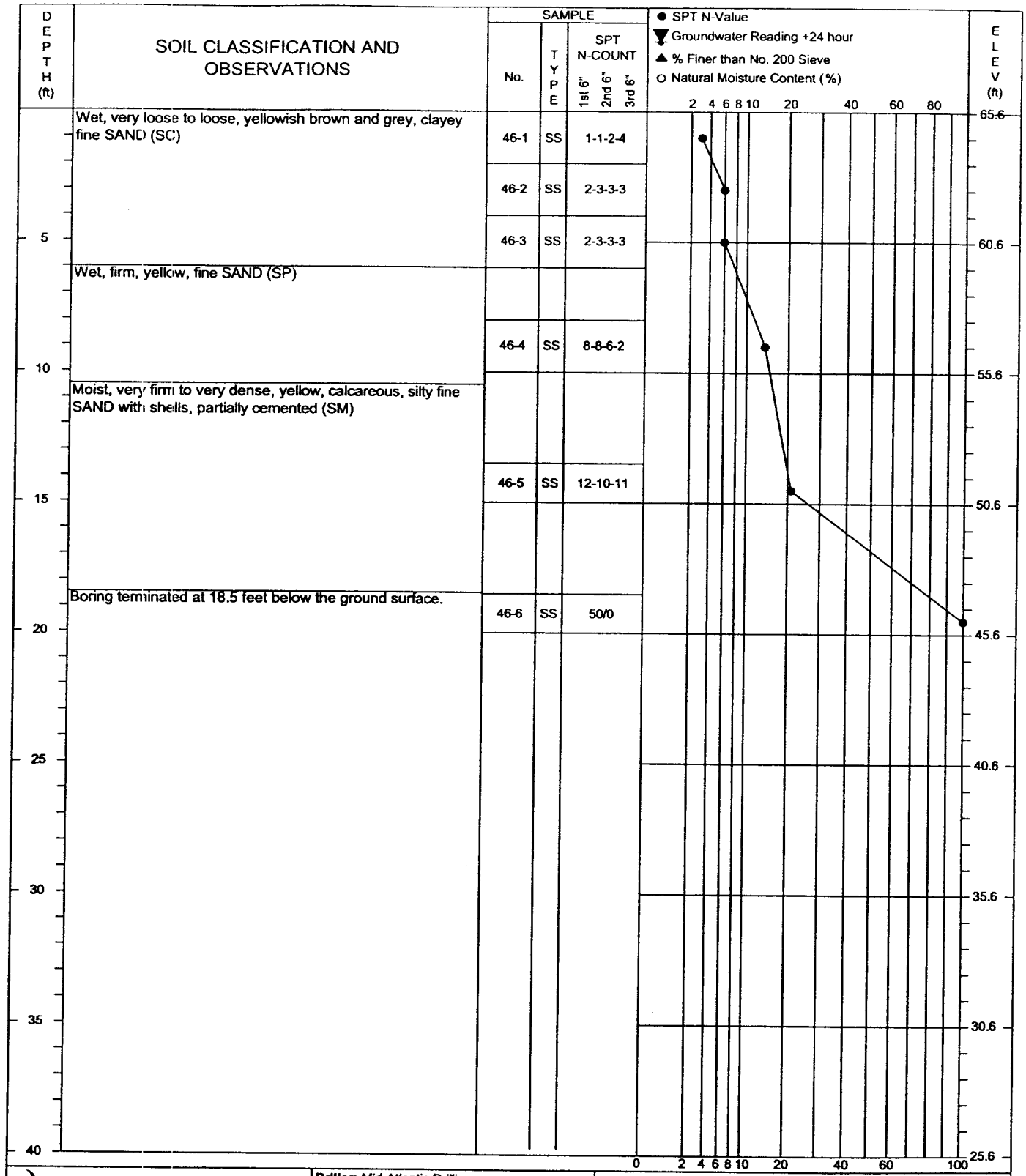
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/8/04
Project No. 01-04-1104
Page 1 of 1

BORING: B-45



Carolina CONSULTING ENGINEERS Inc.

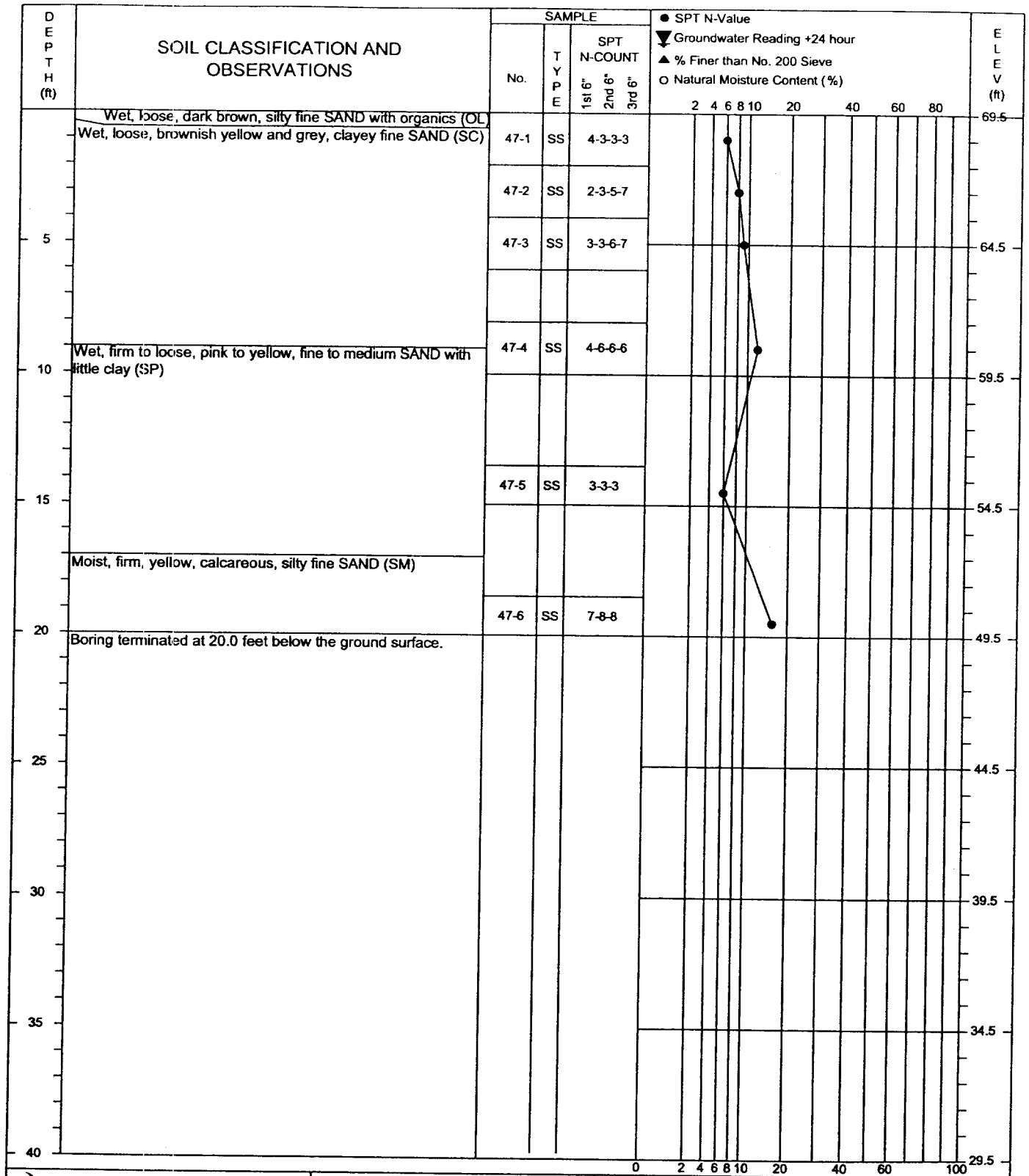
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/8/04
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BORING: B-46



Carolina CONSULTING ENGINEERS Inc.

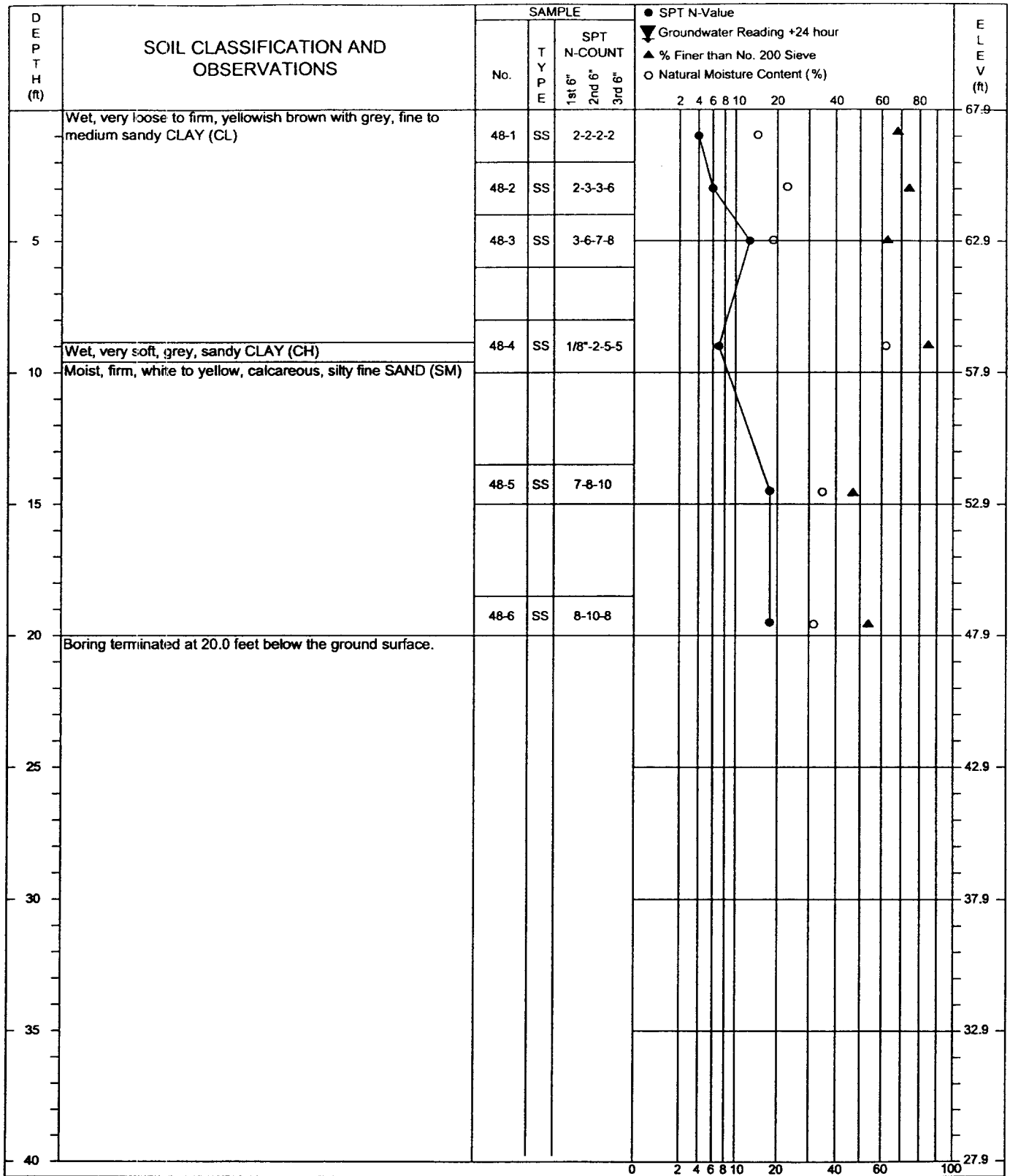
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

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BORING: B-47



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

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BORING: B-48

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
	Wet to moist, very loose to loose, yellowish brown and grey, clayey fine to medium SAND (SC)	49-1	SS	4-2-2-3	68.8
		49-2	SS	3-4-5-6	
5		49-3	SS	2-3-6-7	63.8
	Wet to moist, firm to very firm, yellow, calcareous, silty fine SAND (SM)	49-4	SS	3-5-6-5	
10					58.8
		49-5	SS	13-10-12	
15					53.8
		49-6	SS	9-10-10	
20	Boring terminated at 20.0 feet below the ground surface.				48.8
25					43.8
30					38.8
35					33.8
40					28.8

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
O Natural Moisture Content (%)

2 4 6 8 10 20 40 60 80

0 2 4 6 8 10 20 40 60 100

Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

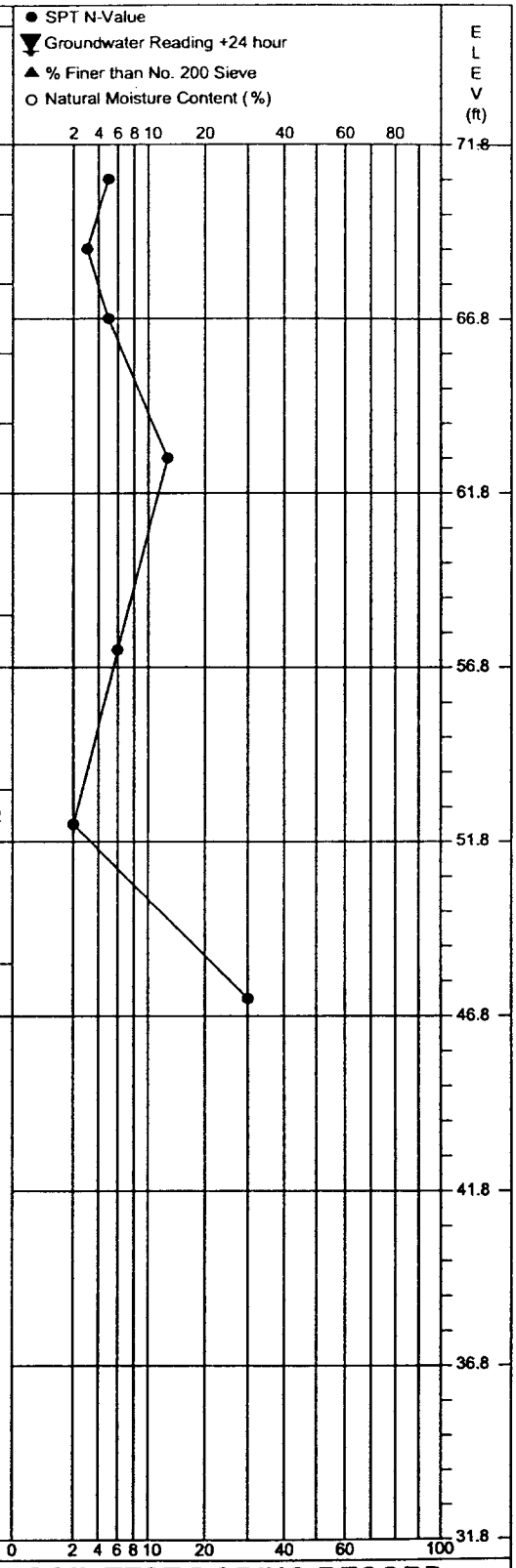
SOIL TEST BORING RECORD

Project: Proposed Railroad

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BORING: B-49

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"	ELEV (ft)
0	Wet, firm to soft, yellowish brown red and grey, fine sandy CLAY (CL)	50-1	SS	2-2-3-3	71.8
		50-2	SS	1-1-2-3	
5	Wet to moist, loose to firm, yellowish brown and grey, clayey fine to medium SAND (SC)	50-3	SS	3-2-3-4	66.8
		50-4	SS	4-6-7-7	
10					61.8
15	Wet, loose, yellow, fine SAND (SP)	50-5	SS	3-4-2	56.8
	Saturated, very loose, yellowish brown, clayey fine SAND (SC)	50-6	SS	WOH/12"-2	
20	Moist, dense, yellow, calcareous, silty fine SAND (SM)				51.8
		50-7	SS	16-13-17	
25	Boring terminated at 25.0 feet below the ground surface.				46.8
30					41.8
35					36.8
40					31.8



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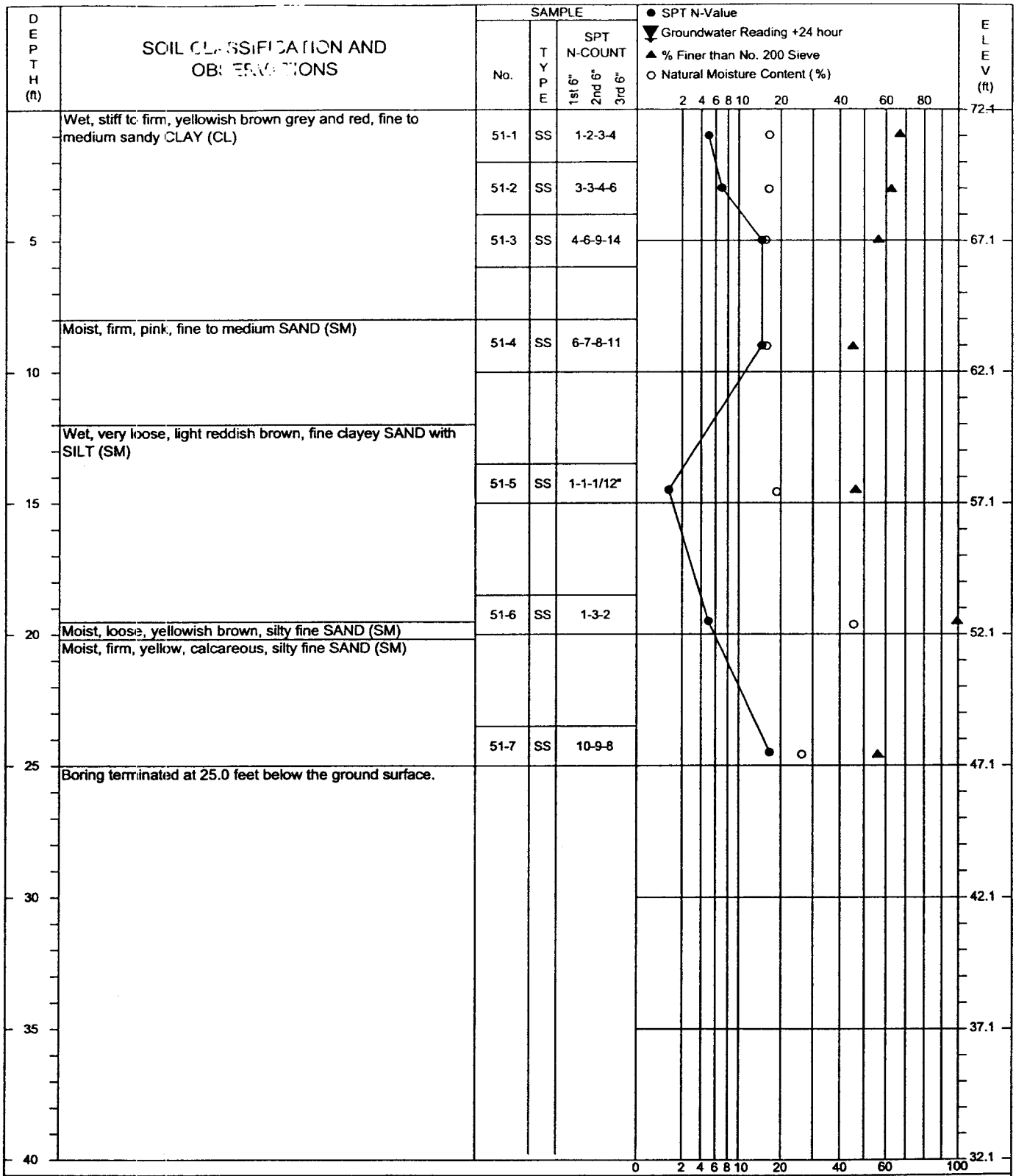
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

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BORING: B-50



Carolina CONSULTING ENGINEERS Inc.

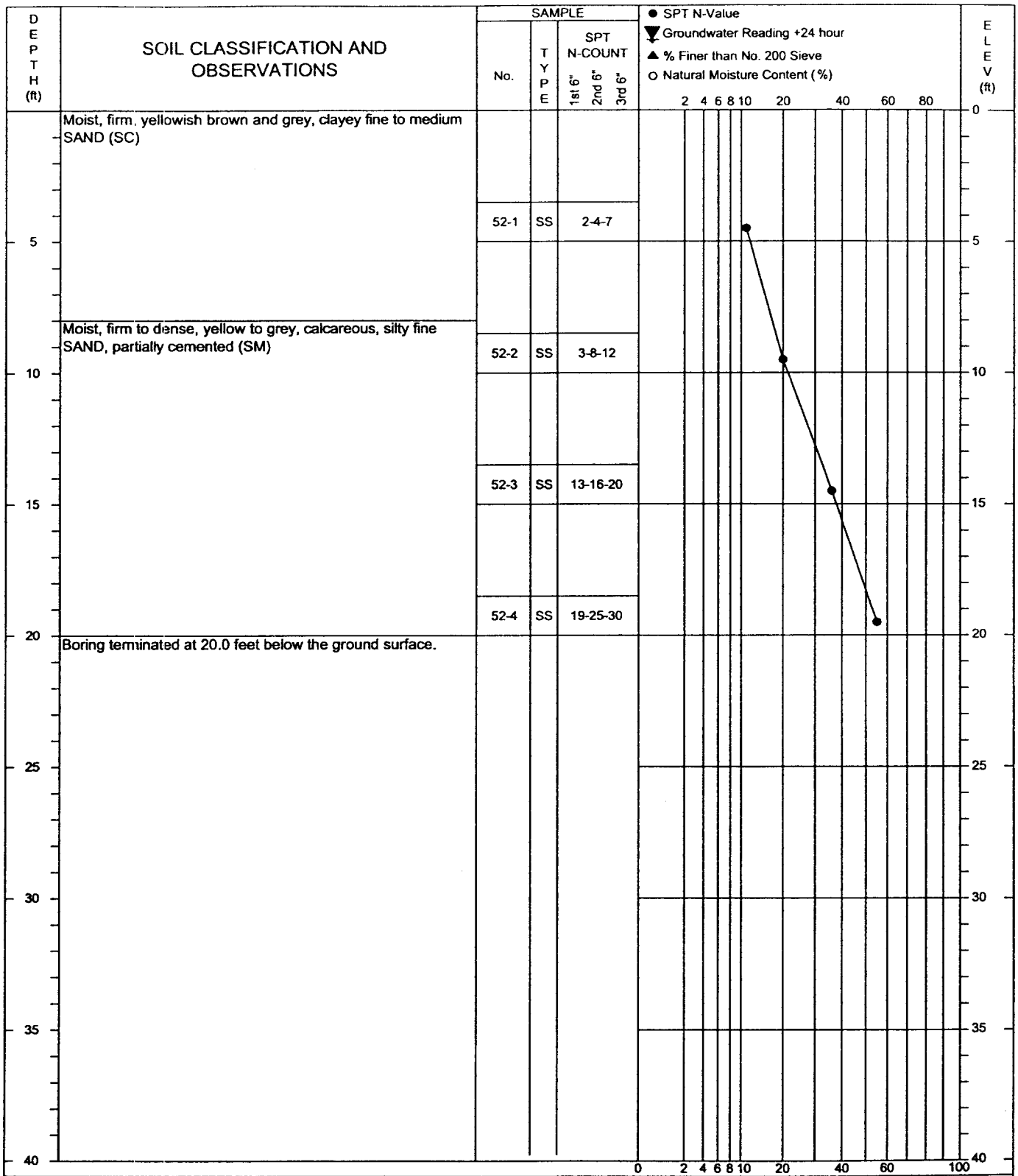
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

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BORING: B-51



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

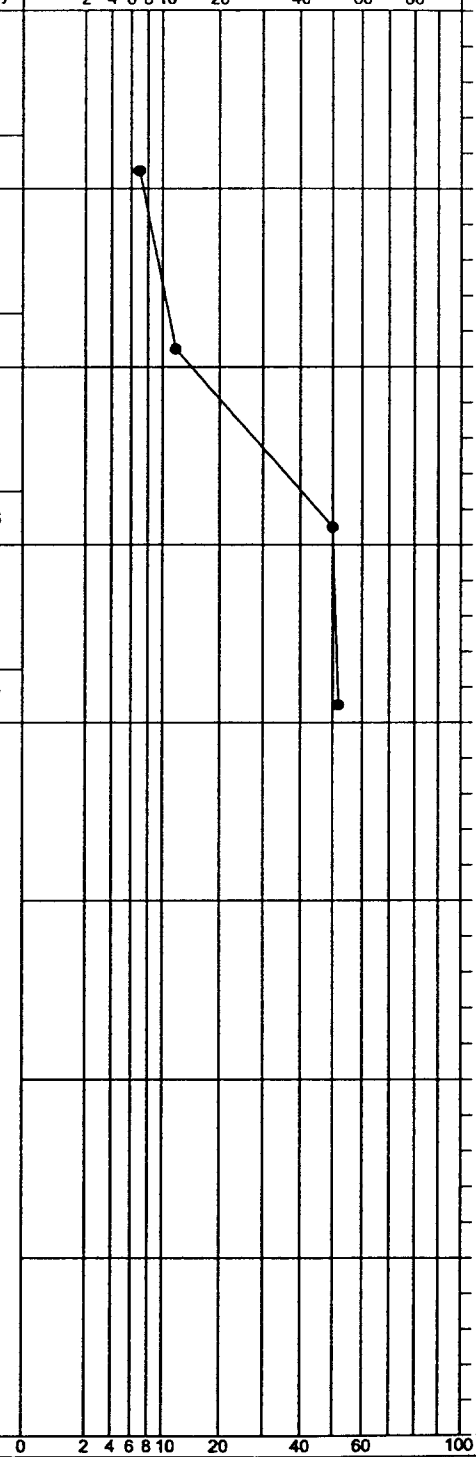
Project: Proposed Railroad

Drilled: 12/9/04
Project No. 01-04-1104
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BORING: B-52

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	SAMPLE TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"
0	Moist to wet, loose to very loose, yellowish brown and grey, clayey fine to medium SAND (SC)			
5		53-1	SS	3-3-4
10	Wet to moist, firm to dense, yellow to grey, calcareous, silty fine SAND, partially cemented (SM)	53-2	SS	1-5-7
15		53-3	SS	25-24-26
20		53-4	SS	21-25-27
20	Boring terminated at 20.0 feet below the ground surface.			
25				
30				
35				
40				

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
○ Natural Moisture Content (%)



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

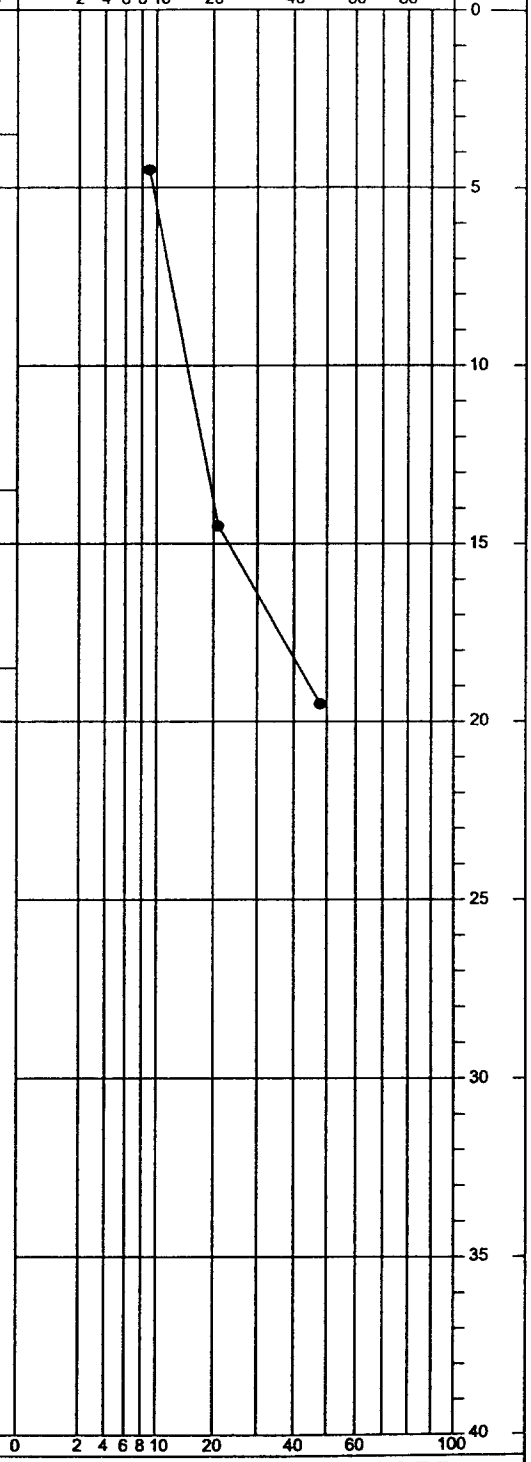
Project: Proposed Railroad

Drilled: 12/9/04
Project No. 01-04-1104
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BORING: B-53

DEPTH (ft)	SOIL CLASSIFICATION AND OBSERVATIONS	SAMPLE No.	TYPE	SPT N-COUNT 1st 6" 2nd 6" 3rd 6"
0	Moist, firm to loose, yellowish brown and grey, sandy CLAY and clayey SAND (CL and SC)			
5		54-1	SS	2-3-6
10				
15	Moist, dense, yellow to light grey, calcareous, silty fine SAND (SM)	54-2	SS	17-22-19
20		54-3	SS	17-23-25
25	Boring terminated at 20.0 feet below the ground surface.			
30				
35				
40				

● SPT N-Value
▼ Groundwater Reading +24 hour
▲ % Finer than No. 200 Sieve
○ Natural Moisture Content (%)



Carolina CONSULTING ENGINEERS Inc.

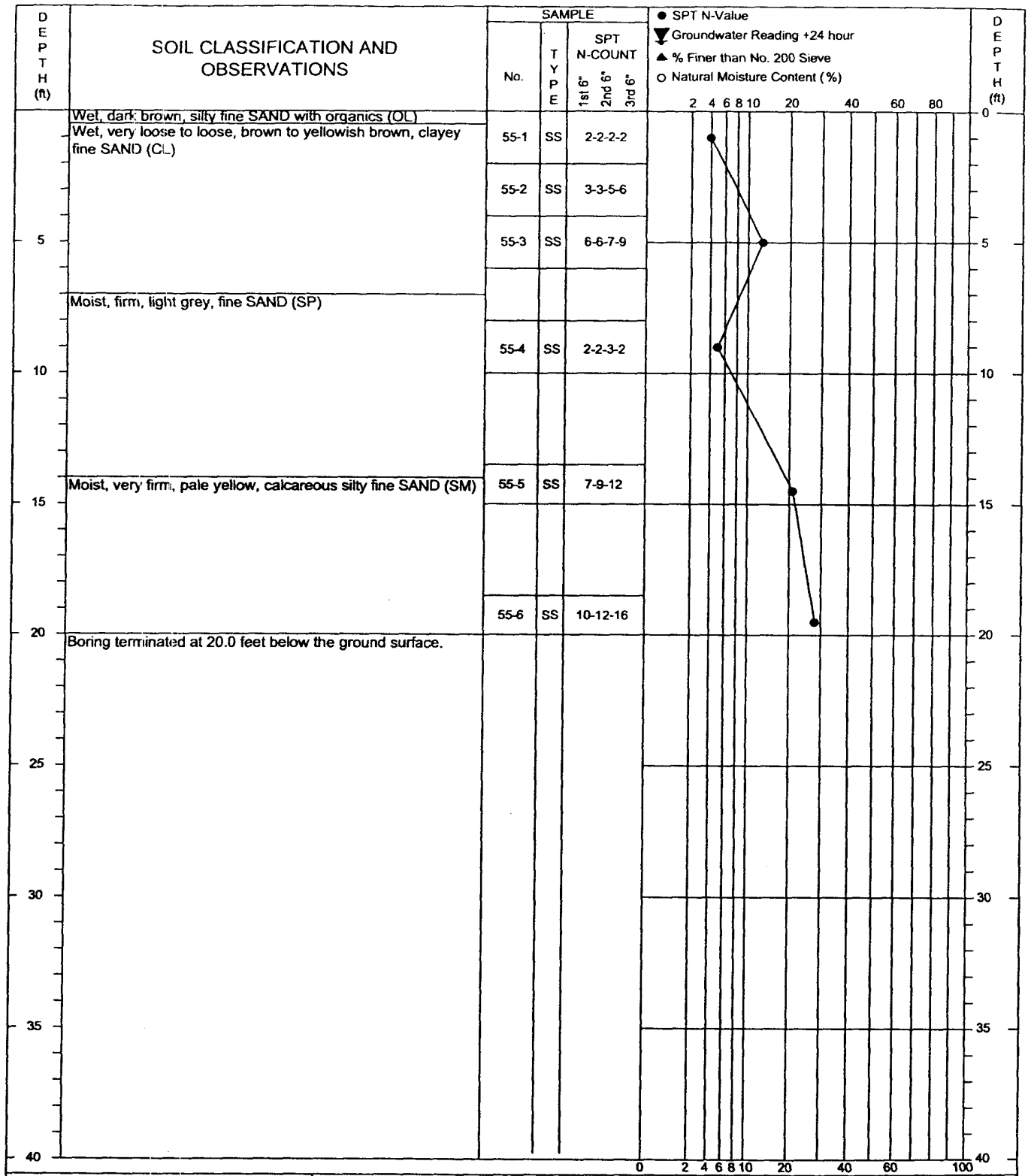
Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/9/04
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BORING: B-54



Carolina CONSULTING ENGINEERS Inc.

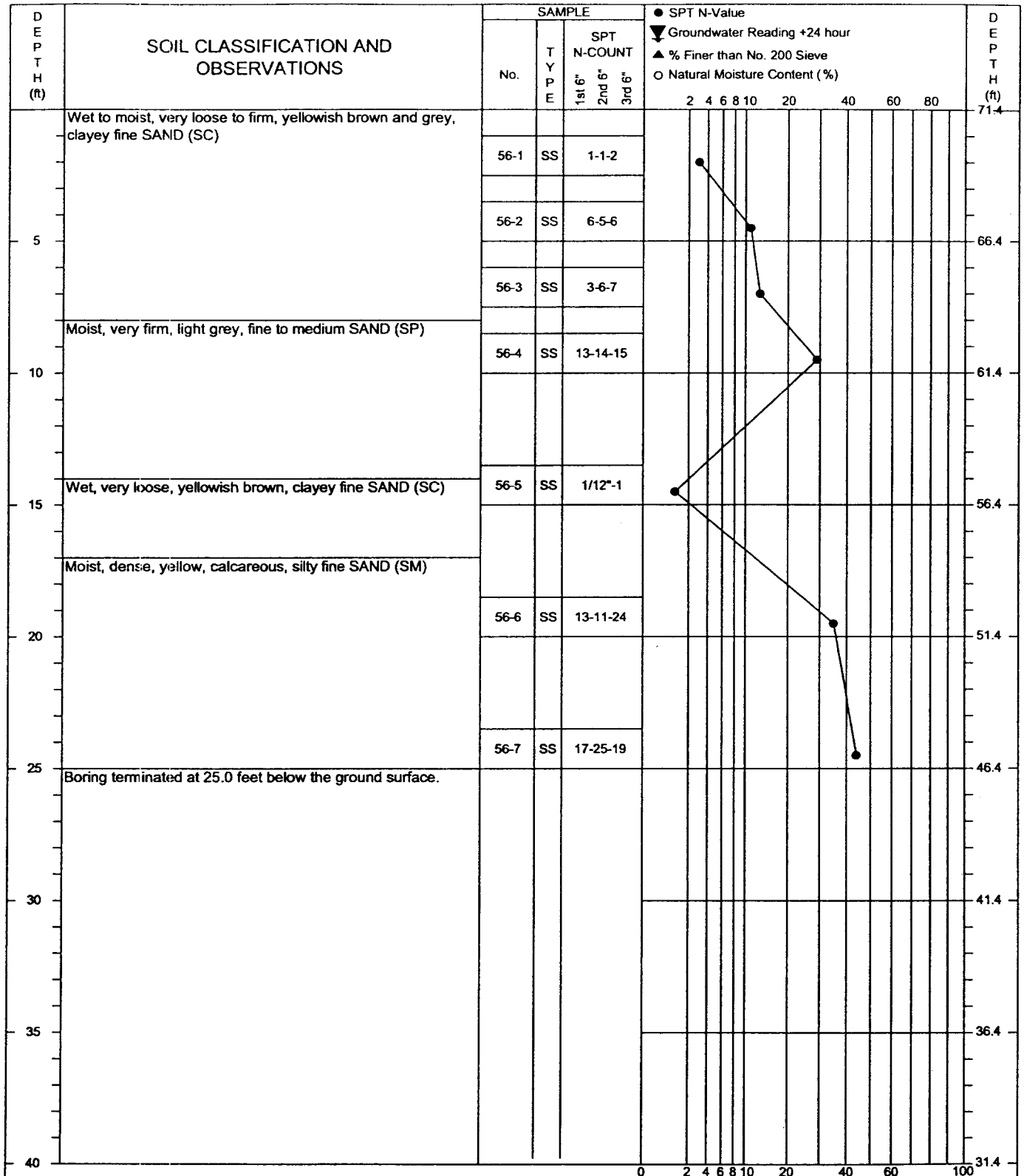
Driller: Carolina Consulting Engineers, Inc.
Equipment: Trailer Tripod, Safety Hammer
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

Drilled: 12/20/04
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BORING: B-55



Carolina CONSULTING ENGINEERS Inc.

Driller: Mid-Atlantic Drilling
Equipment: CME-45 Track Rig
Method: Mud Rotary **Hole Dia.:** 3 inches
Remarks: Sample type (SS) indicates split spoon sample.

SOIL TEST BORING RECORD

Project: Proposed Railroad

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APPENDIX 4

Designation: D 2216 – 98

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass[1]

This standard is issued under the fixed designation D 2216; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This test method covers the laboratory determination of the water (moisture) content by mass of soil, rock, and similar materials where the reduction in mass by drying is due to loss of water except as noted in 1.4, 1.5, and 1.7. For simplicity, the word "material" hereinafter also refers to either soil or rock, whichever is most applicable.

1.2 Some disciplines, such as soil science, need to determine water content on the basis of volume. Such determinations are beyond the scope of this test method.

1.3 The water content of a material is defined in 3.2.1.

1.4 The term "solid material" as used in geotechnical engineering is typically assumed to mean naturally occurring mineral particles of soil and rock that are not readily soluble in water. Therefore, the water content of materials containing extraneous matter (such as cement, and the like) may require special treatment or a qualified definition of water content. In addition, some organic materials may be decomposed by oven drying at the standard drying temperature for this method (110°C). Materials containing gypsum (calcium sulfate dihydrate or other compounds having significant amounts of hydrated water) may present a special problem as this material slowly dehydrates at the standard drying temperature (110°C) and at very low relative humidities, forming a compound (calcium sulfate hemihydrate) which is not normally present in natural materials except in some desert soils. In order to reduce the degree of dehydration of gypsum in those materials containing gypsum, or to reduce decomposition in highly organic soils, it may be desirable to dry these materials at 60°C or in a desiccator at room temperature. Thus, when a drying temperature is used which is different from the standard drying temperature as defined by this test method, the resulting water content may be different from standard water content determined at the standard drying temperature.

NOTE 1—Test Methods D 2974 provides an alternate procedure for determining water content of peat materials.

1.5 Materials containing water with substantial amounts of soluble solids (such as salt in the case of marine sediments) when tested by this method will give a mass of solids which includes the previously soluble solids. These materials require special treatment to remove or account for the presence of precipitated solids in the dry mass of the specimen, or a qualified definition of water content must be used. For example, see Noorany[2] regarding information on marine soils.

1.6 This test method requires several hours for proper drying of the water content specimen. Test Method D 4643 provides for drying of the test specimen in a microwave oven which is a shorter process. Also see Gilbert[3] for details on the background of this test method.

1.7 This standard requires the drying of material in an oven at high temperatures. If the material being dried is contaminated with certain chemicals, health and safety hazards can exist. Therefore, this standard should not be used in determining the water content of contaminated soils unless adequate health and safety precautions are taken.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[4]

D 2974 Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils[4]

D 4220 Practice for Preserving and Transporting Soil Samples[4]

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[4]

D 4643 Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method[4]

D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil and Rock Testing[4]

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

Current edition approved Feb. 10, 1998. Published January 1999. Originally published as D 2216 – 63 T. Last previous edition D 2216 – 92.

[2] Noorany, I., "Phase Relations in Marine Soils", Journal of Geotechnical Engineering, ASCE, Vol. 110, No. 4, April 1984, pp. 539–543.

[3] Gilbert, P.A., "Computer Controlled Microwave Oven System for Rapid Water Content Determination", Tech. Report GL-88-21, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, MS, November 1988.

[4] *Annual Book of ASTM Standards*, Vol 04.08.

*A Summary of Changes section appears at the end of this standard.

D 6026 Guide for Using Significant Digits in Calculating and Reporting Geotechnical Test Data[5]

E 145 Specification for Gravity-Convection And Forced-Ventilation Ovens[5]

3. Terminology

3.1 Refer to Terminology D 653 for standard definitions of terms.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *water content (of a material)*—the ratio expressed as a percent of the mass of "pore" or "free" water in a given mass of material to the mass of the solid material. A standard temperature of 110° ± 5°C is used to determine these masses.

4. Summary of Test Method

4.1 A test specimen is dried in an oven at a temperature of 110° ± 5°C to a constant mass. The loss of mass due to drying is considered to be water. The water content is calculated using the mass of water and the mass of the dry specimen.

5. Significance and Use

5.1 For many materials, the water content is one of the most significant index properties used in establishing a correlation between soil behavior and its index properties.

5.2 The water content of a material is used in expressing the phase relationships of air, water, and solids in a given volume of material.

5.3 In fine-grained (cohesive) soils, the consistency of a given soil type depends on its water content. The water content of a soil, along with its liquid and plastic limits as determined by Test Method D 4318, is used to express its relative consistency or liquidity index.

6. Apparatus

6.1 *Drying Oven*, thermostatically-controlled, preferably of the forced-draft type, meeting the requirements of Specification E 145 and capable of maintaining a uniform temperature of 110 ± 5°C throughout the drying chamber.

6.2 *Balances*—All balances must meet the requirements of Specification D 4753 and this section. A Class GP1 balance of 0.01g readability is required for specimens having a mass of up to 200 g (excluding mass of specimen container) and a Class GP2 balance of 0.1g readability is required for specimens having a mass over 200 g. However, the balance used may be controlled by the number of significant digits needed (see 8.2.1 and 12.1.2).

6.3 *Specimen Containers*—Suitable containers made of material resistant to corrosion and change in mass upon repeated heating, cooling, exposure to materials of varying pH, and cleaning. Unless a dessicator is used, containers with close-fitting lids shall be used for testing specimens having a mass of less than about 200 g; while for specimens having a mass greater than about 200 g, containers without lids may be used (see Note 7). One container is needed for each water content determination.

NOTE 2—The purpose of close-fitting lids is to prevent loss of moisture from specimens before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination.

6.4 *Desiccator*—A desiccator cabinet or large desiccator jar of suitable size containing silica gel or anhydrous calcium sulfate. It is preferable to use a desiccant which changes color to indicate it needs reconstitution. See 10.5.

NOTE 3—Anhydrous calcium sulfate is sold under the trade name Drierite.

6.5 *Container Handling Apparatus*, gloves, tongs, or suitable holder for moving and handling hot containers after drying.

6.6 *Miscellaneous*, knives, spatulas, scoops, quartering cloth, sample splitters, etc, as required.

7. Samples

7.1 Samples shall be preserved and transported in accordance with Practice 4220 Groups B, C, or D soils. Keep the samples that are stored prior to testing in noncorrodible airtight containers at a temperature between approximately 3 and 30°C and in an area that prevents direct contact with sunlight. Disturbed samples in jars or other containers shall be stored in such a way as to prevent or minimize moisture condensation on the insides of the containers.

7.2 The water content determination should be done as soon as practicable after sampling, especially if potentially corrodible containers (such as thin-walled steel tubes, paint cans, etc.) or plastic sample bags are used.

8. Test Specimen

8.1 For water contents being determined in conjunction with another ASTM method, the specimen mass requirement stated in that method shall be used if one is provided. If no minimum specimen mass is provided in that method then the values given below shall apply. See Howard[7] for background data for the values listed.

8.2 The minimum mass of moist material selected to be representative of the total sample shall be in accordance with the following:

Maximum particle size (100 % passing)	Standard Sieve Size	Recommended minimum mass of moist test specimen for water content reported to ±0.1 %	Recommended minimum mass of moist test specimen for water content reported to ±1 %
2 mm or less	No. 10	20 g	20 g[A]
4.75 mm	No. 4	100 g	20 g[A]
9.5 mm	⅜-in.	500 g	50 g
19.0 mm	¾-in.	2.5 kg	250 g
37.5 mm	1½ in.	10 kg	1 kg
75.0 mm	3-in.	50 kg	5 kg

[A]To be representative not less than 20 g shall be used.

8.2.1 The minimum mass used may have to be increased to obtain the needed significant digits for the mass of water when reporting water contents to the nearest 0.1 % or as indicated in 12.1.2.

[5] *Annual Book of ASTM Standards*, Vol 04.09.

[6] *Annual Book of ASTM Standards*, Vol 14.02.

[7] Howard, A. K., "Minimum Test Specimen Mass for Moisture Content Determination", *Geotechnical Testing Journal*, A.S.T.M., Vol. 12, No. 1, March 1989, pp. 39-44.

8.3 Using a test specimen smaller than the minimum indicated in 8.2 requires discretion, though it may be adequate for the purposes of the test. Any specimen used not meeting these requirements shall be noted on the test data forms or test data sheets.

8.4 When working with a small (less than 200g) specimen containing a relatively large gravel particle, it is appropriate not to include this particle in the test specimen. However, any discarded material shall be described and noted on the test data forms or test data sheets.

8.5 For those samples consisting entirely of intact rock, the minimum specimen mass shall be 500 g. Representative portions of the sample may be broken into smaller particles, depending on the sample's size, the container and balance being used and to facilitate drying to constant mass, see 10.4. Specimen sizes as small as 200 g may be tested if water contents of only two significant digits are acceptable.

9. Test Specimen Selection

9.1 When the test specimen is a portion of a larger amount of material, the specimen must be selected to be representative of the water condition of the entire amount of material. The manner in which the test specimen is selected depends on the purpose and application of the test, type of material being tested, the water condition, and the type of sample (from another test, bag, block, and the likes.)

9.2 For disturbed samples such as trimmings, bag samples, and the like, obtain the test specimen by one of the following methods (listed in order of preference):

9.2.1 If the material is such that it can be manipulated and handled without significant moisture loss and segregation, the material should be mixed thoroughly and then select a representative portion using a scoop of a size that no more than a few scoopfuls are required to obtain the proper size of specimen defined in 8.2.

9.2.2 If the material is such that it cannot be thoroughly mixed or mixed and sampled by a scoop, form a stockpile of the material, mixing as much as possible. Take at least five portions of material at random locations using a sampling tube, shovel, scoop, trowel, or similar device appropriate to the maximum particle size present in the material. Combine all the portions for the test specimen.

9.2.3 If the material or conditions are such that a stockpile cannot be formed, take as many portions of the material as practical, using random locations that will best represent the moisture condition. Combine all the portions for the test specimen.

9.3 Intact samples such as block, tube, split barrel, and the like, obtain the test specimen by one of the following methods depending on the purpose and potential use of the sample.

9.3.1 Using a knife, wire saw, or other sharp cutting device, trim the outside portion of the sample a sufficient distance to see if the material is layered and to remove material that appears more dry or more wet than the main portion of the sample. If the existence of layering is questionable, slice the sample in half. If the material is layered, see 9.3.3.

9.3.2 If the material is not layered, obtain the specimen meeting the mass requirements in 8.2 by: (1) taking all or one-half of the interval being tested; (2) trimming a representative slice from the interval being tested; or (3) trimming the exposed surface of one-half or from the interval being tested.

NOTE 4—Migration of moisture in some cohesionless soils may require that the full section be sampled.

9.3.3 If a layered material (or more than one material type is encountered), select an average specimen, or individual specimens, or both. Specimens must be properly identified as to location, or what they represent, and appropriate remarks entered on the test data forms or test data sheets.

10. Procedure

10.1 Determine and record the mass of the clean and dry specimen container (and its lid, if used).

10.2 Select representative test specimens in accordance with Section 9.

10.3 Place the moist test specimen in the container and, if used, set the lid securely in position. Determine the mass of the container and moist material using a balance (see 6.2) selected on the basis of the specimen mass. Record this value.

NOTE 5—To prevent mixing of specimens and yielding of incorrect results, all containers, and lids if used, should be numbered and the container numbers shall be recorded on the laboratory data sheets. The lid numbers should match the container numbers to eliminate confusion.

NOTE 6—To assist in the oven-drying of large test specimens, they should be placed in containers having a large surface area (such as pans) and the material broken up into smaller aggregations.

10.4 Remove the lid (if used) and place the container with moist material in the drying oven. Dry the material to a constant mass. Maintain the drying oven at 110 ± 5°C unless otherwise specified (see 1.4). The time required to obtain constant mass will vary depending on the type of material, size of specimen, oven type and capacity, and other factors. The influence of these factors generally can be established by good judgment, and experience with the materials being tested and the apparatus being used.

NOTE 7—In most cases, drying a test specimen overnight (about 12 to 16 h) is sufficient. In cases where there is doubt concerning the adequacy of drying, drying should be continued until the change in mass after two successive periods (greater than 1 h) of drying is an insignificant amount (less than about 0.1 %). Specimens of sand may often be dried to constant mass in a period of about 4 h, when a forced-draft oven is used.

NOTE 8—Since some dry materials may absorb moisture from moist specimens, dried specimens should be removed before placing moist specimens in the same oven. However, this would not be applicable if the previously dried specimens will remain in the drying oven for an additional time period of about 16 h.

10.5 After the material has dried to constant mass remove the container from the oven (and replace the lid if used). Allow the material and container to cool to room temperature or until the container can be handled comfortably with bare hands and the operation of the balance will not be affected by convection currents and/or its being heated. Determine the mass of the container and oven-dried material using the same type/capacity balance used in 10.3. Record this value. Tight fitting lids shall be used if it appears that the specimen is absorbing moisture from the air prior to determination of its dry mass.

NOTE 9—Cooling in a desiccator is acceptable in place of tight fitting lids since it greatly reduces absorption of moisture from the atmosphere during cooling especially for containers without tight fitting lids.

11. Calculation

11.1 Calculate the water content of the material as follows:

$$w = [(M_{cws} - M_{cs})/(M_{cs} - M_c)] \times 100 = \frac{M_w}{M_s} \times 100 \quad (1)$$

where:

w = water content, %,
M_{cws} = mass of container and wet specimen, g,
M_{cs} = mass of container and oven dry specimen, g,
M_c = mass of container, g,
M_w = mass of water ($M_w = M_{cws} - M_{cds}$), g, and
M_s = mass of solid particles ($M_s = M_{cds} - M_c$), g.

12. Report

12.1 Test data forms or test data sheets shall include the following:

12.1.1 Identification of the sample (material) being tested, such as boring number, sample number, test number, container number etc.

12.1.2 Water content of the specimen to the nearest 1 % or 0.1 %, as appropriate based on the minimum sample used. If this method is used in concert with another method, the water content of the specimen should be reported to the value required by the test method for which the water content is being determined. Refer to Guide D 6026 for guidance concerning significant digits, especially if the value obtained from this test method is to be used to calculate other relationships such as unit weight or density. For instance, if it is desired to express dry unit weight to the nearest 0.1 lbf/ft^3(0.02 kN/m^3), it may be necessary to use a balance with a greater readability or use a larger specimen mass to obtain the required significant digits the mass of water so that the water content can be determined to the required significant digits. Also, the significant digits in Guide D 6026 may need to be increased when calculating phase relationships requiring four significant digits.

12.1.3 Indicate if test specimen had a mass less than the minimum indicated in 8.2.

12.1.4 Indicate if test specimen contained more than one material type (layered, etc.).

12.1.5 Indicate the temperature of drying if different from 110 ± 5°C.

12.1.6 Indicate if any material (size and amount) was excluded from the test specimen.

12.2 When reporting water content in tables, figures, etc., any data not meeting the requirements of this test method shall be noted, such as not meeting the mass, balance, or temperature requirements or a portion of the material is excluded from the test specimen.

13. Precision and Bias

13.1 *Statement on Bias*—There is no accepted reference value for this test method; therefore, bias cannot be determined.

13.2 *Statements on Precision*:

13.2.1 *Single-Operator Precision (Repeatability)*—The single-operator coefficient of variation has been found to be 2.7 percent. Therefore, results of two properly conducted tests by the same operator with the same equipment should not be considered suspect unless they differ by more than 7.8 percent of their mean.[8]

13.2.2 *Multilaboratory Precision (Reproducibility)*[9]—The multilaboratory coefficient of variation has been found to be 5.0 percent. Therefore, results of two properly conducted tests by different operators using different equipment should not be considered suspect unless they differ by more than 14.0 percent of their mean.

14. Keywords

14.1 consistency; index property; laboratory; moisture analysis; moisture content; soil aggregate; water content

[8] These numbers represent the (1s) and (d2s) limits as described in Practice C 670.

[9] These numbers represent the (1s %) and (d2s %) limits as described in Practice C 670.

SUMMARY OF CHANGES

Committee D-18 has identified the location of selected changes to this standard since the last issue. (D 2216-92) that may impact the use of this standard.

(*1*) Title was changed to emphasize that mass is the basis for the standard.

(*2*) Section 1.1 was revised to clarify "similar materials".

(*3*) New 1.2 was added to explain a limitation in scope. The other sections were renumbered as appropriate.

(*4*) An information reference was included in 1.5.

(*5*) An information reference was included in 1.6

(*6*) A new ASTM referenced document was included in 2.1.

(*7*) New Footnotes 2, 3, and 5 were added and identified. Other footnotes were renumbered where necessary for sequential identification.

(*8*) Information concerning balances was added in 6.2

(*9*) Section 6.3 was revised to clarify the use of close-fitting lids, and a reference to Note 8 was added.

(*10*) In 6.4, "anhydrous calcium phosphate" was changed to "anyhydrous calcium sulfate" to correct an error and to agree with Note 3.

(*11*) A typo in 8.1 was corrected from "before" to "below" and a footnoted reference was added for information.

(*12*) A portion of 8.2 was deleted for clarity.

(*13*) A new 8.2.1 was added to clarify minimum mass requirements.

(*14*) Sections 8.3, 8.4, 9.3.3, and 12.1 were changed to substitute "test data form/sheet" for "report".

(*15*) Footnote seven was identified.

(*16*) Section 9.2.1 was revised to improve clarity and intent.

(*17*) The word "possible" was changed to "practical" in 9.2.3.

(*18*) Section 9.3.1 and 9.3.2 were revised to improve clarity and for practicality.

(*19*) A reference to Guide D 6026 was added in 12.1.2.

(*20*) Footnotes 8 and 9 were added to 13.2.1 and 13.2.2, respectively. These were inadvertently omitted from the 1992 version. These explanations provide clarity and information to the user.

(*21*) A Summary of Changes was added to reflect D-18's policy.

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

Designation: D 4318 – 00

Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[1]

This standard is issued under the fixed designation D 4318; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 These test methods cover the determination of the liquid limit, plastic limit, and the plasticity index of soils as defined in Section 3 on Terminology.

1.2 Two methods for preparing test specimens are provided as follows: *Wet preparation method,* as described in 10.1. *Dry preparation method,* as described in 10.2. The method to be used shall be specified by the requesting authority. If no method is specified, use the wet preparation method.

1.2.1 The liquid and plastic limits of many soils that have been allowed to dry before testing may be considerably different from values obtained on non-dried samples. If the liquid and plastic limits of soils are used to correlate or estimate the engineering behavior of soils in their natural moist state, samples should not be permitted to dry before testing unless data on dried samples are specifically desired.

1.3 Two methods for determining the liquid limit are provided as follows: *Method A,* Multipoint test as described in Sections 11 and 12. *Method B,* One-point test as described in Sections 13 and 14. The method to be used shall be specified by the requesting authority. If no method is specified, use Method A.

1.3.1 The multipoint liquid limit method is generally more precise than the one-point method. It is recommended that the multipoint method be used in cases where test results may be subject to dispute, or where greater precision is required.

1.3.2 Because the one-point method requires the operator to judge when the test specimen is approximately at its liquid limit, it is particularly not recommended for use by inexperienced operators.

1.3.3 The correlation on which the calculations of the one-point method are based may not be valid for certain soils, such as organic soils or soils from a marine environment. It is strongly recommended that the liquid limit of these soils be determined by the multipoint method.

1.4 The plastic limit test is performed on material prepared for the liquid limit test.

1.5 The liquid limit and plastic limit of soils (along with the shrinkage limit) are often collectively referred to as the Atterberg limits. These limits distinguished the boundaries of the several consistency states of plastic soils.

1.6 The composition and concentration of soluble salts in a soil affect the values of the liquid and plastic limits as well as the water content values of soils (see Method D 2216). Special consideration should therefore be given to soils from a marine environment or other sources where high soluble salt concentrations may be present. The degree to which the salts present in these soils are diluted or concentrated must be given careful consideration.

1.7 The methods described herein are performed only on that portion of a soil that passes the 425-μm (No. 40) sieve. Therefore, the relative contribution of this portion of the soil to the properties of the sample as a whole must be considered when using these tests to evaluate properties of a soil.

1.8 The values stated in acceptable metric units are to be regarded as the standard, except as noted below. The values given in parentheses are for information only.

1.8.1 The standard units for the resilience tester covered in Annex A1 are inch-pound, not metric. The metric values given are for information only.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 702 Practice for Reducing Field Samples of Aggregate to Testing Size[2]

D 75 Practice for Sampling Aggregates[3]

D 420 Guide to Site Characterization for Engineering, Design, and Construction Purposes[4]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[4]

D 1241 Specification for Materials for Soil-Aggregate Subbase, Base, and Surface Courses[4]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass[4]

D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)[4]

[1] This standard is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

Current edition approved June 10, 2000. Published September 2000. Originally published as D 4318 – 83. Last previous edition D 4318 – 98.

[2] *Annual Book of ASTM Standards,* Vol 04.02.

[3] *Annual Book of ASTM Standards,* Vol 04.03.

[4] *Annual Book of ASTM Standards,* Vol 04.08.

*A Summary of Changes section appears at the end of this standard.

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D 3282 Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes[4]
D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction[4]
D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil, Rock, and Related Construction Materials Testing [4]
D 6026 Practice for Using Significant Digits in Geotechnical Data[5]
E 11 Specification for Wire-Cloth Sieves for Testing Purposes[6]
E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[6]
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[6]

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions of terms in this standard are in accordance with Terminology D 653.

3.2 *Description of Terms Specific to This Standard:*

3.2.1 *Atterberg Limits*—Originally, six "limits of consistency" of fine-grained soils were defined by Albert Atterberg: the upper limit of viscous flow, the liquid limit, the sticky limit, the cohesion limit, the plastic limit, and the shrinkage limit. In current engineering usage, the term usually refers only to the liquid limit, plastic limit, and in some references, the shrinkage limit.

3.2.2 *consistency*—the relative ease with which a soil can be deformed.

3.2.3 *liquid limit (LL, w_L)*—the water content, in percent, of a soil at the arbitrarily defined boundary between the semi-liquid and plastic states.

3.2.3.1 *Discussion*—The undrained shear strength of soil at the liquid limit is considered to be approximately 2 kPa (0.28 psi).

3.2.4 *plastic limit (PL, w_p)*—the water content, in percent, of a soil at the boundary between the plastic and semi-solid states.

3.2.5 *plastic soil*—a soil which has a range of water content over which it exhibits plasticity and which will retain its shape on drying.

3.2.6 *plasticity index (PI)*—the range of water content over which a soil behaves plastically. Numerically, it is the difference between the liquid limit and the plastic limit.

3.2.7 *liquidity index*—the ratio, expressed as a percentage of (1) the water content of a soil minus its plastic limit, to (2) its plasticity index.

3.2.8 *activity number (A)*—the ratio of (1) the plasticity index of a soil to (2) the percent by mass of particles having an equivalent diameter smaller than 2 μm.

4. Summary of Test Method

4.1 The specimen is processed to remove any material retained on a 425-μm (No. 40) sieve. The liquid limit is determined by performing trials in which a portion of the specimen is spread in a brass cup, divided in two by a grooving tool, and then allowed to flow together from the shocks caused by repeatedly dropping the cup in a standard mechanical device. The multipoint liquid limit, Method A, requires three or more trials over a range of water contents to be performed and the data from the trials plotted or calculated to make a relationship from which the liquid limit is determined. The one-point liquid limit, Method B, uses the data from two trials at one water content multiplied by a correction factor to determine the liquid limit.

4.2 The plastic limit is determined by alternately pressing together and rolling into a 3.2-mm (⅛-in.) diameter thread a small portion of plastic soil until its water content is reduced to a point at which the thread crumbles and can no longer be pressed together and re-rolled. The water content of the soil at this point is reported as the plastic limit.

4.3 The plasticity index is calculated as the difference between the liquid limit and the plastic limit.

5. Significance and Use

5.1 These test methods are used as an integral part of several engineering classification systems to characterize the fine-grained fractions of soils (see Practices D 2487 and D 3282) and to specify the fine-grained fraction of construction materials (see Specification D 1241). The liquid limit, plastic limit, and plasticity index of soils are also used extensively, either individually or together, with other soil properties to correlate with engineering behavior such as compressibility, hydraulic conductivity (permeability), compactibility, shrink-swell, and shear strength.

5.2 The liquid and plastic limits of a soil and its water content can be used to express its relative consistency or liquidity index. In addition, the plasticity index and the percentage finer than 2-μm particle size can be used to determine its activity number.

5.3 These methods are sometimes used to evaluate the weathering characteristics of clay-shale materials. When subjected to repeated wetting and drying cycles, the liquid limits of these materials tend to increase. The amount of increase is considered to be a measure of a shale's susceptibility to weathering.

5.4 The liquid limit of a soil containing substantial amounts of organic matter decreases dramatically when the soil is oven-dried before testing. Comparison of the liquid limit of a sample before and after oven-drying can therefore be used as a qualitative measure of organic matter content of a soil (see Practice D 2487).

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740, generally, are considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Liquid Limit Device*—A mechanical device consisting of a brass cup suspended from a carriage designed to control its

[5] *Annual Book of ASTM Standards*, Vol 04.09.
[6] *Annual Book of ASTM Standards*, Vol 14.02.

drop onto a hard rubber base. Fig. 1 shows the essential features and critical dimensions of the device. The device may be operated by either a hand crank or electric motor.

6.1.1 *Base*—A hard rubber base having a Type D Durometer hardness of 80 to 90, and resilience rebound of at least 77 % but no more than 90 %. Conduct resilience tests on the finished base with the feet attached. Details for measuring the resilience of the base are given in Annex A1.

6.1.2 *Rubber Feet,* supporting the base, designed to provide isolation of the base from the work surface, and having a Type A Durometer hardness no greater than 60 as measured on the finished feet attached to the base.

6.1.3 *Cup,* brass, with a mass, including cup hanger, of 185 to 215 g.

6.1.4 *Cam*—Designed to raise the cup smoothly and continuously to its maximum height, over a distance of at least 180° of cam rotation, without developing an upward or downward velocity of the cup when the cam follower leaves the cam. (The preferred cam motion is a uniformly accelerated lift curve.)

NOTE 2—The cam and follower design in Fig. 1 is for uniformly accelerated (parabolic) motion after contact and assures that the cup has no velocity at drop off. Other cam designs also provide this feature and may be used. However, if the cam-follower lift pattern is not known, zero velocity at drop off can be assured by carefully filing or machining the cam and follower so that the cup height remains constant over the last 20 to 45° of cam rotation.

6.1.5 *Carriage,* constructed in a way that allows convenient but secure adjustment of the height-of-drop of the cup to 10 mm (0.394 in.), and designed such that the cup and cup hanger assembly is only attached to the carriage by means of a removable pin. See Fig. 2 for definition and determination of the height-of-drop of the cup.

6.1.6 *Motor Drive (Optional)*—As an alternative to the hand crank shown in Fig. 1, the device may be equipped with a motor to turn the cam. Such a motor must turn the cam at 2 ± 0.1 revolutions per second and must be isolated from the rest of the device by rubber mounts or in some other way that prevents vibration from the motor being transmitted to the rest of the apparatus. It must be equipped with an ON-OFF switch and a means of conveniently positioning the cam for height-of-drop adjustments. The results obtained using a motor-driven device must not differ from those obtained using a manually operated device.

6.2 *Flat Grooving Tool*—A tool made of plastic or noncorroding-metal having the dimensions shown in Fig. 3. The design of the tool may vary as long as the essential dimensions are maintained. The tool may, but need not, incorporate the gage for adjusting the height-of-drop of the liquid limit device.

NOTE 3—Prior to the adoption of this test method, a curved grooving tool was specified as part of the apparatus for performing the liquid limit test. The curved tool is not considered to be as accurate as the flat tool described in 6.2 since it does not control the depth of the soil in the liquid limit cup. However, there are some data which indicate that typically the liquid limit is slightly increased when the flat tool is used instead of the curved tool.

DIMENSIONS

LETTER	A △	B △	C △	E △	F	G	H	J △	K △	L △	M △
MM	54 ± 0.5	2 ± 0.1	27 ± 0.5	56 ± 2.0	32	10	16	60 ± 1.0	50 ± 2.0	150 ± 2.0	125 ± 2.0

LETTER	N	P	R	T	U △	V	W	Z
MM	24	28	24	45	47 ± 1.0	3.8	13	6.5

△ ESSENTIAL DIMENSIONS

CAM ANGLE DEGREES	CAM RADIUS
0	0.742 R
30	0.753 R
60	0.764 R
90	0.773 R
120	0.784 R
150	0.796 R
180	0.818 R
210	0.854 R
240	0.901 R
270	0.945R
300	0.974R
330	0.995R
360	1.000R

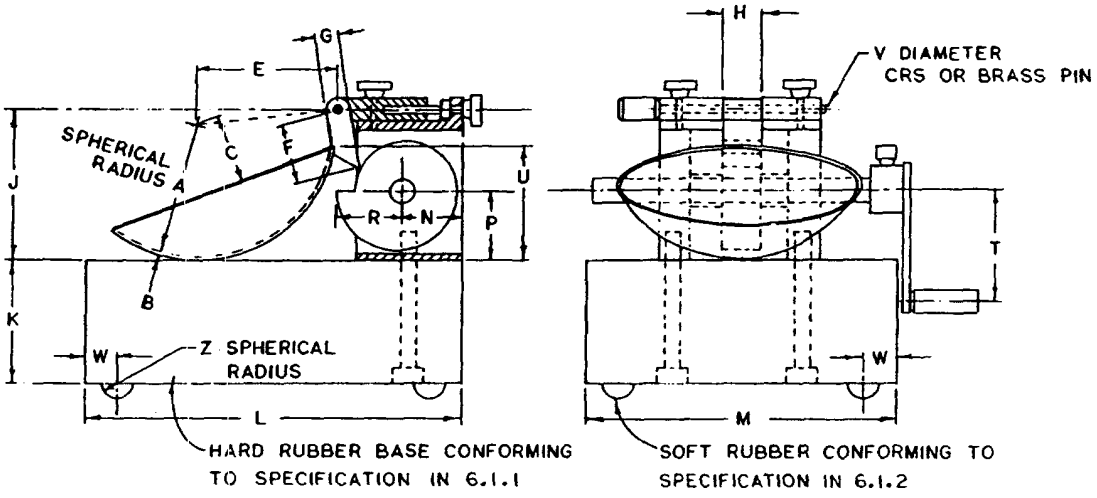


FIG. 1 Hand-Operated Liquid Limit Device

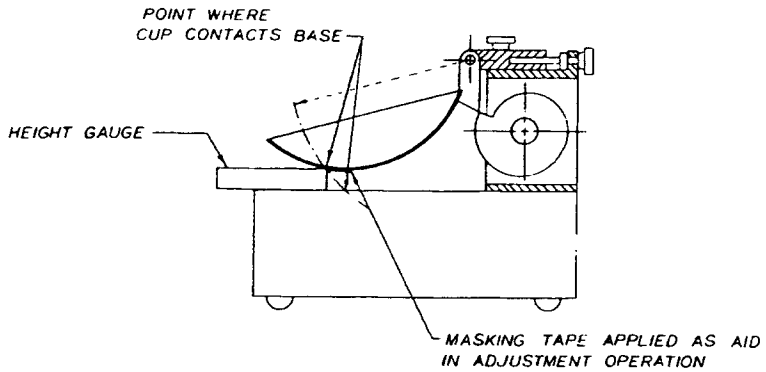


FIG. 2 Calibration for Height-of-Drop

DIMENSIONS

LETTER	A[Δ]	B[Δ]	C[Δ]	D[Δ]	E[Δ]	F[Δ]
MM	2 ± 0.1	11 ± 0.2	40 ± 0.5	8 ± 0.1	50 ± 0.5	2 ± 0.1
LETTER	G	H	J	K[Δ]	L[Δ]	N
MM	10 MINIMUM	13	60	10 ±0.05	60 DEG ± 1 DEG	20

[Δ] ESSENTIAL DIMENSIONS

[□] BACK AT LEAST 15 MM FROM TIP

NOTE : DIMENSION A SHOULD BE 1.9–2.0 AND DIMENSION D SHOULD BE 8.0–8.1 WHEN NEW TO ALLOW FOR ADEQUATE SERVICE LIFE

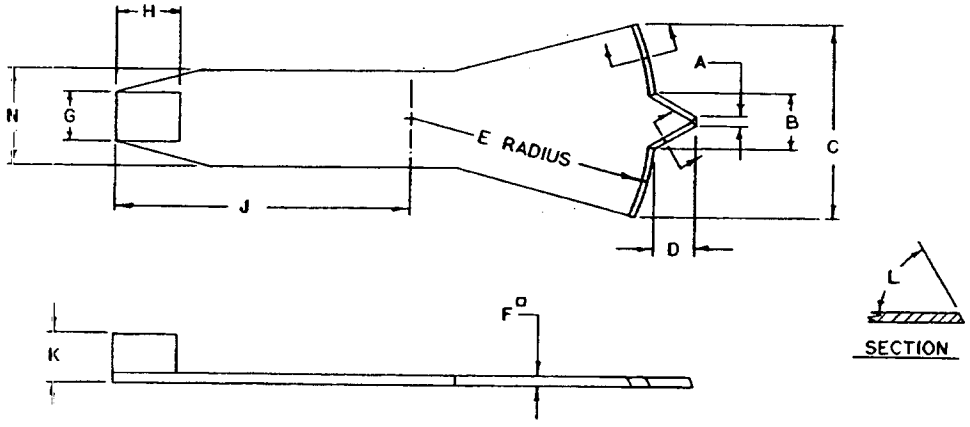


FIG. 3 Grooving Tool (Optional Height-of-Drop Gage Attached)

6.3 *Gage*—A metal gage block for adjusting the height-of-drop of the cup, having the dimensions shown in Fig. 4. The design of the tool may vary provided the gage will rest securely on the base without being susceptible to rocking, and the edge which contacts the cup during adjustment is straight, at least 10 mm (⅜ in.) wide, and without bevel or radius.

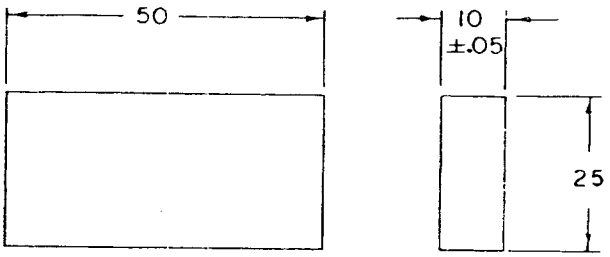
6.4 *Water Content Containers*—Small corrosion-resistant containers with snug-fitting lids for water content specimens. Aluminum or stainless steel cans 2.5 cm (1 in.) high by 5 cm (2 in.) in diameter are appropriate.

6.5 *Balance,* conforming to Specification D 4753, Class GP1 (readability of 0.01 g).

6.6 *Mixing and Storage Container*—A container to mix the soil specimen (material) and store the prepared material. During mixing and storage, the container shall not contaminate the material in any way, and prevent moisture loss during storage. A porcelain, glass, or plastic dish about 11.4 cm (4½ in.) in diameter and a plastic bag large enough to enclose the dish and be folded over is adequate.

6.7 *Plastic Limit:*

6.7.1 *Ground Glass Plate*—A ground glass plate at least 30



DIMENSIONS IN MILLIMETRES

FIG. 4 Height-of-Drop Gage

cm (12 in.) square by 1 cm (⅜ in.) thick for rolling plastic limit threads.

6.7.2 *Plastic Limit-Rolling Device (optional)*—A device made of acrylic conforming to the dimensions shown in Fig. 5.[7,8] The type of unglazed paper attached to the top and bottom plate (see 16.2.2) shall be such that it does not add foreign matter (fibers, paper fragments, etc.) to the soil during the rolling process.

6.8 *Spatula*—A spatula or pill knife having a blade about 2 cm (¾ in.) wide, and about 10 to 13 cm (3 to 4 in.) long.

6.9 *Sieve(s)*—A 200-mm (8-in.) diameter, 425-μm (No. 40) sieve conforming to the requirements of Specification E 11 and having a rim at least 5 cm (2 in.) above the mesh. A 2.00-mm (No. 10) sieve meeting the same requirements may also be needed.

6.10 *Wash Bottle,* or similar container for adding controlled amounts of water to soil and washing fines from coarse particles.

6.11 *Drying Oven,* thermostatically controlled, preferably of the forced-draft type, capable of continuously maintaining a temperature of 110 ± 5°C (230 ± 9°F) throughout the drying chamber.

6.12 *Washing Pan,* round, flat-bottomed, at least 7.6 cm (3 in.) deep, and slightly larger at the bottom than a 20.3-cm (8-in.) diameter sieve.

7. Reagents and Materials

7.1 *Purity of Water*—Where distilled water is referred to in this test method, either distilled or demineralized water may be used. See Note 7 covering the use of tap water.

8. Sampling and Specimen

8.1 Samples may be taken from any location that satisfies testing needs. However, Practices C 702, D 75, and D 420 should be used as guides for selecting and preserving samples from various types of sampling operations. Samples in which specimens will be prepared using the wet-preparation method (10.1) must be kept at their as–sampled water content prior to preparation.

8.1.1 Where sampling operations have preserved the natural stratification of a sample, the various strata must be kept separated and tests performed on the particular stratum of interest with as little contamination as possible from other strata. Where a mixture of materials will be used in construction, combine the various components in such proportions that the resultant sample represents the actual construction case.

[7] The plastic limit-rolling device is covered by a patent (U.S. Patent No. 5,027,660).[7] Interested parties are invited to submit information regarding the identification of an alternative(s) to this patented item to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible subcommittee, which you may attend.

[8] Bobrowski, L. J., Jr. and Griekspoor, D. M., "Determination of the Plastic Limit of a Soil by Means of a Rolling Device," *Geotechnical Testing Journal,* GTJODJ, Vol 15, No. 3, September 1992, pp. 284–287.

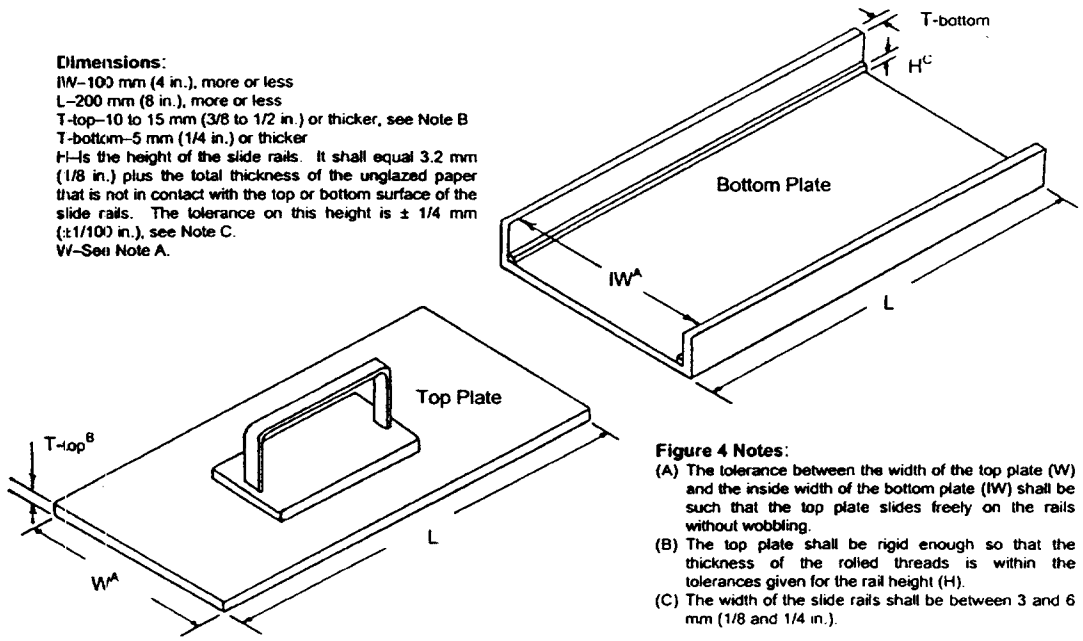


Figure 4 Notes:

(A) The tolerance between the width of the top plate (W) and the inside width of the bottom plate (IW) shall be such that the top plate slides freely on the rails without wobbling.

(B) The top plate shall be rigid enough so that the thickness of the rolled threads is within the tolerances given for the rail height (H).

(C) The width of the slide rails shall be between 3 and 6 mm (1/8 and 1/4 in.).

FIG. 5 Plastic Limit-Rolling Device

8.1.2 Where data from these test methods are to be used for correlation with other laboratory or field test data, use the same material as used for those tests where possible.

8.2 *Specimen*—Obtain a representative portion from the total sample sufficient to provide 150 to 200 g of material passing the 425-μm (No. 40) sieve. Free flowing samples (materials) may be reduced by the methods of quartering or splitting. Non-free flowing or cohesive materials shall be mixed thoroughly in a pan with a spatula or scoop and a representative portion scooped from the total mass by making one or more sweeps with a scoop through the mixed mass.

9. Calibration of Apparatus

9.1 *Inspection of Wear:*

9.1.1 *Liquid Limit Device*—Determine that the liquid limit device is clean and in good working order. Check the following specific points.

9.1.1.1 *Wear of Base*—The spot on the base where the cup makes contact should be worn no greater than 10 mm (⅜ in.) in diameter. If the wear spot is greater than this, the base can be machined to remove the worn spot provided the resurfacing does not make the base thinner than specified in 6.1 and the other dimensional relationships are maintained.

9.1.1.2 *Wear of Cup*—Replace the cup when the grooving tool has worn a depression in the cup 0.1 mm (0.004 in.) deep or when the rim of the cup has been reduced to half its original thickness. Verify that the cup is firmly attached to the cup hanger.

9.1.1.3 *Wear of Cup Hanger*—Verify that the cup hanger pivot does not bind and is not worn to an extent that allows more than 3 mm (⅛ in.) side-to-side movement of the lowest point on the rim.

9.1.1.4 *Wear of Cam*—The cam shall not be worn to an extent that the cup drops before the cup hanger (cam follower) loses contact with the cam.

9.1.2 *Grooving Tools*—Inspect grooving tools for wear on a frequent and regular basis. The rapidity of wear depends on the material from which the tool is made, and the types of soils being tested. Soils containing a large proportion of fine sand particles may cause rapid wear of grooving tools; therefore, when testing these materials, tools should be inspected more frequently than for other soils.

NOTE 4—The width of the tip of grooving tools is conveniently checked using a pocket-sized measuring magnifier equipped with a millimeter scale. Magnifiers of this type are available from most laboratory supply companies. The depth of the tip of grooving tools can be checked using the depth-measuring feature of vernier calipers.

9.2 *Adjustment of Height-of-Drop*—Adjust the height-of-drop of the cup so that the point on the cup that comes in contact with the base rises to a height of 10 ± 0.2 mm. See Fig. 2 for proper location of the gage relative to the cup during adjustment.

NOTE 5—A convenient procedure for adjusting the height-of-drop is as follows: place a piece of masking tape across the outside bottom of the cup parallel with the axis of the cup hanger pivot. The edge of the tape away from the cup hanger should bisect the spot on the cup that contacts the base. For new cups, placing a piece of carbon paper on the base and allowing the cup to drop several times will mark the contact spot. Attach the cup to the device and turn the crank until the cup is raised to its maximum height. Slide the height gage under the cup from the front, and observe whether the gage contacts the cup or the tape. (See Fig. 2.) If the tape and cup are both simultaneously contacted, the height-of-drop is ready to be checked. If not, adjust the cup until simultaneous contact is made. Check adjustment by turning the crank at 2 revolutions per second while holding the gage in position against the tape and cup. If a faint ringing or clicking sound is heard without the cup rising from the gage, the adjustment is correct. If no ringing is heard or if the cup rises from the gage, readjust the height-of-drop. If the cup rocks on the gage during this checking operation, the cam follower pivot is excessively worn and the worn parts should be replaced. Always remove tape after completion of adjustment operation.

10. Preparation of Test Specimen

10.1 *Wet Preparation Method*—Except where the dry method of specimen preparation is specified (10.2), prepare the specimen for testing as described in the following sections.

10.1.1 *Material Passes the 425-μm (No. 40) Sieve:*

10.1.1.1 Determine by visual and manual methods that the specimen from 8.2 has little or no material retained on a 425-μm (No. 40) sieve. If this is the case, prepare 150 to 200 g of material by mixing thoroughly with distilled or demineralized water on the glass plate or mixing dish using the spatula. If desired, soak the material in a mixing/storage dish with a small amount of water to soften the material before the start of mixing. If using Method A, adjust the water content of the material to bring it to a consistency that would require about 25 to 35 blows of the liquid limit device to close the groove (Note 6). For Method B, the number of blows should be between about 20 and 30 blows.

10.1.1.2 If, during mixing, a small percentage of material is encountered that would be retained on a 425-μm (No. 40) sieve, remove these particles by hand (if possible). If it is impractical to remove the coarser material by hand, remove small percentages (less than about 15 %) of coarser material by working the material (having the above consistency) through a 425-μm sieve. During this procedure, use a piece of rubber sheeting, rubber stopper, or other convenient device provided the procedure does not distort the sieve or degrade material that would be retained if the washing method described in 10.1.2 were used. If larger percentages of coarse material are encountered during mixing, or it is considered impractical to remove the coarser material by the procedures just described, wash the sample as described in 10.1.2. When the coarse particles found during mixing are concretions, shells, or other fragile particles, do not crush these particles to make them pass a 425-μm sieve, but remove by hand or by washing.

10.1.1.3 Place the prepared material in the mixing/storage dish, check its consistency (adjust if required), cover to prevent loss of moisture, and allow to stand (cure) for at least 16 h (overnight). After the standing period and immediately before starting the test, thoroughly remix the soil.

NOTE 6—The time taken to adequately mix a soil will vary greatly, depending on the plasticity and initial water content. Initial mixing times of more than 30 min may be needed for stiff, fat clays.

10.1.2 *Material Containing Particles Retained on a 425-μm (No. 40) Sieve:*

10.1.2.1 Place the specimen (see 8.2) in a pan or dish and add sufficient water to cover the material. Allow the material to soak until all lumps have softened and the fines no longer

adhere to the surfaces of the coarse particles (Note 7).

NOTE 7—In some cases, the cations of salts present in tap water will exchange with the natural cations in the soil and significantly alter the test results if tap water is used in the soaking and washing operations. Unless it is known that such cations are not present in the tap water, distilled or demineralized water should be used. As a general rule, water containing more than 100 mg/L of dissolved solids should not be used for either the soaking or washing operations.

10.1.2.2 When the material contains a large percentage of particles retained on the 425-μm (No. 40) sieve, perform the following washing operation in increments, washing no more than 0.5 kg (1 lb) of material at one time. Place the 425-μm sieve in the bottom of the clean pan. Transfer, without any loss of material, the soil-water mixture onto the sieve. If gravel or coarse sand particles are present, rinse as many of these as possible with small quantities of water from a wash bottle, and discard. Alternatively, transfer the soil-water mixture over a 2.00-mm (No. 10) sieve nested atop the 425-μm sieve, rinse the fine material through and remove the 2.00-mm sieve. After washing and removing as much of the coarser material as possible, add sufficient water to the pan to bring the level to about 13 mm (½ in.) above the surface of the 425-μm sieve. Agitate the slurry by stirring with the fingers while raising and lowering the sieve in the pan and swirling the suspension so that fine material is washed from the coarser particles. Disaggregate fine soil lumps that have not slaked by gently rubbing them over the sieve with the fingertips. Complete the washing operation by raising the sieve above the water surface and rinsing the material retained with a small amount of clean water. Discard material retained on the 425-μm sieve.

10.1.2.3 Reduce the water content of the material passing the 425–μm (No. 40) sieve until it approaches the liquid limit. Reduction of water content may be accomplished by one or a combination of the following methods: (*a*) exposing to air currents at room temperature, (*b*) exposing to warm air currents from a source such as an electric hair dryer, (*c*) decanting clear water from surface of the suspension, (*d*) filtering in a Büchner funnel or using filter candles, or (*e*) draining in a colander or plaster of Paris dish lined with high retentivity,[9] high wet-strength filter paper. If a plaster of Paris dish is used, take care that the dish never becomes sufficiently saturated that it fails to absorb water into its surface. Thoroughly dry dish between uses. During evaporation and cooling, stir the material often enough to prevent over-drying of the fringes and soil pinnacles on the surface of the mixture. For materials containing soluble salts, use a method of water reduction (*a* or *b*) that will not eliminate the soluble salts from the test specimen.

10.1.2.4 If applicable, remove the material retained on the filter paper. Thoroughly mix this material or the above material on the glass plate or in the mixing dish using the spatula. Adjust the water content of the mixture, if necessary, by adding small increments of distilled or demineralized water or by allowing the mixture to dry at room temperature while mixing on the glass plate. If using Method A, the material should be at a water content that would require about 25 to 35 blows of the liquid limit device to close the groove. For Method B, the number of blows should be between about 20 and 30. Put, if necessary, the mixed material in the storage dish, cover to prevent loss of moisture, and allow to stand (cure) for at least 16 h. After the standing period and immediately before starting the test, thoroughly remix the specimen.

10.2 *Dry Preparation Method:*

10.2.1 Dry the specimen from 8.2 at room temperature or in an oven at a temperature not exceeding 60°C until the soil clods will pulverize readily. Disaggregation is expedited if the material is not allowed to completely dry. However, the material should have a dry appearance when pulverized.

10.2.2 Pulverize the material in a mortar with a rubber-tipped pestle or in some other way that does not cause breakdown of individual particles. When the coarse particles found during pulverization are concretions, shells, or other fragile particles, do not crush these particles to make them pass a 425-μm (No. 40) sieve, but remove by hand or other suitable means, such as washing. If a washing procedure is used, follow 10.1.2.1-10.1.2.4.

10.2.3 Separate the material on a 425-μm (No. 40) sieve, shaking the sieve by hand to assure thorough separation of the finer fraction. Return the material retained on the 425-μm sieve to the pulverizing apparatus and repeat the pulverizing and sieving operations. Stop this procedure when most of the fine material has been disaggregated and material retained on the 425-μm sieve consists of individual particles.

10.2.4 Place material retained on the 425-μm (No. 40) sieve after the final pulverizing operations in a dish and soak in a small amount of water. Stir this mixture and transfer it to a 425-μm sieve, catching the water and any suspended fines in the washing pan. Pour this suspension into a dish containing the dry soil previously sieved through the 425-μm sieve. Discard material retained on the 425-μm sieve.

10.2.5 Proceed as described in 10.1.2.3 and 10.1.2.4.

MULTIPOINT LIQUID LIMIT—METHOD A

11. Procedure

11.1 Thoroughly remix the specimen (soil) in its mixing cup, and, if necessary, adjust its water content until the constancy requires about 25 to 35 blows of the liquid limit device to close the groove. Using a spatula, place a portion(s) of the prepared soil in the cup of the liquid limit device at the point where the cup rests on the base, squeeze it down, and spread it into the cup to a depth of about 10 mm at its deepest point, tapering to form an approximately horizontal surface. Take care to eliminate air bubbles from the soil pat, but form the pat with as few strokes as possible. Keep the unused soil in the mixing/storage dish. Cover the dish with a wet towel (or use other means) to retain the moisture in the soil.

11.2 Form a groove in the soil pat by drawing the tool, beveled edge forward, through the soil on a line joining the highest point to the lowest point on the rim of the cup. When cutting the groove, hold the grooving tool against the surface of the cup and draw in an arc, maintaining the tool perpendicular to the surface of the cup throughout its movement. See Fig. 6. In soils where a groove cannot be made in one stroke without tearing the soil, cut the groove with several strokes of the grooving tool. Alternatively, cut the groove to slightly less than

[9] S and S 595 filter paper available in 320-mm circles has proven satisfactory.

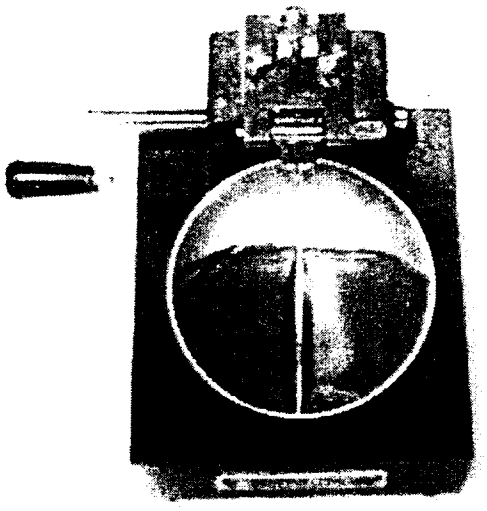


FIG. 6 Grooved Soil Pat in Liquid Limit Device

required dimensions with a spatula and use the grooving tool to bring the groove to final dimensions. Exercise extreme care to prevent sliding the soil pat relative to the surface of the cup.

11.3 Verify that no crumbs of soil are present on the base or the underside of the cup. Lift and drop the cup by turning the crank at a rate of 1.9 to 2.1 drops per second until the two halves of the soil pat come in contact at the bottom of the groove along a distance of 13 mm (½ in.). See Fig. 7.

NOTE 8—Use of a scale is recommended to verify that the groove has closed 13 mm (½ in.).

11.4 Verify that an air bubble has not caused premature closing of the groove by observing that both sides of the groove have flowed together with approximately the same shape. If a bubble has caused premature closing of the groove, reform the soil in the cup, adding a small amount of soil to make up for that lost in the grooving operation and repeat 11.1-11.3. If the soil slides on the surface of the cup, repeat 11.1-11.3 at a higher water content. If, after several trials at successively higher water contents, the soil pat continues to slide in the cup or if the number of blows required to close the groove is always less

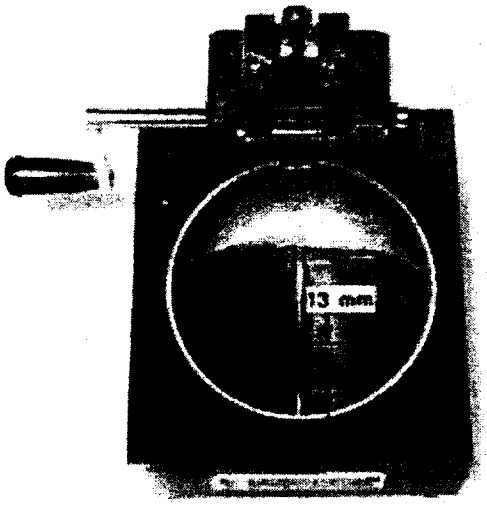


FIG. 7 Soil Pat After Groove Has Closed

than 25, record that the liquid limit could not be determined, and report the soil as nonplastic without performing the plastic limit test.

11.5 Record the number of drops, N, required to close the groove. Remove a slice of soil approximately the width of the spatula, extending from edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, place in a container of known mass, and cover.

11.6 Return the soil remaining in the cup to the dish. Wash and dry the cup and grooving tool and reattach the cup to the carriage in preparation for the next trial.

11.7 Remix the entire soil specimen in the dish adding distilled water to increase the water content of the soil and decrease the number of blows required to close the groove. Repeat 11.1-11.6 for at least two additional trials producing successively lower numbers of blows to close the groove. One of the trials shall be for a closure requiring 25 to 35 blows, one for closure between 20 and 30 blows, and one trial for a closure requiring 15 to 25 blows.

11.8 Determine the water content, W^n, of the soil specimen from each trial in accordance with Test Method D 2216.

11.8.1 Determination of initial masses (container plus moist soil) should be performed immediately after completion of the test. If the test is to be interrupted for more than about 15 minutes, determine the mass of the water content specimens already obtained at the time of the interruption.

12. Calculation

12.1 Plot the relationship between the water content, W^n, and the corresponding number of drops, N, of the cup on a semilogarithmic graph with the water content as ordinates on the arithmetical scale, and the number of drops as abscissas on a logarithmic scale. Draw the best straight line through the three or more plotted points.

12.2 Take the water content corresponding to the intersection of the line with the 25-drop abscissa as the liquid limit of the soil and round to the nearest whole number. Computational methods may be substituted for the graphical method for fitting a straight line to the data and determining the liquid limit.

ONE-POINT LIQUID LIMIT—METHOD B

13. Procedure

13.1 Proceed as described in 11.1-11.5 except that the number of blows required to close the groove shall be 20 to 30. If less than 20 or more than 30 blows are required, adjust the water content of the soil and repeat the procedure.

13.2 Immediately after removing a water content specimen as described in 11.5, reform the soil in the cup, adding a small amount of soil to make up for that lost in the grooving and water content sampling orientations. Repeat 11.2-11.5, and, if the second closing of the groove requires the same number of drops or no more than two drops difference, secure another water content specimen. Otherwise, remix the entire specimen and repeat.

NOTE 9—Excessive drying or inadequate mixing will cause the number of blows to vary.

13.3 Determine water contents of specimens in accordance with 11.8.

14. Calculation

14.1 Determine the liquid limit for each water content specimen using one of the following equations:

$$LL^n = W^n \cdot \left(\frac{N}{25}\right)^{0.121}$$

or

$$LL^n = k \cdot W^n$$

where:

LL^n = one point liquid limit for given trial, %,
N = number of blows causing closure of the groove for given trial,
W^n = water content for given trial, %, and
k = factor given in Table 1.

14.1.1 The liquid limit, LL, is the average of the two trial liquid-limit values, to the nearest whole number (without the percent designation).

14.2 If the difference between the two trial liquid-limit values is greater than one percentage point, repeat the test as described in 13.1 through 14.1.1.

PLASTIC LIMIT

15. Preparation of Test Specimen

15.1 Select a 20-g or more portion of soil from the material prepared for the liquid limit test; either, after the second mixing before the test, or from the soil remaining after completion of the liquid limit test. Reduce the water content of the soil to a consistency at which it can be rolled without sticking to the hands by spreading or mixing continuously on the glass plate or in the mixing/storage dish. The drying process may be accelerated by exposing the soil to the air current from an electric fan, or by blotting with paper, that does not add any fiber to the soil. Paper such as hard surface paper toweling or high wet-strength filter paper is adequate.

16. Procedure

16.1 From this plastic-limit specimen, select a 1.5 to 2.0 g portion. Form the selected portion into an ellipsoidal mass.

16.2 Roll the soil mass by one of the following methods (hand or rolling device):

TABLE 1 Factors for Obtaining Liquid Limit from Water Content and Number of Drops Causing Closure of Groove

N (Number of Drops)	k (Factor for Liquid Limit)
20	0.973
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

16.2.1 *Hand Method*—Roll the mass between the palm or fingers and the ground-glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length (see Note 10). The thread shall be further deformed on each stroke so that its diameter reaches 3.2 mm (⅛ in.), taking no more than 2 min (see Note 11). The amount of hand or finger pressure required will vary greatly according to the soil being tested, that is, the required pressure typically increases with increasing plasticity. Fragile soils of low plasticity are best rolled under the outer edge of the palm or at the base of the thumb.

NOTE 10—A normal rate of rolling for most soils should be 80 to 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position. This rate of rolling may have to be decreased for very fragile soils.

NOTE 11—A 3.2-mm (⅛-in.) diameter rod or tube is useful for frequent comparison with the soil thread to ascertain when the thread has reached the proper diameter.

16.2.2 *Rolling Device Method*—Attach smooth unglazed paper to both the top and bottom plates of the plastic limit-rolling device. Place the soil mass on the bottom plate at the midpoint between the slide rails. Place the top plate in contact with the soil mass(es). Simultaneously apply a slight downward force and back and forth motion to the top plate so that the top plate comes into contact with the side rails within 2 min (see Notes 10 and 12). During this rolling process, the end(s) the soil thread(s) shall not contact the side rail(s). If this occurs, roll a smaller mass of soil (even if it is less than that mentioned in Section 16.1).

NOTE 12—In most cases, two soil masses (threads) can be rolled simultaneously in the plastic limit-rolling device.

16.3 When the diameter of the thread becomes 3.2 mm, break the thread into several pieces. Squeeze the pieces together, knead between the thumb and first finger of each hand, reform into an ellipsoidal mass, and re-roll. Continue this alternate rolling to a thread 3.2 mm in diameter, gathering together, kneading and re-rolling, until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a 3.2-mm diameter thread (see Fig. 8). It has no significance if the thread breaks into threads of shorter length. Roll each of these shorter threads to 3.2 mm in diameter. The only requirement for continuing the test is that these threads can be reformed into an ellipsoidal mass and rolled out again. The operator shall at no time attempt to produce failure at exactly 3.2-mm diameter by allowing the thread to reach 3.2 mm, then reducing the rate of rolling or the hand pressure, or both, while continuing the rolling without further deformation until the thread falls apart. It is permissible, however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal mass nearer to the required 3.2-mm final diameter. If crumbling occurs when the thread has a diameter greater than 3.2 mm, this shall be considered a satisfactory end point, provided the soil has been previously rolled into a thread 3.2 mm in diameter. Crumbling of the thread will manifest itself differently with the various types of soil. Some soils fall apart in numerous small aggregations of particles, others may form an outside tubular layer that starts splitting at both ends. The splitting progresses toward the middle, and finally, the thread falls apart in many small platy particles. Fat clay soils require much pressure to deform the thread, particularly as they approach the plastic limit. With these soils, the thread breaks into a series of barrel-shaped segments about 3.2 to 9.5 mm (⅛ to ⅜ in.) in length.

16.4 Gather the portions of the crumbled thread together

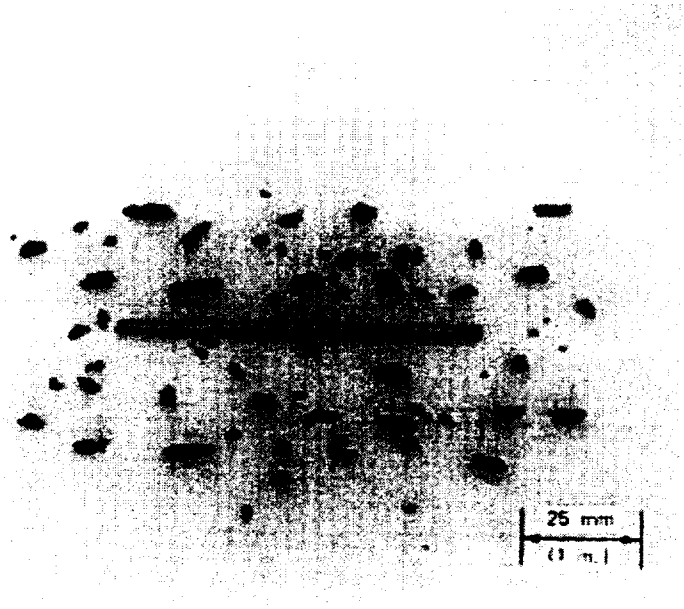


FIG. 8 Lean Clay Soil at the Plastic Limit

and place in a container of known mass. Immediately cover the container.

16.5 Select another 1.5 to 2.0-g portion of soil from the plastic-limit specimen and repeat the operations described in 16.1 and 16.2 until the container has at least 6 g of soil.

16.6 Repeat 16.1-16.5 to make another container holding at least 6 g of soil. Determine the water content of the soil contained in the containers in accordance with Test Method D 2216. See 11.8.1.

17. Calculation

17.1 Compute the average of the two water contents (trial plastic limits) and round to the nearest whole number. This value is the plastic limit, *PL*. Repeat the test if the difference between the two trial plastic limits is greater than the acceptable range for two results listed in Table 2 for single-operator precision, that is, 1.4 percentage points; i.e., (2.8 × 0.5).

PLASTICITY INDEX

18. Calculation

18.1 Calculate the plasticity index as follows:

$$PI = LL - PL$$

where:

LL = liquid limit (whole number), and
PL = plastic limit (whole number).

18.1.1 Both LL and PL are whole numbers. If either the liquid limit or plastic limit could not be determined, or if the plastic limit is equal to or greater than the liquid limit, report the soil as nonplastic, NP.

19. Report

19.1 Report the following information:

19.1.1 Sample identifying information,

19.1.2 Any special specimen selection process used, such as removal of sand lenses from undisturbed sample,

19.1.3 Report sample as air-dried if the sample was air-dried before or during preparation,

19.1.4 Liquid limit, plastic limit, and plasticity index to the nearest whole number, omitting the percent designation. If the liquid limit or plastic limit tests could not be performed, or if the plastic limit is equal to or greater than the liquid limit, report the soil as nonplastic, NP,

19.1.5 Estimate of the percentage of sample retained on the 425-μm (No. 40) sieve, and

19.1.6 Procedure by which liquid limit was performed, if it differs from the multipoint method.

20. Precision and Bias

20.1 *Precision*—Criteria for judging the acceptability of test results obtained by these test methods on a range of soil types are given in Tables 2 and 3. In performing these test methods, Method A and the Wet Preparation Method (except soil was air-dried) were used.

20.1.1 These estimates of precision are based on the results of the interlaboratory program conducted by the ASTM Reference Soils and Testing Program.[10] In this program, some laboratories performed three replicate tests per soil type (triplicate test laboratory), while other laboratories performed a single test per soil type (single-test laboratory). A description of the soils tested is given in 20.1.5. The precision estimates vary with soil type and method(s) used. Judgment is required when applying these estimates to another soil and method used (Method A or B, or Wet or Dry Preparation Method).

20.1.2 The data in Table 2 are based on three replicate tests performed by each triplicate test laboratory on each soil type. The single operator and multilaboratory standard deviation shown in Table 2, Column 4, were obtained in accordance with Practice E 691, which recommends each testing laboratory perform a minimum of three replicate tests. Results of two properly conducted tests performed by the same operator on the same material, using the same equipment, and in the shortest practical period of time should not differ by more than the single-operator d2*s* limits shown in Table 2, Column 5. For definition of d2*s* see Footnote C in Table 2. Results of two properly conducted tests performed by different operators and

[10] Supporting data are available from ASTM Headquarters. Request RR: D18-1013.

TABLE 2 Summary of Test Results from Triplicate Test Laboratories (Atterberg Limits)

(1) Soil Type	(2) Number of Triplicate Test Laboratories			(3) Average Value[A] (Percentage Points)			(4) Standard Deviation[B] (Percentage Points)			(5) Acceptable Range of Two Results[C] (Percentage Points)		
	Type Test											
	LL	PL	PI	LL	PL	PI	LL	PL	PI	LL	PL	PI
	Single-Operator Results (Within-Laboratory Repeatability)											
CH	13	13	13	59.8	20.6	39.2	0.7	0.5	0.8	2	1	2
CL	14	13	13	33.4	19.9	13.6	0.3	0.4	0.5	1	1	1
ML	12	11	11	27.4	23.4[D]	4.1[D]	0.5	0.3	0.6	2	1	2
	Multilaboratory Results (Between-Laboratory Reproducibility)											
CH	13	13	13	59.8	20.6	39.2	1.3	2.0	2.5	4	6	7
CL	14	13	13	33.4	19.9	13.6	1.0	1.2	1.7	3	3	5
ML	12	11	11	27.4	23.4[D]	4.1[D]	1.3	0.9	1.9	4	3	5

[A] The number of significant digits and decimal places presented are representative of the input data. In accordance with Practice D 6026, the standard deviation and acceptable range of results can not have more decimal places than the input data.

[B] Standard deviation is calculated in accordance with Practice E 691 and is referred to as the 1*s* limit.

[C] Acceptable range of two results is referred to as the d2*s* limit. It is calculated as $-1.960 \cdot \sqrt{2} \cdot 1s$, as defined by Practice E 177. The difference between two properly conducted tests should not exceed this limit. The number of significant digits/decimal places presented is equal to that prescribed by this test method or Practice D 6026. In addition, the value presented can have the same number of decimal places as the standard deviation, even if that result has more significant digits than the standard deviation.

[D] For the ML soil, 2 out of 14 triplicate test laboratories reported the soil as nonplastic.

TABLE 3 Summary of Single-Test Result from Each Laboratory (Atterberg Limits)[A]

(1)	(2)	(3)			(4)			(5)		
Soil Type	Number of Test Laboratories	Average Value (Percentage Points)			Standard Deviation (Percentage Points)			Acceptable Range of Two Results (Percentage Points)		
		Type Test								
		LL	PL	PI	LL	PL	PI	LL	PL	PI
CH	24	59.9	20.4	39.5	2.1	2.7	3.1	6	7	9
CL	24	33.3	19.9	13.4	0.8	1.3	1.6	2	4	4
ML	18	27.1	23.2[B]	3.9[B]	1.3	1.2	1.8	4	3	5

[A]For column footnotes, see Table 3.
[B]For the ML soil, 6 out of 24 laboratories reported the soil as nonplastic.

on different days should not differ by more than the multilaboratory d2*s* limits shown in Table 2, Column 5.

20.1.3 In the ASTM Reference Soils and Testing Program, many of the laboratories performed only a single test on each soil type. This is common practice in the design and construction industry. The data for each soil type in Table 3 are based upon the first test results from the triplicate test laboratories and the single test results from the other laboratories. Results of two properly conducted tests performed by two different laboratories with different operators using different equipment and on different days should not vary by more than the d2*s* limits shown in Table 3, Column 5. The results in Table 2 and Table 3 are dissimilar because the data sets are different.

20.1.4 Table 2 presents a rigorous interpretation of triplicate test data in accordance with Practice E 691 from pre-qualified laboratories. Table 3 is derived from test data that represents common practice.

20.1.5 *Soil Types*—Based on the multilaboratory test results, the soils used in the program are described below in accordance with Practice D 2487. In addition, the local names of the soils are given.

CH—Fat clay, CH, 99 % fines, LL=60, PI=39, grayish brown, soil had been air dried and pulverized. Local name—Vicksburg Buckshot Clay
CL—Lean clay, CL, 89 % fines, LL=33, PI=13, gray, soil had been air dried and pulverized. Local name—Annapolis Clay
ML—Silt, ML, 99 % fines, LL=27, PI=4, light brown, soil had been air dried and pulverized. Local name—Vicksburg Silt

20.2 *Bias*—There is no acceptable reference value for these test methods; therefore, bias cannot be determined.

21. Keywords

21.1 activity; Atterberg limits; liquid limit; plasticity index; plastic limit

ANNEX

(Mandatory Information)

A1. Resilience Tester

A1.1 A device for measuring the resilience of liquid limit device bases is shown in Fig. A1.1. The device consists of a clear acrylic plastic tube and cap, a 5/16-in. diameter steel ball, and a small bar magnet. The cylinder may be cemented to the cap or threaded as shown. The small bar magnet is held in the recess of the cap and the steel ball is fixed into the recess in the underside of the cap with the bar magnet. The cylinder is then turned upright and placed on the top surface of the base to be tested. Holding the tube lightly against the liquid limit device base with one hand, release the ball by pulling the magnet out of the cap. Use the scale markings on the outside of the cylinder to determine the highest point reached by the bottom of the ball. Repeat the drop at least three times, placing the tester in a different location for each drop. Tests should be conducted at room temperature.

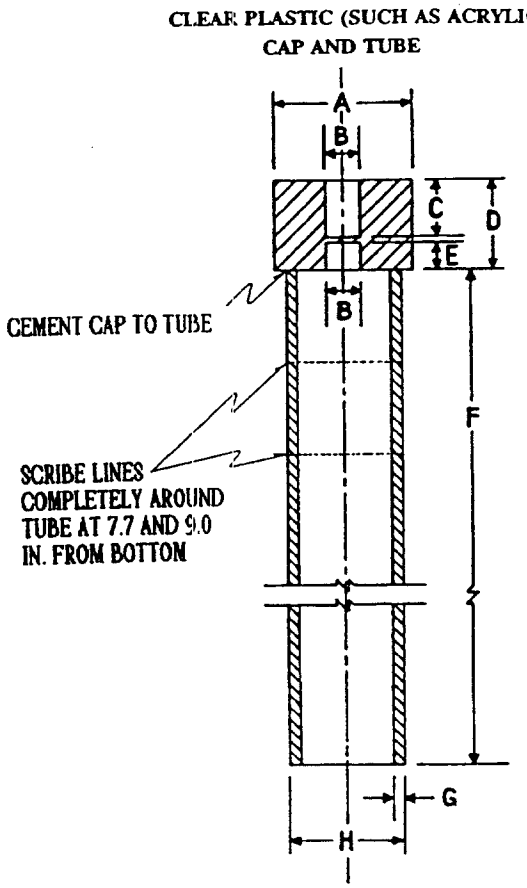


TABLE OF MEASUREMENTS

DIMENSION	DESCRIPTION	ENGLISH, in.	METRIC, mm
A	DIAM. OF CAP	1 1/2	38.10
B	DIAM. OF HOLE	3/8	9.52
C	DEPTH OF HOLE	10/16	15.88
D	HEIGHT OF CAP	1	25.40
E	DEPTH OF HOLE	5/16	7.94
F	LENGTH OF TUBE	10	254.00
G	WALL THICKNESS	1/8	3.18
H	O.D. OF TUBE	1 1/4	31.75

FIG. A1.1 Resilience Tester

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this standard since the last issue (1998) that may impact the use of this standard.

(*1*) Replaced "procedure" with "method," when the topic covers how one is to perform a task.
(*2*) In Scope covering "units," clarified that the standard units for resilience tester are in inch-pound, not metric.
(*3*) Where applicable, replaced "weight" with "mass" or reworded to remove such terms as "weight," "weighing," or "weigh."
(*4*) Where applicable, replaced "natural" as an adjective to water content with such terms as "its" or "as-sampled."
(*5*) In Apparatus, under 6.6, "storage container" was changed to "mixing and storage container" and subsection reworded to indicate this container/dish may be used to mix the soil. Remaining sections in the standard, where applicable, were reworded to indicate "storage dish" may also be the "mixing dish."
(*6*) In Section 8, changed title to include "Specimen," and where applicable reworded to distinguish between the sample and the specimen before processing using the wet or dry preparation method.
(*7*) Under Preparation of Test Specimen: The subsections covering the wet and dry preparation methods were reworded to include the required number of blows for Method A and B. In addition, used the term "material" instead of soil or sample, whenever applicable, and replaced "grains" with "particle.".
(*8*) Under One-Point Liquid Limit, Method B, Section 13 on Preparation of Test Specimen was removed since the information given in that section was moved to 10.1.2.4.
(*9*) In the calculation sections, defined that the calculated test result is rounded to the nearest whole number.
(*10*) References to Practice C 670 were deleted in text, and references to Practices D 3740, D 6026, E 177, and E 691 were incorporated.
(*11*) At the end of the Significance and Use section, a new Note 1 was added referencing Practice D 3740 in accordance with D18 policy, and all subsequent notes were renumbered.
(*12*) Section 20.1 on Precision was revised completely.
(*13*) In Table 1, corrected the factor for 20 number of drops.
(*14*) Appendix X1 was changed to Annex A1, and the scribe

line at "8.0" in Fig. A1.1 was changed to "7.7."

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Designation: D 1140 – 00

Standard Test Methods for Amount of Material in Soils Finer Than the No. 200 (75-μm) Sieve[1]

This standard is issued under the fixed designation D 1140; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 These test methods cover determination of the amount of material finer than a 75-μm (No. 200) sieve by washing.

1.2 Two methods for determining the amount of material finer than the No. 200 sieve are provided. The method to be used shall be specified by the requesting authority. If no method is specified, the choice should be based on the guidance given in 4.2 and 7.3

1.2.1 *Method A*—Test specimen is not dispersed prior to wash sieving.

1.2.2 *Method B*—Test specimen is dispersed by soaking in water containing a deflocculating agent prior to wash sieving

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 702 Practice for Reducing Field Samples of Aggregate to Testing Size[2]

D 75 Practice for Sampling Aggregates[3]

D 422 Test Method for Particle-Size Analysis of Soils[4]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass[4]

D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)[4]

D 3740 Practice for Minimum Requirement for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction[4]

D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil, Rock, and Related Construction Materials for Testing[4]

D 6026 Practice for Using Significant Digits in Geotechnical Data[5]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[6]

E 145 Specification for Gravity-Convection and Force-Ventilation Ovens[6]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[6]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[6]

3. Summary of Test Method

3.1 A specimen of the soil is washed over a 75-μm (No. 200) sieve. Clay and other particles that are dispersed by the wash water, as well as water-soluble materials, are removed from the soil during the test. The loss in mass resulting from the wash treatment is calculated as mass percent of the original sample and is reported as the percentage of material finer than a 75-μm (No. 200) sieve by washing.

4. Significance and Use

4.1 Material finer than the 75-μm (No. 200) sieve can be separated from larger particles much more efficiently and completely by wet sieving than with dry sieving. Therefore, when accurate determinations of material finer than 75-μm sieve in soil are desired, this test method is used on the test specimen prior to dry sieving. Usually the additional amount of material finer than 75-μm sieve obtained in the dry sieving process is a small amount. If it is large, the efficiency of the washing operation should be checked, as it could be an indication of degradation of the soil.

4.2 With some soils, particularly clayey soils, in order to keep the finer material from adhering to the larger particles, it will be necessary to soak the soil prior to washing it through the sieve. A deflocculating agent (dispersing agent) should be added to the soil when it is soaked.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the

[1] This standard is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

Current edition approved June 10, 2000. Published September 2000. Originally published as D 1140 – 50T. Last previous edition D 1140 – 97.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.03.

[4] *Annual Book of ASTM Standards*, Vol 04.08.

[5] *Annual Book of ASTM Standards*, Vol 04.09.

[6] *Annual Book of ASTM Standards*, Vol 14.02.

*A Summary of Changes section appears at the end of this standard.

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criteria of Practice D 3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

5. Apparatus

5.1 *Balance*—A balance or scale conforming to the requirements of Specification D 4753, readable (with no estimation) to 0.1 % of the test mass, or better. To determine the balance needed, multiply your test mass by 0.001 and check Table 1 of Specification D 4753 for the class of balance readable to the number observed.

5.2 *Sieves*—A minimum nest of two sieves is recommended, the lower must be a 75-μm (No. 200) sieve and the upper may be a 425-μm (No. 40) or larger sieve. Chose a sieve with a diameter sufficient to handle the size of specimen required by 6.2. The 75-μm sieve should have a backing to prevent damage. The sieves shall conform to the requirements of Specification E 11. Stainless sieve mesh is preferred, as it is less prone to damage or wear.

5.3 *Oven*—An oven of sufficient size, capable of maintaining a uniform temperature of 100 ± 5°C (230 ± 9°F) and which meets the criteria of Specification E 145.

5.4 *Deflocculating Agent*—A solution of Sodium Hexametaphosphate of any concentration sufficient to cause particle separation can be used. A common amount is 40 g per 1000 mL of water.

6. Sampling

6.1 Sample the soil in accordance with Practice D 75.

6.2 Thoroughly mix the soil sample and reduce the quantity to an amount suitable for testing using the applicable method described in Practice C 702. The test specimen shall be the end result of the reduction. Reduction to an exact predetermined mass is not permitted. The mass of the test specimen, after drying, shall conform with the following except as noted (6.2.1 and Note 2):

Maximum Particle Size (100 % Passing)	Standard Sieve Size	Recommended Minimum Mass of Test Specimens
2 mm or less	No. 10	20 g
4.75 mm	No. 4	100 g
9.5 mm	⅜"	500 g
19.0 mm	¾"	2.5 kg
37.5 mm	1½"	10 kg
75.0 mm	3"	50 kg

6.2.1 If the same specimen is to be tested for sieve analysis according to Test Method D 422, comply with the applicable mass requirements of that Test Method.

NOTE 2—When a minimum mass is not available (split spoon sample, and the like), a smaller mass can be used. The report shall indicate the mass used.

7. Procedure

7.1 Dry the test specimen to a constant mass at a temperature of 110 ± 5°C (230 ± 9°F) and determine its mass to the nearest 0.1 g. To determine the balance needed, multiply the mass by 0.001, check the resultant number with Table 1 of Specification D 4753 for the required balance.

7.1.1 For example: Minimum readability = 276 g (mass) × 0.001 = 0.3 g. A GP-2 with a readability of 0.1 g would be suitable. A more sensitive balance could also be used.

7.1.2 As an alternative, select an auxiliary water content specimen and determine the water content (nearest 0.1 %) in accordance with Test Method D 2216. Calculate the oven-dry mass of the test specimen from the moist mass (nearest 0.1 % of its mass, or better (see 5.1)) and the water content.

7.2 *Method A*:

7.2.1 After preparing the specimen in accordance with 7.1, place the specimen on on the uppermost (coarsest) sieve. Wash the specimen (material) on the sieve(s) by means of a stream of water from a faucet (Note 3). The material may be lightly manipulated by hand, to facilitate the washing process, taking care not to lose any of the retained material. No downward pressure should be exerted on the retained material or sieve to avoid the forcing of particles through the sieve or damage to the sieve. Continue the washing until the water coming through the sieve(s) is clear (Note 4).

NOTE 3—A spray nozzle or a piece of rubber tubing attached to a water faucet may be used for the washing. The velocity of the water, which may be increased by pinching the tubing, shall not cause any splashing of the material over the sides of the sieve. The water temperature should not exceed 32°C (90°F) to avoid expanding the sieve fabric.

NOTE 4—Care should be taken not to let water accumulate on the 75-μm (No. 200) sieve due to clogging of the screen. The clogging can cause overflow of the sieve and loss of material. Lightly hand tapping the sides of the sieve or the bottom of the screen with a fingertip(s) should prevent clogging. Directing a stream of water up from below the screen is another method to unplug the sieve without physically damaging it. Be careful not to overload the screen by sieving too large a specimen, or portion of a specimen, at any one time.

7.3 *Method B*:

7.3.1 As an alternative, particularly for very cohesive soils; after preparing the specimen in accordance with 7.1, place the specimen in a container, cover with water containing a deflocculating agent, and soak for a minimum of 2 h (preferably overnight) (Note 5). The specimen should be periodically agitated manually or by mechanical means to facilitate the complete separation of the particles.

NOTE 5—It will also be easier to separate the particles if the specimen is not dried prior to soaking. The moist mass can be adjusted to a dry mass by using the water content determination procedure from 7.1.2.

7.3.2 After the soaking period is completed, agitate the contents of the container vigorously and immediately pour into the nested sieves. Wash any remaining material into the sieve(s) to make sure all of the material is transferred. Then finish the washing procedure as specified in 7.2.

7.4 When the washing by Method A or B is completed, the material retained on the 75-μm (No. 200) sieve can be dried either in the sieve, or by flushing (transferring) the contents of the sieve into another container. If the soil is transferred, excess water can be removed by decanting or suctioning to speed drying time. Take care not to lose any particles by removing only clear water.

7.4.1 Dry the residue from each sieve to a constant mass using a temperature of 110 ± 5°C (230 ± 9°F) and determine the mass using the same balance as used in 7.1.

NOTE 6—As mentioned in 4.1, if the sample is dry sieved after washing,

some material will pass the 75-μm (No. 200) sieve that did not pass during washing operations. This can be a significant amount for samples with a high percent of very fine sand or coarse silt.

8. Calculation

8.1 Calculate the amount of material passing the 75-μm (No. 200) sieve by washing using the following formula:

$$A = [(B - C)/B] \times 100 \quad (1)$$

where:

A = percentage of material finer than the 75-μm sieve by washing, nearest 0.1 %

B = original dry mass of sample, g, and

C = dry mass of specimen retained on the 75-μm sieve including the amount retained on an upper sieve after washing, g.

9. Report

9.1 Report the percentage of material finer than the 75-μm (No. 200) sieve by washing to the nearest 0.1 %.

9.2 Indicate whether the specimen was soaked and length of time.

9.3 Indicate method used (A or B).

9.4 Sample identification.

9.5 Size of initial dry mass used.

9.6 State whether the dry mass was determined directly or using the water content of the specimen as directed in 7.1.2. If so, note the water content.

10. Precision and Bias

10.1 *Precision*—Criteria for judging the acceptability of test results obtained by these test methods on a range of soil types using Method B are given in Tables 1 and 2. These estimates of precision are based on the results of the interlaboratory

TABLE 1 Summary of Test Results from Triplicate Test Laboratories (Percent of Fines)

(1) Soil Type	(2) Number of Triplicate Test Laboratories	(3) Average Value[A] (Percentage Points)	(4) Standard Deviation[B] (Percentage Points)	(5) Acceptable Range of Two Results[C] (Percentage Points)
Single-Operator Results (Within- Laboratory Repeatability):				
CH	13	98.83	0.15	0.4
CL	13	88.55	0.14	0.4
ML	14	99.00	0.12	0.3
SP	13	2.47	0.20	0.5
Multilaboratory Results (Between- Laboratory Reproducibility):				
CH	13	98.83	0.22	0.6
CL	13	88.55	0.40	1.1
ML	14	99.00	0.13	0.4
SP	13	2.47	0.36	1.0

[A] The number of significant digits and decimal places presented are representative of the input data. In accordance with Practice D 6026, the standard deviation and acceptable range of results can not have more decimal places than the input data.

[B] Standard deviation is calculated in accordance with Practice E 691 and is referred to as the 1s limit.

[C] Acceptable range of two results is referred to as the d2s limit. It is calculated as $1.960\sqrt{2} \cdot 1s$, as defined by Practice E 177. The difference between two properly conducted tests should not exceed this limit. The number of significant digits/decimal places presented is equal to that prescribed by this test method or Practice D 6026. In addition, the value presented can have the same number of decimal places as the standard deviation, even if that result has more significant digits than the standard deviation.

TABLE 2 Summary of Single-Test Result from Each Laboratory (Percent of Fines)[A]

(1) Soil Type	(2) Number of Test Laboratories	(3) Average Value (Percentage Points)	(4) Standard Deviation (Percentage Points)	(5) Acceptable Range of Two Results (Percentage Points)
Multilaboratory Results (Single Test Performed by Each Laboratory):				
CH	25	98.74	0.22	0.6
CL	24	88.41	0.52	1.4
ML	25	99.00	0.18	0.5
SP	25	2.647	0.60	1.7

[A] See footnotes in the Table 1.

program conducted by the ASTM Reference Soils and Testing Program[7]. In this program, some laboratories performed three replicate tests per soil type (triplicate test laboratory), while other laboratories performed a single test per soil type (single test laboratory). A description of the soils tested is given in 10.1.4. The precision estimates may vary with soil type and method used (Method A or B). Judgment is required when applying these estimates to another soil or method.

10.1.1 The data in Table 1 are based on three replicate tests performed by each triplicate test laboratory on each soil type. The single operator and multilaboratory standard deviation shown in Table 1, Column 4 were obtained in accordance with Practice E 691, which recommends each testing laboratory perform a minimum of three replicate tests. Results of two properly conducted tests performed by the same operator on the same material, using the same equipment, and in the shortest practical period of time should not differ by more than the single-operator d2*s* limits shown in Table 1, Column 5. For definition of d2*s* see Footnote C in Table 2. Results of two properly conducted tests performed by different operators and on different days should not differ by more than the multilaboratory d2*s* limits shown in Table 1, Column 5.

10.1.2 In the ASTM Reference Soils and Testing Program, many of the laboratories performed only a single test on each soil type. This is common practice in the design and construction industry. The data for each soil type in Table 2 are based upon the first test results from the triplicate test laboratories and the single test results from the other laboratories. Results of two properly conducted tests performed by two different laboratories with different operators using different equipment and on different days should not vary by more than the d2s limits shown in Table 2, Column 5. The results in Table 1 and Table 2 are dissimilar because the data sets are different.

10.1.3 Table 1 presents a rigorous interpretation of triplicate test data in accordance with Practice E 691 from pre-qualified laboratories. Table 2 is derived from test data that represents common practice.

10.1.4 *Soil Types*—Based on the multilaboratory test results, the soils used in the program are described below in accordance with Practice D 2487. In addition, the local names of the soils are given.

[7] Supporting data is available from ASTM Headquarters. Request RR: D18-1010.

CH—Fat clay, CH, 99 % fines, LL=60, PI=39, grayish brown, soil had been air dried and pulverized. Local name—Vicksburg Buckshot Clay
CL—Lean clay, CL, 89 % fines, LL=33, PI=13, gray, soil had been air dried and pulverized. Local name—Annapolis Clay
ML—Silt, ML, 99 % fines, LL=27, PI=4, light brown, soil had been air dried and pulverized. Local name—Vicksburg Silt
SP—Poorly graded sand, SP, 20 % coarse sand, 48 % medium sand, 30 % fine sand, 2 % fines, yellowish brown. Local name—Frederick sand

11. Keywords

11.1 fines; particle sizes; sieve analysis; washing

SUMMARY OF CHANGES

In accordance with Committee D 18 policy, this section identifies the location of changes to this standard since the last edition (1997) that may impact the use of this standard.

(1) The Summary of Changes section was added.
(2) Title change to reflect multiple methods.
(3) In Scope Section, Methods A and B were defined.
(4) Reference to Practice D 670 was removed and references to Practices, D 3740, D 2487, D 6026, E 177, and E 691 were added.
(5) Following the Significance and Use section, Note 1 was added referencing Practice D 3740 in accordance with the policy of D18. The remaining notes were renumbered.
(6) Under Sampling: moved and reworded the 2nd sentence in 6.1 to 6.2.1. The two sentences following the table presenting recommended mass of test specimens were moved to 6.2.
(7) In 7.1 reworded the mass determination to agree with 7.4.1 and moved the example in 7.4.1 to this subsection. In addition, moved the alternative method (given in 7.1) to a new subsection, 7.4.1, and reworded it so Test Method D 2216 controlled how the water content specimen was obtained and the water content determined.
(8) Reworded 7.4.1 to use the same balance as used in 7.1.
(4) The precision statement in 10.1 was completely revised.

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Designation: D 1586 – 99

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Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils[1]

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This test method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

NOTE 1—Practice D 6066 can be used when testing loose sands below the water table for liquefaction studies or when a higher level of care is required when drilling these soils. This practice provides information on drilling methods, equipment variables, energy corrections, and blow-count normalization.

2. Referenced Documents

2.1 *ASTM Standards:*

D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)[2]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

D 4633 Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems[2]

D 6066 Practice for Determining the Normalized Penetration Resistance Testing of Sands for Evaluation of Liquefaction Potential[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.1.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.1.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.1.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.1.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.1.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.1.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.1.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N*-value, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.1.9 ΔN—the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.1.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by 360° (see Fig. 1).

3.1.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.1.12 *SPT*—abbreviation for standard penetration test, a term by which engineers commonly refer to this method.

4. Significance and Use

4.1 This test method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This test method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and

[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Jan. 10, 1999. Published March 1999. Originally published as D 1586 – 58 T. Last previous edition D 1586 – 98.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.09.

***A Summary of Changes section appears at the end of this standard.**

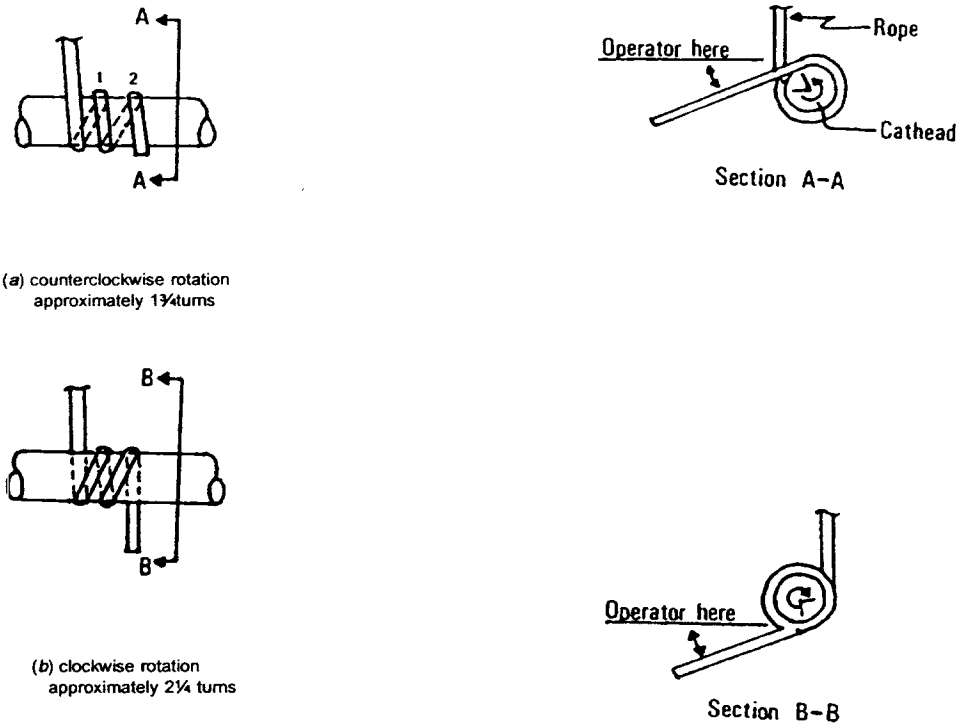


FIG. 1 Definitions of the Number of Rope Turns and the Angle for (*a*) Counterclockwise Rotation and (*b*) Clockwise Rotation of the Cathead

widely published correlations which relate SPT blowcount, or *N*-value, and the engineering behavior of earthworks and foundations are available.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjuction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers*, with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of 1⅝ in. (41.2 mm) and an inside diameter of 1⅛ in. (28.5 mm).

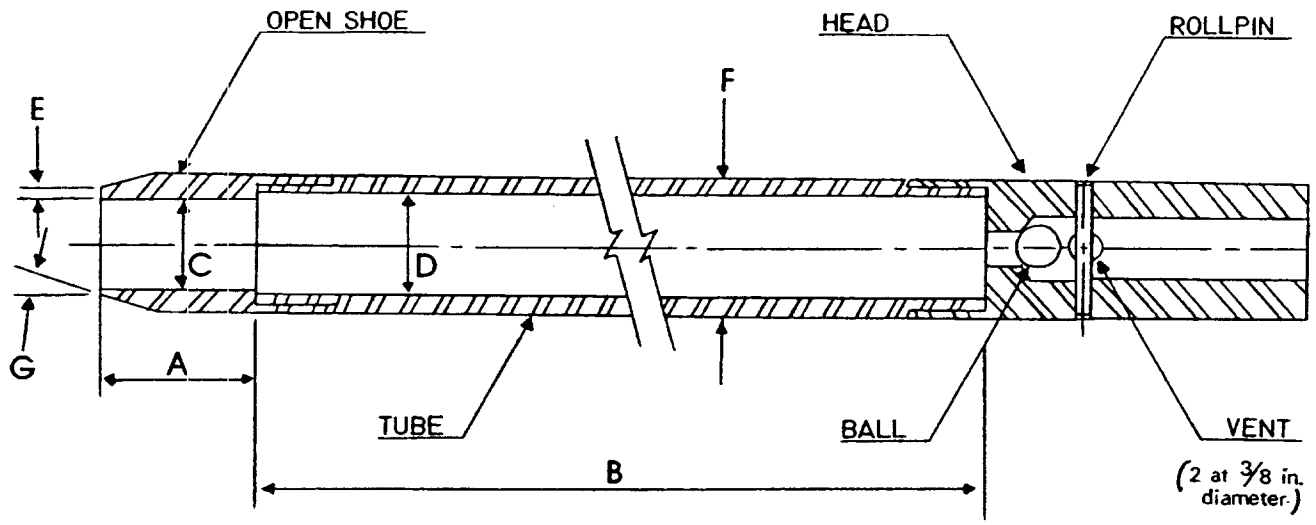
NOTE 2—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the *N*-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1⅜ in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

NOTE 3—Both theory and available test data suggest that *N*-values may increase between 10 to 30 % when liners are used.

5.4 *Drive-Weight Assembly*:

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 − 0.00 in. (38.1 ± 1.3 − 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 − 0.00 in. (50.8 ± 1.3 − 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 4—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 mm) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling

rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance," or the "*N*-value." If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb (63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. (0.76 m ± 25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than 2¼ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 5—The operator should generally use either 1¾ or 2¼ rope turns, depending upon whether or not the rope comes off the top (1¾ turns) or the bottom (2¼ turns) of the cathead. It is generally known and accepted that 2¾or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfrayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

8.1.1 Name and location of job,

8.1.2 Names of crew,

8.1.3 Type and make of drilling machine,

8.1.4 Weather conditions,

8.1.5 Date and time of start and finish of boring,

8.1.6 Boring number and location (station and coordinates, if available and applicable),

8.1.7 Surface elevation, if available,

8.1.8 Method of advancing and cleaning the boring,

8.1.9 Method of keeping boring open,

8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,

8.1.11 Location of strata changes,

8.1.12 Size of casing, depth of cased portion of boring,

8.1.13 Equipment and method of driving sampler,

8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),

8.1.15 Size, type, and section length of the sampling rods, and

8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

8.2.1 Sample depth and, if utilized, the sample number,

8.2.2 Description of soil,

8.2.3 Strata changes within sample,

8.2.4 Sampler penetration and recovery lengths, and

8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 *Precision*—A valid estimate of test precision has not been determined because it is too costly to conduct the necessary inter-laboratory (field) tests. Subcommittee D18.02 welcomes proposals to allow development of a valid precision statement.

9.2 *Bias*—Because there is no reference material for this test method, there can be no bias statement.

9.3 Variations in *N*-values of 100 % or more have been

observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.4 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

9.5 The variability in *N*-values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting *N* on the basis of comparative energies. A method for energy measurement and *N*-value adjustment is given in Test Method D 4633.

10. Keywords

10.1 blow count; in-situ test; penetration resistance; split-barrel sampling; standard penetration test

SUMMARY OF CHANGES

(1) Added note to Section 1, Scope. The note refers to a related standard, Practice D 6066.

(2) Added Practice D 6066 to Section 2 on Referenced Documents.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

TAB C

SKEEN RAILROAD ENGINEERING

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SITE PLANNING, INSPECTIONS
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J. GARY SKEEN, P.E.
B. PATRICK SKEEN, P.E.
45 YEARS EXPERIENCE

March 7, 2005

Mr. Pat Roesler
Terminal Operations Manager
Holcim U.S.A., Inc.
1100 Victors Way
Suite 50
Ann Arbor, MI 48108

RE: CONSTRUCTION PROCEDURES FOR PROPOSED HOLRAIL TRACK SYSTEM AT HOLLY HILL, S.C.

Dear Mr. Roesler:

As per your request, Skeen Railroad Engineering (SRE) will outline below a general procedure that should be followed in the construction of railroad system (both preferred and alternative routes). After all required permitting has been secured, the following steps would outline the order and method of construction.

1. Surveyor would stakeout alignment for proposed tracks and set horizontal and vertical control points.

2. Surveyor will locate limits of proposed bridges and provide horizontal and vertical control.

3. Clear and grubb area within grading limits, and remove materials from site. This will probably be accomplished with crawler equipment capable of mobility in unstable or swampy areas. This equipment will likely be diesel operated.

4. Begin backfilling of roadbed area within the wet areas of swamp with large rock (one

or two man stones). This rock will be applied until stability is achieved and a height above water line of at least 2 ft. has been maintained. A finer course stone (probably No. 4, 2' to 3/8" size) will then be applied to choke off voids in larger rocks. This will then be compacted with vibratory rollers until stability is achieved. At this point, contractor may opt to use select borrow material in lieu of additional stone. In either case, at this point a layer of Geo-Grid should be placed along the roadbed for its full length and width. The roadbed will then be constructed in subsequent one-foot layers until proper height has been attained. A layer of Geo-grid will be placed on roadbed at the start of all subsequent lifts. All of this operation will probably be carried out with diesel-powered dozers (crawler type), over the road tandem axle dump trucks, diesel powered vibratory rollers, etc.

5. After proper height and width of roadbed has been attained, then a six (6) inch layer of dense grade aggregate base stone will be installed and compacted over the top of roadbed (a minimum of 26 ft. wide. The roadbed will then be ready for track construction. In areas where seeding would be appropriate, it would be carried out at this time. Again, this sequence of operations will be carried out with diesel-powered dozers (crawler type), over the road tandem axle dump trucks, diesel powered vibratory rollers, etc.

6. The construction of bridges can progress independently of roadbed, or after roadbed approaches have been completed. Most likely, the bridge construction will commence after the first approach is completed. This bridge (southerly most bridge) can then progress while the rest of roadbed construction continues. If bridge contractor wants to drive all piles for all bridges in one continual sequence, then he would have to provide his own means of access to bridge areas. Since all bridges are in areas of standing water, he would likely use some type of floating or crawling system for his pile driver.

7. The track construction would begin after sufficient roadbed and bridges are completed to allow for uninterrupted workflow. Access for railroad contractor will always be on completed roadbed. Rail tie-ins to existing rail system would be scheduled with CSX and Holcim to assure a minimum of disruption to rail service and operations.

Below are the approximate durations of the three major construction sequences.

1. Roadbed preparation.....8 months (depending on weather).

2. Bridge construction.....7 months

3. Track construction (utilizing 2 full time crews).....6 months

In summary, it can be said that scheduling will play a large role in minimizing the

disruption to existing eco-systems regardless of which route is utilized. However, it can also be said that less disruption to eco-systems will occur if preferred route is constructed. The construction of either route (preferred or alternate) should pose little or no disruptions to existing rail operations in this area.

Sincerely,

J. Gary Skeen, P.E

TAB D

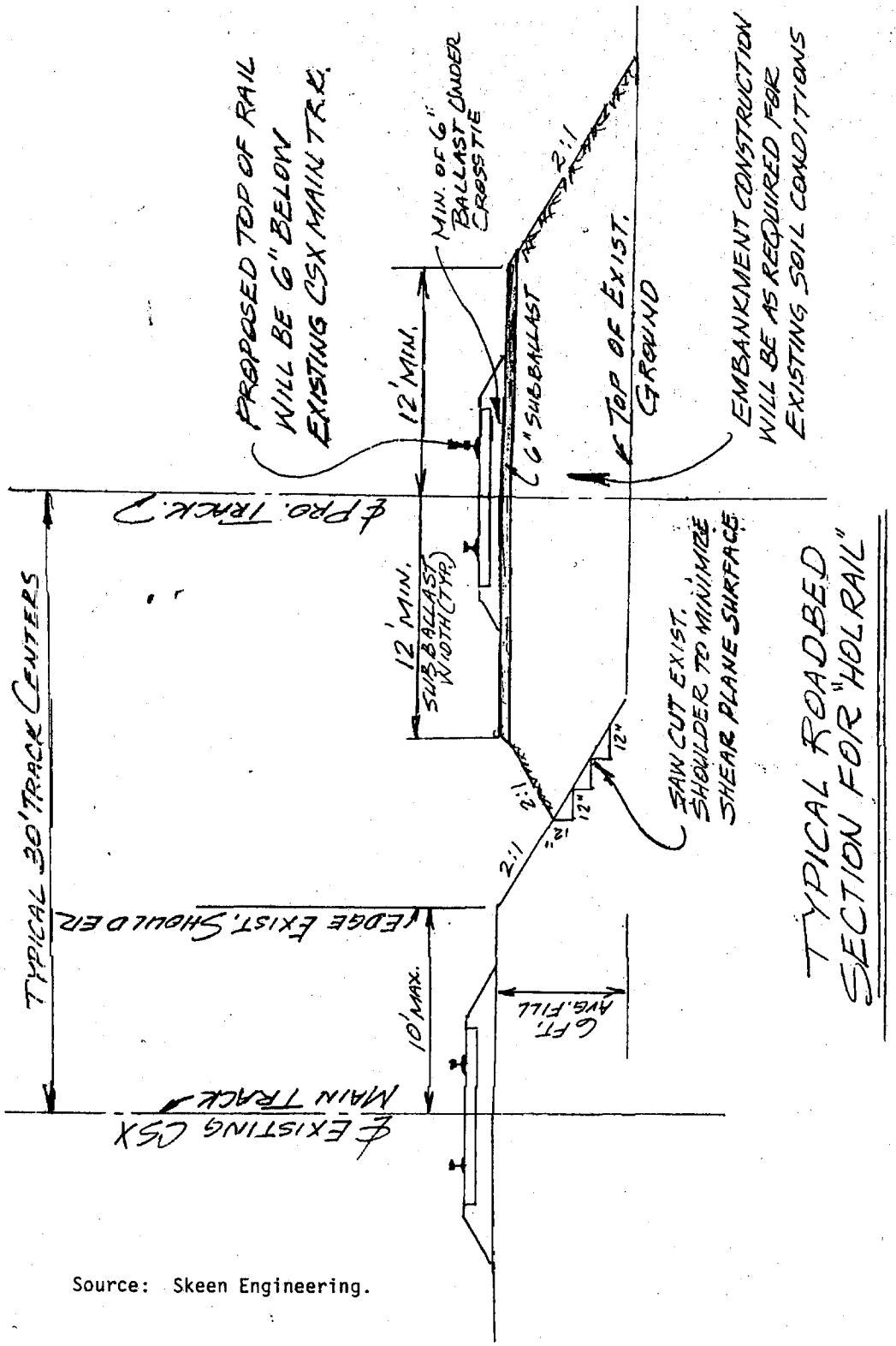
Drawing No. 05-0530

(Oversized Document

Separately Attached)

TAB E

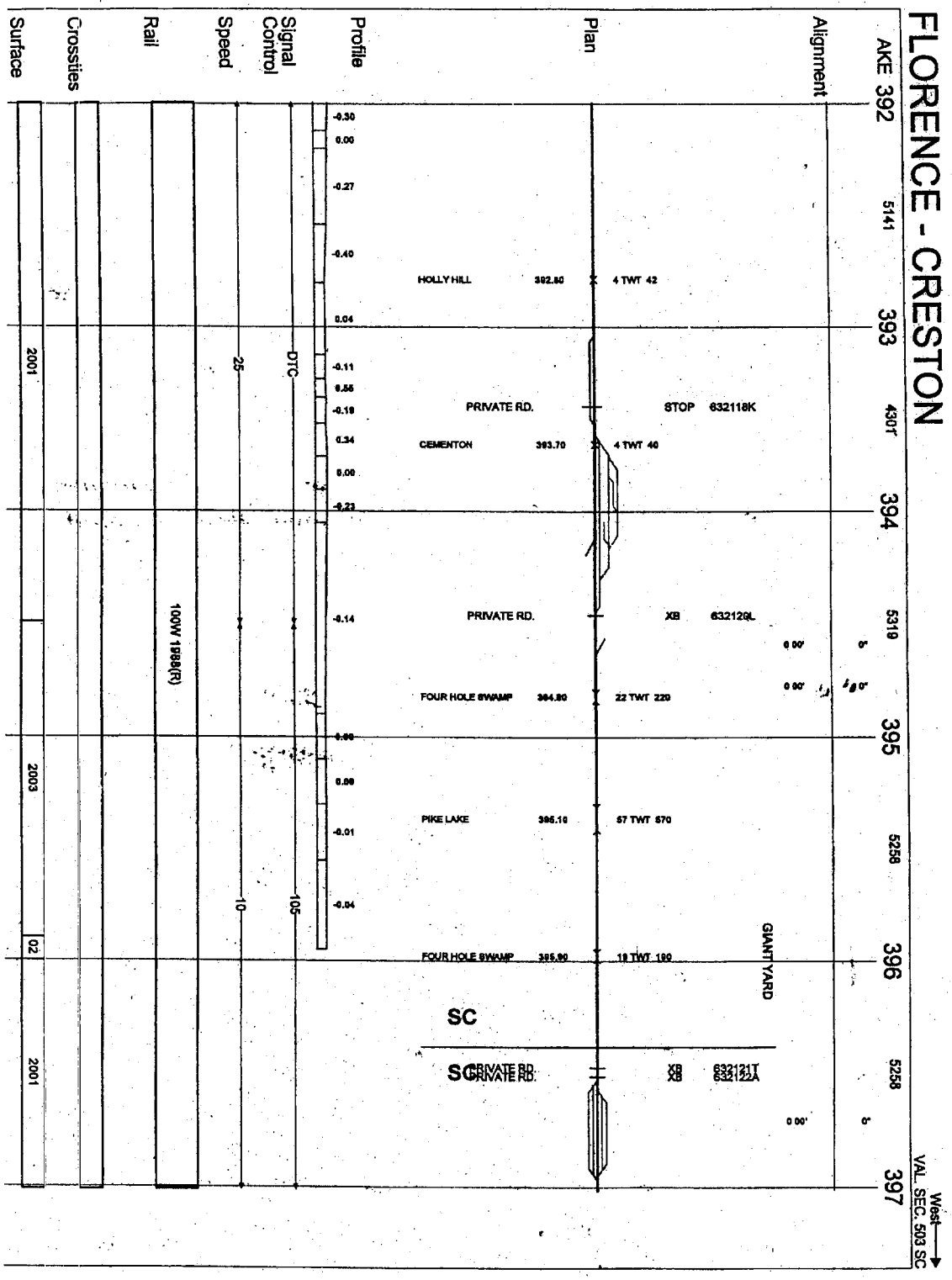
Exhibit E



Source: Skeen Engineering.

TAB F

Exhibit F


FLORENCE - CRESTON
Surface
Crossties
Rail
Speed
Signal Control
Profile
Plan
Alignment
AKE 392
393
394
395
396
397
5141
430'
5319
5258
5258
2001
2003
02
2001
25
10
DTC
105
100W 1998(R)
-0.30
0.00
-0.27
-0.40
0.04
-0.11
0.55
-0.19
0.34
0.00
-0.23
-0.14
0.00
0.00
-0.01
-0.04
HOLLY HILL 392.60
4 TWT 42
PRIVATE RD.
STOP 632118K
CEMENTON 393.70
4 TWT 40
PRIVATE RD.
XB 632120L
FOUR HOLE SWAMP 394.80
22 TWT 220
PIKE LAKE 396.10
57 TWT 570
FOUR HOLE SWAMP 395.90
19 TWT 190
GIANT YARD
SC
SC PRIVATE RD.
PRIVATE RD.
XB 632121T
XB 632122A
0.00'
5°
West
VAL. SEC. 503 SC

TAB G

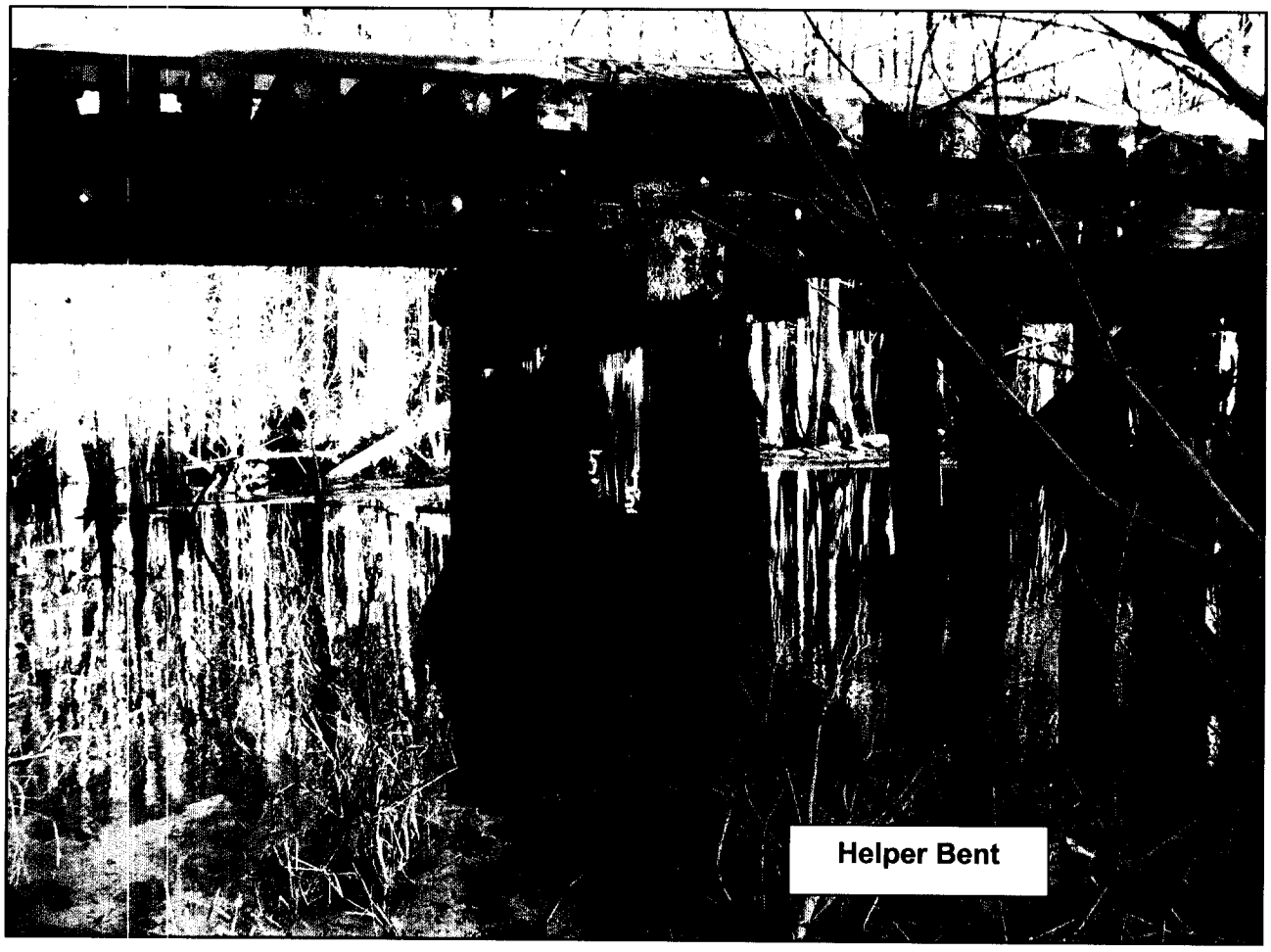
Exhibit G (Photo One)



Exhibit G (Photo Two)



Exhibit G (Photo Three)



Schuchmann V.S.

Before The Surface Transportation Board

STB Finance Docket Nos. 34421 And 34421 (Sub-No. 1)

HolRail LLC - Petition For Crossing Authority

Verified Statement

of

Walter H. Schuchmann

Before The Surface Transportation Board
STB Finance Docket No. 34421 And 34421 (Sub-No. 1)
HolRail LLC - Petition For Crossing Authority

Verified Statement
of
Walter H. Schuchmann

Qualifications

I am Walter H. Schuchmann, a consultant with the firm of R.L. Banks & Associates, Inc. (RLBA), railroad transportation consultants, engineers, economists and planners, located at 1717 K Street, NW, Washington, DC 20036. My title is Director, Railroad Operations and my qualifications are detailed in Exhibit A. I appear in this proceeding on behalf of HolRail LLC.

Scope of Testimony

CSX Transportation, Inc. (CSX) operates a rail line, portions of which are in Orangeburg and Dorchester Counties, SC between Pregnall and Vance, which is the subject of this proceeding. At Holly Hill, SC, CSX currently provides rail service to the Holcim (US) Inc. (Holcim) cement plant. HolRail LLC, (HolRail) seeks to construct and operate a new rail line providing additional rail access between Holcim's facilities and the rail yard adjacent to a cement plant owned by Giant Cement (Cement) about two miles south of Holcim. The "Preferred Route" alignment is in part parallel to the existing CSX main track and is within portions of the CSX right-of-way (ROW). An "Alternate Route" alignment that would not cross CSX property is also being considered by HolRail. This testimony contains my analysis of the operational impacts upon CSX as the result of construction and operation of the proposed new rail line.

Information Sources

In addition to two, on-site physical inspections of the subject property on December 13, 2004 and January 26, 2005, I have reviewed documents produced by CSX in response to HolRail information discovery requests. I also have reviewed (1) a letter from Skeen Railroad Engineering, dated March 7, 2005, that details proposed construction procedures, which is attached as Exhibit C to the Verified Statement of Gene Davis, and (2) proposed track layout drawings that are attached as Exhibit D to the statement of Mr. Davis.

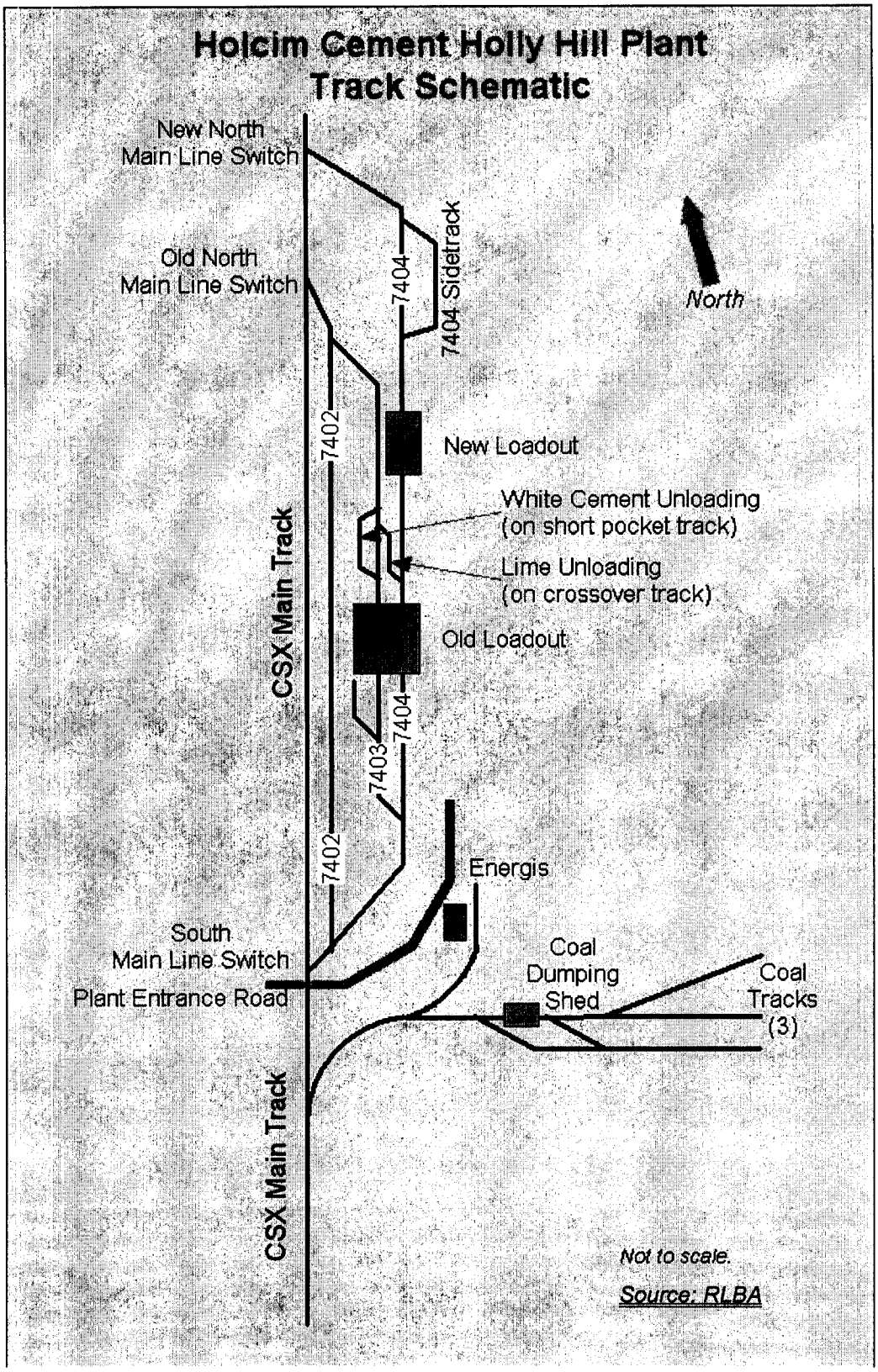
Description of Current Rail Operations

Holcim Cement Plant Rail Operations

Holcim receives and ships outbound cement, inbound lime, inbound white cement and coal by rail. A Holcim subsidiary, Energis, also receives inbound liquid waste materials in tank cars. In 2004, the plant received 2,184 carloads inbound and shipped 3,716 carloads outbound. Holcim currently projects that its outbound loaded shipments will be about 3,600 carloads in 2005 and 5,400 carloads in 2006 if the HolRail project is completed.

Holcim plant employees move railcars on plant trackage using two car movers (tractors equipped with rail wheels and rubber tires, sometimes referred to as trackmobiles). Railcars typically are moved from the tracks where they were delivered by CSX to specific loading or unloading locations within the plant and, once loaded or unloaded, are then moved to tracks from which they will be picked up by CSX for outbound movement. Plant trackage is shown in Figure 1.

Figure 1


Holcim Cement Holly Hill Plant
Track Schematic
New North
Main Line Switch
Old North
Main Line Switch
7404
7404 Sidetrack
North
7402
New Loadout
White Cement Unloading
(on short pocket track)
Lime Unloading
(on crossover track)
CSX Main Track
Old Loadout
7404
7403
7402
Energis
South
Main Line Switch
Plant Entrance Road
Coal
Dumping
Shed
Coal
Tracks
(3)
CSX Main Track
Not to scale.
Source: RLBA

Outbound Cement Products

Outbound product is loaded into two covered hoppers at a time at a new loadout. Time required to load two cars is approximately 35 to 40 minutes. Cars are moved into the loadout in six or seven car cuts (groups) using the trackmobile.

Some specialty products are loaded into covered hoppers at the old loadout.

Outbound shipping averaged over 70 carloads per week in 2004.

Inbound Cement Materials

Inbound shipments include:

- lime, which is spotted (positioned for unloading) occasionally by CSX, but typically by Holcim, and unloaded on a spur south of the old loadout;
- white cement, which is spotted occasionally by CSX, but typically by Holcim, and unloaded on a track north of the old loadout, and
- inbound waste material in tank cars, which is spotted by CSX for unloading at the Energis track near the plant entrance.

Coal

CSX delivers inbound, loaded coal cars on two of the three long tracks south of the main plant near the coal unloading shed. Holcim employees use a car mover to move loaded coal cars from the tracks where they were delivered by CSX to the coal unloading shed. Time required to unload each car is approximately 30 to 35 minutes. Once emptied, cars are moved to whichever of the three long tracks is clear and more cars are then pulled and unloaded. Holcim employees will fill up one of the three tracks with outbound empty cars and then start placing empty cars in whichever track is then clear. As the coal cars are unloaded, the outbound cars are parked on two of the three long tracks awaiting pick up by CSX. Inbound coal averages about two coal trains of 75 cars each per month.

CSX Rail Operations (Other than Coal)

CSX serves Holcim with a Charleston-based train which operates using two crews and handles all Holcim traffic other than coal. The train is designated F759 between Charleston and Holly Hill and then F755 between Holly Hill and Charleston. (CSX Response to First Discovery Request, pp. 3-4). The F759's crew reports at Charleston at 0700; the F755's crew at 1900 (*Ibid.).* The F755 crew relieves the F759 crew at or near Holly Hill, completes the assignment's work (including several other customers) and returns the train to Charleston. The two crews are scheduled to work Monday through Friday, using a single locomotive (*Ibid.).* According to Holcim employees, the time at which CSX switches Holcim varies widely.

CSX use of the Pregnall-Giant line segment results from a provision of the "Carolinas Plan", an agreement between CSX and NS providing for track sharing and coordination of operations in South Carolina. The arrangement was approved by the Interstate Commerce Commission in Finance Docket No. 32299, served on November 26, 1993. Under the agreement, CSX leases and operates the Pregnall-Giant segment from NS and CSX acts as agent of NS to serve industries located on the segment.

Standard Operating Procedure

The CSX crew arrives at Holcim after switching the Giant Cement plant, approximately two miles south of the Holcim plant. The exact method of switching varies from day to day but the following description is representative: Upon arriving at Holcim traveling northward, the crew leaves the train on the CSX main track and the locomotive runs north past the old north main line switch and then backs into the plant, coupling to outbound cars on track 7403 or 7404. The locomotive then pulls the outbound cars out to the main line and couples them onto the inbound train. The entire train is then shoved onto track 7402 from the north. The locomotive then runs around the train on the main track. The locomotive next couples onto the south end of the train on track 7402. The inbound cars are pulled south and shoved into the plant from the south end. The crew places those cars on 7403 and 7404 tracks in the plant south of the old loadout. The CSX crew occasionally spots cars containing inbound lime, calcium, or

white cement at their specific unloading points, although most such cars are spotted by Holcim plant personnel using a trackmobile. When all of the inbound cars are placed, the locomotive then couples to the south end of the outbound cars (and any cars for Energis or other customers) on track 7402.

The CSX crew spots inbound tank cars of waste material for unloading at the Energis track located near the plant entrance. Outbound tank cars are pulled from Energis and included in the CSX outbound train. The CSX crew then makes up its outbound train on the main track or track 7402. It then either departs southward or performs switching at Georgia Pacific and then departs.

Recent Variation in Standard Operating Procedure

Since Holcim completed new track construction on its property in December 2004, CSX has altered its procedure by pulling outbound cars from the plant via two different connections.

The CSX train arrives at Holcim traveling northbound after leaving Giant Cement and uncouples from the train on the main track, as before. The locomotive first accesses the plant from the old north main line switch and pulls cars as described above. Next, the locomotive continues farther north on the CSX main track and enters the plant via the new north main line switch to pull the balance of the outbound cars previously left by Holcim on the north end of track 7404 or the new 7404 siding. The CSX crew then pulls the cars from the plant, shoves them south and couples to cars standing on the main track or track 7402, backs the entire train onto track 7402 and runs around the train on the main track. The locomotive then couples onto the south end of the train on track 7402 and places the inbound cars on tracks 7403 and 7404 south of the old loadout silos as described above. The crew then couples to the cars on 7402. The train then either departs southward or serves other customers and departs.

CSX Coal Operations

Inbound CSX coal trains arrive from the north. Inbound coal arrives in 75-car trains and is spotted east of the dumping shed on two of the three long tracks by CSX. Once the train is emptied, CSX typically sends light engines (engines only) to pick up the outbound empty cars. However, if empty coal cars are on hand when a loaded train arrives, the CSX crew pulls them in the process of delivering the loaded cars. The empty cars are placed on the main track or track 7402 and the CSX locomotives run around the cars using the other track. The empty coal train then departs to the north.

Description of Construction Project

As stated in the Petition for Exemption, HolRail seeks Board authority to construct a new, two-mile line of rail over one of two alternative routes. The "Preferred Route" would be constructed adjacent to an existing CSX line and substantially within the CSX right-of-way. The "Alternate Route" also would be constructed parallel to the CSX line but would be located approximately 105 feet to the east on property owned by HolRail's parent company, Holcim (US), Inc. Details of the construction procedures to be used are contained in Exhibit C to the Verified Statement of Mr. Gene Davis.

Description of Operations During Construction

Mr. Gene Davis, P.E., has concluded that construction of the Preferred Route would not interfere with existing CSX operations (Davis VS, p. 9), and I concur in that finding. He concludes that the only track outages required would be to install new connecting switches at the Giant Yard and as part of the new crossover just south of the Holcim plant. Mr. Davis indicates that each of the installations may be performed in a period of four to six hours and that, if necessary, the work could be done on a Saturday when no train operations are scheduled. (Davis VS, pp.6-7). I have observed and coordinated many such switch installations and agree with Mr. Davis as to the ability to conduct this work with no disruption to CSX.

Construction of the Preferred Route trackage between the two connecting points would be performed under the supervision of a flagman as needed. In addition, the line's slow

speed and infrequent train movements would enable construction workers to move clear of the CSX track and allow the daily train to pass without delay.

CSX Operations between Giant and Holcim

The CSX line between Giant and Holly Hill is lightly used. Coordination of construction activity to avoid interference with train movements should be quite simple. In Interrogatory Response #3, CSX identifies trains F759 and F755 as using the line five days per week. F759 is the Charleston to Holly Hill leg of the daily round-trip train, and F755 is the Holly Hill to Charleston leg of the same train. Thus there is only one round trip train per day, five days per week on the Pregnall-Holly Hill line. The only other customer located on the Giant-Holcim segment is Georgia Pacific Lumber Company, which is located directly across Highway 453 from Holcim and receives only a few cars per week. The other customers served by Trains 759 and 755 are located south of the proposed HolRail construction. Hence the portion of the CSX line located north of Giant Cement is used predominantly to serve Holcim and, then, only once a day, five days per week. Such a low level of use makes it possible to schedule construction activities so that interference with rail service is negligible, if at all.

Preferred Route

As described by Mr. Davis, the preponderance of construction activity will take place off or on the shoulder of CSX right-of-way. It is anticipated that all work done on the CSX right-of-way will be protected by a flagman. Most such work will not foul the CSX track and thus will not interfere with normal CSX operations. Also, work that is done on the CSX right-of-way will be performed using crawler or highway vehicles that, if fouling the CSX track, can move quickly to a location clear of the tracks if so directed by a flagman. CSX train speeds are 10 miles per hour south of MP 394.5, located near the Holcim plant entrance road. Train crews generally contact a flagman by radio to arrange passage through a work area before the train ever reaches the work area, so based on that practice and the existing slow train speed, trains should experience no measurable delay as a result of HolRail construction activities along the CSX ROW.

There are two construction activities which will cause the CSX line to be out of service for a few hours. Those activities are installation of the new connection switch at the north end of the Giant yard near CSX MP 396.55 and installation of the CSX switch that comprises part of the proposed new crossover between CSX and HolRail just south of the Holcim plant, near CSX MP 394.7. Mr. Davis estimates switch installation could be arranged such that the CSX line would be impassible for only four to six hours per installation. That work could be coordinated so as not to interfere with train movements at all on the lightly used line.

The impact upon CSX operations resulting from construction on the Preferred Route would be negligible.

Alternate Route

Almost none of the construction activity related to the Alternate Route would occur on CSX property, and thus would not interfere with train operations. The two switch installations described above would occur under this scenario as well and could be coordinated to achieve the same minimal (or no) impact. Thus CSX operations would be impacted little to not at all by construction on the Alternate Route.

Description of Operations Following Construction

Operations Using the Preferred or Alternate Route

Despite the important environmental and construction differences between the Preferred and Alternate Routes, there is no post-construction operational difference between the two. While switch locations and connecting track alignments would be noticeably different in the area just north of the new crossover (between CSX and HolRail) near CSX MP 394.7, located near the Energis and coal tracks, the ability of CSX and HolRail to serve the various plant spurs is the same under either alignment. The operations discussions that follow apply equally to both alignments.

CSX Operations at the South Connection

The HolRail track would diverge from the north end of the Giant yard by means of a hand operated switch located at MP 396.55. Normal position of the switch would be aligned for the CSX main and locked. CSX crews operating between Pregnall and Holly Hill would be able to proceed through the switch without stopping. That location is currently operated under Operating Rule 105 which governs tracks other than a main track and has a speed limit of 10 mph. Following construction, CSX trains could operate at that same speed and thus would not be affected by the new switch.

NS Operations at the South Connection through the Giant Yard

The HolRail track would be accessed from the north end of the Giant yard by means of a hand operated switch located at MP 396.55. Normal position of the switch would be aligned for the CSX main and locked. NS crews[1] operating between Pregnall and Holly Hill would obtain permission to enter HolRail trackage by radio or telephone before reaching the connection switch. Crews would stop at the switch, unlock it, align it for the HolRail connection and proceed through the switch. As soon as the last car of the train passed over the new switch, an NS crew member would align the switch for the CSX main track, lock it and advise the CSX dispatcher via radio or telephone that the train was clear of the main track. A train of up to 100 cars normally could perform this movement in no more than 10 minutes.

CSX Operations on CSX Track between the South Connection and the New Crossover

CSX operations between the south connection and the new crossover at MP 394.7 would continue as at present. Neither NS nor HolRail would operate over CSX tracks between these points and CSX would not be impacted at all in this segment.

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[1] It is expected that NS service will be performed by a CSX crew under terms of the Carolinas Plan, as previously described.

NS and HolRail Operations on HolRail Track between the South Connection and the New Crossover

It is anticipated that CSX will serve as agent for NS and will perform daily rail service to Holcim on behalf of NS according to the provisions of the Carolinas Plan. Accordingly, allusions to NS in this section actually refer to CSX crews performing service on behalf of NS.

The HolRail interchange tracks will be located along the HolRail alignment just north of the south connection at the Giant yard. The interchange yard will consist of four tracks with a total track capacity of 107 cars, based upon an average length of 60 feet per car. The Alternate Route will have an interchange yard consisting of five tracks with a total track capacity of 101 cars. In all other respects, HolRail's operations over the Alternate Route will be the same as for the Preferred Route. Exchange of cars between NS and HolRail will be conducted in the yard and on the HolRail main track north of the yard, as appropriate given the volumes of cars being exchanged and prevailing operating circumstances.

The interchange tracks may be used in many ways. A typical pattern would be the NS crew pulling into and through the yard until its train cleared the CSX main track. After restoring the south connection switch, the NS train would pull forward until clear of all switches at the south end of the HolRail Yard. The crew would uncouple the portion of the train standing on the yard track and double over (pull ahead and shove back) into one or two other tracks as needed to hold the entire inbound train. One yard track would be left clear as a running track; this could be any of the tracks. Once the inbound train is yarded, the NS locomotive would proceed north along the HolRail main track until it reaches the outbound cars previously placed on that track by the Holcim crew. The NS locomotive will couple to the south end of the outbound cars and conduct a brake test. Upon completion, the outbound NS train will pull south through the HolRail yard and approach the south connection switch to the Giant yard. The crew will have used radio or telephone to seek the dispatcher's permission to enter CSX. Upon

receipt of permission, the crew will operate the hand throw switch, enter the Giant yard track, re-align and lock the switch and depart southward.

The operations described above would permit interchange of outbound cement in blocks of 75 or more cars at a time, as well as miscellaneous inbound commodities including white cement and lime. If interchange volumes are lower, instead of staging outbound cars on the HolRail main track to await pickup by NS, HolRail and NS may choose to have the HolRail operator place outbound cars in one of the HolRail Yard tracks and NS place inbound cars in another. Such decisions would be part of routine coordination between the two parties.

In the event Holcim's inbound coal delivery were shifted to NS, the inbound coal train would be yarded in three of the HolRail interchange tracks. The NS locomotives then would depart to the south. The inbound coal cars would be spotted for unloading by the HolRail operator. To do so, the operator's crew would run south through the fourth track and couple onto the south end of one of the tracks of coal cars. The cars then would be shoved north along the HolRail main track and placed on the Holcim coal tracks, as at present. The process would be repeated to position the remaining inbound coal cars. Once Holcim unloads the train, the operator would move the empty coal cars from the Holcim coal tracks and place them on three of the interchange tracks. NS could return with "light engines" (engines without cars), pull the outbound empty coal cars from Holcim's coal tracks and proceed south. Alternatively, on each day that Holcim unloaded coal cars, they could be attached to the daily outbound train of loaded cement and empty cars. This could eliminate the train movement associated with pulling the empty coal cars and could get the empty cars back into circulation sooner, increasing transportation efficiency.

CSX Operations at the Holcim Plant, Post-Construction

At least two CSX operating scenarios will be possible post-construction. In the first, CSX could access the plant via the new north main line switch and could deliver inbound cars using the north end of track 7404 or the new, parallel siding. Outbound cars could be pulled from the other track, having been placed there by Holcim. The siding has a capacity of about 32 cars and track 7404 could hold up approximately 49 cars between the north switch of the siding and the vicinity of the new loadout facility without interfering with loading operations. Holcim, or the HolRail operator, will assume responsibility for spotting all inbound coal cars for loading or unloading at the plant. (As previously noted, Holcim already does most car spotting.) CSX's role will be reduced to simply dropping off a string of inbound cars and picking up a string of outbound cars. CSX would not have to enter the south end of the plant where there is more Holcim rail activity as well as truck traffic. These changes will reduce the amount of switching time consumed by the CSX crew and reduce CSX's cost to serve Holcim.

As an alternative to the above operating scenario, should Holcim and CSX prefer, some variant of current operations could be adopted, wherein CSX would pull cars from the north end of track 7404 using the new north main track switch and place inbound cars into the plant from the south, as at present.

It is important to note that CSX will retain the same post-construction functional access to all plant trackage as presently enjoyed. Because NS will not operate on Holcim plant trackage, CSX will have no new requirement to coordinate operations at that location with NS. CSX operations at the plant will need to be coordinated only with Holcim, just as at present.

CSX currently delivers coal in trainload quantities delivered by trains which reach Holcim from the north. Post-construction delivery of coal and pickup of empty coal cars will be able to be made just as at present.

To summarize, CSX non-coal operations at Holcim may be simplified by consolidating car delivery and pickup at the north end of the plant (likely) or will be unchanged in that regard if delivery and pickup continue as at present. In either instance, non-coal operations will be simplified by eliminating car spotting by CSX. Coal operations will be unchanged.

HolRail and Holcim Operations at the Plant

As indicated above, following construction, Holcim or the HolRail operator will assume responsibility for spotting all cars for loading or unloading at the plant, including Energis tank cars (which also could be spotted by Energis using its own car mover).. Holcim/HolRail also will gather up outbound cars destined to CSX or NS and will place them on the designated tracks. NS will not operate at the Holcim plant, as it will deliver and pick up at the new HolRail Yard and the adjacent HolRail main line, as described above.

Summary and Conclusion

Summary of Key Points

- Under either route alternative, the potential disruption of CSX rail operations will be limited to two, four to six hour periods during switch construction.
- CSX will retain the same post-construction functional access to all Holcim plant trackage as presently enjoyed.
- Because CSX will serve as NS's agent under terms of the Carolinas Plan, NS will not operate at the Holcim plant, thus CSX will have no new requirement to coordinate operations there with NS. Operations at the plant will need to be coordinated only with Holcim, just as at present.
- CSX operations will be accelerated by not having to spot any of the inbound Holcim cars, thus reducing crew time and the cost to CSX of serving Holcim.

Conclusion

If the proposed crossing authority is granted, construction and post-construction impacts upon CSX operations will be negligible, at most.

TAB A

Walter H. Schuchmann
Director, Rail Operations

Education
MBA, Beta Gamma Sigma business honorary society, Indiana University, 1979
BS Industrial Management, Beta Gamma Sigma business honorary society, Purdue University, 1972

Professional Certifications and Affiliations
Certified Member, American Society of Transportation and Logistics; American Association of Railroad Superintendents; National Defense Transportation Association

Years of Transportation Experience
26

Qualifications
With RLBA since 1988, Mr. Schuchmann has led and/or participated in analyzing operations and viability of numerous regional and short line railroads on behalf of major financial institutions and private investors in connection with rail line acquisitions. He has participated in coal and bulk commodity transportation studies, stand-alone cost development, and rail service, switching and rate studies. Mr. Schuchmann has contributed to evaluations of applicable intermodal technologies and existing and potential intermodal services, as well as intermodal terminal configuration and operations and waste-by-rail movements. He also has advised counsel and prepared testimony in legal proceedings in which railroad safety procedures and violations were at issue.

Relevant Project Experience

- ***Port Authority of New York and New Jersey*** Evaluated capacity of all major rail lines in the North Jersey Shared Assets Area. Inspected lines, identified future shortfalls in line capacity, evaluated nine capacity, improvement initiatives developed by the Authority and its serving railroads for their ability to remedy future capacity shortfalls and prioritized recommended improvements.

- ***County Sanitation Districts of Los Angeles*** Evaluated rail operational aspects in connection with proposed intermodal shipments of municipal solid waste from the greater Los Angeles area to several, remote landfills. Assisted in developing track configuration and rail operations plans at the proposed Puente Hills intermodal transfer station.

- ***States Rail Corporation*** Evaluated operational efficiency, safety, staffing and crew and locomotive utilization of the Kiamichi Railroad. Complemented field observations through review of operational and cost records. Provided several suggestions for improving operational efficiency.

- ***Canton Railroad*** Led the firm's evaluation of opportunities for physical and operational expansion of this Port of Baltimore terminal railroad. Operational, infrastructure, financial and institutional considerations related to assumption of switching duties at Maryland Port Authority terminals and nearby locations were examined.

- ***Mississippi State Port Authority at Gulfport (MSPA)*** Analyzed current through train and switching assignments on Kansas City Southern's 70-mile Gulfport District.

- ***State of New York and New York City Economic*** Development Corporation Assessed the feasibility of operating trains of a to-be-designated carrier on Conrail, Amtrak and Metro-North lines to provide competitive rail access to the east side of the Hudson River, based upon field inspection

and review of merger documents. Submitted testimony to the Surface Transportation Board.

- ***Downtown Indianapolis Railroad Relocation Working Group*** Managed a railroad relocation assessment on behalf of a working group composed of prominent Indianapolis business and government representatives. The team evaluated the reroute of all CSX freight and Amtrak trains off of CSXT's downtown main line on to the existing, circumferential Indianapolis Belt Line. The study addressed: capacity and condition improvements to the Belt; impacts on through and local freight service involving up to 50 trains daily; community impacts; safety, mobility and environmental benefits and relocation capital cost estimation.

- ***Ohio Department of Transportation*** Managed an assessment of impediments to efficient operations and service on Ohio's main line railroads. Surveyed railroads and shippers, screened potential problems, identified remedies, supervised field inspections and estimated capital costs.

- ***Northeast Maryland Waste Disposal Authority*** Participated in development of rail operations plans and track developments at intermodal terminals built at an existing transfer station and at a mass burn plant to support the now-operational intermodal movement of MSW between these facilities. Took part in system acceptance testing.

- ***Northwest Indiana Regional Planning Commission*** Managed an examination of rerouting Norfolk Southern trains onto other rail corridors through congested Northwest Indiana to reduce grade crossing accidents and vehicular conflicts. Necessary rail and highway infrastructure improvements were identified and alternatives evaluated in terms of benefit-cost performance.

- ***Gainesville Regional Utilities (FL)*** Analyzed potential rail operations, arrangements and resources in support of GRU's plan to introduce railroad competition at its power plant through construction of a new rail line largely along former CSX right-of-way. Examined service, equipment utilization and cycle times and transportation contract provisions in conjunction with CSX and Norfolk Southern contract negotiations.

- ***Keystone-Conemaugh Projects*** Analyzed the feasibility and impacts of potential unit train coal delivery over a seldom-used branch line and the main line of a regional railroad. Operations, equipment, grade crossing and safety impacts and necessary improvements were covered in a report.

- ***New Jersey Transit*** Advised the agency concerning shared freight/light rail transit use of the River Line between Camden and Trenton, NJ. Developed freight operating plans and outlined facilities required to conduct joint freight and light rail operations on the Bordentown Secondary trackage owned by Conrail (part of the NS-CSX Shared Assets Area). Participated in acquisition and shared use negotiations with CSX, Norfolk Southern and Conrail as well as review of DBOM contractor solicitation documents. Evaluated impacts of construction upon freight operations and resultant costs and Conrail billings. Construction is complete, including a new freight yard facility proposed by RLBA, and passenger service has been implemented. Current freight operations closely resemble the RLBA plan.

- ***AEP Texas North Company (AEP)*** Simulated a 1,200 mile plus railroad network mirroring Burlington Northern Santa Fe (BNSF) lines linking Powder River Basin origins and AEP's Okla Union generating facility in Vernon, TX, using Berkley Simulation Software's Rail Traffic Controller to assess the capacity of a hypothesized railroad network to handle current and future additional business volumes in support of a stand-alone railroad rate case dispute brought by a subsidiary of the nation's largest electric utility. Tested inputs and design of the model, developed alternatives to be considered by other consultants, sponsored testimony before the STB on the validity of results produced by the model, evaluated and critiqued BNSF reply testimony and presented rebuttal evidence.

- ***Development of a Railroad Transportation System to Transport Three Million Tons of Contaminated Soil*** Developed origin and destination site operating plans along with railcar fleet size and specifications, participated in movement cost analysis and railroad contracting process and reviewed origin and destination rail facility plans in support of a planned seven year project to move PCB-contaminated soils from the Hudson River Valley to one or more landfills by rail.

Prior to joining RLBA, on Norfolk Southern's (NS) busy Pocahontas Division, as Superintendent of Safety, Mr. Schuchmann worked with department heads to develop and administer effective programs to reduce accidents and employee injuries. He participated in NS's first applications of Voice Block Authority to control train movements. At Chicago, he supervised commuter, intermodal and merchandise freight operations. At several locations, he was responsible for service to local shippers as well as road and terminal operations.

Publications and Presentations

"Short Line Railroad Owner/Operator Groups - Empire Builders of the 1980's," accepted by the American Society of Transportation and Logistics in partial satisfaction of membership requirements; Co-authored with Charles H. Banks, "Is Your Railroad Leaving Town? New Transportation Challenges and Opportunities for Coal Producers and Users," invited and distributed by the Utility Data Institute, 1989.

"Lessons Learned in Performing Shortline Due Diligence," AASHTO Standing Committee on Rail Transportation, Indianapolis, 1997; "How Can Short Lines Obtain Better Cooperation from Major Railways," Canadian Short Line Railroad Conference, Toronto, 1993; "Railroads for Non-Railroaders," sponsored by Railroad Financial Corporation, 1989.

Media Recognition

Quoted in the *Wall Street Journal, USA Today, Baltimore Sun, Dow Jones News* and others.
Interviewed by National Public Radio.

Verification

I, Walter H. Schuchmann, verify under penalty of perjury that I am the same Walter H. Schuchmann whose statement of Qualifications appears in Exhibit A of HolRail LLC's Petition for Crossing Authority in this proceeding; that I am responsible for the portion of HolRail LLC's Petition for Crossing Authority in this proceeding related to the track structure and train operations of the CSX Transportation contained in Orangeburg and Dorchester Counties, SC, in particular portions near the cement manufacturing plant owned and operated by Holcim; that I know the contents thereof; and that the same are true and correct. Further, I certify that I am qualified and authorized to file this statement.

Walter H. Schuchmann

Subscribed and sworn to before this 16th day of June, 2005.

Notary Public

GWENDOLYN M. PENN
NOTARY PUBLIC, DISTRICT OF COLUMBIA
MY COMMISSION EXPIRES 9-14-2009

Taylor V.S.

BEFORE THE

SURFACE TRANSPORTATION BOARD

STB FINANCE DOCKET NOS. 34421 AND 34421 (Sub-No. 1)

HOLRAIL LLC PETITION FOR EXEMPTION FROM 49 U.S.C. § 10901 TO CONSTRUCT AND OPERATE A RAIL LINE IN ORANGEBURG AND DORCHESTER COUNTIES, SOUTH CAROLINA

HOLRAIL LLC –

PETITION FOR CROSSING AUTHORITY UNDER 49 U.S.C. § 10901(d)

VERIFIED STATEMENT OF MARK TAYLOR

Qualifications

This verified statement is presented by Mark Taylor, Professional Geologist, of Fletcher Group, Inc., 148 River Street #220, Greenville, South Carolina. My qualifications to provide this statement are based on an education in geochemistry and more than 25 years experience in minerals exploration and extraction and environmental consulting. My consulting practice involves assessment, permitting, design and construction of large land use projects such as solid waste disposal facilities, quarries, and wastewater treatment systems. The environmental impact of such projects must be evaluated, minimized and often mitigated to comply with state and federal regulations as well as owner requirements.

Purpose of the Statement

HolRail LLC, a subsidiary of Holcim (US) Inc., has petitioned the Surface Transportation Board (STB) for approval to construct a railroad across Four Hole Swamp between Harleyville and Holly Hill, South Carolina. The STB requires evaluation of all potential options, ranging from the proposed project to no action. This statement compares the relative environmental impacts of the preferred route, which is located largely on CSX Transportation property east of South Carolina Highway 453 with an alternate route located on Holcim property east of the CSX. (Both routes and the surrounding wetland areas are shown on the map identified as Drawing 3670416-LP01 and attached hereto as Exhibit A)

A third option to construct the railroad in an existing utility corridor west of Highway 453 will not be addressed in this statement. While the third option presents numerous public safety and

operational concerns, its impact on the environment would be comparable to the preferred route. The preferred route and the third option would result in the filling of a comparable acreage of jurisdictional wetlands and corresponding loss of habitat. The sole advantage of the corridor west of Highway 453 is that it is currently maintained in a cleared condition, so that construction in it would result in the loss of less forest than construction of the preferred route.

Wetland Values

Once considered wastelands, wetlands are now valued as important environmental resources. Some scientists refer to them as the "nation's kidneys" for their ability to naturally cleanse the water that flows through them. They are also commonly referred to as "nurseries" due to the many species that depend on them during juvenile development stages. Within the United States, 80 percent of breeding bird populations depend on these highly productive ecosystems for feeding and breeding grounds (Mitsch). Up to 95% of commercially harvested fish and shellfish in the United States also rely on the resources provided by wetlands (Mitsch).[1]

Four Hole Swamp is one of several large inland wetland environments in South Carolina that include the Congaree National Park. Four Hole Swamp covers a drainage basin of 375 square miles upstream of the project area, and is unique in that it is comprised of numerous braided channels without a well-defined river. Four Hole Swamp is so rich in plant and wildlife habitat that the Nature Conservancy and Audubon Society joined forces to create the 7,000-acre Beidler Forest within its bounds. (*See* photos of Four Hole Swamp in Exhibit C)

[1] All referenced material is fully cited in the References on page 11 and included in the workpapers that accompany HolRail's filing.

Regulatory Considerations

In recognition of their resource value, regulatory programs have been established to protect wetland characteristics. National attention is now placed on maintaining healthy wetlands.

The US Army Corps of Engineers (Corps) is the primary regulatory agency responsible for wetlands protection. When evaluating any alteration to wetlands, the Corps uses the following criteria:

1. Avoidance of impacts to wetlands,
2. Minimization of wetland impacts where avoidance is not possible, and
3. Compensatory mitigation for any wetland loss.

Federal regulations governing surface transportation encourage balancing the economic need for increased roadways with the environmental impacts caused by their construction. Research shows that surface transportation systems affect the environment in numerous ways. These include:

- Water degradation,
- Hydrological changes,
- Habitat changes / fragmentation,
- Increased noise levels,
- Air pollution,
- Species alterations, and
- Increased road kills (Federal).

Reports suggest that designing roads and rails within the same corridor should lead to decreased habitat fragmentation.

Reduced Ecosystem Disruption

Minimizing disruption of the entire ecosystem is the overriding reason to keep the HolRail construction project within the existing highway / railroad / utility corridor that already impacts this area of Four Hole Swamp. As shown in both Exhibits A and B, this corridor currently includes above ground power lines, a buried gas line, South Carolina Highway 453 and the CSX railway.

Exhibit B illustrates why the preferred route will be less disruptive to Four Hole Swamp than the alternate route. The preferred route would widen the existing corridor by constructing the additional track beside the CSX track. Widening the existing cleared and filled area will have an impact on approximately 7 acres of wetlands and Waters of the US. The alternate route locates the rail expansion outside the CSX right-of-way. This would require the creation of a separate transportation corridor through undisturbed wetlands. Developing a second rail cut through Four Hole Swamp on Holcim property would affect approximately 27 acres of undeveloped wetlands and Waters of the US plus the currently undisturbed forest between the two rail lines. (*See* photos of existing transportation corridor in Exhibit C)

My professional opinion is that the preferred rail expansion route would be significantly less damaging to Four Hole Swamp than the alternate proposed route. The alternate route would diminish habitat quality by causing an "island effect" between the two rail corridors. A Harvard University study that concluded, "Biodiversity erodes as the road network impacts interior

species" (Forman), supports this opinion. Limiting development to the smallest increase of the existing road effect area would have the least impact to the hardwood bottom cypress tupelo swamp.

Methodology

Potential adverse impacts to the flora, fauna, hydrology and water quality as a result of the proposed rail expansion routes are evaluated in this statement. Several methods have been developed by others to quantitatively determine the value of a wetland. Currently, no one method has been officially adopted on a national level.

Criteria similar to those in the North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS) were used for this evaluation. The NC-CREWS program was created by the North Carolina Division of Coastal Management for performing a functional evaluation of the value of an individual coastal wetland. More rigorous analysis uses the results of the rating system in a complex mathematical equation to compute the optimal placement of a transportation corridor (Roise).

Surface transportation systems have known effects on the flora and fauna surrounding them. A "road corridor" is defined as the road surface area, its maintained road strips and any parallel vegetative strips (*i.e.,* medians) that separate highway lanes. These areas are relatively easy to locate from a brief visual inspection. "Road effect zones" are the areas near roads that experience significant ecological effects. These typically extend outward many times the width from the road surface (Forman). Their total effects are not immediately obvious and are only nominally understood. (*See* photo of road effect area beside existing CSX rail line in Exhibit C)

The major impacts of surface transportation systems are on plant life and habitat, wildlife and habitat, hydrology and water quality. The nature of the disruption is described below.

Plant Habitat

Wetland plant species will be effectively eliminated on the developed and cleared portions of the rail crossings. While limited quantities of wetland grasses and shrubs may prosper temporarily, the palustrine, forested wetlands typical of Four Hole Swamp would no longer exist.

The alternate route would create an additional median in what are now undisturbed wetlands. This currently wooded strip is likely to change significantly in the quality of wetland flora. The clearings and road corridors on both sides will introduce more sunlight into the forest, changing the current conditions that favor native plants.

Reduced forest cover and clearings produce favorable conditions for invasive exotic plant species. The introduction of non-native species would be encouraged by normal use of a separate rail line. Vehicles can act as carriers of numerous seeds, picking them up along their route for later deposit along roadsides. The introduction of these seeds into the undisturbed area deeper in the swamp via the alternate route would create a substantially more significant impact to Four Hole Swamp than the preferred route. (*See* photo of invasive aquatic species below CSX rail line in Exhibit C)

Intensive management of "roadside" strips is common and often includes regular mowing and application of herbicides. Both practices discourage growth of the cabbage palm and other species typically found in this transition zone.

In addition to these disturbances, research has shown that aquatic species are more sensitive to road impacts than terrestrial vegetation species. The native species are commonly replaced by disturbance-tolerant exotic species that tend to thrive in these conditions (Forman).

Construction of the preferred route would result in elimination of wetland conditions on nearly a quarter of the acreage that the alternate route would require. In addition, the alternate option will enlarge the total impact area of the existing transportation corridor by 60 percent while the preferred route will only enlarge it by less than 20 percent.

Wildlife Habitat

In a manner similar to the disruption of plant life, wildlife habitat will be virtually eliminated beneath nearly a quarter of the acreage for the preferred route.

Roadkill is the most obvious adverse impact that highways and railroads have on opossums, deer and other animal species. Amphibians have higher road kill rates than terrestrial species, and are most susceptible on narrow roads with low traffic (Forman). The alternate route would have a lower traffic rate than the preferred route since it would not include a highway. It would create an additional road effect zone rather than increasing traffic in an existing one, potentially doubling the negative effect on wildlife.

Roads with lower traffic are also prime pathways for predators, providing them an un-natural advantage over their prey. While increasing the movement of predators, roadways dissect the land and lead to habitat fragmentation for many other species. Roads through undeveloped areas create barriers that alter or block wildlife movement. This island effect results in the formation of subpopulations.

create barriers that alter or block wildlife movement. This island effect results in the formation of subpopulations.

Partially isolated local populations are more likely to succumb to extinction. Chances for recolonization of native species are decreased due to habitat fragmentation. Road effect areas are much more likely to be taken over by exotic species. Vehicles act as carriers for amphibians and other species, exacerbating the introduction and establishment of invasive exotic species.

Research has shown that species diversity, species density and breeding densities decrease with increased proximity to roadways. Many species show traits of road avoidance due to traffic noise, visual disturbances, pollutants, and vehicle disturbances (Forman).

Surface Water Hydrology

The unique manner in which water flows through wetlands is often mentioned as the major asset of wetlands. Wetlands purify surface water by removing both sediment load and trace elements. In addition, fresh water wetlands can provide important recharge to groundwater resources.

Surface water flows through Four Hole Swamp in a series of shallow, meandering, braided channels. Flow rates are slow and the gradient is very low (flat). During high water conditions, the channels overflow and large areas are flooded. Some areas flood intermittently while others may be under water for a significant portion of the year. (*See* photo of natural water movement through Four Hole Swamp in Exhibit C)

Sediment is removed during flooding because the flow rate slows as the water spreads and the energy required to carry suspended sediment is lost. Deposited sediment is quickly assimilated into organic-rich soil by the abundant vegetation and plant debris on the swamp floor.

Wetlands also remove trace pollutants from solution in surface water by uptake into plant structure. Several species of ferns are known to scavenge arsenic and certain trees concentrate zinc. Other wetland plants convert nitrogen and phosphorous into unavailable forms. The reduction of these nutrients helps to prevent algae blooms and fish kills (Water).

Swamp crossings that involve significant fill and a limited number of trestles (like the existing CSX rail and Highway 453 crossings), constrict the flow at the trestles and inhibit the sheet flow that provides the positive benefits of wetlands. (*See* photos of water flow constriction at existing CSX and highway bridges in Exhibit C) Hydrologic modeling and hydraulic calculations performed by Fletcher Group, Inc. for the project Environmental Impact Study indicate that the existing causeway and trestle system dam the flow of water through Four Hole Swamp. A two-foot difference in water level from the upstream (west) side to the downstream (east) side is predicted during flood conditions. The preferred route would not materially affect this existing condition. Although it was not modeled, the alternate route was expected to exacerbate the existing problem by imposing a second set of constrictions on channels that widen rapidly as they flow east of the existing bridges.

Nestling another fill and trestle development against the existing one will have minor impact on the hydrology of the swamp. However, developing another crossing 130 feet downstream of the

existing crossing would have significantly more impact. The area between the two roadbed fills could effectively become a lake or stagnant backwater.

Conclusion

Evaluation of the proposed route and alternate alignment using nationally recognized criteria leads to the conclusion that construction of the preferred route would result in significantly less environmental impact than the alternate alignment. This conclusion is based primarily on two considerations:

- The preferred route would require less disturbed acreage than the alternate route, and
- The preferred route would avoid the island effect that the freestanding railroad bed required for the alternate alignment would create.

The adverse effect of these factors is additive. The combination of a larger disturbed area with the new transportation corridor and resulting isolated habitat would result in greater impact on plant and wildlife habitat and reduction of surface water quality. The preferred route minimizes these adverse conditions relative to the alternate route.

REFERENCES

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Mark Taylor, P.G.
Vice President

Education
M.Sc., Geological Sciences, The University of Michigan, 1982
B.A., Geological Sciences, Harvard College, 1977
Deep Springs College, 1972

Professional Registrations and Affiliations
Registered Professional Geologist – Alabama, Georgia, North Carolina, South Carolina
Technical Association of the Pulp & Paper Industry, member since 1991
TAPPI Environmental Division Technical Committee and Working Group Chair
Founding Board Member – Upstate Forever (education and advocacy non-profit for land-use planning and sustainable resource development)

Years of Geological and Environmental Experience
28

Qualifications
Mr. Taylor began his consulting career after 12 years of experience in the mining and minerals exploration field. Over the past 16 years, he has managed numerous large-scale environmental projects for natural resource based companies in the mining and pulp and paper industries. Mr. Taylor has experience with all major environmental regulatory programs.

Relevant Project Experience

- ***Alabama River Pulp Company, Inc.*** Provided environmental science and engineering consulting services for permitting, design and construction of an on-site industrial landfill. Services included wetlands delineation, permitting and mitigation, site hydrogeology study, engineering design, landfill permitting, construction plans and specifications, procurement assistance and construction documentation.

- ***Holcim (US) Inc.*** Project manager for large-scale environmental projects. Wetlands delineation permitting and mitigation for rail spur crossing over Home Branch, a tributary to Four Hole Swamp in Orangeburg County, SC. Preparation of RCRA Facility Investigation and Corrective Measures Study for 80-acre CKD pile. Design and permitting of wastewater treatment system modifications to accompany new cement plant. Location Standards Demonstration of Compliance for hazardous waste blending and storage facility. Life-of-mine permitting for quarry operation. Property transaction environmental site assessment, wetlands delineation and site use planning for 600-acre quarry expansion tract.

- ***Mine Operating Permit Appeal - Expert Witness*** Provided geologic, mineralogical and geochemical evidence to dispute claims that process water discharge from an aggregate quarry had silted up a water supply lake. Defense was successful and the operating permit was issued.

- ***International Paper*** Major on-site industrial landfill project involving geotechnical, hydrogeological, and civil engineering disciplines. Alleviated unstable conditions in a 66-acre landfill. Vertical expansion entailed detailed engineering, bidding, borrow selection, construction services and operations planning. New landfill permitting involved siting study, conceptual design, hydrogeological/geotechnical investigation, and detailed design. Designed and permitted landfill closure with fiber sludge cap. Developed innovative secondary sludge dewatering methodology utilizing large-diameter geotextile tubes. Also: geotechnical, hydrogeological, and civil engineering investigation and design to repair sinkhole damage to a process basin at the mill; preparation of SPCC, Cluster Rule BMP engineering evaluation, and waste minimization plans; routine groundwater and geotechnical monitoring; environmental management system development.

- ***MeadWestvaco Coated Board Division*** Solid waste services including liner design selection study, design of liner, leachate collection and cap systems, design of drainage improvements, and operations plan for new facility. Closure plan for existing landfill. Construction services including procurement, bid evaluation, and on-site construction coordination. Fiber sludge cap design. Groundwater and gas compliance monitoring.

- ***Hoechst Celanese*** Project manager for brownfield site restoration, including excavation of on-site landfill (materials recycled or disposed), decommissioning of on-site wastewater treatment facilities, and land reclamation to developable status.

- ***Georgia-Pacific Corporation*** Senior consultant at facilities nationwide on solid waste management, beneficial use of pulp and paper residuals, landfill vertical expansion, landfill closure, groundwater assessment, monitoring and statistical analysis, and wastewater permitting.

- ***Chemical Lime Corporation*** Development of management strategy for facility coproducts, including detailed reclamation plans for mine sites.

- ***Albemarle Corporation*** Design of a unique solid waste disposal facility constructed by pumping wastewater treatment solids into stacked large-diameter geotextile tubes.

Areas of Expertise

- ***Geochemistry*** Fluid inclusion thermometry for minerals exploration and ore deposit research. Groundwater quality assessments, groundwater monitoring and statistical analysis. Mineralogical evaluations to assess environmental impacts on surface water and groundwater. Explosive gas monitoring and assessments.

- ***Project Development*** Integration of planning and permitting for all environmental media on large-scale projects such as quarries, landfills and wastewater treatment systems. Pioneered development of innovative technologies such as the use of large-diameter geotextile tubes to dewater wastewater treatment sludges.

- ***Operations*** Experience with mine, quarry and landfill planning, operations, stability evaluations and closure. Includes permitting, design, budgeting and financial planning, closure, closure certification and monitoring.

St. Joe Minerals Corporation / Doe Run Company Work Experience

- ***Mine engineer and mine geologist (Viburnum Division)*** Responsible for mine reserves and mine development planning for three underground lead mines. Underground mine grade control. Provided relief mine supervision.

- ***Assistant to the Vice President, Exploration*** Supported world-wide minerals exploration program. Exploration planning, budgeting, monitoring and communication of results.

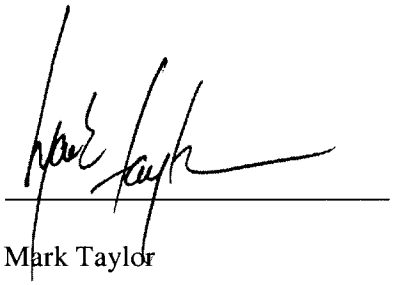
- ***Research Geochemist*** Performed fluid inclusion thermometry, petrographic and mineralogical studies of ores and mineral prospects to guide exploration model development and assist with evaluation of exploration prospects.

Harbert Corporation Work Experience

- ***Exploration Geologist*** Managed core drill crews in Eastern Kentucky. Responsible for program development, reserve identification and calculation and interface with mine planning.

VERIFICATION

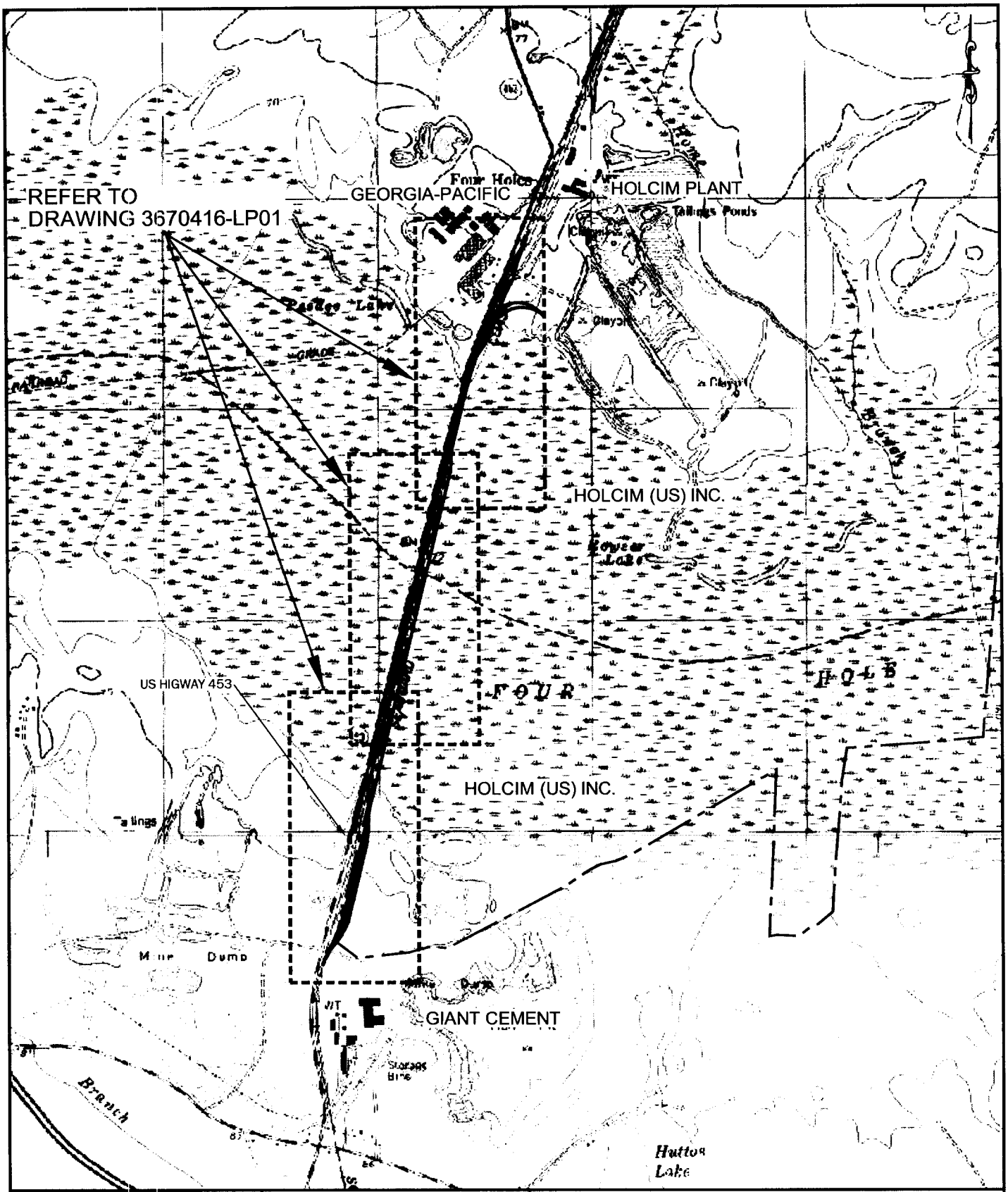
I, Mark Taylor, hereby verify under the penalty of perjury that I am qualified and authorized to submit this Verified Statement on behalf of Holrail LLC and that all of the facts set forth in the foregoing Verified Statement are true and correct to the best of my knowledge. I know that willful misstatements or omissions of material facts constitute Federal criminal violations punishable under 18 U.S.C. § 1001 by imprisonment up to five years and fines up to $10,000 for each offense.



Mark Taylor

1 June 2005

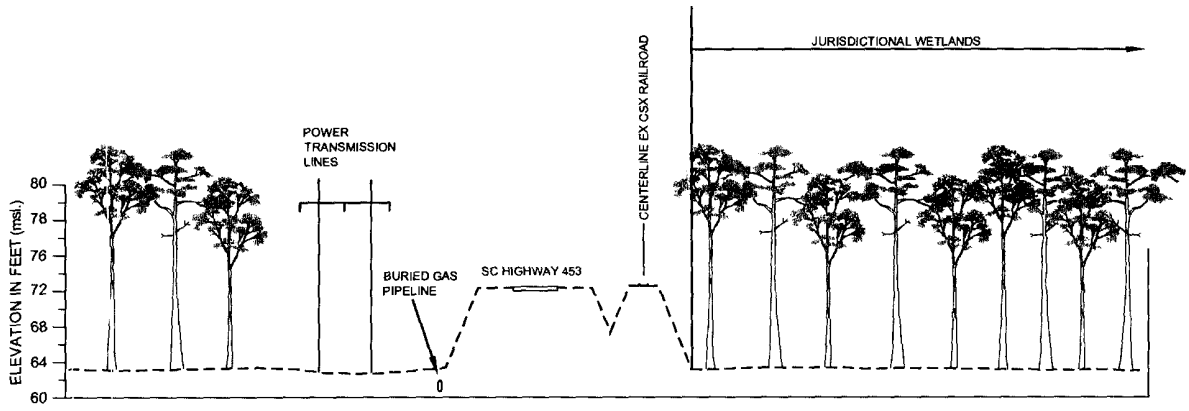
TAB A



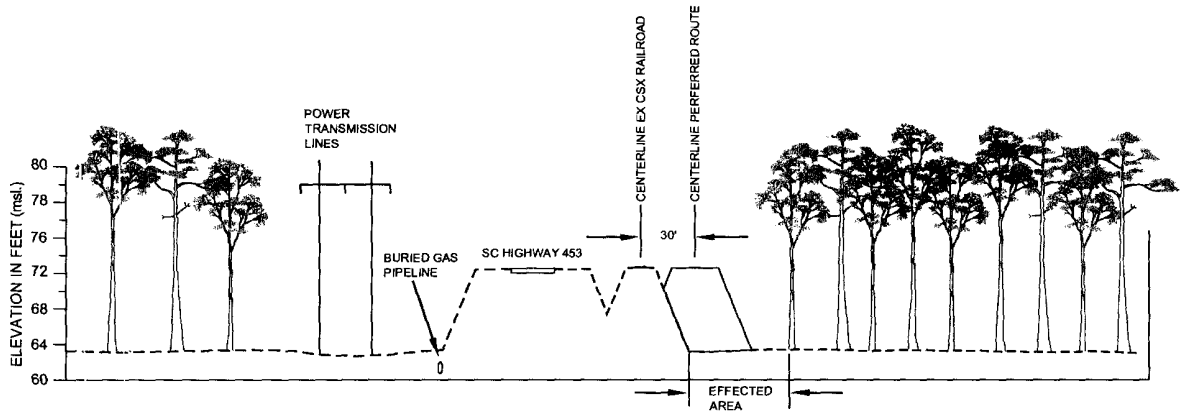
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FIGURE 1
PROJECT LOCATION MAP
HOLRAIL LLC
HOLLY HILL, SOUTH CAROLINA

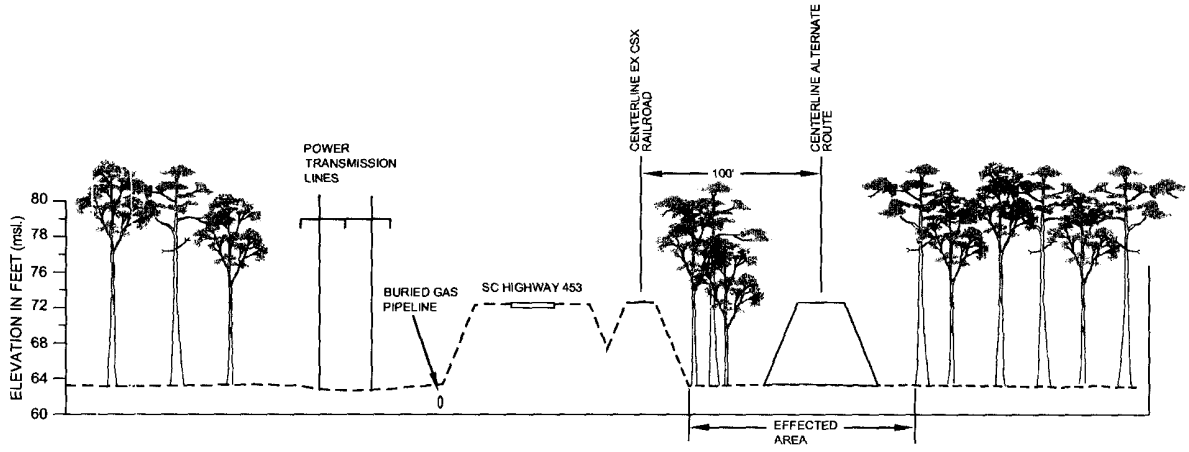
TAB B



EXISTING CONDITION



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ALTERNATE ROUTE

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DRAWN BY: JOHN CHASTAIN DATE: 05/02/2005
PROJECT MANAGER: MARK TAYLOR
LAYOUT: FIG 2 (RR SECTION)

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FIGURE 2
TYPICAL SECTIONS
HOILRAIL LLC
HOLLY HILL, SOUTH CAROLINA

TAB C



Open Water in Four Hole Swamp



Cypress in Four Hole Swamp



SC Highway 453 and CSX rail.



Road effect area beside existing CSX rail line.



Myriophyllum aquaticum, invasive aquatic species below CSX rail line (USDA).



Median separating SC Highway 453 and CSX rail line.



Existing rail crossing over Four Hole Swamp.



Natural horizontal movement of water through the wetlands.



Existing rail crossing



Cypress knee typical of Four Hole Swamp

214673



BEFORE THE
SURFACE TRANSPORTATION BOARD

STB FINANCE DOCKET NOS. 34421 AND 34421 (Sub-No. 1)

HOLRAIL LLC PETITION FOR EXEMPTION FROM 49 U.S.C. § 10901 TO CONSTRUCT AND OPERATE A RAIL LINE IN ORANGEBURG AND DORCHESTER COUNTIES, SOUTH CAROLINA

HOLRAIL LLC—
PETITION FOR CROSSING AUTHORITY UNDER 49 U.S.C. § 10901(d)

HOLRAIL LLC WORKPAPERS

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September 9, 2005

Workpapers

Aquatic and Wetland Plants of South Carolina

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Steven J. de Kozlowski
South Carolina Department of Natural Resources

Algae section contributed by
Lawrence A. Dyck, *Clemson University*



South Carolina Department of Natural Resources
in cooperation with the
South Carolina Aquatic Plant Management Council

June 1996

HOL-00001

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Printed in the United States of America.

Illustrations by Victoria C. Hollowell

Original book design by R. Brian Murrell, RBM Design, Columbia, SC

Cover design by Diane S. Kennedy, SC Department of Natural Resources,
Columbia, SC

Aquatic and Wetland Plants of South Carolina
Second Edition
ISBN 0-9632821-1-5

Copies may be obtained from:

Publications Coordinator
Water Resources Division
South Carolina Department of Natural Resources
1201 Main Street, Suite 1100
Columbia, South Carolina 29201
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Haloragaceae

Myriophyllum aquaticum (Vell.) Verdc.

Parrot-feather

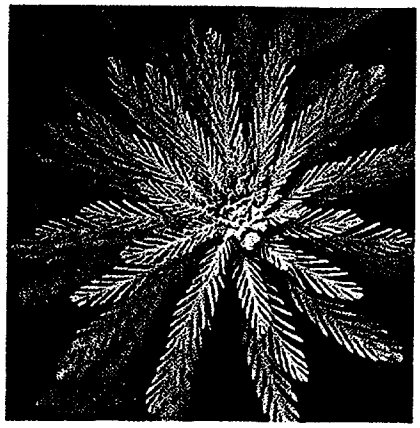
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Submersed and emergent growth habit



191
Flowers formed in axils of leafy bracts

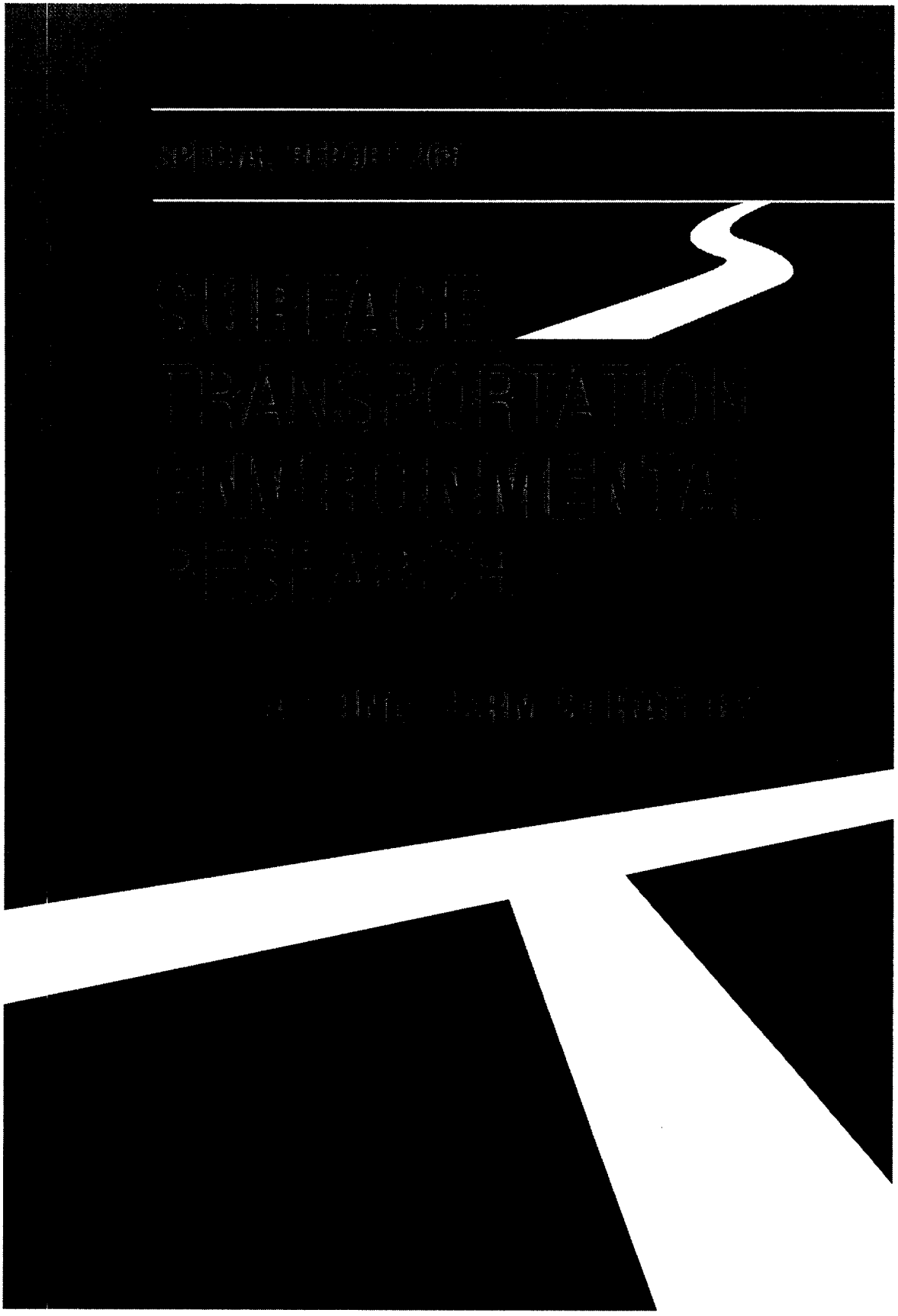


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Detail of feathery whorled bracts

Previously known as *Myriophyllum brasiliense*, parrot-feather is a perennial plant introduced from South America. The stems are often tinged with orange or red. It grows rooted and submersed in up to 3 feet of water and forms numerous adventitious roots; the main branches are emersed. The emersed leaves are in whorls of 3-6, usually pale green to gray-green, ½-2 inches long and to ½ inch wide. The leaves are divided into very narrow segments, appearing feathery. The submersed leaves are larger than the emersed leaves but the capillary segments are narrower and not as firm in texture.

Only pistillate plants occur in the United States. The flowers are inconspicuous and are formed in the axils of the emersed leaves in the spring. However, parrot-feather is rarely found in flower.

Parrot-feather is most commonly found in the late fall, winter and early spring and often forms large, extensive mats on the surface of the water. Alligatorweed and water pennywort are often associated with this species. Parrot-feather grows in lakes, ponds, swamps, and along stream margins throughout the state.



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SPECIAL REPORT 268

SURFACE TRANSPORTATION ENVIRONMENTAL RESEARCH

A LONG-TERM STRATEGY

Surface Transportation Environmental
Cooperative Research Program Advisory Board

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OF THE NATIONAL ACADEMIES

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Washington, D.C.
2002
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Transportation Research Board Special Report 268

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The study was sponsored by the Federal Highway Administration of the U.S. Department of Transportation.

Library of Congress Cataloging-in-Publication Data

Surface transportation environmental research : a long-term strategy /
Surface Transportation Environmental Cooperative Research Program Advisory Board, Transportation Research Board, National Research Council.
p. cm.—(Special report ; 268)
Includes bibliographical references.
ISBN 0-309-07702-8
1. Transportation—Environmental aspects—United States. 2. Transportation—Environmental aspects—Research—United States. I. National Research Council (U.S.). Surface Transportation Environmental Cooperative Research Program Advisory Board. II. Special report (National Research Council (U.S.). Transportation Research Board) ; 268.
TD195.T7 S93 2002
363.73'1—dc21

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The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

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The **Transportation Research Board** is a division of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research results. The Board's varied activities annually engage more than 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

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Kris A. Hoellen, Study Director

PREFACE

In 1998, as part of the Transportation Equity Act for the 21st Century (TEA-21), Congress called for the establishment of an advisory board to recommend a national agenda for environmental research in the domain of surface transportation.[1] Section 5107(c)(1) of TEA-21 states:

> In consultation with the Secretary of Energy, the Administrator of the Environmental Protection Agency, and the heads of other appropriate Federal departments and agencies, the Secretary shall establish an advisory board to recommend environmental and energy conservation research, technology, and technology transfer activities related to surface transportation.

To respond to this legislative mandate, the Federal Highway Administration (FHWA) contracted with the Transportation Research Board (TRB) to create the Surface Transportation Environmental Cooperative Research Program Advisory Board (Advisory Board).[2] The National Research Council appointed the board members, who collectively have expertise in state and metropolitan transportation planning and policy, travel behavior, transit and highway systems, vehicles and fuels, land use, roadside ecology, air and water quality, facility planning and design, management and organization, and decision making and community participation. The board members also represent a broad spectrum of the transportation and environmental communities,

---

[1] The term "environmental" as used here encompasses energy conservation.

[2] In keeping with the language of the congressional directive to the Department of Transportation to establish an "Advisory Board" to advise the agency on environmental and energy conservation research, the ad hoc study committee appointed to carry out this study is referred to in this report as the "Advisory Board." This terminology is different from the normal use of the term "Board" in the National Academies to refer to standing units that have administrative and program oversight responsibilities.

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including academia, state departments of transportation, state environmental protection agencies, metropolitan planning organizations, transit organizations, environmental groups, and industry.

The Advisory Board was formally charged with recommending a national agenda of energy and environmental research for the surface transportation community. During the board's first meeting, it became apparent that planning processes and methods would have to be a major focus of the board's work. The Advisory Board therefore agreed to amend its charge to develop a national agenda for environmental and planning research related to surface transportation.

For purposes of this report, surface transportation encompasses only land-based modes of transportation, thereby excluding water-related travel and all associated environmental impacts. Moreover, the Advisory Board followed the lead of the U.S. Congress in the Intermodal Surface Transportation Efficiency Act of 1991 and TEA-21 in using the term surface transportation to refer to the motor vehicle–highway system and public transit systems, along with pedestrian and bicycle facilities and their use. However, many of the board's findings and recommendations encompass, or could be extended to, other modes and facilities, such as railroads, canals and waterways, and airports. Taken literally, the term surface transportation would encompass all modes, since all modes use the earth's surface for all or a significant portion of the time. However, surface transportation has become a term of art in the United States during the past decade and is widely understood as used by Congress and the Advisory Board.

During the course of a 2-year period, the Advisory Board held six meetings at which members identified and prioritized research areas. At several of these meetings, the board heard testimony from representatives of federal agencies, including the U.S. Department of Transportation's Office of the Secretary, FHWA, and the Federal Transit Administration, as well as the Environmental Protection Agency and the Department of Energy. The board also convened a workshop on research priorities, inviting a broad range of experts from the transportation and environment communities to provide their ideas and advice on the highest research priorities. A summary of the workshop findings is contained in Appendix A.

The Advisory Board wishes to acknowledge the contributions of many individuals and organizations to the development of this report. Kris A. Hoellen managed the study and drafted sections of the report under the guidance of

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making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Suzanne Schneider, Associate Executive Director of TRB, managed the report review process. The report was edited and prepared for publication under the supervision of Nancy Ackerman, Director of Reports and Editorial Services. Rona Briere edited the report. Special thanks go to Frances Holland for assistance with meeting arrangements and to Alisa Decatur for production of the final report.

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EXECUTIVE SUMMARY

For the past 30 years,[1] Americans have addressed the environmental impacts of transportation through policy initiatives, planning and analysis, new programs, and new technologies.[2] Accomplishments have been significant, but much remains to be done. During the next 25 years, significant growth and changes in the nation's population and economy are expected to occur, posing major new challenges for transportation and the environment, but also offering important opportunities for advancement. Major new investments in transportation–environment research will be needed if these opportunities are to be realized.

Many of the challenges to be met stem from America's surface transportation systems, and in particular the motor vehicle–highway system. Private investments in the automobile and public investments in highways have brought Americans unprecedented freedom of movement. Most individuals today have access to automobiles providing them with the means to pursue interests, jobs, recreation, and schooling in ways and places that would have been out of reach for most Americans just a few decades ago. Goods move quickly and efficiently on truck and intermodal truck–rail systems, supporting economic growth. Americans have incorporated the automobile and truck into nearly all aspects of life—the economy, society, and popular culture.

At the same time, the costs of current surface transportation systems are high. As driving levels increase, roads are becoming more congested, and valu-

[1] The National Environmental Policy Act was passed in 1969. Its purpose was "to declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality."

[2] The term "environmental" as used here encompasses energy conservation.

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able time is being lost in heavy traffic. Roads and parking are consuming large amounts of prized urban space. Residences and businesses are increasingly choosing to locate in the suburban fringe to avoid congestion, and the landscape is being fundamentally altered as new developments and new transportation facilities are built on land formerly devoted to farms and ranches, forests, and recreation. Thus traffic and roads are strongly implicated in many of the major environmental problems faced by the United States today: air and water pollution, heavy energy use, fragmented farmlands and habitat, wildlife and biodiversity losses, and community disruption. In turn, these problems are adversely affecting human and ecosystem health and the nation's overall quality of life.

In addition, the negative effects of surface transportation are unevenly distributed. The results of transportation investment decisions—facilities and networks—frequently have a disproportionate impact on inner-city neighborhoods and older suburbs. Outward movement often proves costly to the communities and businesses that are left behind. People who cannot drive have limited access to jobs, services, education, and recreation. Older people, low-income populations, persons with disabilities, and minorities bear a disproportionate share of these adverse impacts.

If the current situation presents significant challenges for transportation professionals, the next 25 years will add to those challenges. The U.S. population is predicted to grow by 60 million, with most of that growth in metropolitan areas. Gross domestic product is projected to reach $29 trillion (approximately 1.5 times today's levels in real terms). If current trends persist, the number of passenger miles traveled is predicted to grow even more rapidly than the population or the economy, swelling from 5 trillion in 2000 to 8.4 trillion in 2025. Americans will expect policymakers and transportation professionals to provide the transportation facilities and services needed to accommodate this growth efficiently, at low cost, and in a socially and environmentally responsible manner. The nation must find ways to deliver a transportation system that simultaneously promotes economic growth, adds to the health of communities and individuals, uses energy efficiently, is inclusive, and enhances the natural and built environments.

Purpose of This Study

The Surface Transportation Environmental Cooperative Research Program Advisory Board (Advisory Board) was formed by the Transportation Research

the Advisory Board and the supervision of Stephen R. Godwin, Director of TRB's Studies and Information Services Division. Cynthia Burbank, Jill Hochman, and Debra Elston served as liaisons and project sponsors from FHWA; all three provided background materials and valuable insights to the Advisory Board.

The board also expresses appreciation to the following individuals for briefing its members on the activities of their respective organizations: John Horsley, American Association of State Highway and Transportation Officials; Donald Chen, Surface Transportation Policy Project; Alexander Cristofaro, Environmental Protection Agency; and Thomas Gross, Department of Energy.

In addition, the Advisory Board wishes to express gratitude to all those who participated in the workshop on research priorities and to those who took the time to provide written responses to questions posed by the board. Input received during the workshop was invaluable to the board in formulating its research recommendations.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

The Advisory Board thanks the following individuals for their review of this report: David G. Burwell, Surface Transportation Policy Project; Aaron Cohen, Health Effects Institute; Robert T. Dunphy, The Urban Land Institute; Gary L. Evink, Florida Department of Transportation (retired); David L. Greene, Oak Ridge National Laboratory; Susan Handy, University of Texas at Austin; Susan Hanson, Clark University; Michael D. Meyer, Georgia Institute of Technology; William W. Millar, American Public Transportation Association; and Neil J. Pedersen, Maryland Department of Transportation. Although these reviewers provided many constructive comments and suggestions, they were not asked to endorse the Advisory Board's findings and conclusions, nor did they see the final draft of this report before its release. Special appreciation is expressed to Michael D. Meyer, who re-reviewed two chapters of this report.

The review of this report was overseen by Lester A. Hoel, University of Virginia. Appointed by the National Research Council, he was responsible for

Board of the National Research Council to recommend a national agenda of environmental research for the surface transportation community that would address the challenges and opportunities discussed above. In the course of conducting this study, the Advisory Board concluded that a major new investment in transportation–environment research is needed to support the nation's growth and meet public expectations for improved transportation system performance. The nation's collective vision of a transportation system that is efficient, equitable, and environmentally benign is clear. To date, however, there exists no comprehensive strategy for realizing that vision.

Background

The United States has enjoyed a remarkable prolonged period of economic expansion since World War II. The standard of living for the average American has increased substantially, with annual personal expenditures tripling on an inflation-adjusted, per capita basis between 1950 and 2000. During this same 50-year period, the population of the United States has grown by 130 million; more than 33 million people were added through immigration and natural increases between 1990 and 2000 alone. Automobiles and trucks have been the dominant means of surface transportation in the United States throughout this period, and have played an important role in supporting and shaping the nation's growth and expansion. They have heavily influenced our consumer goods economy, development patterns, and popular culture. Access to a private vehicle has become the rule rather than the exception for those of driving age, and today more than 95 percent of our person-trips are made by automobile. Truck usage also has grown and now accounts for more than 90 percent of all shipments. The distances traveled are increasing as well: since 1970, Americans have more than doubled their total vehicular travel, and truck travel has more than tripled. There are now more than 200 million vehicles traveling greater than 2.6 trillion miles per year in the United States.

The effects of this level of vehicle ownership and highway use are substantial. Highway travel now constitutes the primary domestic use of imported petroleum. The costs of owning and operating personal vehicles represent 19 percent of the average American household's income—equal to the share of food and clothing combined, triple that of medical care, and second only to housing. Roads and traffic in the United States are estimated to affect

the ecology of more than a fifth of the nation's land area. High reliance on the private vehicle for travel has been a significant contributing factor in the broad spread of urbanized land areas, with the amount of land devoted to residential and commercial land, parking, and streets increasing much more rapidly than population.

Concerns about the environmental implications of surface transportation have assumed a high profile in public discourse. The National Environmental Policy Act of 1969, the Clean Air Act and Clean Water Act (as amended), Corporate Average Fuel Economy standards, and a number of other federal and state environmental laws and requirements have been put in place to help deal with the known and suspected impacts of surface transportation. Provisions of successive Federal-Aid Highway Acts, the Intermodal Surface Transportation Efficiency Act, and the Transportation Equity Act for the 21st Century (TEA-21) have called for stronger roles for metropolitan planning; systematic consideration of social, economic, and environmental effects; protection of parklands; and more public engagement in planning.

Certainly progress has been made: the air and water are cleaner, species have been protected, and many other adverse impacts have been avoided or mitigated as consideration of the environment has increased. Yet these policies have not yet produced what could be termed a "sustainable" transportation system. Changing community perspectives and constrained finances have combined to keep total highway expansion to approximately 2 percent (in lane-miles) during the past 30 years;[3] coupled with the massive growth in motor vehicle use, this constrained expansion has caused the existing road system to experience substantial increases in congestion.

Efforts to improve and expand public transportation in recent decades have resulted in increased usage in some areas, but the gains are uneven. Transit captures a significant share of travel in communities and corridors where services are competitive with the private automobile, such as urban areas, but only about half of the communities in the United States have public transportation systems, and in many other locations only limited service is provided. As of this writing, 47 of the 50 major metropolitan areas in the country have

[3] A recent study of 68 urban areas revealed that from 1982 to 1999, vehicle-miles traveled increased at a greater rate than either lane-miles of freeways and major arterials or population growth. Vehicle-miles traveled increased by 98 percent, freeway and arterial lane-miles by 37 percent, and population by 24 percent.

transit projects under way or under active study. That having been said, as a result of public policy that historically has favored highway and street construction, the United States has the lowest share of transit use of all the fully industrialized economies, at only 2 percent of total travel.

In addition, key trends are moving in the wrong direction. Despite large reductions in vehicle emissions during the past 30 years, many metropolitan regions still have not met basic health standards for air pollution, and several that had achieved compliance have experienced recent excessive violations. Moreover, evidence points to adverse health consequences for children and the elderly at lower pollution levels than were previously recognized. Meanwhile, fuel economy has been declining.[4]

Emerging technologies, policy innovations, and new planning processes offer opportunities for improvement. Relatively little is known, however, about the practical application of these options and whether and where they will succeed.

FINDINGS

The Advisory Board has concluded on the basis of this study that the current state of knowledge and the tools available for environmental assessment are inadequate to ensure informed and effective decisions on transportation and the environment:

- The scale of investment in environmental research related to surface transportation is far too small in relation to the massive scale of transportation activity and its impacts.
- Coordination of the research that does take place is insufficient to derive the greatest benefit from the research effort or to ensure that gaps in the research agenda will be filled.
- Dissemination of research results is often inadequate, and the practical implementation of research findings is too slow. As a result, current

[4] The fuel economy of new cars grew from about 14 mpg in the early 1970s to about 28 mpg by the late 1980s, and that of light trucks slowly improved to about 20 mpg. But massive growth in the ownership of vans, pickup trucks, and sport utility vehicles, now representing about half of the private vehicles sold in the United States each year, has led to a decline in fuel economy. In fact, the average fuel economy of new light-duty vehicles sold is at its lowest level in 20 years.

practice is not up to date, and opportunities for improved performance are being missed.

- A long-term strategy for systematically addressing the environmental effects of transportation on the environment has not been developed, implemented, or integrated into transportation development and management programs. Current policies and investment strategies have tended to focus on short-term solutions.

The stakes are too high to continue to accept the status quo. As in the past, the major transportation system investments and private-sector land development activities occurring today will become fixtures in the landscape and economy of the nation. Better information and improved methods are needed to support policy and investment decisions in the near term, as well as in the long-term future.

RECOMMENDATIONS

National Research Agenda in Surface Transportation and Environment

The Advisory Board has identified six critical research areas for research in transportation and the environment:

1. Human health,
2. Ecology and natural systems,
3. Environmental and social justice,
4. Emerging technologies,
5. Land use, and
6. Planning and performance measures.

While each of these areas is the subject of current research, the Advisory Board believes much more focused and coordinated research is needed in each. More important, many critical transportation–environment topics are all but overlooked, or underfunded. Accordingly, in this report a proposed national research agenda in the above six areas is presented. This agenda includes both basic and applied research elements, as well as education and outreach tasks.

The Advisory Board also concludes that a long-term strategy is critically needed so that research needs in transportation and the environment can be systematically addressed. Current efforts have tended to focus on short-term

issues and short-term responses. These efforts are inadequate for ensuring that the U.S. transportation systems of the 21st century will deliver high-quality economic, social, and environmental performance. The overall strategy entails the development of a research agenda, the conduct of cooperative research, research coordination, and information dissemination.

Need for a Cooperative Research Program

By no means is the Advisory Board of the opinion that the proposed work needs to be done solely by the federal government, or more broadly by the public sector. Universities, public interest groups, and the private sector should be partners in transportation–environment research. The Advisory Board does, however, believe that there is a need for a new, independent entity that can engage all the parties in a cooperative research program on transportation and the environment. This program would be responsible for continuous renewal of the research agenda; sponsorship of substantial levels of new research; and increased coordination, cooperation, and communication among research entities to ensure that the most benefit will be derived from collectively invested dollars.

The Advisory Board recommends the establishment of a new cooperative research program for several reasons. First, the board recognizes that coordinating a comprehensive research program on transportation and the environment across numerous departments and agencies, levels of government, and the public and private sectors is inherently difficult. Yet such coordination is urgently needed. Research on surface transportation and the environment is being carried out today by at least half a dozen departments and agencies of the federal government, their state and local counterparts, academia, public interest groups, the private sector, and numerous international entities. Most of these research programs are functioning with limited resources that, if coordinated, could greatly enhance the ability to devise means of addressing the issues identified in this report. One function of the proposed research program would be to enable cooperative research among these groups, to support parallel investigations and shared efforts, and to aid in the effective dissemination of research findings from all sources.

Second, a new research program could focus resources on critical issues that cannot be resolved effectively by parties whose interests are at stake. For example, the Advisory Board recognizes that in many areas of the country, transportation–environment issues are hotly contested, and proponents and

opponents debate the "facts" on a variety of topics. In some instances the debate has reached—or may soon reach—a stalemate. Research by a credible institution not directly involved in the controversies could help inform these debates. The key is to ensure that this research is conducted in a manner that is both transparent to the parties and accepted by all as free from bias. Cooperative research programs are in a better position to perform this function than are other research sponsors.

Third, for many transportation–environment research topics, there has been little work done to date, or the work has been narrowly scoped or focused on short-term and primary impacts. In contrast, many of the emerging issues in transportation and the environment concern broad, long-term, multimedia, dynamic, and systems effects—for example, the potential effects of transportation emissions in one metropolitan area on air quality in other regions many miles downwind. Research that addresses these longer-term systems effects is needed, but as noted earlier, most existing research programs necessarily focus on immediate issues and the programmatic needs of sponsors. Here, too, a new cooperative research program would be far better positioned to work on the long-term, complex issues now emerging.

It is for all these reasons that the Advisory Board recommends the establishment of a surface transportation environmental cooperative research program, as originally called for in TEA-21. This program would be responsible for ensuring that the national transportation–environment research agenda was implemented, in certain cases by sponsoring the research and in other cases by serving as the coordinating body. Research under the auspices of the program would stem from a clearly articulated mission, be subject to the highest levels of merit and peer review, and be conducted in a manner that was transparent to all parties. The cooperative research program also would conduct an annual review of the research work being carried out by the various federal government entities and survey the work being done elsewhere throughout the world. This review would include development of specific recommendations for enhanced coordination; sharing of resources and findings; and identification of research gaps, with particular focus on long-term needs.

An effective cooperative research program would serve the needs of and therefore require the participation of government agencies, nonprofit organizations, academia, and the private sector. The board overseeing the cooperative research program should likewise represent the full range of interests to achieve a balanced and comprehensive perspective.

Characteristics of a Successful Cooperative Research Program

The Advisory Board reviewed the organizational structures of four leading cooperative research programs: the Health Effects Institute, the Environmental Protection Agency's Science to Achieve Results (STAR) Program, the National Cooperative Highway Research Program (NCHRP), and the Transit Cooperative Research Program (TCRP). Summaries of these programs are included in Appendix B. On the basis of this review, the Board identified a number of specific program elements that appear to be most important for success:

- *Core partners*—entities that should contribute to the overall governance of the program, the primary customers and recipients of the research products.[5] Three categories of core partners should be considered when forming a surface transportation environmental cooperative research program: public entities, the private sector, and nongovernmental/nonprofit organizations.
- *Institutional arrangement*—establishment of the research program in a setting that provides for independence and credibility. A partnership between industry and the public sector enhances a cooperative research program's ability to create a cohesive, integrated research environment and should offer the added attraction of securing private investments while establishing a firewall of independence around the program. Representatives from nongovernmental organizations can form the third leg of the partnership, thereby differentiating the model from that of the Health Effects Institute.[6]
- *Strategic focus*—program direction, as established by the core partners and stakeholders of the program and guided by the national research agenda. To ensure that all core partners and relevant stakeholders are in agreement on the priorities of the cooperative research program, a mechanism is

[5] For purposes of this report, core partners are classified as sponsors, a separate and distinct category from stakeholders.

[6] The primary drawback associated with this option is the customary lag time between the creation of a new entity and its full implementation. This problem can be solved by either establishing the cooperative research program in an existing independent, nonprofit entity with appropriate capabilities for managing such a program, as identified in Chapter 8, or by simply incorporating the lag time into the initial strategic planning stage and communicating clear expectations to all involved in the partnership.

needed for formulating, articulating, and periodically updating the program's strategic focus areas. The Health Effects Institute and STAR, for example, develop multiyear strategic plans.

- *Solicitation and evaluation of research proposals*—the ability to exercise vital quality control mechanisms through open competition and merit review. Establishing clear criteria aids in the selection of the most appropriate research projects, thereby ensuring a selection process that is transparent, fair, and subject to open competition. The Health Effects Institute, STAR, NCHRP, and TCRP all use clear selection criteria in addition to insisting that the selected research projects undergo external merit review. Although the merit review processes differ among the four programs, each incorporates the fundamental elements of both external and internal merit review, as well as open competition.
- *Evaluation of research*—peer review and other approaches designed to ensure the validity and credibility of both the research and the operating functions of the cooperative research program. In addition to evaluating specific research projects upon completion, periodic programmatic evaluations can serve to increase confidence in the operations of the program and may be important when a significant number of end users/customers/stakeholders are to be satisfied.
- *Dissemination*—mechanisms for effectively disseminating research findings. Too often, the research process ends with the publication of findings. Unless research programs make a concerted effort to inform other researchers and research institutions, practicing professionals, decision makers, and the general populace about those findings, a system of fragmented, uncoordinated research initiatives will continue to persist.
- *Funding*—stable funding that enables support of long-term basic and applied research (see below).
- *Competency and availability of staff*—the ability to attract and retain highly skilled and independent staff. Next to stable and sufficient funding, the support of competent staff is the most crucial element in achieving a successful program. If the program is to avail itself of the best and most experienced representatives of the multiple disciplines needed for the research efforts, long-term stable arrangements and flexible contracting processes must be offered with established and emerging institutions that can demonstrate the ability to assemble appropriate teams and complete the tasks assigned. The staffs and institutions involved must also be shielded from political interests and undue influence from

key stakeholders and core partners; that is, they must be granted full independence so they can apply the highest standards of scientific rigor to their work.

- *Stakeholder involvement/communication*—mechanisms for providing for meaningful stakeholder involvement in the selection, evaluation, and coordination of the research.[7] To maintain stakeholder confidence, the process for determining research priorities, selecting and structuring studies, and reviewing the final research products must be clearly understood and readily transparent. All four of the research programs reviewed share common features for actively soliciting stakeholder involvement. Stakeholders are invited to participate in the formulation of the program's strategic plan and strategic focus areas, to submit research proposals, to participate in merit reviews of the research proposals, to participate in workshops at which ongoing research is presented, and to participate in peer reviews of the research products. They are also apprised of the research findings and recommendations.

Funding

Adequate and stable funding must be available on a multiyear basis to support administrative, contracting, and sponsorship activities, including the ability to enter into partnerships with other public and private entities; to support long-term research, both basic and applied; and to sponsor workshops and demonstrations of implementation. Because transportation–environment research has been underfunded during the past 30 years, a significant investment is now needed to address both the backlog of issues that require attention and the issues that continue to arise. The Advisory Board recognizes that a large-scale research program requires a careful startup phase and review of success before a sustainable and effective annual level of research activity is determined. Thus it is prudent to anticipate that the full implementation should and will be phased in over several years. However, the Board finds little reason for the growth of the program to be constrained by a lack of funding. At current federal funding levels, as little as 0.5 percent of annual authorizations of certain federal-aid program categories produces approximately $150 million. While a

[7] For purposes of this report, stakeholders are defined as all entities, excluding core partners, who demonstrate an interest in the work of the cooperative research program or are fundamental to the successful completion of the program's work.

precise annual budgetary estimate for the eventual surface transportation cooperative research program cannot be established until after the start-up phase, it is the Board's opinion that the budget will not exceed such a small fraction of the overall federal transportation program. A national commitment of this scale would not pose a significant financial challenge to the federal transportation program, and given the importance of the environmental issues at stake in the proposed research program, could be expected to produce benefits many times as large.

1
INTRODUCTION

The next 25 years will present a significant challenge for transportation professionals as a result of the anticipated growth of the U.S. population, economic expansion, and increases in passenger-miles traveled (see Box 1-1). As the population grows and the economy expands, Americans will become increasingly more mobile and will expect policymakers and transportation professionals to institute transportation services that are capable of accommodating increasing demand in a manner that is not only efficient and inexpensive, but also both socially and environmentally sound.

While it is true that Americans consistently rank mobility and easy access to transportation[1] as a top priority,[2] they also value the environment. Tolerance for the loss of open space, community disruption, unhealthy air quality, and increased greenhouse gases[3] is diminishing. In this context, the Surface Transportation Environmental Cooperative Research Program

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[1] Currently, no policy has been established to quantify the full environmental costs of transportation; that is, there has not been a national decision to impose user fees or gas taxes to cover environmental costs. If such a policy were to be established, the current priorities of Americans might be altered.

[2] Without suitable means of transport, a person's access to jobs, child-care facilities, shopping centers, recreational facilities, and so on may be severely hindered. On average, Americans make 4.3 vehicle trips per day, equating to a total of 1,568 vehicle trips per person per year. Commuting to and from the workplace is no longer the predominant reason for transportation; work commutes account for only 1 of every 6 automotive trips taken and about 1 of every 5 vehicle-miles traveled.

[3] Despite tremendous improvements in emission technologies during the last 30 years, automotive emissions are still a major source of ozone precursors and other pollutants, and are responsible for about 16 percent of U.S. greenhouse gas emissions.

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Box 1-1

FUTURE EXPECTATIONS BASED ON PRESENT TRENDS

- By 2025, the U.S. population is expected to reach 337 million (an annual growth rate of .82 percent), increasing the population of 2000 by 60 million people.
- Annual passenger-miles traveled is predicted to increase from 5 trillion miles in 2000 to 8.4 trillion miles in 2025.
- Gross domestic product is projected to reach $29 trillion dollars by 2025, approximately 1.5 times today's level in real terms.
- By 2025, freight transportation will expand to just over 5 billion ton-miles, a 29 percent expansion. Trucks will continue to be the dominant mode for transporting freight, but total rail ton-miles is also projected to grow by 2 percent per year between 2000 and 2025.
- The age distribution of the population will change significantly. The median age is anticipated to rise from 35.2 in 1999 to 38.0 in 2025. Currently, 13 percent of the U.S. population is 65 or older; this figure will be 19 percent by 2025.

Source: DOT (2000).

Advisory Board (Advisory Board) was formed to recommend a national agenda of environmental research related to surface transportation.[4]

STUDY CHARGE

The Advisory Board was formally charged with recommending a national agenda of energy and environment research for the surface transportation community.[5] During the board's first meeting, however, it became apparent

[4] The term "environmental" as used in this report encompasses energy conservation.
[5] For purposes of this report, surface transportation encompasses only the land based modes of travel, thereby excluding water-related travel and all associated environmental impacts.

that two additional components would have to be incorporated into the board's formal charge. First, the board determined that a viable agenda for environmental research related to surface transportation would have to include a focus on planning processes and methods. Unless environmental concerns are factored into the transportation planning process, the secondary and cumulative effects of system-level transportation decisions on larger-scale environmental systems will remain insufficiently addressed in the early stages of the process. The Advisory Board therefore agreed to amend its charge to encompass development of a national agenda for environmental and planning research related to surface transportation, with the latter focus being directed specifically at the overlap between planning processes and environmental issues. The Advisory Board's statement of task is presented in Box 1-2.

Second, the Advisory Board believed that the identification of research priorities would be a productive exercise only if existing research programs

Box 1-2

STATEMENT OF TASK

1. The Advisory Board will recommend a national agenda of environmental and planning research priorities and strategies.

   The Advisory Board members will be cognizant of current policy and decision-making processes, the design of institutions, the role of monitoring and education, and the general transfer of knowledge as they seek to develop a national environmental and planning research agenda.
2. The Advisory Board will support outreach and collaboration on research by identifying and recommending opportunities for partnership and collaboration on outreach, research development, and technology transfer and dissemination.
3. The Advisory Board will support the increased visibility of research programs on transportation and the environment.
4. The Advisory Board will provide guidance on assessment methodologies for effectively evaluating research programs.

were structured to implement the new priorities, or a new cooperative research program were created. To be productive, a long-term research agenda would have to be part of a long-term research strategy. Therefore, the Advisory Board's efforts were informed throughout by a long-term perspective on research needs.

Linkage Between Transport and the Environment

Historical Context

Concerns about transportation's impacts on the natural and built environments are hardly new. For example, in the early days of the United States, the building of canals interconnecting waterways and the operation of steamships adversely altered fish populations. The expansion of railroads westward was a factor in the near extinction of the American bison (TRB 1997). Coal-fired locomotives were a source of soot in cities and fires in surrounding farm fields and forests. And in many communities, horse manure had become a severe and growing problem by the late 1800s (FHWA 1976).

The rapid growth of cities during the industrial revolution of the late 19th and early 20th centuries led to concerns about congestion and overcrowding, and to a growing expectation that transportation systems should help alleviate such ills. At the first national conference on city planning held in Washington, D.C., in 1909, urban planners were implored to develop subways and public transit routes to the outer edges of city boundaries. Transportation was seen as the key to improving living conditions, lowering density, and generally enhancing the state of the human environment (Wachs 1999).

Ultimately, horses—and all the travails associated with them as a mode of transportation (e.g., horse manure, disease-infested horse flies)—would be replaced with clean, sterile machines. With the introduction of urban electric streetcars and then the automobile, many believed the transportation systems of the future would be clean as well as efficient. Indeed, both technologies greatly improved sanitation in addition to mobility and access. It would not be until the 1940s that motor vehicle exhaust would first become associated with urban smog and agricultural crop damage (TRB 1997).

The emergence of the automobile (and for freight transport, the truck) transformed American transportation systems. The growing popularity of the

automobile[6] generated demand for better roads[7] and calls for the federal government to become immersed in road development. In 1916 Congress passed the first federal-aid highway legislation—the Federal-Aid Road Act of 1916, establishing the Federal-Aid Highway Program. This act provided for the distribution of federal funds to state highway agencies, creating a financial incentive for the development of a system of improved farm-to-market, intercity, and interstate roads (FHWA 1999). The states also developed major road building and improvement programs, and quickly followed Oregon's lead in adopting a gasoline tax for highway finance.[8] During the same period, mass production of the automobile in the United States made it an affordable means of transport to growing numbers of Americans, who quickly adopted the new technology and began to use it for recreational, goods-carrying, and commuting purposes.

During the Great Depression, automobile purchases declined and expenditures on highway construction slowed, even though road building was used to create jobs and to stimulate the economy. Both automobile manufacturing and road building came to a halt during World War II as materials and industrial capacity were diverted to the war effort (Robinson 1971). When the war ended, housing and automobiles were in heavy demand. Automobile ownership skyrocketed, suburban land development flourished as new homes were built on former greenfields, and state and federal governments began building vast new highway systems (Anderson and Tregoning 1998). New expressways designed to meet suburb-to-city commuting patterns were built; beltways were added to allow long-distance travel to bypass city centers. States led the way with turnpikes and toll roads built in the late 1940s and early 1950s.[9]

Interstate highways, funded with a 90 percent federal share after passage of the Interstate Highway Act of 1956, became the centerpiece of American surface transportation, and land development patterns quickly reflected the greatly increased accessibility provided by the highways. The Interstate program both

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[6] In 1900 there were 8,000 automobiles in the United States. By 1905 there were 77,400 automobiles and 1,400 trucks. By 1910 the number of motor vehicles had grown six-fold to 468,500, and by 1915 the total was 2,491,000 (FHWA 1976).

[7] Bicycles were the first transport technology to necessitate better roads and pavements.

[8] On February 25, 1919, Oregon levied the first gasoline tax: a 1-cent-per-gallon tax on all motor fuel (Bruno 1993).

[9] It should be noted that states had built some limited-access highways in the 1920s, such as the Merritt Parkway and the Pasadena Freeway, and the Pennsylvania Turnpike was built even in the depths of the Great Depression.

supported suburban development and enabled it to accelerate; new forms of development, including the shopping mall and the office park, joined suburban housing tracts in areas served by new highways. By the late 1970s, commercial development lined the periphery of most North American cities (Anderson and Tregoning 1998).

In central cities and inner suburbs, however, new roads were not as easily embraced. In San Francisco, the elevated Embarcadero Freeway blocked city views of the historic Ferry Building; outraged citizens prevented further freeway construction. In New Orleans, a proposal to build an Interstate through the Vieux Carre was rejected. In Memphis, plans to build an Interstate through Overton Park were halted through litigation. Los Angeles' proposals to build freeways through the low-income and minority neighborhoods of Watts, Compton, and Hacienda Park were tabled after massive protests. And Boston's plans for an Inner Belt and a Southwest Expressway were scrapped after a massive restudy. Concerns about the potential adverse social and environmental consequences of highways were increasingly voiced: impacts on community cohesion, historical and cultural resources, and the natural environment became a rallying point for opposition to urban Interstates.

These growing concerns led to passage of the National Environmental Policy Act (NEPA) in the last days of 1969; thereafter, all federally funded highway projects were subject to environmental review. Air pollution from automobiles was a particular concern. With passage of the Clean Air Act of 1970 (and the subsequent amendments in 1977 and 1990), state implementation plans (SIPs) were required to document transportation's contributions to air pollution and to set forth strategies for reducing transport emissions, complementing federal requirements that greatly reduced emissions from new cars and trucks. While the federal government intervened directly on new-car emissions (and subsequently on energy consumption), and state environmental agencies and later metropolitan planning organizations (MPOs) often took the lead in developing SIPs, state highway agencies themselves were given an environmental mandate in the Federal-Aid Highway Act of 1972. That act, which required the detailed evaluation and consideration of social, economic, and environmental effects and increased public involvement in highway decision making, along with NEPA, led many state highway agencies to increase research and development on environmentally sound transportation planning and design practices (FHWA 1976).

As the Interstates were expanding and environmental and energy concerns were emerging as key public policy issues, the plight of American transit sys-

tems also was beginning to receive attention. The heyday of transit had predated the automobile; many systems had begun losing market share by the 1920s (Jones 1985). During World War II, however, heavy usage with little investment in the systems added to their wear and tear,[10] and when fuel and cars became readily available following the cessation of hostilities, many transit riders became automobile commuters.

Transit advocates argued for a federal role in funding transit, both to help rejuvenate the systems and to provide a mobility option that many deemed better suited to dense urban areas. In 1964, Congress responded with the Urban Mass Transportation Act, providing funding for capital grants to upgrade and expand transit services. Successive laws expanded the scope of the federal transit program to include formula-based grants to operators, as well as discretionary capital grants for major new starts, and to provide for rural transit and paratransit. New rail systems were built in several cities, including Washington, D.C.; Atlanta; Los Angeles; Portland, Oregon; Sacramento; and the San Francisco Bay Area. Systems were expanded in many other cities, including Pittsburgh and Boston. Bus services were started or expanded in a number of cities, such as Houston and Phoenix. Some of the services replaced the old streetcar systems that had been dismantled in the 1950s. While these investments generally produced ridership increases, transit's share of travel, even for work trips, remained in the single digits except in a handful of older, denser cities, including New York, Boston, Philadelphia, Chicago, and San Francisco. Still, transit's importance to city centers, its service to those who cannot or do not drive, and its relatively benign environmental impacts continue to attract support.

The story of freight transport in the United States has many parallels with the history of passenger transport. Freight was first transported via waterways, as well as along roads of varying quality. The advent of canals and then railroads in the early to mid-1800s opened up vast new territories for economic development and in so doing transformed the American landscape. Government helped fund the new transportation systems, both directly and through the provision of land. Later, concerned about economic impacts, government stepped in to regulate industrial organizations, tariffs, and conditions of service provided by the powerful railroads. Trucking in its turn was subject to economic regulation and conditions of operation. Yet competition from trucking grew as the automotive

[10] According to the American Public Transportation Association, 1946 was the year of the highest-ever public transportation ridership (23.4 billion).

industry developed and roads were improved and expanded, eventually causing many railroads to face financial difficulties. Partial deregulation, reorganization, and consolidation helped revive some railroads, though others (most notably the Penn Central) ended in bankruptcy. Deregulation of trucking, meanwhile, led to vast numbers of new entrants into the market, and to concerns about the resulting community and environmental impacts.

Problems and Opportunities

Today the nation's surface transportation system encompasses 3.9 million miles of roads, 1.4 million miles of oil and natural gas pipelines, 123,000 railroad route miles, and 26,000 miles of navigable waterways; in addition, 508 public transit operators are located in 316 urban centers. These facilities accommodate more than 5 trillion passenger-miles of travel and 3 trillion ton-miles of freight each year. Approximately 200 million automobiles and light trucks—an average of 1.8 motor vehicles per household—account for 87 percent of total vehicular passenger-miles traveled (U.S. Department of Transportation Report to Congress, 4th edition), and the trend is increasing. Specifically, in 1970 Americans averaged 4,485 automobile-miles per person per year; by 1993, this number had increased 41 percent to an average of 6,330 automobile-miles per person. Between 1983 and 1990, the average trip length for all purposes increased from 8.68 to 9.45 miles.

This growth in transportation activity reflects and supports the nation's economic development and the active social, cultural, and recreational lives of the nation's populace. At the same time, environmental interventions have helped make this growth more acceptable than would otherwise have been the case. Gains are particularly visible in the areas of air quality, with highway emissions having declined by almost 15 percent—from 74.4 million tons in 1993 to 63.7 million tons in 1999. This improvement can be attributed to advances in vehicle fuel systems, the use of catalytic converters, and the development of cleaner-burning fuels. Progress has also been made in energy efficiency, with the average fuel economy of automobiles and light trucks having increased by 54 percent and 63 percent, respectively, between 1975 and 1998. Less well known, perhaps, are the gains in water quality achieved through treatment of highway runoff; the reductions in roadkill due to new animal bypasses and tunnels under highways and railroads; and the decrease in highway noise attributable to the advent of noise barriers, vehicle controls (including quieter engines and improved mufflers), and improved vehicle maintenance (DOT 2000).

Nevertheless, much remains to be done—both problems to be solved and opportunities to be seized:

- While road building has generally slowed now that the Interstate highway system is complete, new roads are still being added both in the high-growth states of the south and west and in many other areas of the country where population and jobs continue to move to the suburbs and beyond. Designing these roads to be environmentally benign will require new planning approaches and new construction and operation methods. Further, as increasing numbers of existing transport facilities (roads, bridges, terminals) require reconstruction, there will be opportunities to introduce new designs that are more environmentally friendly for the natural or built environment.
- The Environmental Protection Agency (EPA) is currently predicting that by 2007 the downward trend in emissions of ozone precursors (nitrogen oxides and volatile organic compounds) will level off and subsequently begin to increase (nitrogen oxides in 2020 and volatile organic compounds after 2007) (EPA 2000).[11] This is cause for concern as epidemiologists have confirmed a link between air pollution and adverse impacts on human health; for example, ground-level ozone has been associated with weakened respiratory functioning, lung inflammation, and increased incidence of childhood asthma. Ongoing research and development will be required to devise additional means of reducing emissions to acceptable levels.
- If energy costs to build infrastructure, produce fuel, and manufacture vehicles were factored into the equation, transportation would account for more than 70 percent of total domestic oil consumption (Davis, 2000). Currently, the United States imports more than half of its oil reserves. Given the uncertainties associated with foreign supplies, growth in demand in other countries, and the finite world supply of oil, the development of methods to reduce petroleum dependence and/or increase energy efficiency may be a necessity.
- Motor vehicles are estimated to be responsible for approximately 20 percent of all U.S. emissions of carbon dioxide, a greenhouse gas[12] (EIA

[11] Should EPA's proposed rule introducing emissions controls on heavy-duty engines and vehicles and diesel fuels withstand court challenges and be adopted, the increases in ozone precursors would be postponed further into the future (EPA 2000).

[12] Passenger cars and light-duty trucks are responsible for approximately 60 percent of total carbon dioxide emissions from the U.S. transportation sector (EPA 2001).

2000). Additionally, 16 percent of all U.S. emissions of chlorofluorocarbons (Burwell et al. 1991), a critical element in the destruction of the ozone layer, can be attributed to motor vehicles. These impacts on the environment are increasingly receiving worldwide attention, and the United States needs strategies for managing greenhouse gases and ozone depletors that suit the nation's own social, economic, and political realities.

- Releases of zinc, cadmium, copper and nickel, chromium, and iron into the environment result in part from the abrasion of tires and brake linings. Deposition of these pollutants near highways can result in contamination of surface dust and soil. Moreover, leakage of brake fluid, antifreeze compounds, lubricating oil, engine oil, and grease onto the highway surface can lead to the contamination of surface water and groundwater. The chain of events of emission, dispersion, deposition, and removal of automotive pollutants—and the resulting impact on the natural environment in the short term—has been well-documented (Ball et al. 1991; EPA 2001), if not well understood. More work is needed to devise methods of reducing these releases and their environmental impacts. Moreover, relatively little is known about the long-term effects of these releases.
- It is increasingly recognized that cumulative, long-term impacts are important and may not be readily understood or managed within the context of the current system. For example, air pollutants when deposited frequently pollute the surrounding soil and water supply. Similarly, system effects are beginning to be understood; for example, it is now recognized that to protect endangered species, one must also protect their habitats and their genetic diversity. Furthermore, institutional approaches to the management of certain transportation-related environmental problems are proving to be inadequate, as in the case of air districts that do not span the pollutant transport area. These issues point to the need for research in a variety of fields, including basic scientific processes, management approaches, planning and forecasting methods, and institutional arrangements.
- Traffic congestion is a stressful experience for many Americans, causing elevated blood pressure and other stress-related health impacts, contributing to absence from work, and lowering tolerance for frustration (Burchell et. al. 1998). Congestion also increases vehicle operating costs, fuel consumption, and emissions and contributes to lost productivity. The Texas Transportation Institute estimated that in 1999, 50 major U.S. cities expended well over $78 billion in congestion-related costs—an estimate

that does not incorporate costs associated with stress-related illnesses. Strategies for managing congestion are being developed, but clearly more work is needed.

- Some population groups, including the young and some elderly, low-income, and disabled populations, have a limited ability to travel by automobile unassisted, and hence are transportation-disadvantaged in a society that uses automobiles for most trips. In addition, some communities are disproportionately impacted by transportation facilities and their adverse effects (e.g., increased traffic and pollution levels, barriers to physical activity, along with the actual physical division of communities by highway structures). Concern about these disparate impacts of transportation has led to calls for better planning methods, including means of developing community-sensitive alternatives, evaluating the distribution of benefits and costs, and providing for mitigation or amelioration of adverse effects.
- Public concerns regarding interactions between land use and transportation, as well as a broad range of community and environmental impacts, suggest the need to search for better methods of planning and achieving public involvement, new organizational approaches and assignments of responsibility, and new ways of managing the transportation system.
- New technologies—ranging from fuels and vehicles to methods for handling and displaying environmental data and forecasting transportation demand—offer possibilities for greatly improving transportation planning and transportation projects. But more work is needed to test, develop, and implement these technologies.

In short, research and development on transportation and the environment is needed to manage the problems of the coming decades. The potential for this research to pay off in substantial improvements and innovations is great.

Intermodal Surface Transportation Efficiency Act of 1991

A full decade ago, concerns about transportation and the environment led to the passage of landmark legislation—the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. ISTEA marked a new era in transportation planning, outlining for the first time measures designed to foster a national transportation policy that transcended traditional modal issues, such as highway construction and transit subsidies, to focus on intermodal considerations

and address broader public policy concerns of economic efficiency and environmental quality. Specifically, the ISTEA policy statement declared:

> It is the policy of the United States to develop a National Intermodal Transportation System that is economically efficient and environmentally sound, provides the foundation for the Nation to compete in the global economy, and will move people and goods in an energy efficient manner.

To meet these new goals, ISTEA authorized the establishment of several new programs. For example, the Congestion Mitigation and Air Quality (CMAQ) program provided earmarked funding for major urban areas that had not attained the National Ambient Air Quality Standards. Another program provided funds specifically for enhancements to transportation projects, such as bicycle and pedestrian facilities, landscaping, and public amenities. Still another program funded research, development, and implementation of intelligent transportation systems (ITS) that use computers and information technology to improve transport capacity and safety.

The provisions in ISTEA that may have initiated the greatest change were those that called for the development of state and regional transportation plans and set forth land use and environmental factors to be considered in those plans. ISTEA assigned to MPOs lead responsibility for the regional transportation plans. State transportation agencies were to take the lead for key facilities (Interstates and a few others), as well as for plans and projects for those portions of the state outside of the major metropolitan areas. The state agencies were thus to work in partnership with the MPOs within the metropolitan areas.

ISTEA designated the U.S. Department of Transportation (DOT) as lead agency for defining national research goals and for serving as the coordinating body for transportation research for all modes. DOT was also charged with conducting an inventory of its own research activities and with developing a strategic framework for transportation research.

Need for a Long-Term Strategy

In September 1996, the U.S. General Accounting Office (GAO) conducted a review of DOT's surface transportation research program to ascertain the status of transportation research prior to the reauthorization of ISTEA (GAO 1996). GAO concluded that DOT's surface transportation research program was lacking in three principal areas:

- From fiscal year 1992 through fiscal year 1996, DOT had received a total of $2.9 billion in federal funding for surface transportation research. The vast majority of this funding had been allocated to highway-related research. Specifically, DOT had allocated $2.1 billion of the total research funding received to the Federal Highway Administration (FHWA), which in turn had allocated nearly half of those funds to the ITS program.
- GAO concluded that DOT had not succeeded in developing a strategic, integrated, or focused approach to surface transportation research as directed by ISTEA. Rather, the needs and activities of the individual modes were still governing DOT's research initiatives, and little attention was being paid to the total surface transportation system.
- GAO noted that DOT was conducting very little long-term or high-risk surface transportation research. Unless the focus of DOT's transportation research program were shifted, GAO cautioned, the transportation community would remain unprepared to fully address the goals espoused in ISTEA.

A targeted, long-term research strategy was clearly needed. The conclusion of the GAO report was that the investment in surface transportation research had been largely inadequate and to date had not reflected the significance of the issues involved. This situation persists today. Research on transportation and the environment is especially underfunded, with the environmental share of transportation research being a mere fraction of the total invested. In fiscal year 2000, DOT allocated less than $10 million of its $400 million annual research and development budget to addressing the environmental effects of transportation. If a long-term research strategy were formulated and sufficiently funded, it could provide a foundation for the development of solutions to some of today's most pressing problems while allowing policymakers to prepare for the future.

Development of a Transportation–Environment Research Agenda

The authors of the Transportation Equity Act for the 21st Century (TEA-21) were cognizant of the problems encountered in the implementation of ISTEA and recognized the need to develop a secure foundation for transportation–environment research. Thus as noted, the act called for the formation of the

Advisory Board to develop a research agenda that would guide the work of research institutions and establish the integrated research framework originally envisioned by the authors of ISTEA.

The Advisory Board identified six critical areas for the focus of its research agenda:

1. Human health,
2. Ecology and natural systems,
3. Environmental and social justice,
4. Emerging technologies,
5. Land use, and
6. Planning and performance measures.

The basis for selection of these six areas was the knowledge and collective expertise of the Advisory Board members, input received from federal agency representatives during board meetings, and the proceedings of a workshop held in September 2000 to solicit input on research priorities from experts within both the transportation and environment communities (see Appendix A for a summary of the workshop proceedings). Each of the six focus areas represents an obvious intersection point between transportation and the environment and typifies the inherent trade-offs involved. It should be noted that the Advisory Board did not attempt to provide a comprehensive list of topics for research, but rather aimed to identify research areas in which troublesome gaps in knowledge exist and further investment in research would pay off, significantly advancing the ability of transportation professionals to provide transportation systems that are socially and environmentally sound, as well as efficient and economical. It should also be noted that the six research areas identified by the Advisory Board are necessarily interconnected; this report is therefore intended to be read in its entirety, and individual chapters are not meant to stand alone.

The issues and the Advisory Board's findings in the six focus areas are reviewed in turn in Chapters 2 through 7; the board's recommendations for a research agenda in each area are presented at the conclusion of the respective chapter. Brief overviews of the six chapters are provided below. Three components necessary for establishing a comprehensive long-term research strategy for the surface transportation–environment arena are outlined in Chapter 8. In Appendix A a summary of the research priorities workshop is provided, and a matrix outlining the various components of four cooperative research programs reviewed for this study is given in Appendix B.

Research Area 1: Human Health (Chapter 2)

Transportation systems can affect human health through a variety of processes, including facility construction, operations, and maintenance, as well as vehicle fueling, operations, and scrappage. Significant health effects result from air pollution emissions, including air toxics; water pollution from runoff; deposition of emissions; leaks from solid waste disposal sites; and noise exposure. However, the links between transportation activities and human health are not yet fully understood or agreed upon. Additional research is needed to substantiate the linkages between exposure to emissions and health impacts, and to understand which transportation activities may pose the greatest threat to human health and thus should be modified. Research should address modal emissions and their implications for vehicle control strategies and transportation system designs, as well as transportation emissions of air toxics, their health impacts, and their policy implications. Research also should examine the potential health impacts from transportation runoff and deposition; the health effects of transportation noise exposure; and strategies for avoidance, minimization, and reduction of these impacts. Strategies for better understanding the economic value of health improvements and for incorporating health considerations into valuation methods also should be researched.

Research Area 2: Ecology and Natural Systems (Chapter 3)

Historically, transportation's impact on the environment has been measured in terms of human health; consequently, issues such as air pollution have received considerable attention. However, little research has been performed on the impacts of these same emissions, both short and long term, on natural systems (TRB 1997). Polls indicate that Americans value a clean environment, but also desire an efficient transportation system. To fully assess the trade-offs involved, both the transportation community and the American public need to understand the impacts of transportation on the environment in both the short and long terms. For example, if key species are reduced or eliminated as a result of the impacts of a transportation project, to what extent will biodiversity be altered? This question can be answered only through long-term monitoring and evaluation of the ecosystem. Another example involves the use of plantings near highways to reduce maintenance and create aesthetically attractive roadsides. To what extent will these plantings disrupt the natural environment and the functions provided by the ecosystem? There are many

examples of transportation's impacts on the natural environment; this chapter provides broad insight into both the spatial and temporal issues associated with transportation and natural systems.

Research Area 3: Environmental and Social Justice (Chapter 4)

ISTEA and TEA-21 mandated increased public involvement and renewed attention to the economic, social, environmental, and energy effects of transportation decisions. Chapter 4 examines issues of equity in transportation, including the distribution of social, economic, and environmental impacts and related issues of environmental justice. Research is needed to understand differences in mobility, access, travel behavior, and travel preferences across socioeconomic groups; to develop improved planning approaches that better reflect and respond to community needs; to improve evaluation methods for examining the incidence of benefits and costs; to examine the differential impacts of current methods of finance and explore alternatives; and to understand the socioeconomic implications of emerging land development patterns and new transportation technologies. Research is also needed to develop innovative applications of technology that would improve the equity of the transport system in a cost-effective manner, and to devise improved methods for community involvement, collaborative planning, and conflict resolution.

Research Area 4: Emerging Technologies (Chapter 5)

In the not-too-distant future, the transportation industry is expected to incorporate two largely new sets of technologies: (*a*) propulsion technologies and fuels that will change the energy, pollution, and noise characteristics of vehicles; and (*b*) information, communication, and control technologies that will change how vehicles are used. The way these paths may unfold and how public policy may influence their direction to achieve enhanced environmental quality are two critical research questions. Research is needed on pathways for the transition to environmentally benign fuels and vehicles for passengers and freight; on user response to and demand for new technologies that could offer improved environmental performance; on possible applications of ITS technologies for environmental benefit; on policy instruments that would encourage the development of beneficial new technologies in a cost-effective manner and would respond to the impacts of new technologies as they gained market

share; and on institutional arrangements, including public–private partnerships for the research, development, and introduction of new transportation technologies and systems.

Research Area 5: Land Use (Chapter 6)

During the past three decades, both land consumption and vehicle-miles traveled have grown more rapidly than population in metropolitan areas across the United States. Empirical studies suggest that transportation investments have contributed to these trends, but many other factors, including housing policies, school quality, and consumer preferences, are also involved. (Deakin 1990). In response to concerns about sprawl, policymakers are implementing growth management and transportation initiatives, but the effects of these initiatives remain to be assessed. Focused, coordinated, and expanded research is needed on these topics, including the impacts of transportation investments on location decisions and land use; the costs and benefits of current development patterns and their transportation implications; the effects of the built environment on people's willingness to walk, drive, or take public transportation; and the roles of public policy and institutional arrangements in current and prospective land use and transportation choices. Research is also needed to develop improved data, methods, and processes for considering land use, transportation, and the environment in an integrated, systematic fashion.

Research Area 6: Planning and Performance Measures (Chapter 7)

ISTEA and TEA-21 call for transportation planners to meet needs for transportation mobility in a manner that supports broader societal goals of economic competitiveness, social equity, and environmental sustainability. To accomplish this, transportation planners must develop a better understanding of travel needs and preferences, as well as a better set of planning methods for system analysis, forecasting, and decision making. Expanded research is needed on consumer choice processes and travel and activity patterns for both local and long-distance trips and both passenger and freight transportation; on the social, environmental, and economic benefits and costs of various transport options; on tools for measuring and forecasting complex transportation decisions for all modes and users; on performance measures and policy analysis approaches that can be used to gauge how well various strategies will accomplish desired

outcomes; and on methods for better linking public involvement, including citizens and private-sector interests, in the transportation planning and evaluation processes.

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Abbreviations

DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
EIA	Energy Information Administration
FHWA	Federal Highway Administration
GAO	General Accounting Office
TRB	Transportation Research Board

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2

Research Area 1

HUMAN HEALTH

Through the use, manufacture, maintenance, and scrappage of vehicles (including passenger cars, trucks, buses and railcars) and the maintenance of the infrastructure they use, the transportation system creates significant harmful effects on human health. Surface transportation is linked to human health (both mortality and morbidity) through vehicle emissions; road dust; degradation of drinking and stream water by road runoff from substances in vehicles, deicing chemicals, or other substances; exposure to toxic contaminants through vehicle and battery scrappage (either directly or through contamination of ground or surface water); and engine and tire noise.[1] The effects of these emissions, pollutants, and wastes on health occur at different spatial scales. Carbon monoxide (CO) emissions, for instance, are generally of concern at the local level; the same is true for larger particulate emissions, which tend to settle out quickly. Finer particles and ambient ozone, on the other

[1] Transportation is directly linked to health through the effects of vehicle crashes. However, these important health and safety issues, including those related to releases of chemical and other hazardous wastes from spills, lie outside the scope of the Advisory Board's deliberations and this report. Also excluded are some of the less significant links of health to pollution from the transportation vehicle life cycle, including the extraction, manufacturing, storage, delivery, and transportation of fuels, and the manufacturing and repair of vehicles. For instance, the automobile repair industry contributes to the hazardous wastes generated in the United States; these wastes include antifreeze, solvents, brake fluids, and linings. Also excluded is the effect of urban form on temperature through the "heat island effect" (McMichael et al. 1996). Transportation infrastructure may contribute directly to this effect via roadways, but the greater effects are seen with urban forms that remove trees and other green spaces. Finally, the Advisory Board recognized the importance of, but excluded, the effect of substituting motorized transport use for bicycling and walking on exercise and fitness levels, with the attendant effect on health and longevity (Hillman 1997).

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hand, can travel for hundreds of miles or more, so that pollution in one state can affect the health of people in many other states and even other countries. While the ground-level emissions from mobile transportation sources tend to be less of a problem with regard to long-range transport relative to stationary sources with tall stacks, they are still significant. And some transport emissions, such as carbon dioxide (CO_2), have global effects (EPA 2001a).

Responsibility for research on transportation, pollution control, and human health is divided among several agencies, and while the surface transportation community may have an interest in every linkage between transportation emissions and health, some are more directly within its purview than others. As a result, gaps in research sometimes develop. Research on transportation and air quality offers a case in point. Under the Clean Air Act, the Environmental Protection Agency (EPA) is responsible primarily for estimating emissions from mobile, area, and stationary sources, linking emissions to concentrations of air pollutants, and linking the resulting air quality to human health. The agency places particular emphasis on documenting the emissions from transportation sources and seeking transportation policies and measures to reduce pollution. Little of EPA's work, however, has addressed the broader question of how current transportation programs affect human health, or how they could be redesigned to avoid or reduce pollution. The Federal Highway Administration (FHWA) takes an active interest in EPA's research and sponsors its own studies on how to meet the requirements of the Clean Air Act. In particular, FHWA is responsible for ensuring that local transportation plans conform to the Clean Air Act. However, neither FHWA nor any other transportation agency conducts research on the health effects of its programs on a regular basis. Thus although both agencies have focused attention on transportation and air quality for several decades, significant research gaps exist.

In this chapter, the Advisory Board proposes a research agenda to address these gaps. This agenda encompasses epidemiological topics of particular significance to surface transportation, as well as research issues related to estimation of the economic health benefits of reducing transportation-related emissions. Also, because health effects and the monetary value of those effects figure prominently in cost/benefit and cost-effectiveness analyses of environmental and transportation regulations, these issues are included in the recommended agenda.

The consequences of transportation for human health are not straightforward, and extensive research is needed, in some cases to substantiate the linkages and in other cases to establish the direct and indirect links. Much of the problem is due to a lack of sufficient data. Determining which transportation activities

pose the greatest threat to human health as a result of environmental impacts and which should be modified is critically important. There is also a need to achieve the greatest possible reduction in risk for the costs incurred; thus the relationship between risk reduction and cost is an important research topic as well.

The specific linkages between surface transportation and human health are described in some detail in the next section. The discussion focuses primarily on air pollution, from which most health effects of surface transportation are believed to occur. Some attention is also paid to water pollution, solid wastes, and noise. Water pollution and noise are both addressed further in the discussion of ecology and natural systems in Chapter 3.

Surface Transportation and Human Health

Air Pollution

Fuel burning due to transportation activities, whether under congested or uncongested conditions, has the potential to increase the risk of death from respiratory and cardiovascular disease; raise the risk of developing certain chronic diseases [including cancer (Pope et al. 2002); chronic bronchitis; and, according to very recent evidence, asthma (McConnell et al. 2002)]; aggravate various existing chronic conditions; and lead to acute cardiopulmonary symptoms, such as cough, a runny nose, and other signs of a cold (Key 1998; Liao et al. 1999; Tolbert et al. 2000). Burning gasoline still leads to significant emissions of volatile organic compounds (VOCs) (some of which are carcinogenic), CO, nitrogen oxide (NO_x), and particulate matter, although each of these pollutants has been heavily regulated under the Clean Air Act by means of emission standards, mandated inspection and maintenance programs, and fuel quality standards. Moreover, because of the large amount of gasoline burned in the United States, even the very small amounts of sulfur present in gasoline can lead to significant emissions of sulfur dioxide (SO_2). (Lead, however, has been virtually eliminated from gasoline.) Burning of diesel fuel (primarily by trucks in the United States) emits NO_x, SO_2, and fine particulates (under 1 micron in diameter), some of which are carcinogenic (EPA 2000). In addition, mobile source air toxics from the combustion of gas and diesel fuel pose potential human health risks.[2] Air toxics are

[2] Mobile source air toxics include the aggregate emissions of acetaldehyde, benzene, 1,3-butadiene, formaldehyde, and polycyclic organic matter (POM). Sources of mobile toxics include cars, trucks, trains, and marine vessels.

not regulated under the National Ambient Air Quality Standards, but are still subject to regulations specified in the Clean Air Act Amendments of 1990. Moreover, in 2001 EPA set new performance standards for gasoline, requiring that refiners maintain their average 1998–2000 performance levels for air toxics. It is estimated that mobile source air toxics may account for 21 to 42 percent of urban air toxics (EPA 1998a; EPA 1998b; HEI 1999).

Efforts to reduce emissions from fuels have consisted primarily of the use of fuel additives, which generate a whole new set of potential health concerns. For example, methyl tert-butyl ether (MTBE), an oxygenate added to gasoline to reduce CO emissions, may be associated with headache, nausea, and sensory irritation in sensitive individuals, and has also been linked to neurotoxic effects and cancer in animals at high exposure levels (HEI 1996). Similarly, the health effects of the cerium-based diesel fuel additive Eolys, which has been used to reduce particulate emissions, have yet to be evaluated quantitatively, though the additive is thought potentially to target the lungs or lymph nodes at high exposure levels (HEI 2001). Alternative fuels (such as ethanol) emit their own signature suite of pollutants, including formaldehyde.[3]

The following discussion of the effects of mobile sources of air pollutants on health begins with a review of the emissions and concentrations of the various air pollutants. The health effects of these pollutants are then examined, followed by a brief discussion of approaches for determining the monetary benefits of mitigating those effects. Each of these linkages is explored in great detail in EPA's regulatory impact analyses of its ambient air quality standards and in both the prospective and retrospective analyses of the costs and benefits of the Clean Air Act and its 1990 amendments (EPA 1997a; EPA 1997b; EPA 1999a).

Emissions

Emissions of automotive air pollutants vary according to many factors, such as the following:

- VOC emissions vary with the Reid vapor pressure of the fuel and the air and engine temperature. VOC emissions also result from certain high-speed accelerations, as well as from fuel leaks and spills and from evaporation.

[3] The Clean Air Act requires areas to meet concentration standards for both gaseous and particulate pollutants. The gaseous pollutants include SO_2; NO_x; and ozone, which comes from emissions of VOCs. The particulate pollutants include lead; PM_{10} (particulates with a diameter of 10 microns or less); and very recently, $PM_{2.5}$ (particulates with a diameter of 2.5 microns or less).

- CO emissions tend to move with VOC tailpipe emissions over many operating conditions; that is, both VOC and CO emissions are high when engines are cold and speeds are low.
- NO_x emissions vary with the heat of the engine. Overall NO_x emissions have a U-shaped relationship with speed: they are high at low speeds as the vehicle accelerates, fall as the vehicle gains speed, and then rise again at higher speeds.
- SO_2 emissions are directly related to the sulfur content of the fuel.
- Road dust varies with the dryness of the pavement and the number and speed of vehicles on the roadway, as well as with certain pavement designs.

In addition to these so-called "conventional pollutants," motor vehicles emit CO_2, a greenhouse gas, proportional to the amount of fuel burned; indeed, motor vehicles are estimated to be responsible for approximately 30 percent of all U.S. emissions of CO_2 (EIA 2001). Global warming attributed to greenhouse gases has been linked to a variety of health effects, some positive (due to warmer temperatures in colder climates), many more negative (due to warmer temperatures in warmer climates), and some exotic (due to the increased range of mosquito populations). In addition, vehicle air conditioners leak chlorofluorocarbons (CFCs), a critical element in the destruction of the ozone layer, which is linked in turn to higher rates of melanoma. This problem is being mitigated over time by the phase-out of production of the most potent CFCs both in the United States and worldwide in accordance with multilateral agreements under the Montreal Protocol.

While policy discussion has focused historically on the long-term health effects of global warming, research has indicated that reductions in mobile source greenhouse gas emissions—provided these reductions are based on lowered fossil-fuel combustion—may provide immediate health benefits. In a study of four major cities, Cifuentes et al. (2001) found that adoption of greenhouse gas mitigation technologies can significantly reduce ambient particulate matter (PM) and ozone concentrations, thereby leading to large reductions in premature mortality, chronic bronchitis, and restricted activity days.

The polluting role of on-road mobile sources is captured by EPA's emission estimates for such sources. As an example, during the period 1989–1998, emissions of NO_x from these sources increased by 1 percent, whereas emissions

of the other key pollutants fell[4] [SO_2 by 50 percent, PM_{10} (particulates of 10 microns or less in diameter) and VOCs by 25 percent]—and this in spite of large increases in vehicle-miles traveled. Change in the composition of the vehicle fleet appears to have played a major role in the latter improvements, as newer vehicles meeting tighter emission standards gradually replaced older vehicles. In their study of PM emissions from light-duty gas and diesel vehicles, Cadle et al. (1999) estimate that 26.8 percent of total PM_{10} mass recorded in the study was from cars dated 1986–1990, and that only 3.8 percent of the total observed PM_{10} was from cars and trucks dated 1991–1996.[5]

Concentrations

In the atmosphere, the conventional pollutants disperse according to atmospheric conditions and their own properties (reactivity, weight, particle size). Some of the pollutants transform, often in highly nonlinear processes. For instance, SO_2 converts to sulfates (a fine particulate) in the presence of ammonia. NO_2 also converts to nitrates (a fine particulate as well) in the presence of ammonia, but the ammonia reacts preferentially with the SO_2; thus, reductions in SO_2 can lead to increases in nitrates. Similarly, VOCs and NO_x react to form ozone in the presence of sunlight. Depending on atmospheric and emission conditions, however, an area may be NO_x- or VOC-limited, meaning that reductions in the nonlimiting pollutant will not affect ozone concentrations. Also, NO_x emissions into an existing ozone-rich atmosphere will "scavenge" (i.e., reduce the concentration of) ozone. An important point to note with respect to transportation is that ozone concentrations evidence a strong association with daytime hours because of their dependence on sunlight; emissions of ozone precursors at night will not create much ozone, but will be available for downwind ozone formation in the morning. Also important for transportation, ozone and fine particulates travel long distances, so emissions in one location can affect human health in downwind locations even 1,000 miles away (TRB 1995).

With regard to trends in air quality and emissions, EPA estimates that as of 2000, 121 million people nationwide lived in nonattainment areas with pollution levels above at least one of the National Ambient Air Quality Standards (set to be protective of health). Yet EPA analysis reveals much improvement.

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[4] It should be noted that data are not available for this time period for fine particulates ($PM_{2.5}$), a particulate size of greater concern from a public health standpoint.

[5] The sample sizes of the two groups were 22 and 20, respectively.

About 85 percent of areas had downward trends in concentrations of one or more of the criteria pollutants (ozone, particulates, NO_x, SO_2, CO, and lead), while only about 10 percent had upward trends. Most of the areas with upward trends had air quality that significantly exceeded the air quality standards, while the rest reflected a lack of compliance with the new (not yet implemented) 8-hour ozone standard. Still, NO_x and ozone levels had fallen only 11 and 10 percent, respectively, overall. At the same time, some cities had experienced remarkable gains. From 1991 to 2000 in Los Angeles, the area with the most severe air pollution in the nation, the number of days for which the air quality index indicated unhealthy air fell from 168 to 48; days on which there were unhealthy levels of ozone declined from 126 to 45.

While monitoring for air quality changes is a principal means of demonstrating how well an area is doing in meeting the National Ambient Air Quality Standards, linking monitored changes in concentrations to mobile source emissions is not a simple matter. Complex air quality models are used to make "source attributions," relating emissions from various source types and source locations to concentration changes in particular receptor locations (EPA 2001b). Key issues with these models include data quality and representativeness, both of which affect the statistical validity and associated error of the models; for photochemical models, representation of the underlying chemistry of pollutant formation and dissipation is also an issue.[6]

Health Effects

In addressing the linkage between motor vehicle emissions and human health, research and discussion have focused primarily on PM and ozone. PM exposure is considered an important risk factor for cardiopulmonary disease and mortality and is associated with other health endpoints, such as chronic bronchitis. Pope and Dockery (1999) review the epidemiology of PM effects. Other studies have addressed the effects of both acute exposure and chronic exposure to PM, though the former studies are more prevalent because of the availability of daily time-series datasets. These studies, such as Dockery et al. (1993) and Samet et al. (2000b), typically have suggested an increase in the daily mortality rate ranging from less than 0.5 percent to as high as 1.5 percent per 10 $\mu g/m^3$ of PM_{10}. Chronic mortality studies, such as Pope et al.

[6] Advisory Board members acknowledge that they lack the expertise required to evaluate the detailed chemical equations of certain air quality models in any depth.

(1995), have suggested a mortality response of 3 percent or greater per 10 $\mu g/m^3$. Pope and Dockery (1999) note that these studies identify complementary effects, and suggest that the implications of chronic exposure may be more important from a public health standpoint. Chronic exposure increases the risk of chronic respiratory disease and of cardiorespiratory mortality, while acute exposure is believed to cause mortality by exacerbating existing cardiovascular and pulmonary disease, thus increasing the number of individuals in the population who die from complications related to such diseases.

While the relationship between PM and health has generally been accepted, there are large uncertainties about the relative potency of particulates by size and composition (NRC 2001). Health-based standards originally were set for total suspended particulates, but this was changed to PM_{10}; in 1997 EPA promulgated standards for $PM_{2.5}$ as well.[7] It has been suggested that particles of smaller size may be more potent because they can be breathed more deeply into the lungs (Pope et al. 1995). With regard to composition, epidemiological studies have been most robust in linking PM_{10} to health outcomes (Pope and Dockery 1992), but some very influential studies have shown a linkage to $PM_{2.5}$, and within this size category to sulfates (Wilson and Suh 1997). A number of studies have evaluated the effects of more than one size category. Krewski et al. (2000), in a reanalysis of work by Pope et al. (1995), finds that $PM_{2.5}$ has a significant association with chronic mortality, while $PM_{2.5-15}$ does not. Some acute mortality studies (Fairley 1999; Ostro et al. 2000) have reported similar findings. On the other hand, Lippmann et al. (2000) suggest comparable effects of PM_{10}, $PM_{2.5}$, and $PM_{2.5-10}$. While few studies have addressed the influence of PM_{10} on health from an epidemiological perspective, a recent study by Wichmann et al. (2000) finds that $PM_{2.5}$ and PM_{10} are similarly yet independently associated with daily mortality levels.

Within these different size classifications of PM, there is additional uncertainty about the relative toxicity of different particle types. One difficulty with pinpointing the potency of pollutants is that statistical results are often sensitive to the types of pollutants included in the analyses. In particular, some recent research (Spix et al. 1998) shows that SO_2 concentrations can overshadow

[7] PM_{10} is thought to consist primarily of crustal particles generated by agriculture, traffic, construction, or similar sources, as well as some naturally generated particles. $PM_{2.5}$ consists largely of particles from fuel combustion by motor vehicles or from power generation, as well as fine crustal particles from road dust and soils (Laden et al. 2000).

particulate effects, potentially leading to an underestimation of the potency of particulate effects in certain cases. Recent research by Laden et al. (2000) attempts to link source-specific particle types within $PM_{2.5}$ to mortality. The results suggest that particles from mobile and coal combustion sources are associated with increased mortality, while crustal particles are not. Given the finding of Cadle et al. (1999) that the majority of PM mass from vehicle emissions is $PM_{2.5}$, the finding of Laden et al. (2000) appears to be consistent with the notion of $PM_{2.5}$ as more potent than larger particulate matter.[8] Also of particular interest in Laden et al. is the finding that particles from mobile sources have a mortality effect about three times that of particles from coal combustion sources.

An additional source of uncertainty is the actual level of exposure to PM and other pollutants from vehicle emissions. Epidemiological studies typically measure ambient concentrations at monitoring stations within a locality and use these measurements as a proxy for actual exposure. The potential measurement error introduced by such an assumption has been cited as a major limitation of these studies (Samet et al. 2000a). Samet et al. note that individuals spend a small percentage of their time outside, making personal exposure levels highly dependent on the ability of pollutants to penetrate indoor spaces and on the quality of indoor air. It is perhaps even more difficult to estimate the percentage of an individual's total level of exposure to air toxics that is due to vehicle emissions, which surely varies with distance from roads and traffic density, among other factors.

However, some estimates of actual exposure exist. Cohen and Nikula (1999) cite estimates from Cass and Gray (1995) and EPA (1993) that human populations in the general urban environment are likely to be exposed to average annual concentrations of diesel exhaust of 1 to 10 $\mu g/m^3$. EPA (1999b) provides annual average exposure projections for benzene and diesel PM for a variety of locations and policy scenarios, ranging from approximately 0.25 to 0.83 $\mu g/m^3$ and 0.24 to 0.40 $\mu g/m^3$, respectively, for 2007. In-vehicle exposures, however, may be substantially higher. In their study of pollution concentrations inside vehicles on Sacramento and Los Angeles roadways, Rodes et al. (1998) find in-vehicle concentrations of benzene and PM_{10} ranging from 3 to 15 $\mu g/m^3$ and 20 to 40 $\mu g/m^3$, respectively, in Sacramento, and 10 to 22 $\mu g/m^3$ and 35 to 105 $\mu g/m^3$, respectively, in Los Angeles. Interestingly, pollutant levels in vehicles traveling in a carpool

[8] Cadle et al. (1999) found that within their study sample, PM mass from gasoline and smoking/diesel vehicles comprised 91 percent and 98 percent $PM_{2.5}$, respectively.

lane were generally significantly lower than those in the righthand, slower lanes. In addition, roadway type, freeway congestion level, and time of day were shown to have some influence on in-vehicle pollutant levels.

Ozone has been the other pollutant of interest in research and policy discussion, though there is less of a consensus in the literature regarding the mortality effects of ozone than is the case for particulate matter. In their review of ozone mortality studies, Thurston and Ito (1999) suggest about a 0.3 percent increase in the risk of premature mortality for a 10-$\mu g/m^3$ increase in daily 1-hour maximum ozone. Touloumi et al. (1997) also find an association between 1-hour maximum ozone levels and daily deaths. However, Samet et al. (2000b) report an association between ozone concentrations and mortality in the summer, when ozone concentrations are at their highest, but not over the full year. In his review of the existing literature, Schwartz (1997) finds no compelling evidence of a mortality effect.

A primary reason for disagreement in the literature is the complications that arise in modeling ozone effects. Thurston and Ito (1999) note that because ozone concentrations are highly correlated with temperature, studies that fail to control adequately for weather are likely to misrepresent the relationship between ozone and mortality. Research has also linked ozone exposure to reduced lung function, aggravation of preexisting respiratory ailments, and hospital admissions and emergency room visits linked to respiratory causes (Thurston and Ito 1999).

Because of the difference in molecular weight between ozone and fine particulates, it is not straightforward to compare the potency of these two substances on the basis of such measures as the percentage change in mortality risk per $\mu g/m^3$ change in pollution concentration. Based on elasticities computed from various epidemiological studies (where the elasticity is the percentage change in mortality risk per average percentage change in pollution concentration across the study sample), acute PM_{10}-related mortality appears to be about four to five times more potent than that related to ozone.[9]

[9] To estimate these elasticities, the percent change in mortality rate per 1 $\mu g/m^3$ (the relative risk coefficient minus 1) taken from the literature was divided by the percent change in baseline concentration, using an average or central concentration value from the study as a baseline. Elasticities were calculated on the basis of the parameters of Samet et al. (2000b) because of the high quality of this study and because both ozone and particulate concentrations are represented in the same model. For acute mortality from particulates, the relative risk estimate is 1.005 for an increase of approximately 38 percent in the mean concentration in the study, for an estimated elasticity of 0.013. For ozone, the relative risk estimate is 1.0013 for an increase of approximately 43 percent in the central concentration in the study, for an elasticity of 0.003.

Mobile source air toxics pose the third major health concern associated with vehicular emissions. EPA has estimated that mobile sources of air toxics account for as much as half of all cancers attributed to outdoor sources of air toxics (EPA 1994). A particular concern is benzene, a known carcinogen that is a component of gasoline. Acetaldehyde, 1,3-butadiene, and formaldehyde are also "reasonably anticipated" carcinogens under the National Toxicology Program's classification system (HEI 1999). Uncertainties in estimating both the actual human exposure to these pollutants and the magnitude of the carcinogenic risk to humans are currently too great to allow for a meaningful assessment of the potential impact of reducing emissions of air toxics (HEI 1996).

Sensitive populations were identified in the process of setting the National Ambient Air Quality Standards under the Clean Air Act. These subgroups, identified through clinical, field, and epidemiological studies of the health effects of the six criteria pollutants, include children, the elderly, those with cardiopulmonary diseases, and pregnant women. Air pollution aggravates existing pathologies among these groups (Key 1998) while also affecting those with underdeveloped or vulnerable immune systems. Woodruff et al. (1997) found a relative increase in mortality risk for infants from PM_{10} exposure similar to that estimated for adults by Pope et al. (1995), though over a shorter time frame of exposure, suggesting that infants face a greater risk from exposure than adults (Pope and Dockery 1999). Cohen and Nikula (1999) describe three studies that examined the association between exposure to vehicular air pollution and respiratory health in children. Brunekreef et al. (1997) and de Hartog et al. (1997) both found evidence of an inverse relationship between indices of pulmonary function and truck-traffic density and/or black smoke concentration in schools. Similarly, van Vliet et al. (1997) found that both truck-traffic density and in-school concentrations of black smoke were positively associated with prevalence of reported respiratory symptoms. Finally, a role for socioeconomic factors in determining risk from air pollution has been suggested. For example, in their reanalysis of the work of Pope et al. (1995), Krewski et al. (2000) found evidence of an inverse relationship between mortality risk from PM exposure and education.

Monetary Benefits

Private and public preferences for reducing negative health outcomes are important to the extent that certain pollutants are more likely than others to

affect particular groups or types of health outcomes (e.g., mortality, hospital admissions, colds). Individuals make trade-offs in everyday living that reveal how much they care about reducing health risks versus meeting other needs or wants, such as spending their incomes elsewhere or arriving on time at a meeting (e.g., by driving faster than they would otherwise).

These preferences have been captured with two types of indexes—quality-adjusted life-years (QALYs) and disability-adjusted life-year (DALYs)—and with monetary values. The life-years approach involves totaling life-years saved as a result of various policies and adding this figure to years with quality-of-life improvements, thereby capturing reduced morbidity. The monetary valuation approach entails converting preferences for reducing mortality and morbidity risks to monetary measures. Both approaches rest on a variety of strong assumptions (with the QALY/DALY assumptions being more restrictive about preferences) and have significant limitations. Research is ongoing to improve these approaches and determine the advantages and disadvantages of each. The life-years approach is widely used in the health care system and has been employed in rulemakings, particularly by the Food and Drug Administration. The monetary approach is used in cost/benefit analysis and by many federal and state agencies, most notably EPA and the U.S. Department of Transportation (DOT).

Water Pollution

In the three decades since passage of the Clean Water Act, vast improvements have been made in the United States and worldwide in cleaning up water resources and preventing future pollution. Cleanup of point (or stationary) sources accounts for most of these advances; little progress has been made on reducing non–point source pollution, including the road and parking lot runoff, airport runway runoff, and railroad runoff associated with transportation.

Studies have shown that increased traffic volume in watersheds increases pollutant loads (Benfield et al. 1999). Routine vehicle operations involve leakage of brake fluid, antifreeze compounds, lubricating oil, engine oil, grease, and gasoline onto the highway surface, which can lead to the contamination of surface water and groundwater, as can the washing of fine particles from tires and road surfaces into water supplies. Routine vehicle maintenance also can result in water contamination, despite regulatory efforts to limit such contamination. Moreover, routine activities such as road repair, deicing, right-of-

way maintenance,[10] and the transport of hazardous materials pose a significant risk of polluting water resources.

People become subject to negative health effects of water pollution by drinking contaminated water (either surface or groundwater), swimming in or otherwise contacting contaminated water, or eating fish or other organisms that have come in contact with contamination or have bioaccumulated contamination in their tissues. Of particular concern is acid deposition to soil and water (as well as to forests; see Chapter 3) from emissions of SO_2 and NO_x due to burning of gasoline and diesel fuel. Such deposition leaches out aluminum, mercury, and other substances in soils, which, through runoff, can bioaccumulate in fish. In addition, there is speculation that high eutrophication levels (caused by excessive nitrification of estuaries, lakes, and streams through nitrate deposition) can trigger Pfiesteria outbreaks.

Upon discovering fish contamination, authorities may issue fish consumption advisories (FCAs) to limit the exposure of recreational fisherman and fish consumers. Direct health effects may occur until the elevated levels of pollution in fish are discovered and as a result of violations (knowingly or not) of the FCA. Economic losses to recreational and commercial fisheries (and consumers) may also result from an FCA. Such losses, while not themselves health effects, are the result of trying to limit human exposure to toxicants. None of the above linkages are well understood.

Solid Wastes

Transportation is a major generator of solid wastes through the disposal of vehicles and parts as well as construction materials. Human health effects from solid waste can occur through the release of toxic substances from scrapped vehicles or parts of vehicles. Although an active battery recycling market exists, exposure to acid or lead from batteries is a possible concern, as is exposure to heavy metals that exist in small but growing amounts in vehicle electronics. Two additional concerns are with oil from scrapped parts and vehicles and with used tires. Oil is regularly recycled through market mechanisms; however, some oil may leach into groundwater or end up in surface water. Used tires are increasingly being recycled in the United States for use in a variety of products,

[10] Most departments of transportation maintain the rights-of-way for roadways, railroads, and mass transit lines through the use of petrochemical pesticides, herbicides, and insecticides. These toxic chemicals leach into groundwater or are washed into surface water during precipitation events.

as well as to fuel industrial processes and generate electricity, yet they are still frequently discarded. There are three potential health problems associated with these tires: pollution from tire fires, pollution from the use of tires as fuel (in boilers not environmentally suited to their burning), and the contribution of tire piles to the propagation of mosquito-borne diseases. The concern with tire fires is primarily with the particulates they emit, which, as noted above, are related to excess mortality; little is known about the frequency and toxicity of such fires, however. Inappropriate use of tires as fuel is not thought to be a problem in the United States, but is a problem in Mexico near the U.S. border (Blackman et al. 2001). Finally, tires provide an excellent habitat for mosquitoes. The extent of this problem in the United States is unknown, although Blackman et al. (2001) found it to be negligible in Juarez, Mexico, where large tire piles exist.

Noise

Noise pollution—defined as any form of unwanted or unhealthy sound (FHWA 1995)—has been studied extensively with respect to air transportation, and research also has addressed the noise effects of highways and transit (TRB 1987; TRB 1990; Balachandran 1992; Wyse 1994). Studies have shown that some of the most pervasive sources of noise, in both rural and urban environments, are those associated with transportation (FHWA 1995). Noise pollution is understood to have a variety of effects on humans, in addition to the obvious direct effects of annoyance and interference with hearing (Gottlob 1985; Green 1987). For example, noise has been shown to have both auditory and nonauditory adverse physiological effects (Kryter 1994), and some studies indicate linkages between noise and hypertension (Fay 1991; Kryter 1994).

In the absence of interventions, growth in surface transportation activities is likely to increase both overall noise levels and population exposure to noise (TRB 1990; Fleming et al. 2000). Strategies to address the problem include redesign of vehicles to reduce noise from engines and tires; redesign of pavements to reduce noise production; location and design of transportation infrastructure to avoid or minimize noise transmission; installation of barriers or other devices to deflect noise away from populations; and design and retrofitting of buildings and outdoor areas to reduce indoor noise exposure, mask noise, or cancel out noise (TRB 1987; TRB 1990). The relative effectiveness of these strategies, their public acceptability, and their efficacy (in terms of noise reduction and overall effects on human health) remain topics for additional

research (OECD 1991; Job 1991; Balachandran 1992; Lansdell and Cameron 1998; TRB 1998).

RECOMMENDATIONS

FHWA, EPA, and other government agencies have taken on the task of developing research agendas related to surface transportation and human health. In the following recommendations, the Advisory Board proposes research that cuts across the concerns of transportation, environmental, and health agencies and is aimed at the development of a stronger understanding of fundamental processes as well as policy linkages.

Recommendation 1-1.
Develop a better understanding of "modal" emissions.[11]

While knowledge about the linkage between emissions and human health impacts is increasing, a better understanding is still needed of how the release of emissions is altered as a result of congestion and travel behavior. Until quite recently, the standard data on emissions were developed for an average vehicle speed and then adjusted by a function for higher or lower average speed. Emissions of the major gasoline-vehicle pollutants (VOCs, CO, and NO_x) are highly sensitive to acceleration, deceleration, and other driving modes. Given this sensitivity, information on "modal" emissions is needed to understand how emissions respond to changes in congestion or in travel behavior that affect driving modes. While research has been conducted on this topic, much more needs to be known before the effects of policy on emissions can be estimated reliably. This need extends to alternative-fuel vehicles (including those with ethanol additives); hybrid and electric vehicles (for which attention also should be given to emissions from power plants for battery charging); and, in the future, vehicles running on fuel cells (with consideration of upstream emissions). This need also extends to increasing the numbers and types of vehicles tested to generate emission estimates.

[11] The repository of accepted information about emissions from mobile sources is embodied in EPA's MOBILE model, which is required for use in developing State Implementation Plans to meet the National Ambient Air Quality Standards. This model has a number of major limitations, both in its goals and in its information base, which represent research needs.

HOL-00061

Recommendation 1-2.
Extend understanding of vehicle emissions to include toxic pollutants.

Understanding of overall PM and VOC emissions has been the objective of considerable research, with the caveat about modal emissions noted earlier. However, better, more detailed characterizations of these vehicle emissions are needed in light of the increasing attention being paid to the VOCs in gasoline and the various fine particulates in diesel fuel, as well as the growing awareness of mobile source air toxics in general as possible carcinogens and contributors to a variety of respiratory ailments, immune and nervous system disorders, and birth defects.

Recommendation 1-3.
Improve the performance and implementation of air quality models.

The development of improved air quality models is critically important for appropriate assessment of the effects of mobile sources of pollutant emissions on human health, as it is through these models that one can trace changes in concentrations at given receptors back to changes in emission source locations and types. Until recently, the effects on ozone of VOCs and NO_x emissions and the effects on particulates of NO_x and SO_x emissions were modeled separately. More recent efforts have focused on the development of models that integrate the air chemistry for producing ozone and particulate species (such as sulfates and nitrates). These models are just beginning to be implemented, and significant validation, testing, and application will be needed before policymakers will trust their output. An additional concern is the data inputs to the models concerning background VOC and ammonia concentrations. Until such models are in the mainstream and the data underlying them are viewed as credible, the contribution of mobile sources to air quality cannot be assessed reliably.

Recommendation 1-4.
Improve the breadth of understanding of the toxicity of mobile source air pollution.

Mobile source emissions comprise several pollutants whose health effects are not well understood. Little research has been done, for example, on the actual human cancer risk from mobile source air toxics at current exposure levels. Likewise, understanding of the potential health risks of fuel additives such as

MTBE at low exposure levels must be augmented, particularly as the use of additives becomes more prevalent and the additives themselves more varied. While the use of additives reduces emissions and thus the health effects of more conventional pollutants, a better understanding of any potential risk trade-offs is necessary.

Finally, road dust entrained by mobile sources has been found to contribute up to 60 to 70 percent of the inventory of total suspended particulates from mobile sources. Little is known, however, about the effect of exposure to road dust on mortality or morbidity risks. A better understanding of these risks is needed so that strategies for reducing road dust can be devised and prioritized.

Recommendation 1-5.
Improve understanding of the relative potency of various air pollutants.

Although EPA recently promulgated the world's first standard for fine particulates (particles with a diameter of less than 2.5 microns), uncertainties exist about the toxicity of various particle types and sizes. Until this uncertainty is reduced, the risk remains that resources will be wasted on controlling pollutants that have little or no effect on public health, while the effects of other pollutants may be underestimated. A good example of this point is nitrates, which are formed from NO_x emissions, water vapor, and ammonia. None of the key epidemiological studies relied upon by EPA in its rulemakings provides information about the effect of nitrate exposure on health. Yet nitrates are routinely assumed to be as potent an agent of mortality risk as the average $PM_{2.5}$ particle. If this assumption were to prove incorrect and nitrates turned out to be far less potent, the rationale for controlling NO_x would be significantly weakened; if, on the other hand, nitrates were shown to be more potent, different strategies might have to be introduced. Research on this topic is sorely needed. At the same time, NO_x emissions have been shown to scavenge ozone, meaning that reductions in NO_x would, at times and in certain locations, lead to higher, not lower ozone concentrations. Also, few studies have found an effect of ozone or NO_x on mortality risk, and there is still no consensus on the effect of ozone on mortality risk. Generally, effects found are of an order of magnitude lower than those found for sulfates and $PM_{2.5}$. Research is needed to establish and rank the potency of various pollutants.

In addition, mobile sources emit a complex mixture of pollutants, making it extremely difficult to establish a direct causal linkage between emission controls (particularly driving reductions or fuel switching) and health benefits.

HOL-00063

A better understanding is needed of the synergistic and antagonistic relationships between pollutants and their effects on human health.

Special concern: Particulate matter measured by mass. EPA's newly promulgated standard for fine particulates is stated in terms of the weight of the particles in the air, i.e., $\mu g/m^3$. However, an emerging school of thought supports measuring particles by the number of particles per volume of air, as well as by mass. Specifically, it has been asserted that the particle surface area to which the lung is exposed probably is more important for determining health effects than the mass of the particles (Key 1998). Additional research is clearly needed in this area.

Recommendation 1-6.
Improve understanding of risks to sensitive populations.

Further investigation is needed of the environmental and genetic risk factors for respiratory and pulmonary disease and the interaction between these factors. Current data and research findings suggest that an exposure–response relationship exists between high levels of air pollution and aggravated conditions among vulnerable populations. More research is needed to determine the disease-specific conditions involved, the conditions of exposure that are most important, and the long-term implications of these findings. Research on the adverse effects of transportation-related exposures for vehicle occupants, travelers on congested highways, residents and workers in buildings near heavily traveled streets, and other vulnerable groups is particularly important for planners and decision makers, who will need to devise appropriate ways to avoid, minimize, or mitigate those effects.

Recommendation 1-7.
Improve understanding of preferences for improved health.

Not all health effects resulting from air pollution are of equal importance. One criterion for allocating scarce research dollars should be to determine those health effects deemed most important by the public. Research has focused on estimating these preferences across health outcomes in terms of people's willingness to pay for health improvements. However, the context and populations involved in these economic studies may have been inappropriate for generalizing such preferences, particularly preferences for reductions in mortality risk associated with air pollution. Addressing the preferences of at-risk

populations—including the elderly and the infirm—should be a major social science research priority.[12] Research should also address parental preferences concerning children's health, including avoidance of problems that arise from fetal exposure, and how such preferences are affected by latency, dread, involuntary exposure, and other features of the air pollution context. Research should be directed as well at describing preferences through the life-years (QALY) approach and at contrasting this approach with the monetary valuation approach.

Recommendation 1-8.

Improve understanding of the relationships between transportation activities and human health with regard to pollution of water bodies and solid waste disposal.

A comprehensive accounting is needed of the many pathways by which surface transportation activities affect human health through contact with polluted water or contaminated fish or through linkages with solid waste from vehicle or parts scrappage. Greater understanding is also needed of the social and economic consequences of attempts to limit such contact, for example, through fish consumption advisories or the creation of more comprehensive recycling markets.

Recommendation 1-9.

Improve cost-effectiveness, cost/benefit analysis.

Information on emissions, air quality, health effects, and valuation is most valuable when used to choose approaches and policies for controlling pollution. To help make these choices, policymakers need information relating the costs of various approaches and policies to the anticipated benefits—either in physical or QALY/DALY terms (which implies a cost-effectiveness analysis) or in monetary terms (which implies cost/benefit analysis). Research is needed on methods for assessing the economic costs of alternative approaches and policies and for combining them appropriately with physical or monetary measures of benefits. This need is particularly acute in light of the new regulatory concern for fine particulates and the need to assess as effectiveness measures not just emission reductions, but also (because they have common precursor

[12] Research on this topic should also consider the effects of such factors as income, education, employment status, race/ethnicity, sex, and age on revealed and expressed preferences.

emissions) reductions in concentrations of both ozone and fine particulates combined. As regulations directed at transportation emissions may affect differentially the various phases of the transportation system, including the production of vehicles and their scrappage, as well as the mix of vehicles in use and the amount they are driven, research methods are needed for capturing these effects across the vehicle life cycle.

Special concern: Technological improvements. Technological improvements in transportation must be evaluated and their costs and benefits fully characterized in terms of their impacts on human health. For example, the fuel additive MTBE was introduced as a technological advance for improving air quality, but also adversely impacts water quality and thus poses potential risks to human health through both inhalation and ingestion. In the past, technological improvements designed to improve air quality have also exacerbated noise pollution. The tightening of standards for vehicle emissions of VOCs, NO_x, and CO and for the sulfur content of diesel fuel and gasoline—as well as the penetration of reduced emissions vehicles required by federal law and regulation as well as alternative-fuel vehicles—will diminish the air quality problems associated with these pollutants. But as new fuels and forms of transport emerge, so, too, will new types of pollution problems. Research efforts should outpace these major changes in transportation technology. More research is needed to understand the potential human health impacts of transportation technologies prior to their full implementation.

Special concern: Regulatory constraints. Conformity requirements in the Clean Air Act were intended to incorporate air quality considerations into transportation planning. In the process, significant requirements were placed on the transportation community not only to meet demands for reduced congestion, but also to achieve and maintain clean air goals. Some of these burdens are tied to the procedural aspects of the conformity process, others are associated with the state implementation plan process, and others are the inevitable result of tensions between the congestion and air quality goals. Research is needed to identify mechanisms for reducing these burdens and for developing constructive and cooperative ties between the agencies responsible for transportation planning and for maintaining air quality. Conduct of this research may necessitate closer linkages between air quality and transportation models.

Another regulatory issue arises because of growing understanding of the long-range transport of important pollutants, such as ozone and fine particulates. Both of these pollutants may travel across half the continent, and long-range transport is an issue for mobile as well as stationary sources. The Clean Air Act

was designed primarily under the premise that localities make their own messes and thus are responsible for cleaning them up. Understanding of long-range transport has challenged that assumption and called into question the appropriateness of making the locality (the air basin) the centerpiece of the regulatory strategy. This issue affects the locus of control of transportation emissions through transportation control measures and other, nonfederal approaches.

Recommendation 1-10.

Conduct further research on the singular and cumulative impacts of transportation-related noise.

Further studies are needed to provide data that can be used to measure the singular and cumulative impacts of transportation-related noise separately—focusing on noise annoyance, noise exposure, and the interaction between the two.

References

Abbreviations

EIA	Energy Information Administration
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
HEI	Health Effects Institute
NRC	National Research Council
OECD	Organization for Economic Cooperation and Development
TRB	Transportation Research Board

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3

Research Area 2

ECOLOGY AND NATURAL SYSTEMS

A 4-million-mile public road network carrying 200 million vehicles covers about 1 percent of the United States—equal to the size of South Carolina. A recent article published in *Conservation Biology* presenting the first calculation of the ecological effects of this road system suggests that roughly one-fifth of the total U.S. land surface is directly affected (Forman 2000).

The extent of what is unknown about the ecological effects of transportation is even more surprising. For example, no one has calculated how many streams, lakes, and wells are polluted by chemicals from roads, airport runways, and railroads, or how many species are potentially endangered because of roadkills and habitat changes. While traffic noise by highways may prove bothersome, little is known about whether it has serious negative effects on numerous native animals. Nor is it known how often the many nonnative plants along roadsides and railroads invade nearby ranchlands, farmlands, and nature reserves. In addition, research remains scarce on how well road-crossing structures for wildlife are working, as well as on the influence of road systems on habitat fragmentation and the ecology of landscapes. And compared with roads, still less is known about the ecological effects of railroads.

The current road network was essentially built prior to the first Earth Day in 1970, long before the explosion in environmental knowledge represented by modern ecology. The numbers of vehicles, vehicle-miles traveled (VMT), and traffic jams have continued to increase, along with resultant air pollutants, traffic noise, water-transported chemicals, barriers to wildlife crossing, and pressure for additions to the road network. Therefore, it is no

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surprise that the cumulative damage to nature due to surface transportation continues to expand and permeate the land. Today, then, the environmental effects of the road system are extensive and growing (as illustrated in Box 3-1), yet they are barely recognized by most people and poorly understood by the scientific community.

The ecosystem services provided to humankind include drinking water, fishing, hunting, nature appreciation, swimming, aesthetics, inspiration, flood control, and more. Indeed, society demands, votes for, funds, and treasures these services. Fortunately, nature is resilient. Although the degradation is substantial, much can be done to mitigate the damage to groundwater, biodiversity, soil surfaces, native vegetation, streams, lakes, fish, and wildlife populations caused by surface transportation.

Major issues loom on the horizon, however. As noted earlier, the American population is expected to grow by another 60 million people in the next 25 years. Where the expanded population will decide to live and the resulting changes in land use are linked directly to changes in the transportation system. Similarly, it is important to estimate how many more vehicles and how much traffic will appear on the road network, as well as which roads will likely be widened and where new roads will emerge. These considerations lead to the further critical questions of how much land will be consumed for development and how many natural systems will be significantly altered or damaged by roads.

A window of opportunity now exists. The key step in exploiting this opportunity is to catalyze and integrate research on transportation and natural systems. New research methods, including displays and models for analyzing geographic information, tracking emissions of pollutants, performing DNA analyses of wildlife, and assessing road/rail-crossing mitigation designs, are beginning to offer major new insights. Research should lead to valuable results. For example, research on alternative road/rail-side designs and road/rail-crossing structures should lead to less habitat fragmentation and more-natural wildlife movement. Studies on chemicals and sediments associated with roads, culverts, airport runways, railroads, and bridges can be expected to result in more native fish populations in streams. And research on the transport of fine particles and dust from vehicle use should help produce clearer lake water and more naturally functioning ecosystems. In view of today's massive road network and vehicle fleet, such restorations of nature will not return the land to a pretransportation state. However, implementation of research results should lead to improvements in natural systems across the road network, as well as

Box 3-1

What Nature Is Like Near a Busy Highway

Consider taking a leisurely stroll or nature walk along the edge of a woods by a busy two-lane highway. The noise level quickly eliminates leisurely from your mind, especially if, say, every 20th vehicle or so is a truck. Underfoot an abundance of objects appears that could have been recycled. If you briefly emerge at the roadside, speeding vehicles evoke a new sense: danger. Drivers stare and occasionally reach for their cell phones. Busy roads and people outdoors seem incompatible.

So you move back into the woods' edge to look more closely. Many of the native forest birds seem to be missing; apparently it is too noisy for them, even quite a distance into the forest. Indeed, few other forest vertebrates—mammals, frogs, turtles, snakes—tend to be around; this must be a road-avoidance zone for them, too. If you had ventured to walk along the roadside, you might have seen roadkilled animals, though carcasses do not last long in areas populated by roadkill scavengers. The combination of a road-avoidance zone and a roadkill strip makes you suddenly realize what a barrier the busy highway is, dividing large natural populations into small ones that could be prone to extinction. Moreover, wildlife movement corridors that connect distant patches across the landscape may be severed. You wonder if this is an inadvertent collective assault on biodiversity.

Unlike the adjoining forest interior, the forest edge is commonly full of generalist "weedy" plants, some being nonnative exotics and all persisting because of the open environment of the frequently mowed roadside. The roadside vegetation growing on earth that was homogenized and smoothed during road construction appears monotonous, largely devoid of its natural heterogeneity and richness. Grasses and exotic plants tend to be abundant at the expense of native wildflowers. Straight open roadside ditches carry warmed-up water, alternating with pulses of rainwater, into a narrow wooded stream that lost its valuable curves during road construction. An array of invisible chemicals has blanketed the roadside and penetrates the forest; heavy metals such as zinc and cadmium, nitrogen oxides, hydrocarbons, herbicides,

(continued)

Box 3-1 *(continued)* **WHAT NATURE IS LIKE NEAR A BUSY HIGHWAY**

and road salt are typical. Entering the streams, wetlands, and groundwater around you, they inhibit all kinds of natural processes and are toxic to countless species.

What is it like next to a busy road? There is no place for a neighborhood walk, or a path in a park, or even a nature reserve. Here nature is both severed and impoverished. With a well-used 4-million-mile infrastructure, U.S. transportation faces a unique challenge: to reconnect nature. Targeted research undertaken now could bring us notably closer to meeting this challenge.

reestablishment and protection of near-natural conditions in areas especially important to society.

It must be recognized that the application of research results poses a formidable challenge because of dispersed data, unclear relationships between transportation and natural-resource bodies, and inertia. Nonetheless, high-quality targeted research precedes effective applications, and therefore is an immediate priority. As in the examples just given, applications based on research should produce visible results quickly, whereas if the research is not done, problems will persist, and effective applications will be delayed.

SURFACE TRANSPORTATION AND NATURAL SYSTEMS

As discussed earlier, although surface transportation includes rail corridors and managed waterways with barge transport, the focus here is on road systems. Four major groups of issues highlight the close linkage between road transportation and natural systems. These issues, together with a summary of the state of knowledge on each, are described below.

Biodiversity and Wildlife

Headlines such as "Roadkill Causes Crash," "Wildlife Corridor Severed," "Amphibian Tunnels Work," and "Rare Plant and Butterfly Discovered in Roadside" increasingly reflect the importance of this subject to society.

Roads and traffic are often mentioned in discussions of endangered species, impacts on stream fish, and the spread of exotic species. In essence, transportation's effects on biodiversity and wildlife are a primary reason why, in state after state, the public raises questions about the environmental impacts of roads and vehicles (Conover et al. 1995; *Natuur Over Wegen* 1995; Evink et al. 1999; Harper-Lowe 1999). Calls for new solutions also are increasingly heard from environmental scientists, the transportation community, and decision makers.

Only two aspects of biodiversity and wildlife associated with surface transportation are well documented: common roadside plants and animal roadkill (Bennett 1999; Fahrig et al. 1995; Romin and Bissonette 1996; Harper-Lore 1999). Many aspects remain as little-explored frontiers: rare plants; habitat heterogeneity related to construction, mowing, maintenance, and management regimes; exotic species invading from roadsides to surrounding lands; the barrier effect on wildlife movement (Fahrig et al. 1995); optimal designs of road-crossing structures for animals (Clevenger and Waltho 2000); roadside microclimate altering adjacent woods; effects of traffic noise on populations (Reijnen et al. 1996); road-avoidance zones of different animals (Rost and Bailey 1979); and designs that can reduce disturbance effects. Because the road system is so extensive, biodiversity and wildlife movement near roads are an enormously important research challenge for the nation. [Similarly, the ecological effects of rail and barge transportation are little known (Nelson et al. 2001)].

Water and Aquatic Ecosystems

Transportation facilities are a defining feature of the hydrologic system of numerous landscapes. Roads crisscross streams, rivers, and wetlands on the land surface, as well as underground lakes in the form of groundwater and aquifers. Drainage patterns are commonly blocked and altered. Thus, because of the need to control water on and around a road, road systems normally have a distinctive defined set of hydrologic conditions. Furthermore, roads typically are the places along streams and rivers where human use and the environment interact most intensively. These interactions may be benign or damaging. Highway runoff can deliver a wide range of contaminants from road surfaces to receiving streams and other bodies of water (GKY and Associates 2001). In fact, to control water on and around the roadway, highway designs usually reflect an attempt to accelerate water flows away from the

road. The result is that natural hydrologic regimes in the surroundings are altered by highway construction, and aquatic ecosystems are regularly shocked by large flushes of water and contaminant loading (Nelson et al. 2001). As a consequence, the overall environmental quality of aquatic systems suffers.

An extensive literature exists on the overall characteristics and composition of water running off of highways. These studies confirm that the wide range of human-produced materials that reach the road surface and roadside, together with spills of diverse materials, contribute heavily to contamination of highway runoff. In contrast, the effects of highway runoff on receiving streams and lakes are less well understood. Contaminants are funneled through road drainage systems to aquatic ecosystems. Some of the direct effects of this runoff on certain plant and animal species have been identified, but most contaminant–species interactions remain unknown. Perhaps more important, the direct effects of highway runoff on patterns and processes of aquatic ecosystems are poorly understood. One major constraint has been that ecosystems typically encompass both the highway and the surrounding landscape. The effects of highway runoff have been difficult to separate from those due to changing land use, permitted pollutant discharges, and natural change that may occur in the absence of a road. Furthermore, placing limits on the assessment of effects transportation systems on the environment is difficult. Separating the direct effects of the road/highway and its design from the numerous broader effects of a road, such as providing access to a new or remote area, remains a research challenge.

Ecological Effects of Air Pollutants

Transportation systems are the path for moving sources of air pollutants (see Chapter 2). Engines combusting fuel produce pollutant emissions, and the passage of vehicles generates dust and suspensions that carry pollutants away from the transportation corridor. Thus an array of pollutants consistent with the traffic volume, type, and, to a lesser extent, road surface emanate from road corridors. These pollutants have numerous effects on the environment—some short term, such as a smog alert, and others long term, such as climate change. At a local scale, wind carries an assortment of materials from roads and vehicles onto roadsides, as well as adjoining lands and communities. Dead foliage from herbicides and road salt catch the eye. Most dust and heavy metals tend to be carried short distances from the road surface. However, materials

such as sulfur dioxide, carbon dioxide, hydrocarbons, nitrogen oxide, and perhaps fine particulates may spread over a larger surrounding area and produce significant ecological effects (TRB 1997; Angold 1997; IPCC 2001). At a regional scale, ozone and nitrogen oxide sometimes accumulate in the lower atmosphere at levels sufficient to alter plants and natural communities. Globally, the greenhouse gas carbon dioxide (plus aerosol-particulate matter) is associated with climate change, which is expected to lead to a range of major ecological alterations at all scales from local to global. Some of these alterations will not only affect natural systems, but also have significant effects on the ecology of infectious disease.

Much is known about the production of pollutants from the internal combustion engine, as well as their aerial transport, destinations, and breakdown. For example, we understand the mechanisms of smog formation and can trace certain pollutants enormous distances around the globe. In contrast, the ecological effects of these airborne pollutants are much less well understood. For instance, dust and fine particles reaching Lake Tahoe and the Great Lakes are believed to be a significant cause of eutrophication, yet little is directly known about the role of road systems—adjacent, nearby, or distant—in this phenomenon. The effects of air pollutants both on terrestrial and aquatic ecosystems and on key plant and animal species need to be studied.

The ecological effects of certain locally airborne pollutants, such as salt, herbicides, and some heavy metals, are well understood relative to those of many other pollutants (TRB 1997; IPCC 2001). As a key greenhouse gas, for example, carbon dioxide is actively studied, but its ecological impacts, though assumed to be large, are uncertain. At the regional scale, ozone, sulfur dioxide, and nitrogen oxide damage certain crop plants and forest trees, but the effects on biodiversity in natural communities remain relatively obscure (Winner 1994). Similarly at the local level, studies have often focused on the relative tolerance of species to road and vehicle pollutants, instead of on the pollutants' effects on food chains or natural communities. Research appears to be scarce as well on the effects of particulates on wildlife populations, and on the ecological effects of hydrocarbons and certain heavy metals.

Landscape Ecology of Transportation Systems

Landscape ecology is a rapidly developing body of knowledge and research that represents a relatively new, highly useful, and far-reaching dimension for consideration in transportation planning and activity. Landscape ecology

(including the related areas of conservation biology and watershed science) provides principles and models that directly address habitat fragmentation, arrangements of green patches, wildlife corridors for foraging–dispersal–migration, groundwater and surface-water flow paths, effects of small populations in enclosed polygons, remote-area impacts due to human access, sources and sinks in the landscape, changing spatial patterns over time, and ecologically optimum spatial models (Forman 1995; Reed et al. 1996; Turner et al. 2001), all of which can be related to transportation networks. Focusing precisely at the scale of road systems, this approach integrates the science of ecology with spatial pattern, process, and change at the whole-landscape, or human, scale. Integrating road systems with these principles, patterns, processes, and models represents a key collaborative opportunity for engineers, ecologists, and planners (Findlay and Houlahan 1996; Canters 1997; Evink et al. 1999). The results of such collaboration should have notable application in transportation planning, evaluation of transportation projects, and overall environmental stewardship. Most important, the results should become visible on the road system and on the land.

Although transportation systems and ecological flows across landscapes operate at the same spatial scale, the two subjects have just begun to be linked (Canters 1997; TRB 1997; Evink et al. 1999). Scattered studies and research done for other purposes point to a promising frontier. Ecologists' rigorous spatial models and analyses of landscapes now need to incorporate road systems (Forman 1995; Reed et al. 1996; Turner et al. 2001). The workings of the major ecological flows and movements across the landscape should be integrated with traffic flows on road networks. Effectively incorporating principles and models of landscape ecology into transportation planning and project evaluation and meshing ecological solutions with other societal goals, such as recreation and reintegration of bisected communities, represent important research opportunities. The development of models for landscape effects near roads is a promising area for collaboration among engineers, ecologists, and planners, but will require research and testing (Forman and Alexander 1998; Forman 2000).

RECOMMENDATIONS

The recommendations presented below fall into the four areas discussed in the previous section. These four research foci differ markedly from the existing

research priorities and programs in transportation. While they represent largely new initiatives, the proposed work would build on strong foundations in transportation research in such areas as hydrology, sediment flow, roadside vegetation management, roadkills, traffic flows, and pollutant emissions. Funding agencies and sources both inside and outside the transportation field have shown little interest in supporting the proposed research; thus very little research is being done in most of these areas. Successful research on the topics outlined below will require expertise from both within and outside the transportation community. Thus research funding mechanisms will be required that can attract researchers from other key disciplines to collaboration with the transportation community. The results produced will then provide a sound basis for effective planning, policy, and implementation.

Biodiversity and Wildlife

Recommendation 2-1.
Expand research and thinking on the uses for and vegetation of transportation corridors in the United States.

Roadsides in the United States cover an area equal to 100,000 football fields for every state,[1] and on intensively used land, railroad rights-of-way are often refuges for rare native plants. With few ecological benefits provided, these areas represent an enormous societal resource warranting creative thinking and careful research. Roadsides today are designed primarily for the safety of vehicles that run off the road, with little attention to other values important to society, such as visibility for wildlife, absorption of some toxic chemicals, harboring of rare plants, and aesthetics. Currently, much is known about the types of roadside plants and vegetation and the relative abundance of native and exotic (nonnative) plants present in these areas (Harper-Lore 1999). On the other hand, only a partial picture emerges for rare plants at roadsides, the ecological effects of mowing, and the effects of vehicle- and road-generated chemicals.

Many important roadside-related questions remain unanswered. For example, which spatial and temporal controls are ecologically best for native plants, butterflies, birds, and whole communities (*Natuur Over Wegen* 1995,

[1] This assumes that about 1 percent of the U.S. land area is road right-of-way (TRB 1997), perhaps half of that is roadside, and a football field averages approximately 1 hectare.

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Forman and Alexander 1998)? What wildlife species should and should not be encouraged by increasing food and/or cover in roadside areas? How can bridges, signs, and other road structures be designed to increase the populations of desirable species? What are the main sources for colonization of roadside exotic species, and how often do exotics spread along roadsides (Harper-Lore 1999)? Which chemical substances from vehicles and roads affect roadside vegetation and animals (FHWA 1996)? How much absorption and breakdown of chemicals occurs at roadsides, and would this increase if there were more woody vegetation and wetland? Finally, how can roadsides be designed to educate neighbors and travelers ecologically?

Recommendation 2-2.
Expand research efforts aimed at understanding wildlife movement near corridors, roadkill rates, and road-barrier effects and at developing efficient mitigation designs for road crossing by animals.

Although crashing into a large animal with a motorized vehicle may involve damage, human injury, or death (Conover et al. 1995; Romin and Bissonette 1996), roadkills overall appear to be a minor problem ecologically. Most animals simply reproduce at a rate that outpaces the losses. The exceptions include flagship species, such as the Florida panther and key deer, and some other state-level endangered species that probably suffer significant roadkill rates. Perhaps equally important are the many wildlife species whose foraging, dispersal, or migration movements are blocked by roads. These disruptions in natural movement patterns doubtless reverberate widely, affecting the nature of both natural ecosystems and production lands.

Certainly wildlife road-crossing structures capture the public's imagination (Evink et al. 1999; Clevenger and Waltho 2000). Humble salamander tunnels, "tunnels for toads," and "tunnels of love" for tiny mountain mammals serve to catalyze aficionados and draw ongoing media attention. Examples include some 30 Florida underpasses that have successfully provided groundwater to Everglades National Park, reduced the roadkill mortality of the threatened Florida panther, restored corridor connectivity for black bear populations, and been used by a wide range of other terrestrial fauna. The impressive wildlife overpasses in Canada's Banff National Park and in several European nations (with antecedents in New Jersey and Utah) are treasured by the respective national publics. A significant information base exists on the numbers of roadkill, and possible ways of reducing roadkill rates have been the subject of considerable

study (Romin and Bissonette 1996). A limited amount of research is also available on the road as a barrier to movement, including the frequencies of attempted and successful crossing by various animals.

Striking research gaps in knowledge also exist, however. For example, how does the arrangement of the surrounding landscape, including wildlife movement corridors, affect where different species tend to cross roads (Evink et al. 1999)? How does road and roadside design affect crossing location? Which species have the highest and lowest road kill rates? And what tunnel, underpass, and overpass designs are most effective and affordable for road crossing by which species (Clevenger and Waltho 2000)?

Recommendation 2-3.

Catalyze research on the effects of corridors and traffic on adjoining land, including traffic disturbance and the spread of invasive species.

People dislike the noise from busy highways, as evidenced by the noise barriers frequently used to separate busy roadways from residential communities. Not surprisingly, other vertebrates, such as birds, also appear to be sensitive to traffic noise (Reijnen et al. 1996). Recent research suggests that traditional avian habitat near roadsides is diminishing as a result of excessive noise levels produced by busy highways, which must have a large cumulative effect across America. Indeed, a similar avoidance zone has been noted for certain mammals, amphibians, and reptiles (Rost and Bailey 1979, Fahrig et al. 1995). Thus the evidence indicates that nature reserves and busy highways are incompatible. Indeed, the effect of roads on endangered species may often be tied to this avoidance zone.

More familiar is the concern with exotic species (Harper-Lore 1999). Ranchers fight range-weed invasions. Farmers spray herbicides and other pesticides against competitors and pest invaders. Park and wildlife refuge managers battle exotics threatening their prime lands. And nature conservationists decry the invaders that threaten the natural functioning of native ecosystems. Roadsides tend to be laden with exotic species, suggesting transportation as the source.

None of the above topics has been well researched. Some information is available on the avoidance zones near highways, where native mammals, amphibians, and reptiles tend to be at low density (Rost and Bailey 1979). Few, though more detailed, analogous studies are available on avian communities (Reijnen et al. 1996). The published literature on microclimate around roads

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appears to be limited, though the basic principles are generally clear. These research gaps are surprising because of the potential importance of the issues involved. Research is needed to determine whether the population size and species diversity of birds within hundreds of feet, even miles, of busy roads have been sharply decreased by traffic disturbance, especially noise (Reijnen et al. 1996, Forman 2000). The effect of traffic volume on species' habitats near lightly traveled roads should also be examined. More research should be conducted as well on which endangered or threatened species are affected by roads and what solutions are best for long-term protection of such species (Evink et al. 1999, Forman and Alexander 1998).

Water and Aquatic Ecosystems

Recommendation 2-4.
Conduct further research on means of restoring natural hydrologic and sediment flows and distributions in the vicinity of roads.

Because roads interact with hydrology in many ways, developing a better understanding of the interactions between roads and hydrologic systems, along with faunal connectivity, is important. These linkages are both critical and conspicuous to society in affecting streams and their channelization/restoration, natural water tables and aquifers, wetland drainage and mitigation, peak flows and floods, stream and river migration, and other natural floodplain processes. In each case, water quantity and quality are linked. For example, road drainage that changes stream flows alters both the physical form and the habitat of the stream channel, as well as the water quality conditions within the channel, and may have a direct impact on faunal movement.

Because hydrologic conditions around corridors are the result of transportation-system design processes, the major patterns of road hydrology are well documented. It is generally clear, for example, how highway hydrology interacts with the hydrologic system of the landscape, as well as how basic geomorphic processes relate changing hydrology to changing channel form. In addition, the principles of erosion and sediment transport appear to be clear. How highway runoff might be modified to mitigate road–hydrology impacts remains a challenge, however, because that goal can be attained only through a better understanding of the specific effects of changing hydrology on aquatic ecosystems. Thus the effects of varying highway runoff levels on the stability of channels or the functioning of wetlands cannot be predicted. Likewise, the

deposition patterns of roadway-generated sediment in streams, rivers, and lakes warrants further study because of the array of ecological effects produced. Although awareness of watershed processes and management has increased in recent years, transportation systems, for the most part, still are evaluated separately from those processes. To build a foundation for mitigating the impacts of transportation systems on watersheds, a better understanding is needed of how road hydrology can be designed to meet the objectives of watershed management programs, which are increasingly focused on maintenance and restoration of environmental quality. Research on water and sediment distributions and flows that link the road corridor to the surrounding land will be key in this regard. Research should also be conducted on the various methodologies for handling and treating highway stormwater quantity and quality to prevent downstream effects.

Recommendation 2-5.

Expand research on transportation's effects on water quality, aquatic ecosystems, and fish in various bodies of water and on ecologically effective solutions.

Major and visible effects—such as shoreline alteration, reduced connection to adjacent upland, sediment filling-in, eutrophication, reduced oxygen levels, and altered fish populations—are attributable to roads altering coastal, lake, reservoir, pond, and vernal-pool ecosystems. Similarly, stream and river water quality is significantly altered by roads, as illustrated by bridge effects, eroded sediments, turbidity, reduced diversity of stream habitats, warm water from roadside ditches, movement of chemical substances, truncated food webs, and altered fish populations (FHWA 1996; Findlay and Houlahan 1996; Evink et al. 1999). However, a broader view of the cumulative impacts is critical.

Transportation systems provide a major mechanism for dispersing human influences across the landscape. This dispersion begins with single pathways, expands to networks, and culminates in increasing release of contaminants and corresponding environmental damage around the networks. The cumulative effects of transportation systems on water quality, considering all points of corridor–waterway interaction, must be recognized. Such a cumulative-effects analysis would go beyond simple toxicity determinations or parameter-specific regulation to examine the effects, both small and large, of water quality change over expansive spatial and temporal scales, focusing in particular on the functioning of aquatic ecosystems.

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An extensive literature on the hydrology of transportation systems includes the effects of roads on water and of water on roads. The contaminants in highway runoff have also been widely characterized, though much remains poorly known. For example, the specific ecosystem effects of highway runoff and their relative contribution to overall environmental quality in receiving waters remain elusory. The situation is complicated by the fact that some effects of highway runoff are site-specific, while others are general; moreover, runoff may exacerbate problems created by other activities in watersheds. Although general consequences may sometimes be predicted, the information available on the aquatic effects of roads often is inadequate to support effective planning. For example, although contaminant loading can be estimated, regulatory authorities often require site-specific studies, which seldom follow a uniform protocol that would permit extrapolation to other sites. Research on certain aquatic–ecosystem processes operating over decades and centuries, as is the case with road systems, also would enhance extrapolation for planning. Thus both the state of knowledge and transportation planning would be advanced by conducting broader analyses of cumulative effects instead of the narrower analysis of transportation-related effects.

Ecological Effects of Air Pollutants

Recommendation 2-6.

Support, expand, and initiate research on the ecological effects of air pollutants from roads and vehicles at the roadside, neighborhood, regional, and global levels.

Climate change is predicted to vastly alter major areas of the United States. New rainfall and temperature conditions not taken into account in initial road designs will have to be considered by transportation engineers and planners if unplanned-for failures of road components are to be avoided. At the same time, transportation is a major source of carbon dioxide, a leading greenhouse gas linked to global climate change (TRB 1997; IPCC 2001). The ecological ramifications of climate change include inundation and movement of coastlines far inland; greater climate variability; and rearrangement of soil erosion–deposition patterns, flood zones, water bodies, agricultural crops, livestock lands, and vegetation types. Regional ozone pollution in the lower atmosphere may also inhibit plants and vegetation (TRB 1997). In addition, nitrogen oxides may alter the soil, plants, and vegetation. Usually on a more local scale,

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many road- and vehicle-related materials are carried and deposited by wind, producing ecological effects; these pollutants include herbicides, road salt, dust, nitrogen oxides, and heavy metals (Angold 1997). Developing solutions that can both support viable future transportation and reduce the ecological effects of air pollutants is extremely important.

There is an extensive literature on vehicle emissions and atmospheric pollutant levels, as well as a growing literature on contaminants associated with roadways. A limited amount of information has accumulated on ecological damage associated with pollutants close to roadways. Perhaps most is known about the ecological effects of salt, herbicides, sulfur dioxide, and some heavy metals. At least some useful ecological information is probably available on the remaining air pollutants. The fate of pollutants and the underlying processes involved are incompletely understood, however. Global climate models agree that major environmental changes are probable, but the amount, timing, and spatial distribution of those changes remain the subject of much disagreement. For effective transportation planning, research is needed on the ecological effects of pollution at both regional and local scales, as well as on measures that can be used to control the sources of pollutants.

In contrast with the high-profile subjects of greenhouse gases and aerosol particulates, climate change and ecological effects remain poorly understood (TRB 1997; IPCC 2001). Much of the research on ozone has centered on plants of economic value and on forest growth (Winner 1994; TRB 1997), whereas little is known about the effects of ozone on natural-community patterns. Despite large amounts of nitrogen being deposited on land and ecosystems from nitrogen oxide, the resulting effects, especially near highways, require study. Much of the research on airborne dust, salt, and herbicides focuses on the relative tolerance of different species, rather than on understanding effects on nat grasslands, deserts, and arctic areas also warrant study. Moreover, some heavy metals are not well understood in ecological terms, while others warrant further study with regard to toxic and food-chain effects. After all, if the size and density of fine particles is important to human health, wildlife populations are undoubtedly affected as well, and these impacts require study. Furthermore, little appears to be known about the ecological impact of hydrocarbons. Finally, while the effects of sulfur dioxide on vegetation located near point sources, as opposed to those located near highways, are relatively well known, significant questions remain about carbon monoxide, PCBs, and other pollutants. In short, for all of the transportation-generated pollutants, major knowledge gaps exist in

the timing, distance, amount, and interaction of effects on plants, animals, and ecosystems.

Landscape Ecology of Road Systems

Recommendation 2-7.
Develop road-network models and approaches for reducing habitat fragmentation, population extinction, wildlife-corridor, and remote-area impacts.

Road systems link human communities together and provide access to landscape and regional resources. However, the same networks slice the land and nature into pieces. Large mammal populations, fire, floods, and other important ecological characteristics are sensitive to road density (e.g., number of road-miles per square mile) (Findlay and Houlahan 1996, Forman and Alexander 1998). Yet the form of road systems, less well explored, is doubtless a better ecological predictor and basis for planning. Habitat fragmentation is widely cited as a major cause of declining biodiversity (Reed et al. 1996; Canters 1997). Road systems may play a role when a population is reduced and genetic inbreeding thus increases, with both processes heightening the risk of local extinction (Reh and Seiz 1990; Fahrig et al. 1995). Road networks also disrupt nature's networks of green patches and corridors across the landscape, while remote roads built to provide human access result in disturbance to natural populations and communities.

A fair amount of information on the effects of road density on large mammals exists, although not on many other ecological aspects (Forman and Alexander 1998; Evink et al. 1999). Moreover, a limited but useful literature is available on the human impacts in remote areas and on the disruption of wildlife corridors. Some information developed in other fields may be useful for developing models of alternative road-network forms. Some information is available on reducing habitat fragmentation. However, little is known about small populations or genetic inbreeding leading to extinction relative to road networks (Reh and Seiz 1990), though the theory has been reasonably well developed in other domains.

Existing knowledge gaps in this area are significant. Issues that need to be examined include which road and roadside designs are crossed most successfully by animals and therefore serve to reduce habitat fragmentation (Romin and Bissonette 1996); which temporarily closed or permanently removed roads in a network best reduce human-access impacts in remote areas or produce the

greatest ecological gain; which network designs best concentrate or distribute traffic disturbance impacts (e.g., how different road networks alter natural ecosystems and biological diversity by affecting fire frequency, size, and control); and what ecological form is best for a road network in a forestry landscape or, alternatively, in a rapidly developing exurban fringe area where roads are to be built (Reed et al. 1996; Findlay and Houlahan 1996).

Recommendation 2-8.

Foster collaborative landscape-wide environmental analyses by engineers, ecologists, and planners, with an emphasis on combining ecological solutions with other societal objectives.

Landscape ecology integrates traditional ecology with spatial patterns at the landscape or regional scale, precisely the scale of road systems (Forman 1995, TRB 1997). If transportation planners incorporated landscape ecology in the planning process for both improvements and additions, many useful insights might be anticipated (*Natuur Over Wegen* 1995; Canters 1997; Evink 1999). For instance, promising solutions should emerge to address ecological flows and movements across the landscape, including wildlife routes for foraging, dispersal, and migration; groundwater and surface-water flows; sediment and chemical sources, routes, and sinks; and sources and sinks for air-transported materials. In effect, how natural systems in the landscape work and how they interact with the road system would be elucidated. Further benefits would include an understanding of landscape spatial patterns, their linkage to the road system, and their changes over time, as well as ecological spatial models with and without the road system. The principles and models thus derived would aid in targeting restoration actions for a road system built largely in another era. Engineers and ecologists also would find much common ground in the environmental stewardship of transportation.

While transportation primarily provides safe and efficient transport, its secondary goals include maintaining ecological systems, public health, viable communities, and more (see Chapter 1). The basic infrastructure is in place. Thus, opportune times to accomplish goals related to natural systems are during maintenance, redesign, and upgrading of projects (*Natuur Over Wegen* 1995, FHWA 1996). Combining ecological and other public goals in the same project is an additional gain and—based on good research—should become the norm.

A scattering of useful studies appears to exist on using landscape-wide analysis to repair ecological damage, evaluate transportation projects, and

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mesh ecological and other societal objectives. A road-effect-zone model has been proposed and tested (Forman and Alexander 1998; Forman 2000). When a road or bridge is enlarged, an opportunity exists to enhance wildlife crossings, create recreational paths, and reconnect a community bisected by the road. Systematic interdisciplinary research is needed to fully capitalize on this highly promising area.

Recommendation 2-9.

Stimulate research on understanding public preferences for improvements in natural systems of both short- and long-term significance to society.

Both transportation and natural systems serve and generate support in society. Natural-resource economists seek monetary valuations of natural systems or components thereof. For instance, what are people willing to pay for a clean aquifer, an endangered species, or a distant wildlife refuge? Broadly speaking, values underlying public support can be divided into "use values" (e.g., a clean aquifer for drinking water) and "existence values" (e.g., the simple existence of an unseen wildlife refuge). Native foods and medicinal plants and vegetation along streams provide direct services to society. Their value is often less difficult to estimate, and tends to be lower, than existence values such as those of natural ecosystems for aesthetics or inspiration.

Research linking these issues to transportation is scarce. Yet to set planning and policy priorities for addressing the diverse dimensions of natural systems, it is important to consider people's preferences and consequent public support when allocating scarce resource dollars. The research challenge includes not only understanding the attitudes of different groups of people, but also determining what is included in the valuation and developing the best methodologies for conducting the valuation. For example, the closing of a forestry road that borders a fragile pond and favorite fishing spot could be valuated on the basis of accessibility, or accessibility plus the fishing equipment used and the store where it would be bought. Furthermore, some implementation actions, such as restoring a trout population or planting shrub cover for deer, provide a short-term ecological gain. Others provide a long-term sustainable value for society, such as altering land uses to prevent eroded sediment from filling a key reservoir or planting trees far from a road for future harvest. Such long-term values, so important for planning and policy, may deserve but not receive strong public support.

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Abbreviations

FHWA	Federal Highway Administration
IPCC	Intergovernmental Panel on Climate Change
TRB	Transportation Research Board

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4

Research Area 3

ENVIRONMENTAL AND SOCIAL JUSTICE

Concerns about the community impacts of transportation projects have been voiced since the 1950s and 1960s, when community leaders first challenged proposals to build freeways through inner-city, minority neighborhoods and commercial districts.[1] Citizens opposed to freeways in the 1960s and 1970s used a variety of methods—from demonstrations, to political action, to litigation—to slow or stop freeway construction through urban neighborhoods (Lupo et al. 1971; Colcord 1974; Dittmar 1996). Following passage of the National Environmental Policy Act (NEPA) in 1969, the anticipated environmental effects of government-funded projects had to be documented and mitigation measures proposed. Citizen groups questioned many of these reports, in particular for their adequacy in documenting community impacts. NEPA and civil rights statutes were both used to challenge transportation projects that appeared to have disproportionate negative consequences for the poor, people of color, and the politically disenfranchised (National Commission on Urban Problems 1969; Baldassare 1997).

[1] One early freeway controversy occurred in Boston in the 1950s, when the Central Artery was proposed to be routed through the site of the Chinese Merchants Association building, a recently completed symbol of community pride in Boston's Chinatown. The controversy was resolved by placing the road in a tunnel, avoiding the building. During this period, however, most urban analysts and journalists were favorably inclined toward freeways. Two notable exceptions were Lewis Mumford and Daniel Patrick Moynihan, who warned that freeways would likely disrupt the urban fabric.

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In successive highway bills in the 1960s and 1970s, Congress responded to community concerns regarding transportation impacts by expanding citizen participation and requiring increasingly detailed analyses of social, economic, and environmental effects. Reflecting legislative mandates, a National Cooperative Highway Research Program (NCHRP) project in 1975 set forth basic approaches for "highway agencies that were . . . evolving into transportation agencies . . . [and] asked to consider a broader range of possible direct and indirect social, environmental, and economic effects in all aspects of their decision-making" (Manheim et al. 1975). Three key findings of this research informed the proposed approaches: (*a*) "social, economic, and environmental considerations" in transportation planning are important because "inevitable conflicts among competing interests" must be resolved; (*b*) "social equity must be explicitly recognized and taken into account in transportation decision-making"; and (*c*) "different groups of people can be expected to have different interests and different priorities." The report presents a proposed new approach to transportation planning and decision making that relies on ongoing community involvement; considers a wide range of alternatives; and produces information on social, economic, and environmental impacts in ways that clarify their magnitude and incidence.

Almost two decades later, Congress renewed the call for consideration of social, economic, and environmental effects in transportation planning and decision making for both highways and transit with passage of the Intermodal Surface Transportation Efficiency Act (ISTEA),[2] a call that was reiterated in the Transportation Equity Act for the 21st Century (TEA-21). Today, earlier recommendations regarding social equity and environment are being revisited not only by transportation professionals, researchers, and policymakers, but also by the affected population groups. Their common task is to establish a more equitable transportation system characterized by choice in mode, high-quality access, and equity in spending for operations and infrastructure.

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[2] ISTEA listed social, economic, and environmental factors to be considered in both state and metropolitan transportation planning. In addition, the act declared that the national transportation system should include "significant improvements in public transportation necessary to achieve national goals for improved air quality, energy conservation, international competitiveness, and mobility for elderly persons, persons with disabilities, and economically disadvantaged persons in urban and rural areas . . ." (ISTEA declaration of policy).

SURFACE TRANSPORTATION AND ENVIRONMENTAL AND SOCIAL JUSTICE

The concept of "community impact" has broadened during the past 30 years. In the 1960s and 1970s, impact studies focused primarily on the direct effects of highways and transit investments on economic development and community vitality, on regional levels of transportation system–generated air pollution, and on corridor noise levels. Today, attention is equally devoted to such issues as the effects of transportation investments on metropolitan patterns of growth and decline, neighborhood quality, the comparative accessibility of jobs and other important activities, the impacts of transportation noise and air pollution on different population groups, and differentials in per capita spending for transit. Increasingly recognized as well are the varying transportation needs and interests of men and women, children and adults, the elderly, and those with differing physical or mental abilities.

Civil rights have become a prominent consideration in transportation,[3] as has the related notion of environmental justice.[4] Though first used in connec-

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[3] Title VI of the Civil Rights Act of 1964 has two provisions, known by their U.S. Code designations as Sections 601 and 602. Section 601 bars racial and ethnic discrimination in any federally funded program. Section 602 authorizes federal agencies to promulgate rules and regulations implementing section 601. The Department of Transportation's (DOT's) regulations explicitly prohibit actions that result in a disparate impact upon minorities. According to 40 Code of Federal Regulations (CFR) 7.35 (b) and (c), "(b) A recipient shall not use criteria or methods of administering its program which have the effect of subjecting individuals to discrimination because of their race, color, national origin, or sex, or have the effect of defeating or substantially impairing accomplishment of the objectives of the program with respect to individuals of a particular race, color, national origin, or sex. (c) A recipient shall not choose a site or location of a facility that has the purpose or effect of excluding individuals from, denying them the benefits of, or subjecting them to discrimination under any program to which this Part applies on the grounds of race, color, or national origin or sex; or with the purpose or effect of defeating or substantially impairing the accomplishment of the objectives of this subpart." Administrations within DOT have promulgated regulations for their own specific programs. For example, the Federal Highway Administration has promulgated regulations pursuant to Title VI that require state agencies to conduct annual reviews to ensure compliance, require state highway agencies to develop procedures for the collection of statistical data on participants in and beneficiaries of state highway programs, develop Title VI information for dissemination to the public (and, where appropriate, in languages other than English), and establish procedures to identify and eliminate discrimination.

[4] Work in the 1980s indicating that low-income and minority communities disproportionately housed toxic waste disposal sites led to a series of organized citizen actions that has come to be known as the environmental justice movement. In 1991, advocates adopted "Principles of Environmental Justice" (1991), which have since been widely disseminated. Executive Order 12898, promulgated in 1994 to further the implementation of Title VI civil rights provisions, is commonly

tion with toxic waste sites, the term "environmental justice" commonly refers today to the equitable distribution of both negative and positive impacts across racial, ethnic, and income groups (with environment being broadly defined to include social, economic, and ecological effects). Environmental justice advocates, along with others supporting community reinvestment, have focused their attention on the distribution of transportation benefits and costs and have begun to seek transportation investments that will increase social equity, improve access and mobility among disadvantaged populations, and help improve the quality of life in low-income and minority neighborhoods.

This increased emphasis on the incidence and distribution of costs and benefits is generating new demands on the transportation planning process. Methods that can be used to disaggregate impact information and display effects on different communities and socioeconomic groups are increasingly needed in place of, or as complements to, existing methods and measures. Both metropolitan planning organizations and community groups have been trying out new techniques of data collection and analysis that provide information by neighborhood and city, race and ethnicity, sex and age. At the same time, community members not only are seeking additional information about transportation investments and their impacts, but also want to bring about substantive changes in transportation policies, programs, and projects. In some cases, recognizing the value of transportation research and analysis in achieving these objectives, they have sought to reproduce and test current transportation models and evaluation measures on their own, and have conducted original research that has resulted in important findings (see, e.g., Almanza and Alvarez 1995; Grimshaw 1995; Mann and the Planning Strategy Center 1996).

In this chapter some of the key findings emerging from studies of transportation equity and the distribution of transportation impacts are reviewed,

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known as the Executive Order on Environmental Justice. It called for federal agencies to develop environmental justice strategies that (*a*) promote enforcement of health and environmental statutes in low-income and minority areas; (*b*) "ensure greater public participation"; (*c*) improve research and data collection; and (*d*) "identify differential patterns of consumption of natural resources among minority populations and low-income populations." In response to Executive Order 12898, in April 1997 DOT issued an order that provides guidelines for Title VI compliance. Programs that may disparately affect racial and ethnic groups are permissible only if they can be justified by a "substantial need for the program" and if the alternatives would have "other adverse social, economic, environmental or human health impacts that are more severe" or if they would involve higher costs "of extraordinary magnitude." The Order explicitly prohibits judicial review, and states that its purpose is simply to regulate the functioning of the executive branch, not to establish substantive rights. Shortly thereafter, the various federal agencies that comprise DOT began to advance internal policies reflecting these principles.

and recommendations for an initial program of research in this area are presented. In keeping with the dual charge of the Advisory Board, both environmental and planning issues are examined. Throughout this chapter, people of color are often referred to, as is typical in the literature, as belonging to "minority communities." The terms "lower-income" and "economically disadvantaged" are used interchangeably to describe those in the bottom one-quarter of the U.S. income scale. Demographic data show that people of color typically account for more than 50 percent of this income group, and many are also women, children, or elderly (U.S. Bureau of the Census 1999). A high percentage of this group lives in poverty; indeed, despite economic gains in the 1990s among much of the U.S. population, reports of deprivation and inability to purchase food, health care, and clothing are as widespread now as in past decades (Pew Research Center for the People and the Press 1991).

The natural and built environments and the quality of life in a community are inextricably linked to the distribution of transportation system impacts and the social equity of transportation policies and programs. Research carried out during the last decade has only begun to reveal the varied travel needs of different population groups, and to identify planning processes and substantive solutions that can address long-standing concerns about transportation equity and disparate impacts. A decade after the passage of ISTEA, there remains a compelling need for better methods of planning, evaluation, community involvement, and decision making to ensure that environmental and social justice goals are achieved. Some of the fundamental research questions related to transportation, environmental justice, and social equity that must be addressed if those goals are to be met are explored in the remainder of this chapter.

Differences in Mobility, Access, and Travel Behavior

A growing body of research conducted at the national level or for particular regions has identified significant differences in mobility, access, and travel behavior across racial and ethnic groups (Myers 1997; Zmud and Arce 2001; Polzin et al. 1999), across age groups (Myers 1997; Burkhardt and McGavock 1999), and by sex (McGuckin and Murakami 1999; Mallett and McGuckin 2000; Spain 1997). The research suggests, among other things, that minorities are more likely than whites to use transit (Polzin et al. 1999); that women drive more than men, mainly because they shoulder greater responsibilities for home work and children's transportation (Rosenbloom and Burns 1993);

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and that older people are driving more at more advanced ages than they did in the past, resulting in an increased number of accidents among this age group despite the widespread adoption of coping mechanisms (Rosenbloom 1988.)

While this research has provided important evidence on the differing travel behavior and transportation needs of specific population groups, it has done so in a very limited way. In particular, the available studies have not always controlled for other possible explanatory factors, most notably income. Nor has most of the research examined changes in travel behavior over time or accounted for likely changes in behavior under varying conditions of transportation supply and cost. In addition, very little work has examined the policy implications of observed differences in behavior, especially with regard to variations among racial and ethnic groups. There is a large body of work on the transportation needs of the disabled (e.g., Rosenbloom 1981; Rosenbloom 1994); a modest but growing body of work on the needs and concerns of the able-bodied elderly (e.g., Rosenbloom 2001); and a growing but very recent body of work on the travel concerns of current and former welfare clients (e.g., Blumenberg et al. 1998; Chapple 2000). But relatively little work to date has focused on how well various transportation strategies address the observed needs of children, of women versus men, of poor people who have not received public assistance, or of different racial and ethnic groups.

Alternative policy instruments and their differential consequences for costs and affordability have also been explored only briefly. Compared with other important consumer goods such as food, housing, and public utilities, relatively little work has been done relative to transportation to set standards for affordability or to examine how affordability is affected by different policy instruments. Thus while it is understood that low-income households pay a higher share of their income for transportation (and most other necessities) than do more affluent households, there is no equivalent in transportation policy to Section 8 housing subsidies or food stamps.[5]

A limited amount of research has been conducted on the impact of transit fares on low-income groups (e.g., Cervero 1984). Very little work has been done on whether and how a lack of income constrains travel and activity

[5] According to the Consumer Expenditure Survey, households with incomes between $12,000 and $25,000 spend 27 cents of every dollar on transportation; for those with incomes below $12,000, the share is 37 cents of every dollar. This compares with less than 18 cents on the dollar for the average household.

choices for travelers of either sex or any age or ethnic group. There has been some research on the socioeconomic effects of alternative taxation methods (e.g., Cameron 1994; Wachs 2001) and pricing strategies (e.g., Deakin et al. 1996), but relatively little work on how broader investment choices, such as highway versus transit investments, affect different racial, ethnic, or income groups or how such choices affect women versus men.

The Concept of Environmental and Social Justice

Civil rights and environmental justice have been the impetus for a number of challenges to transportation programs and projects in recent years, including cases concerning the provision of transit service and the siting of highways. Some of these conflicts have resulted in litigation.[6] Underlying these controversies are concerns not only about the adverse effects of transportation projects on different population groups, but also about the fairness of the decision-making processes involved. While a recent court decision may reduce litigation over alleged disparate impacts of transportation projects,[7] transportation professionals and community leaders continue to seek ways of ensuring the fairness of the planning process and the equity of the resulting plans and investment programs. Research on equity, or justice, is particularly relevant to today's and tomorrow's transportation planning and decision-making processes.

According to one definition, justice means having a basis in fact and following established rules and procedures to produce an impartial result. Impartiality, or the absence of prejudice or favoritism, was Cardozo's definition of fairness and justice under the law (Cardozo 1948). Yet long-standing tradition

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[6] See, e.g., *The New River Valley Greens, et al. v. U.S. Department of Transportation.* T1996 U.S. District LEXIS 16547, Civil Action No. 95-1203-R (U.S. District Court, W. Dist. of VA), *affirmed* 1997 U.S. App. LEXIS 32166; 46 ERC (BNA) 1155 (4th Cir. 1997); *Coalition of Concerned Citizens Against I-670 v. Damian,* 608 F.Supp. 110, 127 (S.D. Ohio 1984).; *Tolbert v. Ohio Department of Transportation,* 992 F. Supp. 951, 953-56 (N.D. Ohio 1998); *Labor/Community Strategy Center, et al. v. Los Angeles Metropolitan Transportation Authority,* 263 F.3d 1041; 2001 U.S. App. LEXIS 19410; *New York Urban League, Inc. v. Metropolitan Transportation Authority,* 905 F.Supp. 1266 (S.D.N.Y. 1995), *Community for a Better North Philadelphia v. SEPTA,* 1990 WL 121177 (E.D.Pa. 1990).

[7] In the recent decision of *Alexander v. Sandoval,* 532 U.S. 275, No. 99-1908 (April 24, 2001), the U.S. Supreme Court ruled 5 to 4 that private individuals cannot bring a lawsuit to enforce regulations promulgated under Section 602. The case does not affect aggrieved parties' rights to appeal for relief to administrative agencies such as the Federal Highway Administration and the Federal Transit Administration.

supports the idea that justice does not always mean treating everyone in the same way. For example, the law considers context, evaluating the circumstances in interpreting the facts. In addition, in Anglo-American jurisprudence, equity developed as a formal body of doctrines and rules of procedure designed to supplement, and if necessary override, common law and statutes to protect substantive, fundamental rights of individuals. The law of equity addresses those circumstances in which the "ordinary" rules, applied in a blind or narrowly rigid fashion, would produce a result that violates the notion of justice in another sense: that a just result is a good one. Today both the law of equity and the rules of administrative procedure directing how government should operate recognize that due process may require varying rules and approaches to reflect acknowledged differences in circumstances (Deakin 1999).

Rawlsian conceptions of justice offer a still broader notion of equity. Rawls based his theory of justice as fairness on two principles: the first dictates equality in the assignment of rights and duties; the second holds that social and economic inequalities are just only if they result in compensating benefits for everyone, and in particular for the least-advantaged members of society (Rawls 1971). The idea that justice necessitates an examination of the distribution of gains and losses and sometimes requires compensatory action has been a powerful one for planners (Davidoff 1975; Krumholz and Forester 1990), and work on the distributional consequences of public policies has provided an important factual basis for reforms.

Research and policy studies have demonstrated that discrimination has occurred in the provision of public services, from the paving of streets and installation of sewers to the delivery of quality education (see, e.g., Ratner 1968; Inman and Rubenfeld 1979; Haar and Fessler 1986; Gillette 1987). Researchers have also sought to address unfairness in the allocation of public burdens, from the routing of highways through inner-city neighborhoods to the siting of landfills, incinerators, and hazardous waste disposal sites (Lazarus 1993; Been 1993). The latter studies have consistently shown that neighborhoods having these locally undesirable but regionally necessary facilities tend to be poorer and to house a higher percentage of minorities than other neighborhoods. It is less clear, however, whether this result is due to discriminatory siting practices or to other forces that lead minorities and the poor to settle in impacted areas—such as racial and ethnic discrimination; a shortage of affordable housing; and constraints on the availability of jobs, transportation, and services (Been 1993). Because appropriate remedies depend on the causes of a problem, research is needed to better understand infrastructure siting

processes, household location decisions, and other factors that lead to disproportionate impacts (Bowen 2001; Foreman 1998; Dobson 1998; Gelobter 1992). Research is needed not only for new projects, but also for situations in which adverse community impacts already exist (Bowen 2001). This research could augment current studies that use available data on demographics, travel patterns, ridership, and impacts to show the incidence of impacts (see, e.g., Camacho 1998; Faber 1998).

Box 4-1 describes a number of environmental justice actions taken by transportation advocacy groups in lower-income and minority communities. While in some instances the advocacy groups opposed particular government programs or projects, in each case the groups proposed other approaches that in their view involved preferable social, economic, and environmental consequences. Many of the advocacy groups specifically linked transportation improvements with additional measures that would produce a cleaner environment and expanded economic opportunities (e.g., investments in revitalization of community retail areas, park cleanup).

A review of these and other community actions leads to the following conclusions:

- Transportation is a major issue for low-income and minority communities, tied to the quality of daily life and economic well-being.
- Despite federal legislation during the last decade mandating public input into transportation planning and development in low-income and minority communities, many are dissatisfied with the processes used for this purpose.
- Low-income populations and communities of color are increasingly challenging the equity of transportation agency policies for the funding and operation of public transportation systems.
- Organizations representing low-income groups and communities of color increasingly are carrying out their own analyses of transportation issues. They are developing research techniques, models, and data collection methodologies that can be used to develop alternative transportation policies and spending scenarios for comparison with those promulgated by local transportation agencies.

Equity of Transportation Costs and Funding

As the cases in Box 4-1 illustrate, during the past few years community members in several large U.S. metropolitan areas have taken action to address inequities

Box 4-1

TRANSPORTATION AND ENVIRONMENTAL JUSTICE: SOME RECENT EXAMPLES

The **Clean Buses for Boston Coalition** movement began in the lower-income South Boston/Roxbury area to combat what the communities considered to be inequities in transit service. The motivation for the movement was public health statistics showing a disturbing increase in asthma among younger children and young adults in the area. Community leaders began to research the causes of the asthma problem and found a linkage to diesel emissions. Because diesel buses tended to idle for extended periods at street corners in the neighborhood, the assistance of the Massachusetts Bay Transit Authority was solicited. The coalition also conducted research, collected data, and made recommendations for alternatively fueled buses and changes in operating procedures.

In Austin, Texas, predominately low-income Hispanic communities headed by **PODER** have been fighting for equal financing of public transportation systems for their residents. Members, who include academics and researchers, have developed models for analyzing improvements in basic transit services. In addition, the community has developed a public monitoring system that tracks transportation decisions, policies, and recommendations.

The **Labor/Community Strategy Center Bus Riders Union,** representing several hundred thousand riders in East and South Central Los Angeles, argued against diverting transit funds from bus services to light rail and urged the Los Angeles Metropolitan Transit Authority (MTA) to instead upgrade the buses and keep them running at an affordable cost. The MTA had been spending 30 percent of its funding on buses and 70 percent on light rail, while the buses carried almost 94 percent of total transit customers. About 80 percent of the bus riders were people of color.

In Harlem, the **NYC Environmental Justice Association** has taken steps to get the New York Transit Authority and the New York metropolitan planning organization to change their policies on siting transportation infrastructure facilities, such as bus maintenance depots, in communities of color.

(continued)

Box 4-1 *(continued)* **TRANSPORTATION AND ENVIRONMENTAL JUSTICE: SOME RECENT EXAMPLES**

Using a geographic information system (GIS), the investigators found six transit diesel facilities in a 7.4-square-mile area near playgrounds and schools, and more were planned. No other area of the city showed a similar pattern of transit facility operations.

Chicago community activists teamed with organizations such as the Center for Neighborhood Technology to gather GIS and economic data showing how light rail improvements would benefit both the city and communities of color economically while costing less than abandoning the lines altogether. The Campaign for Better Transit brought low-income Chicago residents and those from the Gold Coast together after providing research findings indicating how bus line closures would cause disruption to both communities.

Sources: Almanza and Alvarez (1995); Grimshaw (1995); Garcia (2000); Mann and the Planning Strategy Center (1996). Case study summaries taken from expert panelist participants at the Title VI/EJ Expert Panel Forum, sponsored by the Federal Transit Administration and convened by Planners Collaborative and Alternatives for Community and Environment, Roxbury, Mass., June 6, 2001.

in transportation costs (particularly fares), services, and funding. Transportation investment disparities have also been identified in rural and suburban areas where low-income populations reside (Dittmar and Chen 1995). Case studies of funding disparities have shown, for example, that heavily used bus services in low-income communities and communities of color were cut back or had to rely on old, poorly maintained equipment, while new investments with high levels of amenity were provided in wealthier suburban areas (Wypijewski 2000; Mann and the Planning Strategy Center 1996). A few cases also documented the community coalitions that successfully changed these conditions (Grimshaw 1995).

While these cases expose the problems and sometimes describe successful remedies, few of the available studies document how the disparities came to exist—whether they were exceptions or commonplace, the result of policy decisions or unintentional. Nor do the studies document how corrective

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actions were developed or explain whether the actions taken addressed only the particular situation or led to more general and permanent policy reforms. In short, the available cases rarely provide enough detail to allow generalizations to be made about their causes, effects, and cures. And for the most part, the cases lack sufficient specificity for their solutions to be easily adopted by others who may be facing similar situations.

As noted earlier, transportation research has shown that minorities and low-income households are more dependent on public transport than is the U.S. population as a whole, although this effect declines with income and, for immigrants, with length of time in the United States (Polzin et al. 1999; Myers 1997). Because so many people of color and minority and low-income individuals are transit users, the relatively low level of funding available for transit can have significant mobility implications, as well as environmental and social justice consequences. Research on alternative methods for financing transit and for improving service to make it more attractive to a wide range of users should address these issues by including an explicit analysis of the distribution of benefits and costs according to income, race, and ethnicity.

Many low-income workers are dependent on automobiles for much of their transport, in many cases using older vehicles.[8] The costs of automobile ownership and operation are affected by public policies in myriad ways, many of which are devised to meet environmental objectives. These policies in turn have impacts that vary with household income, but for the most part, the distributional consequences are not well understood. Studies have examined the equity effects of parking pricing policies, safety and emission standards, vehicle scrappage programs, and insurance costs, among other factors (see, e.g., Deakin et al. 1996; Cameron 1994; Dill 1998). But most of the studies are for a single state or region, often California, and in many instances the researchers were able to investigate only a few broad income levels and not the full range of socioeconomic issues of interest. A wider range of investigation is warranted.

[8] Congress noted in TEA-21 that fewer than 6 percent of those on welfare owned an automobile, and a General Accounting Office (1998) report cites a 1997 U.S. Department of Health and Human Services study showing that for those 6 percent, the average reported value of their vehicle was $620. While the majority of low-income households have never received welfare or faced its restrictions on automobile ownership, they, too, tend to have fewer cars than their more affluent counterparts, and the vehicles they own are of relatively low value.

Policies regarding street maintenance and traffic operations also are issues in many economically disadvantaged communities. Maintenance disparities have been documented by some researchers along with policies that tend to produce or exacerbate these disparities (Bullard et al. 2000a; Bullard et al. 2000b; Wilner 2000). Adverse consequences of these disparities can include neighborhood exposure to higher levels of noise, as well as reduced safety and more wear and tear on vehicles traversing poorly maintained roads.

The high traffic levels often present in low-income and minority communities also can be detrimental to the quality of the community environment, resulting in increased noise and congestion, reduced comfort and convenience for pedestrians, and reduced levels of neighborhood and community cohesion (Appleyard 1980). Here, too, policies on traffic management, especially those that call for resident finance of data collection or remediation, can result in disparate availability of remedial actions (see, e.g., Weinstein and Deakin 1999). While there is general agreement that funding mechanisms (e.g., reliance on abutter assessments and property taxes for local transportation improvements) often produce such disparities, generally by reflecting or magnifying underlying income differences, little work has been done to identify alternative methods of transportation finance that would be more equitable.

Equity Impacts of New Technology

Intelligent transportation systems and other technological advances are becoming important strategies for many state and local transportation officials. Transportation technology can result in cleaner, safer, more reliable, more convenient, and more efficient transportation (see also Chapter 5). An important equity issue is that many of these new technologies are or will be available only to those who can afford to invest in them and can learn to use them. For example, those who have a home computer and know how to use it can obtain traffic advisories and route information; those not so equipped find it much more difficult to obtain such information. A "digital divide" will exacerbate existing disparities in access and mobility (Mack 2001).

Studies of how different technology implementation pathways might affect various racial, ethnic, and income groups differentially are warranted. Research in this area could involve examining access to and use of such new transportation technologies as smart cards, electronic toll tags, and onboard and hand-held route guidance systems.

It is important to note that new technologies may offer ways to overcome or offset disparities associated with transportation. Work is already proceeding on determining how technological advances could be used to increase the equity and accessibility of transportation systems for disadvantaged populations, for example by making distance-based fees and fares practical or by providing an "invisible" discount to qualified low-income travelers (see, e.g., Bushnell 1995; Fleishman et al. 1996). More work of this sort is clearly needed.

Analysis Methods and Equity Issues

For years transportation planners have used models for forecasting travel demand and evaluating system improvements. Most of these models produce aggregate estimates of travel choices and traffic flow without regard to cultural and racial differences in opportunity and preference. Neither the sex nor the age of the traveler is considered, unless the traveler is too young to have a driver's license. Likewise, racial and ethnic differences are typically omitted from the model specification. While income enters into most standard models in relation to time (and value of time) and cost variables, the typical models use aggregate data (often zonal averages) that mask disparities in income and ability to pay (Harvey and Deakin 1993). When air quality and noise models are used, they typically are applied at the level of the corridor or region without regard to recipients' characteristics. Thus, both in specification and in application, standard models provide little information on social and economic differences.

Disaggregate travel demand models and methods such as sample enumeration and microsimulation offer significant opportunities for greatly improving transportation-related forecasts. These approaches can allow forecasts to be made for any subgroup of interest as long as the underlying data are adequate to support the analysis. To date, however, these methods have been applied in only a handful of metropolitan areas. Furthermore, the complexity of the models suggests that the level of effort required to understand and apply them may be quite high. Thus there is a need for both more testing and dissemination of models capable of disaggregate analyses, and the development of simplified sketch planning models and heuristics for evaluating the effects of transportation projects on different demographic and socioeconomic groups. These latter models and heuristics would be used as a first-cut alternative to the more complex models.

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Improvements also are needed in cost/benefit analysis methods. Most of the existing methods (often based on available software) share with travel forecasting models the tendency to aggregate data in a way that masks rather than displays the incidence of impacts on various groups and interests. In addition, most cost/benefit methods omit measures that cannot easily be quantified, such as quality of life (Forkenbrock and Schweitzer 1999). While alternative approaches, including impact tableaux, cost-effectiveness analysis, and community-based rating and ranking schemes, have been available for many years, they are not frequently applied at present.

A promising method for both analyzing and displaying impact information involves using geographic information system (GIS) tools to create maps showing the location and intensity of various transportation-related effects. By using overlays of socioeconomic and demographic data, jurisdiction and neighborhood boundaries, and the like, relationships between transportation projects and their community effects can be visualized. Both beneficial aspects, such as access and mobility measures, and negative impacts, such as pollution concentrations, can be mapped. Increasingly, GIS-based methods of impact display are being used both by public agencies and community activists to examine transportation project effects. Indeed, those who represent low-income populations in transportation delivery and planning have begun to develop their own GIS tools for evaluating the next generation of transportation services (Almanza and Alvarez 1995; Rothman et al. 1998). Some researchers also have experimented with user-friendly, community-focused information systems and models that assist communities in matching their transportation needs with the best alternatives for meeting those needs. These models are designed to be used independently or in cooperation with transportation agency staff and policymakers (Zimmerman et al. 1997). Research is needed to examine these emerging planning methods and evaluate their efficacy.

Transportation, Sprawl, and the Distribution of Impacts

The role of transportation in shaping land use and patterns of development (urban, suburban, and rural) has emerged as a significant research topic during the last decade (see Chapter 6). From an environmental justice perspective, sprawling suburbs compete for jobs, housing, and other resources with the inner city and older suburbs, which together are home to the majority

of low-income and minority households. In turn, few suburbs are developed in a pattern that can be served successfully by transit. As the share of a metropolitan region that is transit-oriented declines, those who depend on transit for their basic mobility become vulnerable to service cuts and accessibility losses. Further, as more people depend on automobiles to meet their travel needs, costs for highway infrastructure rise and traffic impacts increase; these costs and impacts fall heavily on low-income and minority households.

Demographic analyses conducted during the last four decades indicate that a majority of the nation's metropolitan areas are divided spatially by race, ethnicity, and income (Massey and Denton 1993; Bullard 1997; Benfield et al. 1999). Research also suggests that this segregation is not solely the result of market choices or discrimination in the housing market, but also a consequence of public policies, including investments in suburban highways, preferential tax policies for home ownership, infrastructure policies favoring new construction over maintenance and rehabilitation, and government and private redlining[9] in inner-city neighborhoods (Burrington and Heart 1999; Powell 1999; Richmond 1995). The consequences of such policies warrant more research to identify their relative contributions to these urban segregation patterns.

Today, policies intended to slow or reverse the decline of inner cities and older suburbs are being tested, as discussed in detail in Chapter 6. Just as further study of sprawl is warranted, it is important for research to address the possible unintended consequences of antisprawl policies on minorities and low-income communities. One such consequence of increasing concern is "gentrification" and its possible effects on existing residents (ranging from rising costs to outright displacement) (Beauregard 1985; Anderson 1990; Smith 1996; Kennedy and Leonard 2001). The factors underlying gentrification are highly contested, and there is little certainty about the efficacy of policies being proposed to protect lower-income households (transit-oriented design, job development, affordable housing development). Policy research on suburbanization and community revitalization thus could have both transportation and environmental justice aspects.

[9] Redlining was the practice of labeling certain neighborhoods or districts high risk, making insurance expensive and loans and mortgages costly and difficult to obtain. Redlining was often based on racial and ethnic characteristics of the population, hence was discriminatory, and is now illegal.

Emerging Approaches to Public Involvement

Federal statutes mandate that state and regional planning agencies ensure public input on transportation investment and spending decisions. Most states have similar requirements. Yet many community groups are dissatisfied with the current planning processes. Public agencies hold hearings and workshops, run focus groups, conduct surveys, and respond to comments on environmental impact statements. As Arnstein (1969) notes, however, actual participation in the development, evaluation, and selection of alternatives is unusual. Innes and Booher (1999) believe the biggest obstacles to change are two institutionally entrenched models of planning: the technical bureaucratic model, which focuses on analyses and relegates citizen involvement to minor feedback, and the political influence model, which operates with the powerful players and does not welcome direct citizen involvement at all.

Certainly citizens are concerned about discrepancies between the comments and suggestions made by community members during the planning process and the way public funds are ultimately spent. Public agencies are concerned about the legitimacy of their decision processes and whether the participants in the planning process are representative of the larger public. Given the importance of outcomes as well as processes, research on public involvement and its effects on funding decisions, project design, impact assessment, and outcomes is an essential element in making transportation planning and decision making more effective.

In addition, there has been growing recognition that the sheer diversity of views requires a new approach to decision making (Schlosberg 1999). Many researchers have concluded that social justice requires a democratization of the planning and decision processes, and that this objective can often be attained through cooperative approaches (Ostrom 1990). The success of such approaches depends, however, on building individual and group capacity to participate in the process and to identify and communicate one's interests. Success also depends on developing sufficient mutual trust and other forms of social capital (including leadership) to keep the process going. The increased use of capacity-building and consensus processes in a variety of planning applications (Innes 1992; Innes 1998) is an important step toward broader participation and democracy, and hence greater social equity, in planning. Innes and Booher (1999) report that newly emerging collaborative planning processes, implemented as a loose network of communicating citizens and public and private entities, enable citizens to learn how to deliberate effec-

tively. They note that people involved in such processes come to prefer them to confrontation. A recent handbook by Susskind et al. (1999) provides examples and guidance, but specific applications for transportation need further development.

Emerging citizen coalitions in low-income and minority communities have advocated a basic theme of "back to local control," reflecting the policies of ISTEA and TEA-21. This participatory activism is particularly apparent in communities of color, where transportation is regarded as a civil right. The roles and limitations of local control are appropriate topics for study, especially because there are both supporters and critics of localism as a strategy. Innes and Gruber (2001), for example, caution that devolution can make it difficult to address regional issues and concerns.

Research also is needed to evaluate alternative models of decision making and the role of social justice coalitions. Questions to be addressed include how various groups frame the debate on environmental and social justice issues, what process is used by people and communities to interpret and express their transportation needs, and why some disengaged communities have developed the ability to organize and resolve transportation problems while others are still not empowered.

RECOMMENDATIONS

The following recommendations are organized into seven areas: (*a*) differences in mobility, access, and travel behavior across demographic groups; (*b*) definitions of social equity and understanding of environmental justice problems and issues; (*c*) effects of costs, funding, and finance methods; (*d*) new technologies and their impacts; (*e*) methods and processes for the evaluation of impacts and their distribution; (*f*) effects of sprawl on social equity; and (*g*) approaches to public involvement.

Recommendation 3-1.
Conduct research on variations in mobility, access, and travel behavior among different social, economic, and demographic groups.

While currently available studies offer some insights into differences in travel options and behaviors for various social, economic, and demographic groups,

much more work is needed to explore choices, constraints, and preferences more thoroughly and to understand their consequences. Research needs include, for example, documentation of changes (or stability) in various groups' behavior over time; consideration of the effects of experience, changing income, aging, and other life-cycle changes; and examination of changes in the transportation options available. The social and environmental impacts of identified differences in transportation preferences and choices should be explored as well. Cross-sectional as well as longitudinal research designs are needed, as are case studies that provide depth and richness of understanding.

Recommendation 3-2.

Develop operational definitions and indicators for environmental justice and social equity as the concepts pertain to transportation.

Working definitions and indicators of environmental justice and social equity that are widely understood and accepted remain to be developed. The process of definition will need to occur through a collaborative effort involving a range of stakeholders in meaningful discussions, and it may need to be revisited and updated from time to time. Similarly, the development of indicators for use in measuring environmental justice is likely to require research conducted through collaborative processes.

Recommendation 3-3.

Investigate the social and economic effects of current investment policies for both transit and highways, and conduct research on the equity and impacts of alternative methods of finance.

Research is needed to identify and document how current investment policies affect different groups and interests, with particular attention to minorities and the economically disadvantaged. Both detailed case studies and cross-sectional and longitudinal studies are appropriate. Findings from this research should, over the longer run, support investigations into alternative methods of finance and their comparative equity and impacts.

Policy analyses and empirical research that illuminate the causes of disparities in transportation investment are needed. Such research could examine decision-making processes, including models of decision making and "world views," that result in greater or smaller disparities, and could help identify ways to improve transportation equity and avoid, minimize, or mitigate adverse effects.

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Recommendation 3-4.

Conduct research on the effectiveness and impacts of transportation technology innovations for different socioeconomic and demographic groups, particularly economically disadvantaged communities. Also examine methods for making new technologies available to diverse population groups.

Research on new technologies should be expanded to include evaluation of their accessibility to low-income and minority communities, the young, the elderly, and the disabled. Research should also address how new technologies might be used to overcome existing gaps between advantaged and disadvantaged groups and to enable communities to become better integrated into the transportation decision-making process.

Recommendation 3-5.

Develop and demonstrate methods that can be used to display the incidence of transportation project and program effects, both beneficial and adverse. Also, develop improved methods for evaluating costs and benefits when they are not evenly distributed. Include environmental and social justice impact criteria in system performance measures used in transportation planning and investment decisions.

Current evaluation methods are often too aggregate to reveal social, economic, demographic, and community-based differences in the impacts of transportation programs and projects. Low-income and minority communities have been shown to suffer disproportionate negative impacts from transportation projects. If such consequences are to be avoided in the future, better methods are needed for performing transportation forecasting and analysis, as well as for carrying out and communicating the results of program and project evaluations. The role of the public in such evaluations is an appropriate topic for research, as discussed in recommendation 3-7 below.

Research aimed at identifying performance measures that adequately reflect the distribution of transportation impacts also should be carried out. Research should be conducted as well to develop new strategies for avoiding, minimizing, and mitigating adverse impacts and disparate burdens associated with transportation programs and projects.

Innovative data analysis procedures, utilizing qualitative as well as quantitative criteria, should be further developed and refined. Methods that use GIS

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and other new impact analysis and display methods should be given particular priority, since work to date indicates that these methods have considerable potential for effectively communicating analysis results to decision makers and the general public. Methods that draw on community-based knowledge and resources, such as communities' own assessments of their assets and concerns, also should be given research attention.

Recommendation 3-6.

Continue and expand studies on the comparative costs of transportation and the effects of different development patterns, particularly for economically disadvantaged communities.

Research is beginning to identify the connections among sprawl, inner-city decline, lengthy commutes, congestion, and damage to the urban and natural environments. While the work to date is revealing, it is neither comprehensive nor definitive, and more research is warranted. Research should be carried out to evaluate "smart growth" alternatives and their efficacy, as well as their effects on housing prices, environmental quality, regional and local economic development, and the well-being and satisfaction of various social and economic groups.

Recommendation 3-7.

Develop and test new methods for integrating public involvement into transportation analysis and decision making, and examine the implications of emerging citizen coalitions for environmental and social justice.

New approaches to public involvement that focus on collaboration and mutual learning, rather than on mere comment and feedback, show significant promise. Research should help elucidate the conditions under which these methods are effective, and evaluate their effectiveness in transportation planning and environmental assessment. The role of social justice organizations in transportation and environmental decision making also needs to be examined. The participatory activism displayed by social justice organizations has challenged traditional notions of transportation planning and research. Social justice coalitions are introducing their own data, analyses, cost/benefit calculations, and alternatives into transportation planning processes, creating new political dynamics and issues for transportation agencies and decision makers that are only beginning to be examined. Research is needed on planning frameworks that can accommodate

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a broader spectrum of data and perspectives, as well as on improved ways to include the public in transportation analyses and evaluations.

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Abbreviations

GAO	General Accounting Office
TRB	Transportation Research Board

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Research Area 4

EMERGING TECHNOLOGIES

The transportation industry is arguably on the cusp of a technological revolution. In coming years, the industry will be incorporating two largely new sets of technologies that are the focus of this chapter: (*a*) propulsion technologies and fuels that will change the energy, pollution, and noise characteristics of vehicles; and (*b*) information, communication, and control technologies that will change the way vehicles are used. An important challenge is to create a policy environment that will facilitate and encourage the proliferation of these environmentally beneficial technologies (DeCicco and Delucchi 1997).

In this chapter, technology is addressed from two perspectives: as a key element of transportation systems that often leads to adverse environmental impacts, and as a source of solutions to environmental problems. The primary concern is with rapidly evolving technologies for vehicles, fuels, vehicle–highway user-support systems [i.e., intelligent transportation systems (ITS)], and telecommunications in the context of energy efficiency and supply, air quality, and climate change. A proliferation of new propulsion, fuel, information, communication, and control technologies are becoming available, promising major enhancements to the performance and environmental sustainability of transportation services and activities. The focus of this chapter is on those emerging technologies that have the largest potential environmental impacts, both negative and positive, but have not yet been fully addressed by publicly supported research and development (R&D).

Since technology is a broad category encompassing a vast array of material and knowledge sets, the aim in this chapter is not to be all-encompassing. Not addressed here, for example, are technologies for the construction and

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maintenance of safe, environmentally friendly facilities; technologies and infrastructure for protecting wildlife (e.g., tunnels and road overpasses for animals); technologies that provide incremental information-based improvements in traffic and fleet management; conventional transit and railroad services and technologies; telecommunications electronics; fuel manufacture and distribution; crashworthiness and crash-avoidance technologies; and whole-vehicle design and manufacture. The Advisory Board elected not to discuss these technologies because they are adequately covered by other research programs, such as the National Cooperative Highway Research Program; because they are central to industry R&D activities; because they may have little effect on environmental quality; because they facilitate only small incremental changes; or because they are covered in other chapters (in particular, technologies to protect wildlife are covered in Chapter 3, while improved planning and decision-making tools are covered in Chapter 7). On the other hand, emerging mass information services, although not technically classified as transport technologies, are included in this chapter to the extent that they have the potential to transform the manner in which the transportation system is currently utilized. This transformation could dramatically influence transportation's impact on the environment.

Surface Transportation and Emerging Technologies

Government plays a central role in guiding the development and diffusion of environmentally beneficial technologies. It regulates emissions, energy use, and safety; provides R&D funding through various programs; and owns and manages many transport services, facilities, and activities. But rapid advances in a range of technologies can render government policies, rules, and R&D programs anachronistic, while the marketplace treats environmental attributes largely as externalities.

A role for government is necessary to ensure the wise use of technology—this despite the fact that government seldom has perfect information and is routinely lobbied by special-interest groups that may have little or no interest in environmental protection. The problem is illustrated by the unintended consequences of some government-inspired initiatives, including the federal-aid highway program, which has led to species separation; dredging by the U.S. Army Corps of Engineers, which has reduced wetlands and destroyed marine habitats; and the development of large state- and municipal-owned airports that have

expanded noise footprints. Moreover, the government's decision not to price the use of congested roads at the point of consumption has led to excessive road use, with associated pollution and noise impacts. It is important, then, that any government role regarding the use of transportation-related technologies be premised on a strong knowledge base to minimize the chances of negative environmental impacts. And given government's expanding role in overseeing the environmental effects of transportation technologies, the challenge is to ensure that the potential benefits of new transportation technologies are realized in a cost-effective manner. These benefits are direct in reducing pollution, energy use per vehicle-mile traveled (VMT), noise, and so on, but also indirect in catalyzing shifts in travel patterns to more environmentally benign travel forms.

Industry is spending billions of dollars annually on transportation-related technologies R&D (AAAS 2000), and major technological changes are about to occur—with or without government direction. A range of new and enhanced research is needed to ensure that government exploits these changes effectively and wisely. A strong, sustained research agenda can address both the opportunities and concerns presented by new technologies. The goals of this research would be as follows:

- To define and articulate an appropriate and effective role for public R&D in accelerating the development and commercialization of environmentally beneficial technologies (given that government resources are at a much smaller scale than the private investment in transportation technologies).
- To create a scientific basis for effective and wise government policymaking, investment, and regulation with respect to transportation technologies to serve the ultimate government role of environmental stewardship.
- To understand the relationship between government regulations and private-sector investments in R&D.

Grounded in such a research base, public investment in transportation-related technology R&D can fill critical gaps, leverage billions of private R&D dollars, and ensure the development of a more sustainable and healthy transportation system. The potential payoff is great. At the same time, it must be recognized that user response to technological change can be complex. The environmental balance sheet following the introduction of new technologies depends substantially on large numbers of micro decisions made by both consumers and suppliers about how to exploit the resulting new opportunities. It is important to note that those opportunities are not always

anticipated by the designers and promoters of new technologies; some are discovered or invented by consumers. A recent example is provided by consumers who offset fuel-efficiency improvements by buying more powerful vehicles and driving more miles. The aggregate effects of user responses to simultaneously introduced innovations, as well as interactions between responses, are even more difficult to anticipate. Behavioral responses to the two major technological revolutions discussed in this chapter may result in major changes in vehicle use patterns and concomitant environmental impacts.

Current Technology Context

The current situation in the United States with respect to transportation and the environment is one of both promise and concern. The largest success story is in the area of air pollution, though progress here is neither uniform nor—as population and travel patterns expand—ensured. Major reductions in vehicle emission rates have resulted mainly from technological advances in combustion efficiency, fuel reformulation, and the treatment of exhaust substances. Urban regions and major corridors have benefited from the elimination of lead in fuel and from major reductions in carbon monoxide. In addition, low-level ozone pollution is slowly improving, primarily as a result of large reductions in hydrocarbon emissions from vehicles.

The continuing challenge with regard to air pollution is to reduce the high levels of nitrogen oxides and ultra-fine particulate matter emitted by vehicles. Diesel engines, largely unnoticed by air quality regulators until the late 1980s, are responsible for a significant proportion of these two pollutants. Dramatic reductions in emission rates (per VMT) have been accomplished for carbon monoxide and hydrocarbons, but less so for nitrogen oxides. With large offsetting increases in VMT, the overall effect has been substantial net reductions in carbon monoxide and hydrocarbon emissions, but no net reduction in emissions of nitrogen oxides.[1]

[1] High nitrogen oxide levels contribute to acid precipitation and thus have interregional and international implications, as well as impacts on urban air quality. Vehicular emissions of nitrogen oxide and sulfur oxide combine with industrial sulfur emissions to acidify soils and lakes over long distances. Although a concern for more than three decades, some cumulative effects of soil acidification have only recently been proven (for example, the serious degradation of sugar maple forests in Eastern Canada). Sulfur oxide emissions are a prominent contributor to acid precipitation in most regions. Sulfur oxide emissions from diesel engines were at one time important, but sulfur levels in fuel have been reduced, resulting in a significant decrease in these emissions.

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An emerging issue related to vehicles is newfound evidence of the negative health impacts of fine particulate matter (see Chapter 2). Very small particulate matter emitted from diesel engines, but also from gasoline engines, is now recognized as posing perhaps the most significant health hazard of any vehicle-related pollution. Historically, however, improvements in transport-related air pollution have been attributable largely to technology advances. New emission standards continue to be adopted, spurring the development of technologies to meet those standards. It is believed that progressively tighter standards are likely to lead to continuing improvements in the near future, ultimately resulting in near-zero air pollutant emissions from vehicles.

Other, more problematic areas in which trends are moving in the wrong direction are fuel consumption and related greenhouse gas emissions. Such emissions are continuing to increase 1 to 2 percent annually in the U.S. transportation sector (Oak Ridge National Laboratory 2000). A growing body of evidence links carbon dioxide (CO_2) and other greenhouse gas emissions to major changes in global climate and to such consequences as the flooding of human settlements and natural habitats, changes in growing seasons and water supplies for agriculture, desertification, and the introduction of tropical disease vectors into temperate regions (IPCC 2001) (see Chapters 2 and 3, respectively, for discussion of the human health and environmental impacts of greenhouse gas emissions). The contribution of the U.S. transportation system to greenhouse gas production, in particular the increasing output of CO_2, is a major concern internationally.

As noted, while the technical energy efficiency of engines continues to improve through more efficient combustion and the use of lightweight materials and improved vehicle designs, fuel consumption continues to increase as a result of the production and sale of larger and more powerful vehicles and growth in travel. Indeed, as noted earlier, both motor vehicle stock and total VMT are growing more rapidly than the nation's population. This pattern is repeated throughout the world. In other countries, however, private vehicles are, on average, substantially smaller and driven substantially less.

At present, the processes by which environment-enhancing technologies are introduced, diffused, and utilized are poorly understood, as is the role the public sector can play in guiding the commercialization of these technologies. As illustrated by the paradox cited above, rapid advances in energy and materials technologies have not automatically led to reduced fuel consumption per VMT. There is a need to refocus research on the demand for vehicles, fuels, and transportation, along with new means of reducing the environmental impacts asso-

ciated with increases in that demand. These issues are addressed below for the two categories of technology advances noted earlier: fuels and propulsion technologies, and information, communication, and control technologies.

Fuels and Propulsion Technologies

Technologies are now being developed that could further reduce pollution from internal combustion engines in the near term, and new energy-efficient hybrid-electric propulsion technologies are being introduced. More efficient fuel-cell electric technologies also appear to be imminent. Fossil fuels will continue to be available for transport uses throughout the 21st century, mainly as a result of large supplies of natural gas being discovered around the world and increasing use of unconventional sources of petroleum, such as heavy oils and tar and oil sands. Natural gas is attractive because it has lower carbon content than petroleum and is cleaner burning; it also has the advantage that it can be converted to clean-burning liquid fuels at modest cost. However, use of these fuels will increase U.S. trade imports, and after energy losses from conversion and long-distance transport are taken into account, these fuels will tend to generate greenhouse gas emissions at levels similar to those produced by petroleum fuels.

Industry is spending billions of dollars annually to develop and commercialize environmentally enhanced fuels and vehicles. A major debate is under way, however, in both public and industry circles over which vehicle technologies are most attractive, which fuels should be used, and which policy instruments are most appropriate. Policymakers today are concerned primarily with reducing air pollutant emissions from diesel engines and with improving fuel economy. Vast sums of R&D funding are directed at these goals, primarily by the automotive and energy industries, but also by government. International, national, and some state governments spend millions of dollars addressing the health effects of diesel emissions; the automotive industry spends billions on reducing emissions from both gasoline (spark ignition) and diesel (compression ignition) engines; and the oil industry is spending billions on reducing sulfur levels, reformulating petroleum fuels, and designing new processes for converting natural gas to clean transport fuels. Consequently, internal combustion engines operating on cleaner petroleum fuels will continue to dominate the automotive market for many years, with natural gas–based fuels and next-generation electric-drive propulsion technologies gradually entering the market.

It is largely accepted that the conventional internal combustion engines and drive trains of passenger and freight vehicles will eventually be replaced by electric-drive technologies; that is, vehicles will be propelled at least in part by electric motors (Box 5-1 provides a brief overview of these vehicles). Less certain is which technologies are most attractive to society, and when and how these changes will occur and what the strategy for transition will be. Related technological issues include recycling of vehicles and the design and manufacture of vehicles using lightweight materials (technologies that are not addressed in this chapter).

The overall question is how R&D, public policy, regulatory controls, and public investments can be directed so as to accelerate the development, commercialization, and use of environmentally beneficial technologies in the most cost-effective manner. What publicly funded R&D is needed, and what public and public–private R&D processes need to be put in place to ensure continuity in these public efforts? The huge size of the automotive and energy

Box 5-1

ELECTRIC-DRIVE VEHICLES

Electric-drive vehicle technologies may be divided into four generic types:

- Pure battery electric vehicles that store wall-plug or charging-station electricity on board in batteries, ultracapacitors, and flywheels;
- Pure electric vehicles that obtain their electricity as needed from a rail, wire, or other off-board source;
- Hybrid electric vehicles that generate some or all of their electricity on board using a combustion engine; and
- Fuel-cell electric vehicles that convert chemical energy into electricity on board using a fuel-cell system.

Common to all four is an efficient and reliable electric motor that drives the wheels, the use of batteries (or other devices) to store energy captured during braking (known technically as regenerative braking), and the advantageous use of electronic technologies for a variety of vehicle control and auxiliary functions.

companies and the cyclical nature of public attention to energy issues have seriously undermined independent R&D capabilities in energy-related transport technologies. At present, major automotive companies, most of which are abandoning plans to build and market conventional-sized battery electric vehicles, are on the verge of deciding whether to make substantial investments in fuel-cell electric vehicles and are beginning to invest in hybrid electric vehicle production.

Automotive and energy companies are motivated to develop and commercialize these technologies by a variety of considerations. During the past three decades, the principal motivation for developing and introducing more environmentally benign vehicles in the United States and most other countries has been the desire for clean air and the resulting Clean Air Act regulations. The result has been an extraordinary reduction in vehicle pollutant emissions: average emissions from cars in real-world conditions declined by about 60 to 80 percent per VMT between the mid-1960s and mid-1990s (Pickrell 1999). As suggested above, continuing reductions are certain during the next decade as a result of even more stringent regulations scheduled to take effect in the next few years for both cars and trucks. These emission reductions have been the central focus of automotive research since the early 1970s. The improvements have centered on in-cylinder combustion and treatment of exhaust gases. This high level of R&D attention has generated many important side benefits, including the introduction of computer controls, first deployed to better control the mix of fuel and air entering cylinders. Other strong motivations have been reducing noise, and decreasing the costs and increasing the availability of energy. Much of the motivation for more environmentally friendly vehicles has derived from government through a mix of incentives and technology-spurring regulations.

While clean air will continue to be a strong motivation for enhancing vehicles and fuel, climate change is anticipated to play an increasingly important role. Mounting concerns about climate change are strengthening the resolve of governments and automakers to develop cleaner and more efficient vehicles. The European Union signed a voluntary agreement with automakers to reduce CO_2 emissions per VMT by 25 percent between 1995 and 2008, and Japan adopted significantly tighter fuel-economy standards in 1999 (Plotkin 2001). The United States has not increased fuel-economy standards for many years, but pressure is mounting for more stringent car and light-truck standards (currently at 27.5 and 20.7 mpg, respectively) and for abandonment of the distinctions between cars and light trucks (NRC 2001a; NRC 2001b).

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Information, Communication, and Control Technologies

Innovation and change in the transport sector have tended to be slow and incremental. In part, this pattern reflects the institutional complexity of transport systems: a large proportion of transportation activities is in the public sector (e.g., building, operating, financing, and regulating facilities and vehicles); companies in a multitude of industries participate in a variety of ways; and an enormous number of individuals and companies operate vehicles. Nonetheless, system-transforming innovations have occurred that have led to dramatic advances in productivity and societal benefits. We now appear to be on the verge of another such transformation.

In the past two centuries, only a few major system innovations have transformed surface transportation. They include interurban railroads in the mid-1800s; electric urban rail, introduced a few decades later; and automobiles in the early 1900s. Railroads transformed the nature of business; electric rail changed patterns of neighborhood development and contributed to the emergence of metropolitan regions; and the automobile altered the locus and variety of human activities. By increasing the speed of travel, these innovations transformed not only transportation, but also much of society. The catalysts for these earlier transformations in transportation were (respectively) the steam engine, electric traction, and the internal combustion engine, together with the associated fuel supply infrastructures.

The next era of transformation in transportation will reflect the integration of information and communication technologies into lifestyles and modal choices. The catalyst for this era of "smart transportation" will be electronic and wireless communication systems.[2] The major thrust of research in the area of ITS has been advanced transportation management and information systems, which serve to provide a new class of information to drivers, fleet operators, and traffic managers. One of the public goals for these systems is to maximize the throughput and usage of existing roadways. The private goal is to create markets for new products and services, such as navigation devices

[2] The one notable exception to the incremental advances in this area is the aborted automated highway program, funded by the Intermodal Surface Transportation Efficiency Act with substantial industry partnerships. This program was not continued under the Transportation Equity Act for the 21st Century, largely because of weak interest by industry (due in part to liability concerns) and opposition from the environmental public-interest community, which feared accelerated urban sprawl. The automated highway R&D program was converted into the Intelligent Vehicle Initiative, a program aimed at near-term safety innovations.

and information services for drivers. Attention and resources are directed primarily at using that information to improve safety and the efficiency of travel and goods movement. Tens of billions of dollars are being invested, mainly by the private sector. The net result of these initiatives will clearly be to improve the current system. At the same time, it is important to note that, as in the past, most innovations and initiatives are aimed at enhancing existing services and patterns. However, lifestyles are also evolving. A broader vision and more systems-level initiatives would likely result in a wider choice of access to activities, services, and products, and in shifts in patterns of consumption that could generate far greater benefits through reductions in congestion and environmental impacts.

The potential for a major break from the past is highlighted by the following trends and relationships. Light-duty vehicles account for 95 percent of all person-miles of surface travel in the United States; these vehicles are typically unused 23 hours per day, and all are designed to operate with roughly the same speed performance. Since World War II, transit has progressively lost overall market share, although transit ridership has grown in absolute terms in most major urban regions.[3] Personal-vehicle occupancy rates declined until fairly recently and remain low. Vehicle ownership has steadily increased, and more than 60 percent of U.S. households own more than one private vehicle. The overall effect is unprecedented mobility and accessibility. But the situation also leads to massive consumption of resources and the generation of many adverse environmental impacts, while contributing to various social ills.

The opportunity may now exist to enhance access to goods, services, and activities while reducing the need for motorized transportation and mitigating its adverse impacts. In the past 50 years, vehicles and roads have been standardized and privately operated vehicles more widely embraced because no alternative could compete with the personal (and often single-occupant) vehicle except in specialized circumstances, such as dense downtowns. However, the widespread availability of low-cost communication and information tech-

[3] Although transit has progressively lost market share since World War II, investments in public transportation in recent decades have resulted in dramatic increases in its use in some areas. That being said, in the United States, transit still accounts for only 2 percent of all person-miles traveled in vehicles. To evaluate the effectiveness of public transportation, however, one must consider where it is provided. Only about half of the communities in the United States have public transportation systems, and even in those communities, proper evaluation of public transportation requires route-by-route comparisons of places where people have a choice between their private vehicle and public transportation.

nologies, including the Internet, may allow vehicles to be used in a far more specialized and efficient manner. This could come about directly from a better match between personal travel needs and the system of private vehicles (e.g., access to a variety of vehicle types through car sharing), or indirectly from user adaptations (discussed in the next section). However, there is no consensus on the probable size and direction of these benefits of communication and information technologies, and the distributional impacts are largely unknown.

Analogous observations about vehicle information systems can be made for the freight sector, which has led in the application of these technologies to improve logistics and exploit new forms of supply-chain management. Again, however, resulting shifts in the distribution of benefits and undesirable environmental consequences are poorly understood, notably in the area of urban trucking.

Role of Publicly Funded Research

New and improved technologies play a central role in the evolution of the transportation sector. Huge investments have been made in R&D, especially by the private sector, to enhance transportation technologies and improve their environmental performance. For example, the global automotive industry spends about $50 billion on R&D per year (5 percent of revenue) (GAO 2000); about a third of that total is spent by U.S.-based companies, with a large proportion of those expenditures going to energy and emissions research. Government-funded research is a small fraction of that amount.

New industrial R&D is increasingly being directed at hybrid and fuel-cell electric vehicles and at applications of information, communication, and control technologies. In all of these cases, rapid innovation is taking place. Rapid innovation, however, does not necessarily translate into environmental improvements, primarily because the innovations are generally introduced as technology fixes; that is, they are designed to enhance existing technologies without disrupting current patterns, investments, or lifestyles. Arguably, much greater improvements in environmental quality, resource utilization, productivity, and quality of life would be possible if these technology solutions were incorporated into *system* innovations that led to a transformation of transportation, energy, and information systems, including the market mechanisms that enable these systems to function.

In any case, government can and does play an important role through a variety of means in directing industrial R&D toward those innovations that

have larger environmental benefits and in targeting public investments to systems and services that offer the greatest benefits. The means employed include corporate tax policy, participation in public–private R&D partnerships, leveraged R&D awards, consumer tax incentives, and rules and regulations. Recent examples include R&D partnerships with the automotive and battery industries [e.g., the Partnership for a New Generation of Vehicles (PNGV), the U.S. Advanced Battery Consortium, the Intelligent Vehicle Initiative, and the Future Truck Initiative], as well as regulations regarding the safety, air and water pollution, solid waste disposal, and energy use aspects of vehicles. The market implications of these rules and incentives and the value of the R&D partnership investments easily amount to tens of billions of dollars per year.[4] Even a modest improvement in government rules and R&D strategies could generate billions of dollars per year in savings while enhancing the environment.

The Advisory Board concludes that an enhanced public R&D program is needed to generate the knowledge base required to develop a broad view of system-enhancing transportation technologies. This conclusion is supported by a number of observations on the current state of policy, knowledge, and practice:

- Government regulations and policies largely reflect a historical tendency to address problems within a narrow, single-issue framework. Some policies and regulations address air pollution, others fuel consumption, others safety, and still others congestion; few policies address several problems simultaneously. Policy conflicts sometimes result from this narrow focus, and trade-offs can be difficult to make. For example, more fuel-efficient vehicles by themselves do nothing to reduce congestion and may even support more driving by reducing operating costs; higher fuel prices may encourage conservation but reduce mobility. Policies may need to allow for a flexible technological response to satisfy multiple goals. Research could contribute to the design of policies that would be sensitive to synergies and unintended interaction effects.
- To date, air quality improvement has been achieved primarily through technology, and this has reduced motivation for behavioral changes.

[4] Reliable data do not exist. It is estimated that on average, $2000 is spent per car for safety and emissions; with about 15 million light-duty vehicles being sold each year in the United States, the expenditures are $30 billion annually. In addition, billions of dollars are spent annually on R&D partnerships.

- Improvements in energy efficiency have not been exploited in the United States to achieve greater fuel economy. The technical energy efficiency of vehicles has increased about 30 percent in 15 years, but fuel consumption rates have increased because vehicles being sold are, on average, larger and more powerful.
- New technologies such as fuel cells, information technologies, wireless communication, and advanced vehicle control technologies tend to be used first as substitutes and as a means of enhancing existing patterns and only much later as a way to transform overall patterns. This evolution can be accelerated.
- In many ways, the United States is out of step with the rest of world in terms of the size and use of vehicles. Better understanding of how this situation evolved could be a first step in developing effective policies for managing the energy and environmental policy consequences of new technologies.
- A majority of households have access to more than one vehicle and are tending to move toward ownership of specialized vehicles (and perhaps new ownership patterns and mobility services).
- The potential social benefits of information and telecommunication technologies and telesubstitution are great, but their realization will require innovative, system-level thinking and designs.

RECOMMENDATIONS

The recommendations that follow address five topics: (*a*) fuel and propulsion technologies and their impacts; (*b*) intelligent transportation technologies and their impacts; (*c*) user behavior and consumer choice and demand; (*d*) policy instruments related to evolving technologies; and (*e*) institutional arrangements for R&D. For each topic, examples of the kinds of research envisioned by the Advisory Board are given.

Recommendation 4-1.
Analyze transition pathways to environmentally beneficial fuels and vehicle propulsion technologies.

The United States is seriously considering a transition away from petroleum fuels and internal combustion engines. With intensifying calls for more environmentally

benign vehicles and fuels and rapid innovation in propulsion technologies, major changes are about to take place. Better understanding is needed of the choices and pathways of those changes. An improved knowledge of the new technologies and their impacts would inform the policy and R&D processes with respect to pollution, energy use, energy supply, and climate change.

Government and the public need to be well informed to ensure that environmental factors are adequately considered in the development, evolution, and use of vehicles and fuels. The petroleum and automotive industries are among the largest in the world, are global in their operations, and spend billions of dollars every year on product development and market research. The challenge is to complement, leverage, and influence industrial R&D, not duplicate it.

Example: Toward a hydrogen economy. It is widely believed that hydrogen will be the dominant energy carrier at some point in the future. But how will hydrogen be produced and distributed? How will it be used in vehicles? What is the desirability of introducing an interim fuel such as methanol? How should emissions and energy rules be modified and when? Are new standards and codes needed for storage tanks, pipelines, and fuel handling? Should investments for converting remote natural gas into liquids be encouraged (through basic R&D at national laboratories and universities, R&D tax incentives, and fuel quality and vehicle emission standards)? Any actions that are or are not taken can influence billions of dollars in industrial investments and can have far-reaching implications for the environmental impacts of the transportation system.

Example: Handling and distribution of alternative fuels. The recent reversal of California regulations concerning methyl tertiary butyl ether (MTBE), a chemical made from natural gas and added to gasoline to reduce air pollutant emissions, highlights the need for better scientific and policy research. MTBE is being banned in California because leakage from storage tanks has polluted groundwater, even though oil refiners had been required by regulators just a few years earlier to invest billions of dollars in MTBE's production and distribution. Every fuel has a different set of safety and environmental impacts, and more research is necessary to understand and measure the full spectrum of those impacts. Research is needed on the costs and safety implications of infrastructure for new fuels (e.g., where hydrogen fuel stations might be located and at what cost), on issues of industry competitiveness associated with introducing new fuels, and on strategies for sequestration of carbon from new fuels (e.g., from natural gas converted into hydrogen).

Example: New propulsion technology and fuels in heavy-duty vehicles. Even though medium- and heavy-duty trucks are a principal source of air pollutants (responsible for about one-third of nitrogen oxide emissions from vehicles) and greenhouse gases, they have received little scrutiny from regulators and policymakers until recently. Emission regulations and emission control technology on large diesel engines lag perhaps a decade behind those for light-duty gasoline engines. Data and knowledge about freight transport and its energy and environmental impacts are sparse. Research is needed on truck usage patterns (including idling), emissions and energy-use characteristics, policy instruments that can reduce energy use and emissions, development of infrastructure for new truck fuels, and vehicle and fuel tax policy.

Example: System-transforming transport-energy opportunities. Research is needed on new transport and energy system designs that have the potential to yield dramatic improvements in energy consumption and other environmental attributes. These might include designs incorporating not only non-fossil-based hydrogen, but also CO_2 sequestration, entirely new forms of hydrogen and electricity storage, and new energy-serving vehicle guideways. In the latter case, for instance, electricity could be supplied easily and cheaply to battery-powered vehicles along a guideway. The vehicles would have small (inexpensive) battery packs for short access and egress trips off the electrically powered guideway at either end of the line-haul portion of the trip. Other related system designs are possible, with the potential for large reductions in energy use and emissions.

Recommendation 4-2.
Design and analyze the application of intelligent transportation technologies to achieve environmental benefits.

R&D on ITS technologies is dividing into two groups. One is dominated by the transportation departments of the state and federal governments and is focused on better management of the road infrastructure. The other group involves automotive, telematics, and other information technology companies that are working to develop profitable products and services for vehicle buyers and travelers. In each case, beneficial research and product development are taking place. However, the resulting changes are of an incremental nature and may or may not have environmental benefit. For instance, providing better traffic information to drivers may smooth traffic flows but also encourage more driving.

Little effort is being devoted to investigating technology-based strategies, designs, and services—for example, use of ITS technology to facilitate the use of public transportation—with the potential to generate a transformation of transportation patterns that could greatly reduce environmental impacts. These new options and services might include smart car sharing, smart paratransit, dynamic ridesharing, and teleservices, as well as a variety of other innovative new mobility services. Currently, none of these options can compete effectively with the private motor vehicle. However, combined with each other and with other innovations, such as neighborhood cars, they could lead to a basic change in transportation patterns with attendant environmental, economic, and social benefits. The challenge of research is to determine how wireless technologies can be used to connect the various modes and services seamlessly in a way that will be attractive to consumers and service providers and yield major societal benefits. It is also important to understand that particular services and products are likely to evolve over time and may develop differently in different communities and institutional settings.

Example: Demonstrations and pilot tests of innovative transportation services. Standardized software and hardware technologies now being developed are key to the successful emergence of the above new services and products; in many cases, they are a necessary precondition. But the key challenge, again, relates to market and institutional issues, many of which are situational and specific to local settings. There is a need to experiment with means of developing effective market strategies, creating local partnerships, and educating local communities about the possibilities for innovative transportation. Demonstrations need to be launched with the idea that they are pilot tests expected to evolve into full-fledged businesses and services.

Example: Economic, financial, environmental, and social equity analyses of innovative transportation businesses, services, and products. New transportation services and businesses will usually build on partnerships and have multiple revenue streams. They may evolve within entirely new mobility companies that own and maintain passenger vehicles. These companies may spring from car rental firms, car-sharing organizations, local affinity groups, automotive companies, large business parks, or any number of other organizations. They may have links to transit operators, fleet managers, and large employers. Unfortunately, limited experience is available on which to build. A research initiative is needed to explore various economic and business models; to determine whether these models might better meet the needs of particular user groups, such as the elderly and mobility-disadvantaged; and to examine envi-

ronmental impacts. The overall effects on the amount of travel and the types of vehicles used could be great. The research would address vested interests of taxi and transit operators and the organizational behavior of prospective service providers, whether traditional businesses or wholly new types of mobility enterprises. Existing travel demand, energy, and emission models need to be extended to handle these new applications, modes of travel, and services, including delivery of packaged goods.

Recommendation 4-3.
Analyze user response to and future demand for environmentally beneficial vehicles, fuels, and mobility services.

Public policy addresses the continuing tension between the desires of the individual and the interests of society. If travel were free and involved no delay, individuals would travel more frequently. Travel, however, is not free, and many of the associated costs are not borne by the traveler. Relative to other countries, the United States has been less restrictive regarding the travel desires of its citizens. Fuel prices are relatively low, vehicles are lightly taxed, and road capacity and quality have been expanded rapidly.

To provide a better knowledge base for public policy, research is needed on the demand for and use of environmentally beneficial vehicles, fuels, and mobility services. Under what conditions and with what incentives would individuals and organizations embrace environmentally friendly products and services? What might be the anticipated and unanticipated consumer responses to different packages of innovations? What would be the aggregate consequences for the environmental balance sheet of the ready availability of such products and services on a large scale? Do we even have suitable analytical tools to address these questions?

Example: Demand for and use of new environmentally beneficial vehicles and fuels. With the proliferation of vehicles (overall, more than one per licensed driver) and the introduction of new fuels and propulsion technologies, the opportunity arises to match specialized vehicles with appropriate applications. However, U.S. vehicle users are familiar with only a narrow range of vehicle attributes. The nation's population of private automobiles and light trucks tends to be more homogeneous than those of other countries, with fewer small vehicles and almost all vehicles operating on gasoline and diesel fuel. Nonetheless, multivehicle households (about two-thirds of all U.S. households) increasingly own a mix of vehicle types, suggesting increasing specialization of use. In this

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context, little is known about the demand for home recharging and refueling, the driving "feel" of electric motor propulsion, the perceived safety aspects of new fuels, the use of smaller vehicles in various settings, or the attraction of new auxiliary services made possible by on-board high-power electrical systems.

A number of other questions also arise. Are companies following the market? Under what conditions might consumers shift buying patterns toward "green" vehicles? Does the development of new technologies, even without mass commercialization, lead to a restructuring of demand patterns? How might more environmentally benign vehicle technologies be introduced to the marketplace? How might the market be segmented differently? What is the role for social marketing? What additional research is needed to understand the demand for new attributes unfamiliar to consumers, especially those associated with fewer environmental impacts?

Example: Demand for and use of new packages of communication, ITS, and vehicle technologies. Many of the above research priorities for vehicles and fuels also apply to new modes of transport and mobility services now being created, including smart car sharing, smart paratransit, and dynamic ridesharing; they apply as well to information services that can permit the spatial and temporal reorganization of activities, notably work and shopping. Under what conditions will individuals and organizations pay for and use new mobility and information service packages? To what extent will purely electronic services complement or replace physical movement? People are already using telecommunications spontaneously to become more mobile and more flexible. In the work domain, this trend appears to have influenced travel behavior more than organized telecommuting, but will the penetration of flexible work become more substantial if it is coupled with smart car sharing and other innovations? In any case, patterns of travel and access could be transformed in ways that would lead to radically different life and work styles. A particular case of interest is the role of integrated transportation and information services in meeting the mobility needs of the growing elderly segment of the population; for this segment, these services may also be packaged with housing. What will be the effect of these technologies on total travel, and what will be the energy and environmental impacts? Again, would environmental benefits be greater if governments actively promoted these transformations?

Example: New methods for estimating demand and simulating adoption paths. In addition to research on the demand for environmentally beneficial vehicles, fuels, and mobility services, research is needed on methods for estimating the penetration of these technologies and alternative paths for their adoption.

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Conventional models and other methods of projecting private-vehicle and travel demand are likely to be increasingly less helpful in answering these complex questions about emerging technologies, individually or in combination.

The challenge is to estimate a sufficiently broad set of interacting outcomes in a future that may, in some respects, be unfamiliar. Most survey methods that address stated preferences for particular attributes of new products and services do not provide stable results except for questions that are highly limited in scope and frame. Research is needed on how to improve the design of simulations of consumer responses, such as those used for conducting some premarket surveys of new vehicle types or for exploring responses to unusual circumstances, such as fuel shortages. The focus of these methods should be on understanding decision processes as much as on forecasting outcomes. Understanding demand for technologically advanced packages of mobility, access, and information services will also require new urban modeling tools that can take into account interactions with land use (as discussed in Chapter 6).

Recommendation 4-4.

Develop policy instruments to encourage environmentally beneficial vehicles, fuels, and mobility services.

To a large extent, public policy is predicated on previous and current circumstances—environmental, political, economic, and technological. The advent of new system-transforming technologies means that many of the central premises of existing policies and policy instruments may no longer be relevant or appropriate. For example, emission and fuel economy standards are based on the use of internal combustion engines and petroleum fuels. Road standards and traffic rules are premised on all vehicles using all roads. Road financing is based on vehicles consuming petroleum fuels roughly in proportion to their use. Rules limiting jitney services are grounded in the ubiquity and effectiveness of conventional bus and rail services. All of these fundamental understandings and conditions are likely to become anachronistic with the introduction of new fuels and propulsion technologies and the widespread availability of inexpensive wireless communications. And new understandings of environmental threats—largely with respect to climate change and particulate matter—necessitate even further overhaul of policy instruments. New policy research is also needed on how to maximize environmental and social justice benefits, with explicit attention to opportunities and problems created by new technologies (see also Chapter 4).

Example: Reform of policy instruments for reducing energy and environmental impacts of technologies. Today's policy instruments are rapidly becoming anachronistic and inefficient and have a distorting effect on innovation, new technology, and fuel investments. What type of policy structure might be used to reduce greenhouse gas emissions from transportation? Might it replace or be added to the existing air quality regulatory structure? How might emissions trading be employed to reduce greenhouse gases? What is the role of voluntary instruments? How might policy instruments be crafted to integrate behavioral and technological strategies? What are the potential advantages and problems associated with introducing passive vehicle monitoring, such as onboard diagnostics linked to a pollution pricing system? How can instruments be devised that would allow for trade-offs between different goals (such as diesel's lower greenhouse gas emissions but higher particulate emissions)? How should fuel taxes evolve given that they are now calculated on a volumetric basis and provide most of the funding for U.S. roads? As vehicles become more energy-efficient and use different fuels with differing units of measurement, energy characteristics, and greenhouse gas emissions (from the vehicle and upstream), the current fuel tax system becomes not just inadequate, but grossly distorted. And beyond this empirical research is a need for fundamental social science research on associated political processes and public attitudes.

Example: An equitable regulatory environment for emerging transportation systems. Minimal research has been devoted to analyzing the policy implications of new transportation system configurations. The more specialized nature of future fuels and vehicles, coupled with the potential to reduce the transaction costs for intermodal travel (with low-cost information and communication technologies), creates the opportunity to link vehicles to applications in a more efficient and socially and environmentally desirable manner. Instead of buying and using conventional-sized personal vehicles for all trips, travelers could choose readily available alternatives, for example, shared-lease arrangements (e.g., for an everyday vehicle for exclusive use, plus an allotment of time on a vehicle with a larger carrying capacity or some other attribute, such as four-wheel drive); shared-use vehicles; smart paratransit services that would promptly pick one up at home or elsewhere; and small neighborhood vehicles powered by batteries. All of these concepts require policy research on regulatory structures that would maximize the associated environmental and social justice benefits, with due regard for the opportunities and problems created by enabling technologies, such as electronic toll collection, integrated smart cards for parking, and vehicle positioning technology. Research is also needed with respect to standards and codes,

insurance requirements, and taxi and jitney regulation, as well as the best ways to address safety concerns, such as the operating limits of neighborhood vehicles.

Example: Conception of environmental life-cycle policy approaches. Over time, efforts to reduce environmental degradation have shifted toward prevention through better product design and more efficient use of resources. In the future, the emphasis is likely to proceed one step further toward the use of materials and resources that are fully regenerative, rather than depletive, and that are fully biodegradable or reusable (McDonough and Braungart 1998; Hawken et al. 2000). Research is needed to determine what role government can play in encouraging new and existing companies to design and produce transport technologies that are more environmentally sustainable. A knowledge base needs to be developed to better understand the opportunities, costs, and benefits involved. Possibilities range from the use of more recyclable and less toxic materials to technologies that leave a smaller environmental footprint. A strategy needs to be developed for determining the types of products and companies that merit support, the nature of that support, and the economic and environmental benefits of those investments.

Recommendation 4-5.
Design an independent institutional arrangement for transportation technology R&D.

Technology development is principally an industrial activity. However, transport technologies have large environmental externalities and major societal impacts, and many transport facilities and services are owned, managed, or regulated by government. The public sector plays an important role in encouraging the development of technologies that are more environmentally and societally beneficial. The R&D resources of industry, especially in the automotive, energy, and information technology sectors, dwarf those of government. The challenge is to devise a cohesive public-sector R&D strategy that can leverage and stimulate industrial investments in environmentally beneficial technologies, and provide a knowledge base for designing and implementing efficient and effective public policy regarding transportation technologies. A stable and independent institutional arrangement is needed to oversee public R&D investments associated with transport-related technologies and to ensure the continuity of the knowledge base.

Example: R&D on vehicles and fuels. Considerable government funds are invested in cutting-edge research aimed at developing cleaner-burning and

more efficient vehicles and fuels (as well as increasing the global competitiveness of domestic companies). In recent years in the United States, much of this R&D has been conducted under the rubric of PNGV. Substantial R&D funds are also spent in this area by the military and under various other programs. Historically, little of this research has been directed through the Department of Transportation (DOT), even though DOT administers fuel economy standards. Better R&D strategies and more effective R&D programs are needed in the area of vehicles and fuels. The question of what strategies and R&D activities would be most effective needs to be considered, as well as what relative priority should be given to safety, greenhouse gas emissions, particulate matter and other pollutants, acid precipitation, basic science research, and the role of Original Equipment Manufacturers (OEM).

Example: Improving the effectiveness of public R&D and public–private R&D partnerships. Challenges and problems increasingly cut across many institutional jurisdictions, political and national borders, and disciplines. More and more transportation and energy companies are mounting joint R&D ventures, within and across industries. What is the most appropriate and effective role for public R&D?

Public–private research partnerships for transport technologies launched in the 1990s include PNGV, the U.S. Advanced Battery Consortium, the Intelligent Vehicle Initiative, and the Future Truck Initiative. While PNGV is often cited as a model (Chapman 1998), and a series of National Research Council reports have evaluated its progress, no evaluation has been performed of the overall benefits of the program or of its effectiveness and efficiency in meeting the goal of developing affordable advanced technology (Sperling 2001; NRC 2001b).

From the public-sector perspective, a better understanding is needed of the opportunities and challenges presented by partnerships between federal agencies, and even more so by those among federal agencies, universities, state and local governments, small companies, other countries, energy companies, and automaker OEMs. Intra- and interindustry partnerships (for instance, between automakers and major suppliers to develop new technologies, and between automakers and oil companies to develop new fuels), are becoming more common and also need to be understood. Such research should thus be aimed at evaluating the *processes* of partnership. It should shed light on the types of companies and partnerships that are most likely to bring environmentally beneficial products to market and help identify the best methods for leveraging public R&D funds.

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Abbreviations

AAAS	American Association for the Advancement of Science
IPCC	Intergovernmental Panel on Climate Change
NRC	National Research Council
GAO	General Accounting Office

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6

Research Area 5

LAND USE

Research on transportation and the environment has only recently begun to explore in any significant depth the complex relationships among land development patterns, transportation investments, travel behavior, and consequent environmental impacts.[1] Decision makers and practitioners have little knowledge about, for example, the role the built environment may be playing in causing Americans on a per capita basis to drive more and to transport goods farther each year, as has been the pattern for several decades. Transportation professionals need to know more about other factors, in addition to land use, that have contributed to today's travel patterns and that interact with land use in sometimes subtle ways to influence travel choices. Decision makers and practitioners also know very little about the reverse—how driving habits and related factors affect land use and community life. In general, a better understanding is needed of the complex forces that shape land development and subsequent community form so

[1] Several recent publications provide detailed reviews of the literature on transportation, land use, urban design, and growth patterns. For example, the National Transit Institute's *Coordinating Transportation and Land Use Course Manual* provides a detailed discussion of transit-oriented development studies (NTI 2000); Handy (1997) reviews research on travel behavior and urban design; Burchell et al. (1998) summarize findings on sprawl and its relation to infrastructure needs; and Burchell et al. (2002) analyze sprawl, its costs and benefits, its relation to infrastructure, and its personal and social effects. A study by Kuzmyak et al. (forthcoming) for the Transit Cooperative Research Program will provide a summary of literature on traveler responses to land use and site design. These publications also note substantial gaps in the research to date and identify research needs, ranging from more systematic and longer-term analyses of trends and more comprehensive case studies to the development of better policy tools and evaluation methods.

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that decision makers and the public can evaluate alternative policy and investment strategies for the future.

These are immensely challenging topics, in part because the causal relationships involved are two-way: land use has profound impacts on transportation, and transportation has profound influences on land use. Figure 6-1 illustrates this relationship. The land use–transportation relationship is depicted as two closed-loop systems that exert influence over each other. Simply put, the development of land for a particular use can generate new trips, thereby influencing demand and ultimately the need for new transportation facilities. Conversely, improvements to transportation systems have the ability to influence accessibility to existing activity centers, thereby improving land values and influencing location decisions and development patterns (Meyer and Miller 2000). Improving the knowledge base on these subjects is critical because—through the marketplace, public policy, or, more likely, a combination of the two—Americans will be making decisions about how to accommodate a likely 50 percent increase in population during the next half-century. These 140 million new residents will need mobility to access homes, schools, shops, workplaces, and recreation. Where and

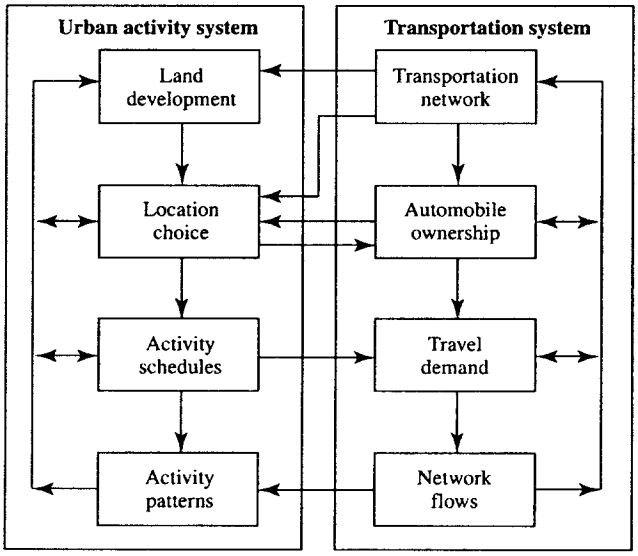


FIGURE 6-1 Urban activity (including land development) and transportation systems interaction. (Source: Meyer and Miller 2000, Figure 3.7, p. 130.)

how this expected growth is distributed on the landscape is likely to have major implications for surface transportation, as well as for the landscape itself. The transportation community needs better information on ways to handle this growing population that better account for, respond to, and, where possible, avoid transportation-related environmental impacts.

Surface Transportation and Land Use

Metropolitan areas in the United States expanded at rates from 2 to as many as 20 times faster than population growth during the second half of the 20th century (see Tables 6-1 and 6-2). Expansive land development has come to rural areas and small towns as well. According to the Department of Agriculture, in the 1990s Americans converted open space to developed land at a rate of 2.2 million acres per year or 251 acres per hour—a rate of conversion 50 percent greater than that of the 1980s[2] (USDA 2000). The land most affected by the extent and pace of expansive development is that closest to existing cities and towns—the farms and open space that Americans often care most about. Development on the metropolitan fringe typically is low-density, scattered, and automobile-dependent. Some of the longest commutes in metropolitan regions are made by residents who live at the metropolitan edge. Not only are citizens and their leaders questioning the transportation impacts of such development, but they are also concerned about the effects of sprawling land development on ecosystems, farmland, scenic and historic resources, and Americans' senses of place and community (see also Chapters 3 and 4). Citizens are concerned, too, about the economic and social consequences of prevailing development patterns, both for new communities with new fiscal burdens and for older communities left behind as investment and employment opportunities flow outward[3] (Orfield 2002; Burchell et al.

[2] A comparison of the midpoint of the more recent period surveyed by the U.S. Department of Agriculture, 1995, with the midpoint of the earlier period, 1987, indicates that nationwide traffic volume increased 25 percent, from 1.92 trillion to 2.4 trillion vehicle-miles traveled per year (FHWA 1996a). During that same period, the U.S. resident population grew only 8.5 percent, from 242.3 million to 262.8 million (U.S. Bureau of the Census 2000).

[3] For a sampling of opinion data, see, e.g., Princeton Survey Research Associates (2000) (finding that 18 percent of Americans mention issues related to development, sprawl, traffic, and roads as "the most important problem facing the community where you live," tying that cluster of issues with crime and violence as the most mentioned categories, above education and the economy); Janes (1999) (finding that 68 percent of state and local policy makers believe that concern

TABLE 6-1

GROWTH IN POPULATION AND LAND CONSUMPTION, 1950-1990

Urbanized Area	Population Growth, 1950–1990 (%)	Developed Land Growth, 1950–1990 (%)	Ratio of Area Growth to Population Growth
Pittsburgh, Pa.	9.50	206.30	21.72
Buffalo, N.Y.	6.60	132.50	20.08
Milwaukee, Wis.	47.90	402.00	8.39
Boston, Mass.	24.30	158.30	6.51
Philadelphia, Pa.	44.50	273.10	6.14
St. Louis, Mo.	39.00	219.30	5.62
Cleveland, Ohio	21.20	112.00	5.28
Cincinnati, Ohio	49.10	250.70	5.11
Kansas City, Mo.	82.70	411.40	4.97
Detroit, Mich.	34.30	164.50	4.80
Baltimore, Md.	62.70	290.10	4.63
New York, N.Y.	30.50	136.80	4.49
Norfolk, Va.	243.60	971.00	3.99
Chicago, Ill.	38.00	123.90	3.26
Minneapolis–St. Paul, Minn.	110.70	360.20	3.25
Atlanta, Ga.	325.40	972.60	2.99
Washington, D.C.	161.30	430.90	2.67
34 metropolitan areas with population > 1 million	92.40	245.20	2.65

Source: Meyer and Miller (2000).

over livable communities is growing, naming traffic congestion, urban sprawl, and housing development as three of the top four "most serious issues" facing their communities); National Association of Local Government Environmental Professionals (1999) ("In recent years, more and more business leaders have come to realize that sprawl can be bad for their bottom lines and economic competitiveness . . . Business leaders whom NALGEP interviewed overwhelmingly cited the impact of sprawl on quality of life as the primary concern . . ."); American Planning Association (2000); Smart Growth America (2000); American Farmland Trust (2001); and National Association of Realtors (2001).

TABLE 6-2

GROWTH IN POPULATION AND LAND CONSUMPTION, 1982–1996

Urbanized Area	Population Growth, 1982–1996 (%)	Developed Land Growth, 1982–1996 (%)	Ratio of Area Growth to Population Growth
Detroit, Mich.	–1.1	19.6	–
Rochester, N.Y.	–3.1	15.5	–
Buffalo–Niagara Falls, N.Y.	0.0	52.0	–
Pittsburgh, Pa.	6.6	39.0	5.9
Harrisburg, Pa.	14.5	72.0	5.0
Boston, Mass.	5.6	26.9	4.8
Chicago, Ill.–Northwestern Ind.	10.9	44.2	4.1
Cleveland, Ohio	6.3	23.8	3.8
New York–Northeastern N.J.	2.9	10.1	3.4
St. Louis, Mo.–Ill.	9.2	30.8	3.3
Baltimore, Md.	26.2	64.4	2.5
Nashville, Tenn.	25.0	53.9	2.2
Tucson, Ariz.	42.2	86.7	2.1
Las Vegas, Nev.	138.9	243.8	1.8
Los Angeles, Calif.	23.4	22.7	1.0
Houston, Tex.	27.5	9.8	0.4
Avg. of 70 U.S. metropolitan regions	20.2	28.8	1.43

Source: Meyer and Miller (2000). Calculated on the basis of data from Texas Transportation Institute (1998). Developed land growth as represented by urbanized area in census data.

2002). The cumulative effect of individual development decisions is that development continues to occur in a dispersed pattern, for reasons that are not fully understood but that include a range of individual preferences, market forces, and public policies.

At the same time that metropolitan areas have been expanding, the amount of driving in personal cars and light trucks (mainly minivans, sport utility vehi-

cles, and pickup trucks) has also grown substantially. As with developed land area, driving has grown at a significantly faster rate than population. For the 5 years 1996 through 2000, driving grew at an average rate of more than 2 percent per year, ranging from a 3.1 percent increase in 1997 to no increase in 2000, a year of higher fuel prices and a dampened economy.[4] Although the relationships of association and causation between the two trends are complex and only partly understood, their implications are significant for the future of community development, transportation planning, transportation system efficiency, and environmental quality.

Environmental Problems Associated with the Land Use–Transportation Connection

Understanding how metropolitan growth and travel trends are related—how land use and other factors, including national and local policies and investment decisions, influence travel behavior—will be fundamental to the choices American society must make as the country's population and economy grow in the 21st century. What is apparent now is that, whatever the causes, the absolute and per capita growth in vehicle travel has been associated (either directly or indirectly) with the expansion of metropolitan areas and with a number of environmental problems.

Tailpipe Emissions

While improved emissions technology has resulted in cleaner air in many parts of the country, transportation in the United States still contributes some 450 million metric tons annually of carbon dioxide, a major greenhouse gas, to the atmosphere (see Chapter 2). This figure represents about 32 percent of total U.S. carbon emissions, and the amount is growing rapidly. Carbon emissions from transportation are increasing at a 20 percent faster rate than overall

[4] The number of miles driven nationally remained essentially the same from 1999 to 2000. While it is possible that this leveling will be sustained, nothing in the previous 4 years or the past three decades indicates that the drop-off represents a trend. In 1999, miles driven increased 2.5 percent, the same rate of growth observed in 1998 and close to the average annual rate for the 1990s as a whole. The reasons why 2000 was different have yet to be fully explored. Lower rates of driving associated with the energy shortages of the late 1970s and early 1980s were short-lived. If the leveling is sustained, research will be needed to explain why and to indicate ways of taking maximum advantage of the trend for transportation efficiency and the environment.

emissions from all sources.[5] In addition, as discussed in Chapter 2, cars and other highway vehicles constitute a continuing major source of air pollutants that are harmful to human health, including carbon monoxide, volatile organic compounds, nitrogen oxides, diesel soot, and a number of carcinogenic and toxic chemicals.[6]

A publication of the U.S. Environmental Protection Agency (EPA) summarizes the situation and suggests that the rising trend in emissions from transportation sources is due in substantial part to urban sprawl and changes in land use:

> Despite considerable progress, the overall goal of clean and healthy air continues to elude much of the country. Unhealthy air pollution levels still plague virtually every major city in the United States. This is largely because development and urban sprawl have created new pollution sources and have contributed to a doubling of vehicle travel since 1970. (EPA 1994)

Government analysts are concerned that current trends in vehicle trips and miles driven, even with continuing incremental improvements in emission control systems, threaten to reverse recent national improvements in air quality by causing increases in total emissions of not just carbon dioxide, but also other pollutants (including sulfur dioxide and particulates) (EPA 2001a; EPA 2001b; FHWA n.d.; EPA 1993). Nitrogen oxide emissions are of particular concern. Despite improvements in the emission performance of individual vehicles, total nitrogen oxide emissions from highway vehicles rose

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[5] Changes in the world's climatic patterns due to the greenhouse effect have already been detected by consensus among international scientists, and the eventual damage to human health and ecosystems is predicted to be widespread and serious. As of this writing, it is unclear what the ultimate American response will be to international agreements negotiated in Rio de Janeiro and Kyoto on containing greenhouse gas emissions or whether new agreements will be negotiated. Under any scenario, however, it will be difficult to meet national obligations if emissions from the transportation sector continue to rise so dramatically.

[6] Although air is getting cleaner in many areas of the country as a result of better emissions technology, highway vehicles still emit some 60 million tons of carbon monoxide per year, about 62 percent of the nation's total inventory of that pollutant. Cars and other highway vehicles still emit some 7 million tons per year (almost 26 percent) of total volatile organic compounds and 8 million tons per year (about 32 percent) of total nitrogen oxides. Volatile organic compounds and nitrogen oxides are both precursors of ozone smog. Motor vehicles also continue to emit as much as 50 percent of the country's carcinogenic and toxic air pollutants, such as benzene and formaldehyde. And heavy vehicles, particularly diesel-powered buses and freight trucks, constitute a significant source of soot and other unhealthy fine particles.

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some 2.1 percent from the mid-1980s to the mid-1990s. Although there was some leveling in the latter part of the 1990s, Department of Transportation analysts predict that nitrogen oxide emissions from highway vehicles will grow between now and 2015 in metropolitan areas that experience continued traffic growth unless tighter vehicle controls than those currently scheduled are adopted (FHWA 1996b, 19; DOT 1995, 12).

Infrastructure-Related Impacts

Transportation decision makers have frequently responded to the increasing volume of automobile travel by building more roads. The mileage of public roads and streets in the United States grew steadily after 1900 to nearly 4 million miles in 1999 (BTS 2000, 6, Table 1-4). Nationwide, roads now occupy 11.1 million acres, an area equal in geographic size to the states of Maryland and Delaware combined. Parking lots are estimated to occupy an additional 1.2 to 1.9 million acres (EPA 2001a; EPA 2001b). Private infrastructure has grown as well: analysts report that in the 1990s more space was devoted to parking than people in typical new suburban workplaces, providing as much as 1,400 square feet of parking, usually in surface lots, for every 1,000 square feet of office space (Downs 1992). As discussed in Chapter 3, transportation-related pavement is a major source of runoff water pollution in many watersheds.[7] Highways also fragment wildlife habitats and significantly alter previously pristine areas. In addition, it is becoming increasingly clear that new highway capacity can itself induce additional travel and land development, which in turn can necessitate still more roadway space and other infrastructure, although the extent and workings of this dynamic are still largely to be determined, and more research is needed before any definitive conclusions can be drawn (Noland and Lem 2002).

Social and Economic Impacts

Although the focus of this report is on the environment, it bears mention that the impacts of traffic and land development go further. With growth in driving

[7] Non-point-source pollution remains the nation's most serious water-quality problem. Although agriculture's unfortunate grip on first place as a contributor to non-point-source pollution nationally is not threatened, the impact of pavement on urban and suburban watersheds is immense.

has come increased congestion.[8] Today 70 percent of peak-hour travel on urban Interstate highways occurs on congested roads operating at more than 80 percent of capacity. Researchers have estimated the annual cost to the American economy of lost productivity from congestion-related delays to be $78 billion in 1999. At current rates of population growth and urban expansion, public agencies lack sufficient fiscal resources to keep pace with congestion and Americans' increasing propensity to travel by automobile through the construction of expensive new highway lanes, even if the provision of more roadway space were to constitute an adequate response.

Growth in traffic and land development has substantial impacts on communities in addition to congestion. As investment follows transportation facilities to the fringe of metropolitan regions, existing communities in central cities and traditional towns can suffer declining jobs and opportunities. This pattern can have serious consequences for populations left behind, including a disproportionate number of low-income neighborhoods (see Chapter 4).

Dispersed and low-density land development also requires increased expenditure of scarce economic resources for additional infrastructure beyond that related to transportation, such as schools, sidewalks, crosswalks, public safety, water, sewer, natural gas, electric power, telecommunications, and other utility lines. Some have estimated that the infrastructure needed to serve low-density development costs 9 to 12 percent more per capita than that required for more compact land use (Burchell et al. 2002). Moreover, service routes for mail and parcel delivery, police, and fire and ambulance units may become longer and less efficient.

Current State of Knowledge

Researchers have studied the causes of growth in automobile and truck travel and the relationships of that growth to urban and regional development patterns. However, most of the work has been conducted on a limited scale and scope; there has been little or no coordination of the research. Researchers have evaluated cases of local transportation and land development policies,

[8] While the average commute to work has increased in length, so has the travel time to work, but at a slower rate. Between 1983 and 1995, commuting trips grew 37 percent longer in miles, while travel time increased 14 percent. Reasons cited for the disparity include decentralization of metropolitan areas, greater flexibility in work hours, and increasing use of single-occupant vehicles.

but have used such widely different variables and definitions that comparisons across studies are not always possible. A number of studies have examined correlations between travel and land development patterns, but have not controlled for such variables as household income, household size, automobile ownership, and age of household members, leaving the findings subject to interpretation. Research has also been limited by a lack of data or a lack of resources to assemble available data from local sources. Other than in a few regions, the subject has not been a major focus of government or other institutional activity.

Despite these shortcomings, it is generally accepted that travel is substantially affected by land use and urban development patterns; that federal, state, and local government policies significantly affect both travel and land use choices; and that current trends have significant adverse consequences for air and water pollution, emissions of greenhouse gases, natural ecosystems, and the American landscape (Giuliano 1995; Garrison and Deakin 1991). Questions remain concerning the magnitude of the effects, the relative contribution of transportation policies to travel and development choices, the role of current public policy in steering these choices and outcomes, and alternative policy instruments that might be considered. In many cases, the findings of current research suggest where future study should be directed.

Effects of Development Patterns on Travel Behavior

Much of the research undertaken to date has focused on the relationships between the density of residential neighborhoods and household travel behavior. Some of this research has been performed by environmental organizations, in cooperation with the federally chartered mortgage institution Fannie Mae and other federal agencies, to investigate the impact of neighborhood characteristics on transportation spending patterns.[9] Related research on household density, neighborhood characteristics, and travel behavior has been scattered among a number of institutions. For example, such research has been conducted in the private sector at the Urban Land Institute and at a number of academic institutions, and summarized in presentations at meetings of the Transportation Research Board.[10] International research on the subject includes

[9] See, e.g., Holtzclaw et al. (2002); Holtzclaw (1994).
[10] See, e.g., Ewing and Cervero (2001).

that sponsored by the World Bank, as well as that conducted by the Organisation for Economic Cooperation and Development and the European Council of Ministers of Transport.[11]

The overall body of work on density and travel, notwithstanding differences in methodologies and variations in specific results, is generally consistent in its findings: as population and employment density decline, as occurs with expansive land development, travel distances lengthen, vehicle trips and usage increase, and transit usage and walking decline. Indeed, these associations have been demonstrated in research dating as far back as 1963 (Handy 1997).

An extensive 1998 review of the literature on the costs of sprawling land development performed for the Transit Cooperative Research Program found support for all of these conclusions. With respect to growing vehicle-miles traveled (VMT), the review led to the following conclusion:

> Three factors have contributed about equally to the growth in VMT—changing demographics, growing dependence on the automobile, and longer travel distances. Thus, sprawl, which creates the longer travel distances and increased dependence on the automobile, is a major source of increased vehicle use. (Burchell et al. 1998)

The review also revealed support in the literature for the proposition that sprawling land use reduces the cost-efficiency and effectiveness of transit service as compared with more compact development, and causes households to spend higher proportions of their income for personal transportation. Moreover, travel in sprawling areas generates higher social costs. Findings on the effects of sprawl on total travel times were mixed.

Researchers have investigated a number of other factors in addition to land use density that contribute to travel patterns. One important category of such factors encompasses the effects of other neighborhood characteristics, such as the extent to which jobs, housing, and other activities are mixed or separated from each other in development parcels; the presence or absence of pedestrian amenities; and proximity to central business districts and transit stations (see, for example, Frank and Pivo 1994; Cervero 1996; Ewing and Cervero 2001; Dunphy and Fisher 1996). Most of the studies addressing these factors

[11] For explication of the existing research on relationships between urban form, including neighborhood density, and transportation behavior, see, e.g., EPA (2001b); EPA (2001a, 15–21); Burchell et al. (1998, 6–72, 159–175).

are small, and there are wide variations among the results. Nevertheless, the available evidence indicates that these factors also are relevant to the number of driving trips made and the distances driven.

Other Factors Relevant to Land Use and Travel

In addition to research on the effects of development patterns on travel, several scattered lines of inquiry are addressing other factors that may be relevant to land use, travel, or both. One such factor is government policies that may have the ancillary effect of causing or contributing to low-density development patterns. These policies include, for example, zoning regulations; state and federal tax policies; subsidies for sewage treatment facilities; and even implementation of state or federal regulatory statutes, such as the Clean Air and Clean Water Acts. There is little existing research on these subjects. The same can be said for research on how highways and public transit facilities affect development patterns and communities, although the issue has been examined both in histories (e.g., Warner 1962; Jackson 1985) and in a long but sparse series of empirical case analyses (e.g., for transit, Spengler 1930; Boyce et al. 1972; Gannon and Dear 1972; Webber 1976, Knight and Trygg 1977; Landis and Loutzenheiser 1995; Weinberger 2001; for highways, U.S. Congress 1961; Payne-Maxie and Blayney-Dyett 1980; Forkenbrock et al. 1990; Boarnet 1995; Hansen et al. 1993).

Research is even more widely scattered and piecemeal on other potentially relevant phenomena, such as the effect on travel of such factors and trends as changing demographic characteristics, shifts in consumer and household opportunities and preferences, changes in the organization and location of workplaces, and shifts in shopping habits (Kitamura 1988; Kitamura et al. 1994; Redmond and Mokhtarian 2001; Ferrell and Deakin 2001). Knowing more about such factors is essential to understanding the true impacts of land use.

Sparse research has also been undertaken to test a number of claims about the positive transportation-related impacts of expansive land use. The 1998 literature review noted above (Burchell et al. 1998) and a more recent study on sprawl by the same authors (Burchell et al. 2002) cite a number of these claims, including shorter commuting times (if not distances), reduced congestion, lower governmental costs (because transit is claimed to require greater subsidy than driving), and travel efficiency. These reviews reveal that the work to date on these claims has failed to produce a consensus. Yet these claimed benefits are highly relevant to the attractiveness and likely success of attempts

to affect travel behavior through alternative forms of land development, and need to be understood.

Ultimately, a critical goal of scientific inquiry into the relationships between land use and transportation must be improving the ability of decision makers, practitioners, and the public to evaluate the likely effects of different policy and investment choices on travel behavior and communities. New, technologically advanced tools, such as geographic information systems and other forms of visual imaging, are becoming available to assist in these efforts. In some applications, technology for forecasting land use patterns and integrating land use and transportation models is improving as well. The substantial LUTRAQ (land use, transportation, and air quality) effort undertaken in Portland, Oregon, in the 1990s and the ongoing SMARTRAQ (Strategies for Metropolitan Atlanta's Regional Transportation and Air Quality) research initiative in Atlanta illustrate how these tools can be applied (1000 Friends of Oregon 1997). The need to strengthen existing tools and models for assessing land use and transportation has been documented at recent conferences of modeling experts (Shunk 1995).

Lack of Research Coordination

One of the most challenging obstacles to advancing understanding of the relationships between transportation and land use is that there is no central repository, coordinating body, or effective cataloging operation to which one can turn to locate salient data and evidence and assess relevant studies.

Looking only at the federal government, for example, no agency or institution is in charge of tracking and assembling land use–transportation information, to say nothing of communicating such information to potential users and the public. Instead, there are numerous independently conceived and managed studies scattered among separate institutions, including the Department of Housing and Urban Development, the Federal Highway Administration, the Federal Transit Administration, the Environmental Protection Agency, the Department of Agriculture, the Department of Energy, Fannie Mae, and others. These institutions rarely coordinate closely with each other; in fact, they frequently lack sufficient internal coordination. This fragmentation is also apparent in the scattered undertakings among the 50 states, various real estate development interests, environmental organizations, transportation service providers, universities and other research institutions, trade associations, and private corporations.

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Benefits of Increased and More Focused Research

A better understanding of the interactions among land use, public and private transportation infrastructure, and travel behavior could have profound economic and environmental benefits by helping states, localities, and their federal partners allocate both public and private resources more wisely. Better-informed decisions about the consequences of alternative development and transportation investment scenarios could help reduce public expenditures and private costs and generate potentially large reductions in air emissions and other pollution from transportation, while avoiding unnecessary impacts on the landscape.

Although many of the problems associated with transportation and development patterns (e.g., increasing congestion, loss of open space due to urban sprawl) are evident to most Americans, the solutions are far less obvious. A commitment to better, expanded, and more systematic research on these issues could aid in finding ways to meet the access and mobility needs of America's citizens while reversing, or at least limiting the growth of, travel and development patterns that have significant environmental impacts.

Recommendations

Recommendation 5-1.
Expand and focus research on the impacts of development patterns and characteristics on travel behavior.

Existing research indicates that neighborhood density, mix of uses, pedestrian amenities, and related characteristics may have significant impacts on travel behavior. The research suggests that encouraging different development patterns could play a significant role in helping to reduce infrastructure needs and limit growth in the number of vehicle trips made and miles driven, thereby playing a role in reducing environmental impacts as well. If the land use and mobility needs of a growing population and economy are to be met, it is critical that this research be intensified and expanded. Examples of useful future research in this area are presented below.

Example: Expanded geographic scope. To date, study of the influence of neighborhood form on travel has been geographically limited. For example, the research on travel expenditures and urban form being conducted by nonprofit environmental organizations in cooperation with Fannie Mae is currently

limited to three major U.S. cities; other research has been even more limited, to specific neighborhoods or developments. Additional studies should extend this type of inquiry to other cities, including smaller ones, and to nonmetropolitan areas as well. The research should be coordinated so that comparisons can be made across cases. Comparison of the results for different communities could both enhance understanding of the dynamics of the land use–transportation relationship and suggest different approaches for encouraging greater travel efficiency that may be appropriate to particular areas.

In addition, Americans drive cars and trucks nearly twice as much as do Europeans per capita, and more than twice as much as do the Japanese[12] (FHWA 1998, Section VI). Neighborhood density and related factors could perhaps explain this difference, but so might fuel or automobile prices, or differences in policy or culture. It would be useful to expand and refine current knowledge of the extent to which the associations with neighborhood characteristics found in American cities also apply in European and Asian cities—for example, whether differences in household income levels have similar impacts in different countries. If the general tendencies are the same throughout the world, the findings might assist in other lines of inquiry, such as the extent to which gasoline and automobile price differences affect travel behavior.

Example: Refinements in methodology. Research is needed to improve on the current methodology used to study the impacts of development patterns on travel behavior. For example, studies of urban design and its relation to travel behavior have typically relied on available data that may be too aggregate to capture all relevant effects. Future research might assess more precise characteristics of neighborhoods and locations, as well as various aspects of driving, walking, use of public transit, and other transportation behavior. The relative significance of other variables known to affect travel behavior, such as household size and income, could be tested more completely as well. An additional important line of inquiry is better understanding of the shape of the curve of the relationship between neighborhood density and driving: At what points of increased density do we reap the most benefit in terms of reduced driving?

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[12] It is important to include both cars and trucks in any international comparison, because many data sources classify minivans and sport utility vehicles as trucks. In 1997, the United States, with a population of 276 million, recorded nearly 4 trillion km of car and truck travel. France and the United Kingdom, each with a population of 59 million, recorded some 470 billion and 434 billion km, respectively. Japan, with a population of 127 million, recorded 731 billion km.

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Also needed is a better understanding of causality rather than mere correlation between neighborhood characteristics and travel. Given that a host of factors affect travel decisions and behavior, to what extent can trends and differences among locations be properly attributed to neighborhood characteristics instead of, for example, differences in income or household demographics? For instance, research shows that denser neighborhoods are associated with less travel, but how much of that effect might be explained by lower incomes, lower automobile ownership levels, and smaller household sizes that are often found in denser neighborhoods? Also, how much does travel behavior reflect urban form and travel opportunities versus personal and household characteristics? How important are transportation characteristics in housing location choices? Do people's preferences for driving, taking transit, walking, and so on remain largely the same regardless of their location and the options offered? Or do those who move from more compact to more dispersed areas end up driving more and owning more cars? If behavior changes, how long does it take for the adjustment to occur? Are the results the same if the direction is reversed; that is, as people move from dispersed areas to compact neighborhoods, do they immediately begin driving less?

Finally, although it is likely that future research will confirm and refine the current understanding that development patterns play a significant role in influencing how much Americans travel and by what means, it is probable that other factors are significant and help explain rising rates of vehicle use. These factors might include, for instance, economic growth, rising personal incomes, new living options made possible by communications technology, entry of multiple household members into the workforce, and continued relatively low fuel prices, among others. To understand the true influence of land development patterns on travel behavior, it will be necessary to identify and assess the impact of these other factors as well (see also Chapter 7).

Example: Study of impacts on public transit. Another important linkage among land use, urban design, and travel behavior is the relationship between land use and public transit usage. Although transit still represents a small portion of total trips made nationwide, it represents a major and growing share in many places (APTA 2001; STPP 2001). Indeed, recent years have seen striking increases that reverse decades of declining ridership, and many public transit systems are now struggling to keep up with demand. One special focus of research on the relationship of neighborhood and location characteristics to travel behavior should be the impacts on transit usage, along with other factors affecting transit ridership, such as the comfort, safety, and

convenience of transit systems. Transportation planners and decision makers need to identify those combinations of factors most conducive to transit usage.

Example: Commercial locations and concerns. Much of the quantitative work to date relates to differences in travel behavior associated with various characteristics of residential locations—the typical origins of trips. Intuitively, however, it appears plausible that such characteristics as density, transit access, and pedestrian amenities could make a difference on the destination side as well. Indeed, the impacts might vary with particular types of commercial locations, such as workplaces, shopping areas, and service providers. Future research could explore these potential influences.

Some intriguing corollary questions concerning commercial locations also need to be explored more fully than in the past. The most recent comprehensive study of the impact of commercial development on travel is a Transportation Research Board study on travel characteristics of large-scale suburban activity centers (Hooper 1989). There is a need to update this study. For example, do suburban campus-style offices generate more or less travel than more compact or centralized alternatives, and is there any difference in travel time? Do regional malls and other suburban shopping centers generate different patterns of travel from those associated with traditional downtown areas? Does the concentration of jobs in a single location (a downtown) correlate with reduced or increased travel and travel times, and if so, to what extent? To what degree are differences in the distribution of high-paid versus low-paid (or professional versus industrial) jobs responsible for these effects? If a region has multiple centers or one center with subcenters, does this lead to more or less efficiency than having one large center? How much does the provision of parking, either paid or free, affect these results? What is the price elasticity connecting parking fees with the propensity to drive to work?

Moreover, nearly all of the existing research on these subjects is related exclusively to personal transportation. But one might hypothesize that areas with certain density and proximity characteristics are associated with reductions in trips and mileage for package delivery and other freight transportation as well, because the distances from retailer to distributor and from distributor to final recipient, for example, are smaller. An alternative hypothesis would be that freight transportation has a very different set of controlling variables from personal transportation and does not vary with urban design characteristics. These and related hypotheses should be tested.

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Recommendation 5-2.
Continue and expand research on the impacts of transportation facilities.

Another important category of research encompasses the impacts of highway, transit, walking, and bicycling facilities on travel behavior, as well as on land use and the community.

Example: Transportation facilities and travel behavior. The body of evidence from the United States and elsewhere supports the notion of "induced demand": that the demand curve for travel is like that for other goods and services and that, at least under some conditions, the construction or expansion of highway lane capacity will lead to more driving, not just make a preexisting amount of driving more efficient by relieving traffic congestion (Hansen et al. 1993; Cervero 1991; Boarnet 1995). Knowing the extent to which this supposition is true can help in making a more accurate determination of the long-range efficiency of transportation investments (see also Chapter 7). Moreover, while a helpful body of international research on the subject is available, it has not been applied extensively in American transportation planning. Thus there is also a need for better linkages between research on this subject in other countries and the United States.

Transportation professionals and decision makers need to have a better understanding of a range of factors relevant to behavioral responses to added capacity (induced travel), as well as to congestion. What conditions must be present for induced travel to occur? What role is played by land development induced or facilitated by highway construction? To what extent is induced traffic a cause of increasing regional travel volume? And given that added lane capacity may also produce at least short-term benefits, how does induced traffic affect the cost–benefit analysis of highways in particular situations? As metropolitan highway networks become more congested, it is also important to understand better how people and businesses adapt over time. Do they move farther out, relocate to more transit-accessible locations, move to less congested communities, or otherwise internalize the added costs of congestion?

Such research should not be limited to the impacts of highways. What happens when system providers add public transit access or capacity? What conditions must be present for the level of transit demand to be changed by facilities and investments? To what extent do transit facilities affect regional rates of driving? What effect do additional bicycle and pedestrian facilities have on transportation behavior, including rates of driving?

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Example: Transportation facilities and land use, development, and community. Decision makers, practitioners, and the public need to know more about how transportation facilities affect land development, not just how development affects transportation. For example, it is evident from observation that the opening of new freeways is often followed by the construction of commercial facilities near exits. Is it reasonable to hypothesize that highway construction induces expansive land development? If so, can the development impacts be predicted? What is the geographic zone of influence of roadways and intersections in affecting development? How do these factors interact with changes in land prices due to improved access to influence development? To what extent, if any, does induced development play a role in the amount of and changes in overall regional vehicle use? (See Meyer and Miller 2000; Forkenbrock et al. 2001.)

There is also inadequate research on the influence of public transit facilities, especially fixed-rail transit construction, on property development near stations. Most of the research done on this subject examines residential property; only a few studies have addressed commercial property as well (Weinberger 2001). In addition, most of the available research has taken a very short-term perspective; more research concerning effects over a 25- or 50-year time horizon would be helpful. Research is also needed to examine the overall impacts (beyond those related to transportation per se) of transit stations and facilities on communities, and how those impacts vary with different types of communities and transit-facility designs.

Another important category of inquiry is the effects of transportation facilities on the social environment of communities as places to live, work, and play (see Chapters 4 and 7). What effects do highways have when they bisect existing communities and when they detour traffic around communities? Moreover, just as some communities are beginning to dismantle unpopular public housing projects, some are deciding not to repair or replace freeways, as was the case following the last major San Francisco earthquakes. How has the decommissioning of highways affected surrounding communities and travel behavior?

Roadway design has also become an important topic in many communities. Efforts are under way to reconsider design standards for major roads; these efforts include federal and state initiatives to develop context-sensitive designs. However, the concern that standard designs are often not sufficiently sensitive to impacts on place and community extends across the entire range of facilities, including regional and local arterials, collectors, and residential streets. Research should address the impacts (including but not limited to land use) of various design types on different kinds of rural areas, suburban communities, and urban

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neighborhoods. Can an adequate template for context-sensitive design be developed? What are the impacts of alternative street designs on the affected neighborhoods, districts, and corridors and their inhabitants, and on transportation system performance? What effects do different forms of highway access management have on communities, development patterns, and related travel?

Finally, many municipalities have begun to implement measures designed to further community cohesion and safety, as well as to encourage walking and bicycling. Examples include traffic-calming measures, enhanced pedestrian crossings, shaded sidewalks, and dedicated bicycle lanes, among others. The transportation community needs to learn more about the effects of these measures on both travel patterns and affected neighborhoods and communities.

Example: Agency evaluation of impacts. The National Environmental Policy Act and many state laws require that the environmental impacts of major actions, including significant new transportation facilities, be evaluated prior to implementation. It is important that decision makers and other reviewers of impact statements understand not just the immediate impacts of a proposed facility (e.g., the loss of a particular wetland supplanted by a new roadway), but also the secondary and cumulative impacts, including the likely effects of the facility on travel behavior and land development. Research is needed to address emerging knowledge on these subjects and provide information and understanding that can serve as a basis for best practices.

Recommendation 5-3.
Conduct and expand research on the causes and benefits of current development patterns.

Evidence suggests that expansive land development and so-called "leapfrog" development that skips over undeveloped land are associated with increased motor vehicle use per capita. Such development patterns also cause or are associated with a wide range of additional environmental and social impacts (Burchell et al. 2002). In opinion polls, Americans register increasing concern about these impacts, as well as growing interest in and preference for alternatives.[13] But there is little question that, despite the problems associated with low-density development and citizens' expressed concerns about concomitant impacts, such development remains the dominant pattern of land use in the

[13] See, e.g., Smart Growth America (2000, 1–7).

United States. Thus there is an apparent dissonance between what people say they would like to experience with respect to community and their actual behavior. Given the emerging national interest in smart growth and other alternatives to sprawling development, researchers need to identify and understand the factors that contribute to dispersed growth patterns so these factors can be addressed to the extent possible. Research in this area might focus on two important categories of forces driving sprawl, as described below.

Example: Personal benefits and preferences associated with housing and business location. It has long been held, largely on the basis of anecdotal evidence, that residents and businesses have been choosing outer-suburban locations to escape problems that plague central cities, and now inner suburbs as well. These problems include a real or perceived greater risk of crime; unaffordable housing; expensive land prices; and, especially for families, inferior public school systems. There are also those who contend, with some empirical justification, that racism has caused white flight to the suburbs.[14] In addition, residents and businesses are increasingly choosing outer-suburban locations simply to be closer to each other or to find a quieter environment (Burchell et al. 1998). Dispersed development patterns may also be caused or influenced by Americans' patterns of time management, which are shifting because of emerging technology (see Chapter 5).

As noted earlier, some perceived benefits of suburban sprawl, such as shorter commuting times and reduced traffic congestion, are related directly to transportation. Others relate to the environment, such as the larger yards and personal open space available in some outlying developments, as well as real or perceived greater access to public and private open space beyond the metropolitan edge or on land passed over by leapfrog development. In many cases, residents who perceive their local environment to be threatened by any new development, regardless of how well designed, resist changing an expansively developed community to one that is more supportive of transportation efficiency. At the same time, higher inner-city housing values and the rapid sale of new residential offerings in more urban locations, as well as in more compactly designed new suburban developments, suggest that demand for urban and denser suburban locations remains high.

Government officials and other interested parties need to understand the extent to which these and other consumer preferences drive location decisions

[14] See, e.g., Powell (2000); Brookings Institution (2000).

and which of these factors are most important. Developers and land use planners need to learn whether the attributes preferred by residents and businesses can be provided in communities and developments with different urban designs. For businesses, it is especially important that the convenience of access to various markets (workers, clients, users) be among the attributes studied.

Example: Public policy influences. A range of public policies appears to be important in influencing the shape and location of development. Examples include zoning and building codes that once made sense (such as those mandating large lot sizes or separation of residential and commercial uses), but that now often limit market-based decisions that could support the building of developments more conducive to walking and transit. A related topic is local governments' frequently apparent preference for revenue-generating commercial developments and opposition to developments (particularly those with affordable housing) that require expensive government services, such as schools. Some observers have also expressed concern that interpretation of certain federal regulatory statutes, such as the Clean Air and Clean Water Acts, may unintentionally contribute to dispersed development. Research is needed to investigate such claims.

A number of related questions need to be explored. For example, how do federal, state, and local tax policies, including special policies for particular developments, influence development decisions? To what extent do competitive tactics among different municipalities—for instance, offering subsidies, free infrastructure, and tax breaks to attract businesses—lead to some forms of development? To what extent do state and federal assistance programs for infrastructure, such as roads, schools, and water treatment, provide incentives for choosing dispersed rather than central or compact suburban locations? And what impact does the location of government facilities themselves, such as courthouses, post offices, and agency offices, have on local development patterns? Participants in location decisions need to learn more about which of these factors have been most influential in shaping the built landscape and how shifts in policy are most likely to produce different results.

Recommendation 5-4.
Assess and compare alternative transportation and land use strategies.

Closely related to causes of vehicle use and expansive land development are questions concerning how different transportation and land use strategies will most likely affect travel patterns (see Chapter 7). Many communities are

interested, for example, in obviating the high cost of building new highway capacity to free resources for maintenance of the existing system; many are also struggling to overcome increasing traffic congestion. In addition, finding effective methods for educating the public on the connections between land use and transportation is critical.

Example: Effectiveness of strategies. Because of the complexity, difficulty, and cost of modeling long-run changes in land use and travel behavior given different transportation investment scenarios, many metropolitan areas do not use very sophisticated techniques to analyze land use as part of the transportation planning process by incorporating the interaction over time among new facilities, subsequent land development patterns, and altered travel behavior. A striking exception is the LUTRAQ study in Portland, Oregon, which involved extensive evaluation over several years. A somewhat more developed body of international research has also been undertaken, although its applicability to the U.S. context is uncertain (see, e.g., Mackett 1985 and Wegener 1987).

Efforts such as LUTRAQ and SMARTRAQ that involve simultaneously evaluating land use and transportation scenarios need to be applied elsewhere and made simpler for communities with limited resources. In addition, a broad range of research should be undertaken at multiple sites across the United States to determine what effects different strategies have on travel behavior and which approaches are most effective in reducing pollution and other environmental impacts. Available options might include the following: transit-oriented development and other land use strategies, such as those discussed earlier; ride-share strategies, including increased use of paratransit services; road pricing; improvements to public transit systems; park-and-ride lots or structures at transit stations; and other market-oriented or regulatory techniques. All of these options should be explored.

Research should also address the effectiveness of, and problems associated with, policy measures being developed and applied across the country to shape land development in a more environmentally benign manner. These measures include, for example, urban growth boundaries (such as those pioneered in Oregon), limits on infrastructure spending in locations less desirable for development (such as those being applied in Maryland), land conservation measures (such as conservation easements and programs for the purchase of development rights), financial incentives to homebuyers in smart-growth locations (such as the location-efficient mortgage), direct acquisition of lands that should be protected from development, tax policies, the imposition of local impact fees and exactions, and special zoning in areas targeted for development.

American communities are increasingly employing variations on and combinations of these growth-management techniques, all of which have potentially significant implications for transportation investment needs and travel choices. A portion of the research agenda should be directed to studying the impacts and effectiveness of all the available strategies, and identifying those aspects and combinations that are most effective, as well as the social and economic conditions and institutional and policy frameworks most supportive of particular approaches. Studies might also be undertaken to compare and improve our understanding of the current differences in land use and travel behavior among communities with widely divergent characteristics, such as Portland, Houston, Phoenix, and Boston. In addition to investigation at the community level, analysts should compare the likely effects of alternative policy and investment scenarios at the state and federal levels.

Example: Development and refinement of models for assessing strategies. In investigating the above questions, researchers will frequently need to develop better methodologies that are sensitive enough to predict the likely outcomes of alternative policy choices. Such new models might encompass many variations. One example is the development of a better method for assessing the economic attractiveness of alternative scenarios comprising different combinations of transportation investment and management decisions and land use planning and development patterns. Transportation is one of the largest categories of public expenditure, yet there is not a valid and accepted methodology for comparing, within a given geographic sector of a metropolitan region, the economics of roadway investments versus different sorts of transit expansions and land use strategies in a way that accounts correctly for the likely effects of development patterns on travel behavior.

The performance of integrated land use–transportation models also should be examined to determine what refinements to the models are needed. For example, forecasts of the LUTRAQ model could be evaluated and their prediction accuracy assessed. With each passing year, more data become available to illuminate how accurate that model has been in predicting travel behavior and what refinements might be appropriate. Other applications of integrated transportation land use models might similarly be evaluated.

Transportation professionals are hampered by the fact that current models used to predict travel behavior do not deal well, if at all, with walking and bicycling and with short trips in general. Since many land use and community design strategies are aimed at encouraging walking and cycling and reducing trip lengths, this is a major shortcoming. Models should be developed that are

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capable of accurately evaluating the potential substitution of walking trips for motorized travel under different land use scenarios. Some current research suggests that the effects of transit facilities and walking on travel patterns may be more extensive and subtler than is allowed for by current models.

Using existing research as a starting point and developing additional methodologies, researchers and planners might attempt to create a template that could be used by a region to satisfy its accessibility and mobility needs at minimum cost. The objective of such a template would be to determine optimum investments in highway capacity and transit expansion for any given land use pattern, while taking into account economic incentives for development that is more compact. A tool that would aid in least-cost planning could have immense practical benefits in supporting what are now mainly informal and underinformed evaluative processes. (Additional issues with respect to planning methods are discussed in Chapter 7.)

Example: Models for regional cooperation. Changes in federal transportation law—the most important of these being the Intermodal Surface Transportation Efficiency Act and its successor, the Transportation Equity Act for the 21st Century—have made a difference in encouraging states, municipalities, and metropolitan regions to work together in planning a region's major transportation investments (at least those that receive federal funds). This change is important because regional economies and travel patterns predominate in today's highly mobile and interconnected world. Residents and businesses seldom remain within their own jurisdictional borders as they go about their daily business. Yet many metropolitan regions have yet to achieve the level of cooperation anticipated by Congress in federal transportation legislation. For example, concerns are frequently raised about the adequacy of representation of different jurisdictions and constituencies within metropolitan planning organizations.

One of the most significant challenges to be met is the coordination of transportation and land use planning (see also Chapter 7). Ideally, it is desirable to plan the two together because of the extent to which they influence each other. While some incremental progress has been made in regional transportation thinking, minimal progress has been achieved with regard to regional decision making for land use, which remains the near-exclusive domain of the smallest units of government in most locations. The difficulties posed by this dynamic can be immense given the sheer number of government units that can be involved in a given region. Metropolitan Chicago, for example, has been estimated (though the reported estimates vary) to comprise some 267 municipalities and counties

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and some 1,250 "governments" of one sort or another, including various school and service districts and regional authorities. All of these entities can have impacts on land use patterns and, by extension, on the transportation system. Such jurisdictional fragmentation can make regional coordination of transportation and land use virtually impossible.

Portland (Oregon), Minneapolis–St. Paul, and Atlanta are among the metropolitan regions that are attempting to overcome this challenge with new regional institutions. Other arrangements are being developed in various locales around the country, with wide variation among strategies and methods. As regions gain experience with coordination mechanisms, it is important that these undertakings be monitored and assessed, and that further study be undertaken to ascertain which mechanisms hold the most promise in furthering the ability of regions to consider land use and transportation together rather than separately. Both evaluation research and exploration of new forms of cooperative planning would be important.

Recommendation 5-5.
Translate research findings into accessible tools for practitioners and citizens.

As noted earlier in this chapter, research on the interactions between land development patterns and transportation has been piecemeal and scattered with respect to both substance and geography. The field comprises a rather bewildering array of disconnected literature and undertakings that even experts find difficult to identify, assemble, and apply. And nowhere is the bewilderment felt more acutely than at the state and local levels, where transportation planners and engineers, along with elected officials and their citizen constituents, must make sense of policy options. Practitioners and citizens need new tools that can make this body of evolving information more accessible and easy to use. Such accessibility can take many forms—from the development of so-called "sketch" models that can reveal quickly and broadly the likely impacts of alternative development scenarios, to sophisticated new visual applications using geographic information system technology, to traditional best-practices manuals (see Chapter 7). Development of such tools is an essential component of any meaningful research agenda on transportation and land use.

In making this complex body of research more accessible, some attention needs to be paid to the dissemination of data on overall land development and transportation trends and patterns. Currently, a lack of standards and uniform

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practices in collecting and reporting these data limits their availability and usefulness. In fact, more research should be conducted on means of assessing and improving upon current methods for measuring land use characteristics and patterns. Special emphasis should be placed on techniques that use computer imagery and other visual media.

At the same time, there is a need to improve education and training among transportation professionals so that state departments of transportation and other public agencies will have enhanced expertise on these often rapidly developing issues. There is a particular need for urban planners and other land management professionals to help coordinate transportation and land use planning at the state level.

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Abbreviations

APTA	American Public Transportation Association
BTS	Bureau of Transportation Statistics
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
FHWA	Federal Highway Administration
NTI	National Transit Institute
STPP	Surface Transportation Policy Project
USDA	U.S. Department of Agriculture

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7

RESEARCH AREA 6

PLANNING AND PERFORMANCE MEASURES

The planning and decision-making processes surrounding surface transportation in the United States will have to address serious challenges in the 21st century as a result of the nation's continuing demographic growth and changing makeup, global trade and environmental issues, and rapidly changing technology and travel behavior (Burwell 2000; Tate-Glass et al. 1999). While these challenges are great in themselves, they are compounded by arguably inadequate planning and decision-making methods and tools. Methods and tools that address contemporary concerns regarding environmental protection and enhancement, sustainability, economic impacts, efficient goods movement, community quality of life, customer satisfaction, and the performance of an oversaturated highway system are few and far between. Moreover, a strong case can be made that the methods and tools available to planners for understanding travel and economic behavior lag behind current issues by at least a generation. Likewise, the methods and tools used by engineering and environmental professionals for integrating environmental considerations into various aspects of transportation decision making are quite rudimentary, having originated in the major highway construction era of the 1950s and 1960s (Marshment 1999). [The cooperative venture of the U.S. Department of Transportation and the Environmental Protection Agency to develop TRANSIMS (the Transportation Analysis and Simulation System) is a notable exception.] In addition, consideration of the various modes—highways, transit, trucking, shipping, rail freight, and so on—as an integrated system is uncommon, making it difficult to foster efficient investment policies (Pedersen 1999; Neumann 2000).

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This foundation promises treacherous footing in addressing the growing concerns cited above.

The situation is exacerbated by the fact that, as discussed in previous chapters, public-sector decision-making processes demonstrate spotty and often inadequate integration of transportation, land use, economic development, and environmental considerations. Additionally, most private-sector transportation decisions are made in isolation from the public-sector planning process. When public–private partnerships are sought, considerable difficulty is encountered in harmonizing the short time frame and site-specific nature of private-sector investment decisions with the long time frame and community-wide nature of public-sector investments.

Surface Transportation and the Planning Process

The environmental significance of transportation planning and decision-making processes lies in the fact that transportation facilities, services, and usage directly affect community cohesion, human health, ecosystem health, global energy consumption, and climate change. Moreover, transportation is an arena of American life in which market forces are significantly constrained by public policy. Individuals and businesses make rational transportation decisions based on the choices available. However, the private sector has a limited role in contributing to a range of consumer options. In contrast with retail trade, for example, firms have an extremely limited ability to enter major portions of the transportation market (siting and building of highways, transit systems, and intermodal facilities). Major elements of transportation supply and pricing are defined by public policy and public agency decisions. Yet the effectiveness of these public agency decisions that form the framework for consumer and business travel practices is typically compromised by a limited understanding of underlying complex travel behavior and by frequent disconnects between real-world issues and institutional decision processes.

The major, dominating influence of public policy on the effectiveness of the transportation system raises the stakes with regard to the effectiveness of the planning and decision-making processes. Decisions made by individuals and businesses may be far from optimal in a system in which a largely monopolistic supply of transportation infrastructure is inadequate, inflexible, inappropriate, or over- or underpriced.

Current State of Knowledge

The effectiveness of current transportation planning and decision-making methods and tools is limited by the fact that they are based in engineering principles, facility standards, and an emphasis on mobility defined as travel time and cost. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, reinforced by the 1998 Transportation Equity Act for the 21st Century (TEA-21), provided a strong impetus to move transportation planning and decision-making practices toward a more holistic approach. In response to ISTEA, TEA-21, the Clean Air Act Amendments of 1990, and similar legislated initiatives, the nation's transportation planning community has worked hard, with varying success, to make the transition from using engineering standards as the basis for their efforts. The new criteria for evaluation are multidimensional, and include access to jobs and other personal and economic needs; availability of alternative modes; community quality of life; environmental protection and enhancement; freight and intermodal concerns; social equity and environmental justice; and service quality, reliability, and flexibility. Frequently, however, metropolitan planning organizations and state departments of transportation find themselves adapting existing methods and technical tools to explore new issues. Too often, planners and other interested parties become frustrated with the inadequacy of these old methods and tools for dealing with current problems.

With regard to the current state of transportation planning knowledge, there is a reasonable understanding of travel behavior at the broadest level, and there are specific techniques available for modeling discrete events and measuring limited impacts. The dynamics of travel demand are apparent at an aggregate level, but not at a detailed level: planners may be competent at creating models to estimate the total number of trips emanating from a subarea, for example, but cannot describe why a particular household chooses to drive a teenaged child a third of a mile for soccer practice even though sidewalks are available. Without understanding the underlying activities, preferences, and travel options of householders and businesses, planners are left with the challenge of using aggregate models to estimate the subtleties of complex, emerging travel behavior. Evening, weekend, and nonwork travel models and trip-chaining models are underrepresented (Winters 1999).

Aggregate person-trip models are also being adapted across the nation in an attempt to reflect commercial and freight travel behavior. Unfortunately, limited understanding among the transportation planning community of the dynamics of the manufacturing, distribution, retailing, and freight transportation sectors

challenges the effectiveness of these freight modeling efforts. Too often, the adaptation of long-standing aggregate models to meet current challenges conjures the image of someone using a cannon to hit a moving target on a rifle range: the tool was not designed for the application and is too cumbersome and imprecise to be effectively adapted.

Similarly, while detailed highway network models are able to simulate the dynamic interactions among vehicles under varying circumstances on a highway, planners are not yet able to determine how frequently such circumstances will occur, nor can they point confidently to effective operational practices that can address problem circumstances. Institutional arrangements frequently separate those individuals responsible for operating the highway and transit systems from those planning the systems, further limiting the effectiveness and responsiveness of the institutions.

Vast experience lies behind models used to estimate the amount of user time and cost savings that will result immediately upon completion of a highway improvement, but there is little information about how the complex decision processes of individuals and businesses will respond to those savings over time. How much new traffic will the highway system see a month or a year after the improvement? What is the nature of this new travel? Does it reflect new economic or social opportunities that travelers previously were discouraged from pursuing, or diversion from a less efficient mode or means of achieving the desired objective?

Current understanding of the precise nature of the various interactions described above is poor, and few methods and tools are available to allow planners and other decision makers to incorporate these interactions into evaluation or decision making. Coupled with decision processes that are disjointed between the public and private sectors, between planning and project design, between construction and operations, between land use and transportation, and among various levels of government, the current knowledge base is too weak for addressing the critical transportation planning issues of the 21st century. Such fundamental questions as how an oversaturated highway system behaves and how the presence of an oversaturated system influences other personal and business decision processes cannot be answered reliably at present. Yet such questions are central to effective transportation decision making.

The level of interest in advancing the state of the art and the state of the practice in transportation planning and decision making is quite high, however. As a result, effective research will find a receptive audience and can be expected to produce rapid changes in planning and decision-making practice.

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New methods and tools will be gratefully received by practitioners. A successful planning and decision-making research program will produce modern methods and tools that will give practitioners greater ability to meet ever-increasing demands and expectations.

The transportation community and many others readily acknowledge the inadequacy of current planning and decision-making methods and tools and of the underlying knowledge of specific behavioral interactions. Reflecting this concern, the Transportation Research Board (TRB) convened two conferences in 1999 on the subject of Refocusing Transportation Planning for the 21st Century. The conferences, which continued a 40-year tradition of meeting on a recurring basis to assess the transportation planning process, produced more than 100 research statements to help address the issues involved (Annex 7-1 lists these statements). The list reflects awareness of the significant need for research and development on new transportation planning techniques and institutional arrangements.

Despite acknowledgment of the inadequacy of current processes, the conferences offered grounds for optimism. Through federal participation, major metropolitan transportation decisions are now among the most open, participatory public decision processes in the nation. The transportation program has, through federal transportation law and planning requirements, directly empowered local elected officials, established an intergovernmental policy forum, facilitated a structured technical process, and encouraged outreach to other stakeholders. Current cooperative research programs, such as the National Cooperative Highway Research Program and the Transit Cooperative Research Program, have a structured agenda and oversight, thereby increasing knowledge on a continuing basis. However, the pace of investigation, the development of methods and tools, and the refinement of institutions are slow and unsatisfactory to many stakeholders. Given both the large role of public agency decisions in establishing the transportation framework for the nation and the interest of such institutions in seeking improved knowledge, the benefits of better-informed planning and decision-making processes will be substantial—commensurate with the scale of the U.S. transportation system, whose usage is measured in the trillions of dollars and tens of billions of person-hours per year.

Research Needs

A large number of recent reports have identified research requirements for the transportation planning and decision-making processes. These include the

proceedings of the Refocusing Transportation Planning for the 21st Century conferences; the Federal Highway Administration's *Strategic Plan for Environmental Research, 1998–2003;* the National Science and Technology Council's 1999 *National Research Agenda for Transportation and Sustainable Communities;* background materials for TRB's October 2000 Conference on Performance Measures; *Transportation Research Circular 469: Environmental Research Needs in Transportation*; the proceedings of the July 2000 National Conference on Transportation and the Environment for the 21st Century; and other materials, such as the numerous "millennium papers" prepared by TRB committees.

In addition to research problem statements, the Refocusing Transportation Planning conferences produced documentation identifying a number of cross-cutting challenges that will be faced by practitioners in the first decade of the 21st century:

- Developing a customer- and user-based planning process;
- Linking planning to the political decision process;
- Creating a vision for the community and defining the role of transportation in achieving that vision;
- Understanding the current and future movement of freight;
- Addressing the unsatisfactory nature of current technical processes, including models;
- Exploring the role and impact of technology in the transportation arena;
- Relating land use and transportation;
- Resolving questions about the adequacy of existing institutions and relationships;
- Ensuring professional development for those in the transportation field;
- Linking transportation planning to other program-area processes; and
- Encouraging the consideration of certain transportation solutions or outcomes.

These cross-cutting challenges underscore the growing recognition that improvement of the methods and tools to be used in meeting tomorrow's transportation planning challenges is a critical need.

Previous efforts have gone a long way toward articulating research needs for transportation planning. Meyer (2000) has suggested a framework for transportation planning research for which "a logical starting point is the identification of enabling research, that is, those issues, societal trends, and

needs for knowledge that lead to subsequent research on the planning process and the tools that are used in this process." Figure 7-1 depicts Meyer's conceptual approach. Research would flow from basic (enabling) research to the development of tools, then to creation or refinement of decision-making processes, and finally to methods of institutionalizing the new approaches.

With respect to transportation planning, performance measurement, and institutional issues, the research program recommended below can be grouped more simply and the contributions of other work incorporated more effectively by combining the bottom two levels of the pyramid into a basic research category labeled "More Effective Understanding of Travel Dynamics." The top two levels of the pyramid can likewise be combined into a single applied research category labeled "Effective Techniques and Responsive Institutions." The recommendations that follow are grouped in these two categories. In some cases, these recommendations generalize those made in earlier chapters to address the transportation planning context. In the interest of brevity, however, recommendations covered in depth elsewhere in this report, such as those pertaining to land use and transportation, are excluded here.

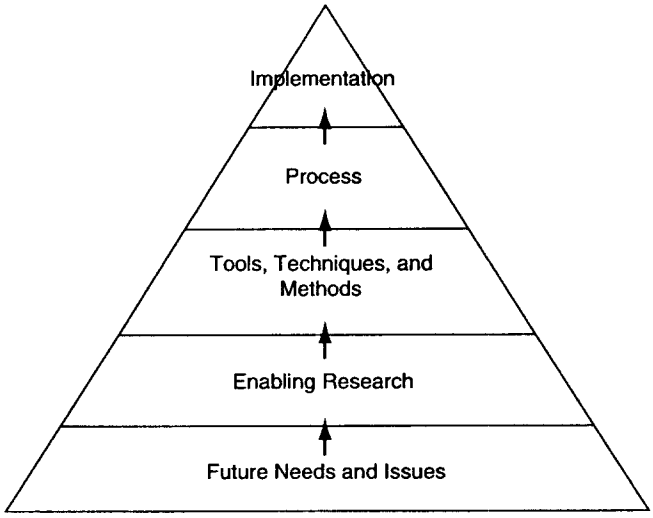


FIGURE 7-1 Conceptual framework for transportation planning. (Source: Meyer 2000.)

RECOMMENDATIONS

More Effective Understanding of Travel Dynamics

The foundational research required for effective transportation planning and decision making must focus on understanding travel dynamics. No methods, tools, techniques, or institutions can succeed if developed without this information. The breadth of the need for basic travel research is great.

Recommendation 6-1.
Develop a more effective understanding of the perceptions and priorities of the transportation system's customers (users and taxpayers).

The importance to customers of travel time brevity (the traditional goal of transportation plans) as compared with, for example, travel time reliability, requires further research. Apparent paradoxes in customer attitudes must be identified and reconciled. Questions about the value the public assigns to such attributes as the availability of an alternative mode also require research. States and municipalities are spending considerable financial resources on quality-of-life improvements (such as streetscaping) on the one hand and on major highway investments on the other without reliable information about customer expectations or desires. Better methods are needed to address this subject.

Recommendation 6-2.
Develop a more effective understanding of the nature of personal travel, as well as associated trends and decision processes.

There is a need for serious exploration of personal travel behavior, structured according to underlying needs and desires, activities, resources, and constraints. While much work is being done in the international arena on this subject, the work is still largely in the exploratory stage, and the results have not reached the mainstream of the transportation planning community. Research in this area needs to address questions about why a particular travel event (a trip from point A to point B at a specific time by a particular mode along a given route) occurs, instead of merely accounting for the occurrence of the event. Such analysis must also be performed for each sector of society, giving special consideration to unique population groups. Information for decisions

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related to travel demand can no longer be based on aggregated data for all travelers at a specific zone or subarea level. The research proposed here would provide a behavioral basis for examining the effects of further technological advances on travel patterns.

Special concern: Changing demographics and unique population groups. The aggregate transportation planning approaches used by most transportation agencies are particularly ineffective in interacting with the increasingly diverse and complex population of the United States. In the real world, traditional suburban workers commuting to the central city in the morning have been replaced to a great extent by entrepreneurial immigrants; single parents shuttling between day care and work; families executing lengthy, complex trip chains on Saturday afternoons; elderly individuals maintaining part-time employment (and perhaps also different residences in the summer and winter); and teenagers traveling long distances to spend time at the mall (Pisarski 1996). Innovative research is needed to identify the travel practices and choice processes of different market segments, given that the travel behavior of one segment may have little in common with that of another. Research is also needed to understand the correlation between changing economic patterns (e.g., changes in the location of economic activity, changes in wealth distribution) and travel behavior. Populations that are difficult to survey (such as recent immigrants, non-English-speaking residents, migrant workers and other transients, and individuals with low levels of literacy) require particular research attention. Research is also needed to determine the appropriate demographic parameters with which to explain particular travel choices.

Further, there is a need to examine the likely shift in travel by purpose, vehicle occupancy, and time of day caused by the expected increase in the average age of the U.S. population. It is possible that an older population base in 2030 with a smaller percentage of residents in the workforce and more leisure time may make more daily trips but fewer peak-hour trips per capita than does today's population base. If so, planning processes must adjust to these changing circumstances.

Special concern: Effects of technological advances on travel behavior. Telecommuting, Internet shopping, and similar shifts in economic practices may lead to significant changes in the nature, amount, and time of day of travel demand. Planners struggle to address such issues as the likely extent of substitution of electronic communication for personal travel. A 5 percent increase in the penetration of telecommuting into the workplace or electronic shopping

into the retail arena could be safely overlooked in system investment policies; in contrast, a 40 percent penetration would call for a radical reconsideration of policies. Future rush-hour traffic forecasts continue to exert a heavy influence on the design of highway facilities, and near-term capital decisions are being made across the nation without a reasonable understanding of likely future shifts in travel behavior.

Recommendation 6-3.

Develop a more effective understanding of the nature of commercial travel and the freight industry, as well as associated trends and decision processes.

During the past 10 years, states and metropolitan planning organizations have sought to include private-sector stakeholders from the freight community more fully in the planning process. Unfortunately, the combination of the public sector's traditional emphasis on personal travel and the private sector's reticence to share proprietary data makes it difficult to incorporate freight dynamics into planning decisions. Research is needed to identify the appropriate means of obtaining effective information about commercial traffic and its dynamics without compromising firms' competitive positions. This research is essential to the ability of the United States to compete in a global economy while enhancing the environment and protecting other core values. Free-trade agreements and other burgeoning aspects of international freight have raised policy questions regarding the appropriate priorities in using scarce public resources for costly, location- and mode-specific freight and intermodal investments. Answers to questions about the expected functional longevity of major infrastructure investments cannot be obtained without a better understanding of the risks involved. At present, knowledge on this subject is scarce (Neumann 2000).

Special concern: E-commerce and e-freight. E-commerce and just-in-time delivery of both manufacturing components and consumer products are generating significant changes in the nature and amount of long-distance freight traffic and local-delivery traffic. Research is required to understand this aspect of commercial traffic so that further changes resulting from the maturing of e-commerce can be anticipated and factored into the planning process. The economic impacts of e-commerce and e-freight must also be analyzed and related to current travel patterns and behaviors.

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Recommendation 6-4.

Develop a more effective understanding of the role of transportation services and facilities in the economy.

Many if not most transportation investments in the United States are justified to some extent on the basis of their anticipated economic benefit. Whether this benefit is expected to accrue to society primarily through decreased travel time or through removal of barriers to access, economic impact is central. Further research is required to produce a more meaningful understanding of these relationships and methods for better incorporation into transportation decision processes. Once a location is served with a basic level of accessibility, what further contribution to economic health does the next level of improvements offer? Does traffic congestion cost a community its economic well-being, or is it a sign of economic vitality?

Recommendation 6-5.

Develop a more effective understanding of the role of transportation services and facilities in the culture and social fabric of the United States.

Research is needed on the effect of the transportation system on individuals' sense of self-worth, civic pride, and personal aspirations. Community impacts of transportation, such as neighborhood integration or disintegration, improved or diminished sense of place, and connectivity to the regional community, are also generally not well understood, but they are critical areas of knowledge in a holistic decision-making process. Note that this recommended research overlaps with the critical research recommendations presented in Chapter 6 regarding the causal relationships between transportation investments and land use patterns and between community design and travel choices.

Effective Techniques and Responsive Institutions

Improved understanding of the nature and dynamics of personal and commercial travel and the impacts of the transportation system on communities and the environment will be useful only if there are techniques available to apply the knowledge, as well as institutions ready to use those techniques. The following recommendations address this need.

Recommendation 6-6.

Develop techniques for identifying community aspirations and crafting community and regional visions related to transportation planning.

There is a great need for transportation planning practices that can effectively engage disparate elements of a community and produce a vision for the community's future that is both desirable and achievable. Research is required to identify techniques for public outreach, methods for assessing public preferences, and approaches to consensus building, and to determine which market research techniques (e.g., polling) have the most credibility with elected officials.

Special concern: Underrepresented population groups. Efforts to articulate a community vision can focus too easily on the attitudes and perceptions of community leaders, business representatives, advocacy groups, and community activists. Research is required on effective methods for engaging populations that are not predisposed to participate in such activities. Such research should examine, for example, the effectiveness of polling and various survey techniques (Pedersen 1999).

Recommendation 6-7.

Develop tools that incorporate the complex dynamics of travel behavior.

Improved understanding of travel dynamics is useful if it can be incorporated into the tools used by planners and decision makers. TRANSIMS is one effort in this direction. This model provides a micro simulation of all individual travelers on a metropolitanwide network, and is designed to produce more accurate and more sensitive travel forecasts by integrating six modules: population synthesis, activity-based travel demand generation, intermodal trip planning, traffic microsimulation, emissions/air quality analysis, and a feedback selector. However, the true utility of this complex model cannot be realized until its mechanics are tested, and behavioral relationships (the why's of travel behavior and location decisions) are incorporated and validated against observed behavior.

TRANSIMS is not the only initiative requiring research support in this area. Numerous independent research efforts are required to identify the most effective tools for addressing specific policy or technical questions. As noted in Chapter 6, explanatory models that incorporate the relationships between transportation actions (location and quality of facilities and services) and land use are needed. Too often the lack of a good understanding of these relation-

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ships causes transportation professionals to treat settlement patterns and development trends as factors exogenous to the transportation system.

Special concern: Data needs. Complex behavioral relationships and comprehensive models require large and reliable datasets. Research is required on data collection methods that can meet the demands of new models and emerging issues while remaining timely and affordable (Tate-Glass et al. 1999). Journey-to-work data from the long form of the decennial U.S. Census will be replaced during the next decade by data from the continuous American Community Survey. Research is required to understand the reliability of these data and to develop methods for their use in transportation planning. At the same time, the coming years will be marked by rapid advances in the use of Global Positioning System devices, electronic transponders, satellite imagery, and other remote methods of gathering travel information. Research is needed to identify the extent to which technology can be used to supplement or replace costly surveys and other data collection methods.

It should be noted that few of the research recommendations presented in this chapter can be pursued effectively without a process for obtaining and interpreting large amounts of data. Greater use of available technology is perhaps the most promising avenue for meeting the long-standing need for more robust datasets.

Recommendation 6-8.
Develop tools that can be used to estimate the impacts of transportation-related public policy and decisions on comprehensive measures of performance.

Performance measurement is a technique for assessing the degree to which current transportation systems and usage match community aspirations, as well as the ability of available policy, investment, and operational options to help achieve those aspirations. Defined in this manner, transportation system performance extends far beyond traditional measures of travel time and cost, ranging from effects on economic vitality to levels of customer satisfaction (Pedersen 1999). Issues such as transportation's effects on human health, ecosystem health, global energy consumption, climate change, and the ability to respond to unforeseen conditions must be incorporated into evaluation tools. While some measures may not lend themselves to quantification, research must still identify ways of ensuring equitable consideration of such measures in decision-making processes.

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Special concern: "Back-casting." Back-casting is an approach that has been applied to good effect in Europe but not used widely in the United States. Once a vision of a desired future in a metropolitan area or local community has been defined, the approach is used to determine what actions are required to achieve that vision. This approach differs from the traditional focus of models, which attempt to predict the impacts of anticipated growth and change, including a defined set of transportation investments and related policies. Research into best practices for back-casting could be of particular benefit for strategic planning and policy development efforts.

Special concern: Travel safety. While travel safety research is generally not within the environmental arena addressed in this report, methods for integrating a variety of safety initiatives more adequately into the planning process are essential. Research is required to understand complex safety-related interactions among facility design, site and community design, driver demographics, experience and education, and law enforcement, and to incorporate these interactions into planning and design tools, thus moving current practice away from a simple focus on accident countermeasures.

Special concern: Sustainability and growth. In the realm of transportation system performance, one of the greatest demands from both within and outside the transportation planning community is for assessment of the sustainability of planned transportation and land use arrangements. There is a need for methods and tools that can be used to test alternative visions and public policies against the ability of a metropolitan area or community to maintain its systems over time. Research regarding the impacts of transportation policy and investments on environmental protection and enhancement, energy consumption, land consumption, economic health, and affordability must be translated into tools available for use at the front lines of transportation decision making (Burwell 2000). The need for this particular facet of performance measurement is compounded by the fact that the United States will have to accommodate the activities of tens of millions of additional residents in the coming years. Metropolitan areas such as Atlanta and Dallas–Fort Worth continue to absorb population growth in excess of 10,000 residents per month. These rapidly growing areas have a tremendous need for tools that can be used to assess the long-term sustainability of current practices.

Special concern: Distribution of impacts. There is a need for performance evaluation techniques that acknowledge the often differing impacts of the transportation system (both positive and negative) on various segments of the

population. Federal civil rights laws require that federal transportation programs distribute impacts equitably. Tools are needed to both clarify the types of differential impacts and estimate their scale (Kennedy 2000).

Special concern: Policy-level tools. There is a need for quick-response, order-of-magnitude tools in addition to TRANSIMS and comparably detailed forecasting and analysis models. Often, policy questions are amenable to techniques that focus on scale (Are there enough people to support the investment?) and that use transferable parameters (How will incident-related delay increase as freeway traffic volumes increase?). The availability of sketch tools would allow timely responses to policy questions without requiring full-scale operation of TRANSIMS or other detailed network models. Availability of sketch tools would expand the scope of issues that can be addressed by smaller planning staffs.

Special concern: Multimodal performance measures. The current emphasis on performance-based planning has highlighted several key areas requiring improvement. One such area is the development of multimodal performance measures and methods. This is an area in which research to date has been inadequate and that will require additional research and resources if planners are to be expected to make truly multimodal decisions.

Recommendation 6-9.
Develop techniques and ensure institutional arrangements that support integrated, performance-based planning and decision making.

Improved evaluation methods and tools must be accompanied by improved decision processes, particularly when public–private partnerships are sought. To achieve improved decision processes in turn requires research into methods of articulating critical choices and communicating performance comparisons to decision makers and the public. Undeniably, the more sophisticated and comprehensive a technical process becomes, the more opaque it becomes, and the more difficult it is to apply the process in accommodating the often short time frame and site-specific nature of private-sector investment decisions. Moreover, the nation does not want key public decisions to rest on the products of "black-box" technical tools. Rather, the goal in a representative form of government is to craft public policy through elected officials on the basis of both sound technical information and open access by all concerned. Simultaneously maintaining the comprehensiveness and transparency of technical processes to allow informed and intelligent debate about policy choices,

as well as making the processes more responsive to private-sector decision making, is one of the greatest research challenges facing the transportation planning community.

Special concern: Effective institutional arrangements. Decision-making institutions must be capable of meeting the challenge of an integrated process such as that described above. At a minimum, this capability requires capacity building at both the policy and technical levels of transportation agencies, planning organizations, and state and local governments. It may also require investigation of the barriers to effective coordination between transportation decisions and land development (Marshment 1999), along with exploration of means of streamlining the current transportation decision-making process to allow for a multitude of decision makers without generating fragmentation and gridlock. New or modified institutions may be needed.

Special concern: Incorporating customer preferences and priorities. A related concern is that of increasing the role of identified customer preferences and priorities in the decision-making process. To this end, planners and decision makers need guidance in interpreting public attitudes. Failure to address this issue could lead to an overreliance on technical information regarding travel behavior, external impacts, and the like in the decision-making process. Research that can be of assistance in approaching the matter of dispute resolution is also needed.

Special concern: Integrating transportation, land use, and environmental decision making. Of particular concern is the need for research on methods of better integrating transportation, land use, and environmental decision making. Improved integration would significantly enhance the time- and cost-efficiency of decision making by weeding out unworkable and undesirable alternatives early in the planning process. Integration would also allow a shift from environmental impact assessment to environmental protection and enhancement, and from transportation problem solving to comprehensive community planning. The required research must focus as much or more on institutions as on techniques. It must examine the contribution of institutional barriers to the current lack of integration and suggest structural changes that can eliminate the most significant barriers.

Special concern: Climate change and transportation planning and decision making. Weather patterns in recent years have been characterized by unusual ambient air temperatures, as well as greater frequency and severity of flooding, drought, tropical storms, and hurricanes. These weather patterns have put considerable stress on affected transportation facilities and

services. If climate change due to greenhouse gas emissions causes such weather patterns to become more frequent and widespread, significant impacts on the transportation system will result. These impacts will be experienced in three categories:

- *Emergency preparation and response*—Transportation facility siting and design are based on engineering principles incorporating climatological expectations (e.g., 100-year flood plains, historic frost depths, prevailing wind patterns). The transportation system has not been crafted to withstand the demands of unexpected weather events. Severe storms, flooding, and unprecedented extremes in temperature or precipitation can produce circumstances beyond the design characteristics of the transportation system. As a result, the life expectancy of facilities may be shortened, and weather-related failures (e.g., road washouts, frost heaves and heat buckling, bridge failures) may exceed historical frequencies. Moreover, emergency planning for evacuation may need to be extended to areas beyond those typically exposed to weather-related disasters.
- *Lasting changes*—Measurable changes in sea levels can drastically alter the nature and location of coastal areas, as well as inland waterways. Given the strong proximate relationship between water bodies and human development (i.e., development is close to water for transportation, power, drinking water, and recreation), changes in coastlines and waterways will cause significant damage to developed areas and transportation facilities. Lasting changes to sea levels would necessitate redesign and reconstruction of many major transportation facilities, including affected ports, airports, major highways, and rail facilities—at considerable expense.
- *Actions to influence greenhouse gas emissions*—Transportation is currently highly reliant on combustion processes that generate carbon dioxide (see Chapter 2). If concerns about climate change become part of the planning agenda, transportation planners will be expected to produce reliable estimates of the effectiveness of available public actions in reducing carbon dioxide emissions. Few of the transportation planning tools available today address fuel use, let alone carbon dioxide emissions, or account for changes in travel behavior or in vehicle technology and fuels that might be considered in planning to reduce the impacts of climate change (see Chapter 5). The current need for investment in the development of reliable transportation planning tools and decision-making techniques is heightened by the significant role that may be played by such tools and techniques in the future.

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Special concern: Development of environmental information and environmental management methods and tools for efficiently integrating environmental protection and enhancement into transportation planning and decision making. In view of the extremely complex and technical nature of transportation planning, decision making, and environmental management, there is a need to develop methods and tools that are easy to understand and use. These methods and tools must be integrated, as must the processes they support.

Special concern: Transportation financing. At the broadest level, transportation decision making must be more closely related to the formulation of public policy regarding the collection and allocation of public revenues. Of significant concern within the transportation community is the need for research on new options—such as value pricing—for generating revenue to provide and maintain transportation services. This concern also reflects a need for research on the potential impacts of dampened travel growth and increased vehicle fuel-efficiency on the adequacy of revenues based on fuel consumption. Both technical information and understanding of public preferences are important objectives of research aimed at identifying the appropriate mix of user-based and general tax revenue sources. Further, research is required to help clarify the priority of transportation funding within the universe of financial demands on government.

Recommendation 6-10.
Develop methods and institutional structures for integrating transportation planning, programming, design, and operation.

Beyond integration of decision-making processes across disciplines, improvement is needed in the institutional arrangements and practices within the transportation discipline. Too frequently there is a disconnect between system plans and the prioritization of projects for funding, while design and environmental impact assessment processes discount decisions made earlier in the planning process regarding scale and purpose. Commonly, the operation of transit services (route design, service scheduling, and fare policy) and of highways (incident detection and response, information system management, computer signal control) have little structured interaction with the planning and programming processes. Research on new institutional structures and on ways of improving the interaction of operational management with system planning and programming is a critical research need.

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Special concern: Traditional orientation to capital projects. A particular challenge is to find workable approaches that can help transportation institutions transition from a traditional focus on capital projects to a more integrated approach that involves exploring both capital and operational actions for achieving stated goals. The urgency of this challenge is related to the nation's demand for accommodation of increasing levels of economic activity and limited support for expansion of transportation infrastructure.

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Annex 7-1

TRANSPORTATION PLANNING RESEARCH STATEMENTS FROM CONFERENCES ON REFOCUSING TRANSPORTATION PLANNING FOR THE 21ST CENTURY

More than 100 research statements pertaining to the transportation planning process were provided by participants in the two conferences on Refocusing Transportation Planning for the 21st Century held in 1999. The specific statements cover the majority of the research needs identified in this chapter. The list below is arranged according to the cross-cutting issues identified by the conference participants. Because of the strong influence of planning practitioners at the conferences, a majority of the research statements reflect a desire to identify and disseminate improved practices. The suggested research topics and the estimated cost for addressing each topic (in thousands of dollars) are listed below. Where a range of costs was offered in the conference report, the value presented here is the low end of the range. If no cost was estimated by the authors of the research statement, the cost column is left blank (–). The total cost of the identified research items exceeds $60 million.

A More Robust Planning Process

Identifying emerging 21st-century user needs driving demand for transportation services	200
Extent to which transportation investments result in economic development and growth	450
Future trends and expected changes in goods movement	200
Barriers to intermodal freight	150
Overcoming institutional barriers to multimodalism	150
Role of planning in improving the reliability of transportation system performance	200
Effect of system reliability on freight-sector planning and decisions	200
Comparative benefits of investments in management, operations, system preservation, and capacity expansion	500
Institutional issues associated with addressing maintenance and operation (M&O) in the planning process	200

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How congestion-pricing projects could redistribute financing responsibility for transportation improvements	150
Understanding the linkages between transportation systems and sustainable communities: evaluating alternative plans and policies	200
Consideration of environmental factors in transportation planning	750
Identifying and communicating the purpose of and need for transportation projects	250
Integration of transportation corridor and land use planning	300
Defining and analyzing disparate impacts in the context of environmental justice	350
Methods and techniques for better identifying transportation issues of disadvantaged populations and costs associated with providing potentially different transportation services to these populations	350
How to examine the equity of benefits and disbenefits in the planning process	150
Understanding the travel characteristics of welfare recipients and low-income individuals	200
Planning for effective coordination of nonemergency transportation services	200
Systemwide approaches to planning for safety	250
Creative approaches to transportation planning	150
Identifying transportation planning needs of the future	250
Applying new information technology to improve the transportation planning process	300
Integrating new environmental concerns into the transportation planning process	350
Survey of international best practices in planning processes and implementation	250
Resource and energy consumption and sustainable transportation	200
Using performance data generated by intelligent transportation systems (ITS) in the planning process	200

Developing a Customer- and User-Based Planning Process

Identifying what basic research is needed to develop customer-related planning and to create a vision for the community	–
User's guide to the transportation planning process	60
Promoting effective public involvement in the greatest transportation challenges	250
Tools for fostering stakeholder collaboration and dispute resolution in transportation planning	180
Public involvement and customer interaction in analysis for transportation decisions	250
Cultural sensitivities and communication with diverse populations	75
Measuring the effectiveness of Internet tools for soliciting public involvement	50
Tools for assessing the effectiveness of public-involvement processes	250
Institutional barriers to integrating public involvement into transportation planning	200
Incorporating visioning into the transportation planning process	100

Aligning Planning Processes, Decision-Making Institutions, and the Political Process to Meet 21st-Century Challenges

Measuring the impact of transportation systems decisions in terms that matter to decision makers and the public	300
Effectively defining and communicating investment trade-offs and choices for decision makers	200
Closing the gap between regional planning and positions taken by decision makers and the public	500
Improving the linkage between decision making and accountability through performance audits and program assessments	250
Aligning the planning process with faster-paced political change and participatory democracy	200
Reinventing transportation planning	250

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Documenting for elected officials the importance of M&O investments to the performance of the overall transportation system	350
Forty years of regional plans: critical review of lessons learned	500
Administrative reform by states, metropolitan planning organizations, and transit agencies: integrating environmental and economic factors into business and investment decisions	300
New cooperative relationships for planning, design, construction, operation, and management	200
Changing institutional capacity of planning organizations: benchmarking progress	500
New or reformed political institutions: Is there a better way to make planning decisions?	1,000

Understanding the Current and Future Movement of Freight

Understanding the freight industry: trends and future characteristics	250
Integrating freight needs into regional land use planning	200
Strategic measurement for evaluating and assessing the impacts of freight-related projects	2,000
Identifying freight forecasting guidelines and methods	100
Impact of technology on the way commodities are purchased and delivered	250
Land use and circulation implications of express package-delivery services	50
Intermodal terminal capacity and access	100

Unsatisfactory Nature of Technical Processes, Including Models

Socioeconomic research program for metropolitan and nonmetropolitan areas	250 + 150/year
Techniques for equity analysis in metropolitan transportation planning	120
Enabling research program on travel behavior	25,000

Development of guidelines for collecting impact and performance data	400
System operation considerations in planning models	900
Integration of current travel demand forecasting procedures with dynamic assignment models	500
M&O performance indicators	120
Multimodal evaluation	200
Methods for assessing public preferences and incorporating them into transportation decision making	150
Development of a holistic ecosystem evaluation tool	840
Tools for assessing the impacts of neighborhood-scale projects	180
Sensitivity analysis and error assessment in travel demand forecasting models	450
Comparison of forecast and actual travel trends	400
Integrating significant and emerging emission-factor elements with travel demand models	1,080
Techniques for improving communication with community groups and the general public	250
Package of quick-response planning tools for small communities	120
Time-use research to support a new generation of travel and activity models	300
Induced travel and mode substitution as reactions to transportation improvements	400
Interactions between telecommunications and travel	900
Statewide planning model	240
Development of procedures and tools for investing in transportation assets to improve the overall transportation system	5,000
Strategic data research: transportation equity	250

Role and Impact of Technology on Transportation

Technology and organizations: learning from other industries	400
Bringing transportation planning alive: use of advanced technologies to enhance the interactivity of the transportation decision-making process	300
Using ITS data to enhance the transportation planning process	250

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Evaluation of benefits provided by information technology to transportation system operations	500
Reexamination of transportation planning assumptions that may have become outdated as a result of technological advances	500
Technology scanning 2025	150 every 3–5 years
Best-practice survey methods for capturing impacts of information technology on transport activity	425
Applying technology to improve performance measurement for transportation systems	400

Land Use and Transportation

Land use and the transportation planning process: evaluation of existing land use tools applied in transportation decision making, and development of improved tools for use by decision makers in demonstrating the effects of managed growth	100
Transportation strategies for successful redevelopment of established areas	525+
Analytical methods using geographic information systems to evaluate potential transportation and land use impacts on new land development, redevelopment, and rural community development	–
Considering environmental and land use issues and community values in the transportation planning process	–
Techniques to increase multimodal accessibility in suburban communities	150
Flexible approaches to parking development	–
Linking metropolitan travel growth and sprawl	100
Integration of corridor and local land use planning	300
Best practices in metropolitan land use planning and regulation	500
Impacts of new community and neighborhood designs on household travel behavior	1,000

Professional Development

Professional development in transportation planning	150

Linkages to Other Programs and Outcomes

Development of a national shared-knowledge network for social and environmental aspects of transportation planning	350
Information sharing among planning processes	495
Rural participation in transportation decision making	400
Determining and planning for the impacts of tourism on transportation infrastructure	100
Analysis of network connectivity for bicycling and walking	400
Revisiting vision in the planning process	425

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ESTABLISHMENT OF A LONG-TERM RESEARCH STRATEGY

In 1996, the General Accounting Office recommended the development of a long-term research strategy for surface transportation (GAO 1996). In 1998, in the Transportation Equity Act for the 21st Century, Congress called for the establishment of a surface transportation environmental cooperative research program, along with the development of a national research agenda on transportation, energy, and the environment. Congress recognized that a research program with a targeted national agenda is critically needed to help transportation decision makers effectively provide for mobility while simultaneously protecting and enhancing the environment.

In the preceding chapters, the Advisory Board has outlined a proposed agenda for the cooperative research program called for by Congress. The work to be carried out under the program encompasses further developing the research agenda and updating it from year to year; sponsoring and coordinating the research itself; and fostering increased coordination, cooperation, and communication among research entities as part of a long-term national research strategy on transportation and the environment.

Research can be used to identify new policies and approaches for resolving, mitigating, and managing adverse environmental impacts resulting from transportation, as well as for enhancing the environment and contributing to public health and community integrity. For example, research could be conducted to refine the current sketchy understanding of the impact of the expansion of transportation facilities on travel behavior, enabling policymakers to predict associated land use changes more accurately. As another example, additional research could lead to better definition of the relationship between

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roadway width and wildlife habitat fragmentation, thereby assisting transportation planners in protecting and reestablishing wildlife migratory routes.

Current research on transportation and the environment is making valuable contributions, but its ultimate impact is limited because of low levels of funding, inadequate coordination across research entities, and the short-term focus that characterizes most of the work done to date. The Advisory Board has concluded that there is a pressing need for a new strategy for transportation environmental research. This strategy is necessary to (*a*) fill gaps in the existing research programs of the multiple agencies with interests in transportation, energy, and the environment; (*b*) extend the scope of research to system-level and long-term issues as well as short-term needs; (*c*) ensure that all related research initiatives are coordinated; (*d*) provide for broad dissemination of research findings; and (*e*) present research findings in forms and formats that are easily accessible to transportation professionals and policymakers. Absent such a strategy, a fragmented, primarily short-term approach to research will persist without a strong relationship to transportation investment policies and operating practices (GAO 1996).

A long-term, coordinated research strategy with sufficient funding is the only way of adequately preparing transportation policymakers to confront the substantial challenges of an increasing population and expanding economy. In this chapter components of a national research agenda for a proposed surface transportation environmental cooperative research program are outlined; the characteristics of successful cooperative research programs are detailed; and mechanisms for funding and implementing the proposed program, as well as fostering increased cooperation and coordination between the surface transportation community and other research entities, are examined.

National Research Agenda for a Surface Transportation Environmental Cooperative Research Program

The first step in formulating a long-term research strategy for transportation and the environment is to develop a national research agenda that responds to current and anticipated problems and policy choices. That first step has been taken in the previous chapters of this report, in which problems and policy choices have been outlined and six key areas in which targeted research is needed have been identified:

- Human health,
- Ecology and natural systems,
- Environmental and social justice,
- Emerging technologies,
- Land use, and
- Planning and performance measures.

As noted earlier in the report, these six areas were chosen because they represent the points of intersection between transportation and the human and natural environments. While research is being conducted in each of these areas, important gaps exist. Without new research in each of the six areas, decision makers will lack important information needed to make sound decisions on transportation and the environment.

A new surface transportation environmental cooperative research program is needed to ensure that the national research agenda on these critical issues is implemented. This would be accomplished under the program proposed herein in two ways: in some cases, the program would serve as the sponsoring organization for research, while in others the program would serve as the coordinating body for research carried out by others.

Typically, cooperative research programs are formed for two primary reasons. The first is to leverage financial and other resources, as is the case with the National Cooperative Highway Research Program (NCHRP). For example, NCHRP was formed by state departments of transportation (DOTs) for the express purpose of pooling funds to conduct research of common value. State DOTs realized that many of the problems that were occurring in one state were also occurring in many others. Pooling funds for research to solve these problems instead of duplicating efforts enables the state DOTs not only to carry out more research than would be possible on an individual state basis, but also to conduct this research in a more cost-effective manner.

The second primary reason for forming cooperative research programs is to resolve political stalemates and scientific debates. In other words, when tough political choices are made more difficult by scientific uncertainty or conflict, forming a cooperative research program can be the key to producing credible research results that are accepted by multiple parties. For example, the Health Effects Institute (HEI) was formed in 1980 to produce research necessary for resolving disputes between the automotive industry and the Environmental Protection Agency (EPA) regarding the health effects attributable to vehicle emissions. By thus bringing EPA and the automotive manufacturers

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together, it was possible to reach agreement on the questions that needed to be researched and the methodologies to be employed. Interpretations of the results may still vary, but underlying conflicts over basic data have been resolved. Essentially, the primary benefit of such cooperative research programs is the ability to conduct research in a manner that is both transparent to and accepted by all relevant parties.

Today, transportation policy choices have become more polarized than necessary because interested parties hold different positions on the likely answers to important but unresolved scientific questions. For example, what combination of transit and automobile-oriented investments will best provide for population growth while minimizing environmental harm? Do noise barriers produce more benefit or harm to wildlife near highways? Will denser land use configurations lead to decreased automobile dependency? Does transportation influence land use, or is the converse true? Can travel behavior be significantly altered if the right incentives are provided? What are the right incentives? The list of questions currently unanswered ranges from the complex to the relatively simple. Unfortunately, in the areas in which research has been conducted, definitive results have remained elusive. The primary reasons for this are that the research generated is often narrowly scoped, frequently because funding is limited; there is not always agreement on the scientific interpretations, the conclusions, or even the fundamental methodology used to conduct the research; and new forums for discussion of the findings and their interpretations and implications have emerged. Further, research findings are often narrowly disseminated, so that they are known within academe but not the broader community of professionals, or are known in the state where the work was conducted but not elsewhere. If a surface transportation environmental cooperative research program were established, all parties representing contending perspectives could be brought together to define the research questions, review the research methodology, and jointly interpret the findings, thereby increasing the likelihood of acceptance of the results.

Characteristics of a Successful Cooperative Research Program

Cooperative research programs must have certain characteristics to succeed. These characteristics, listed below, are designed to instill a basic level of trust

and confidence in the integrity of the research process, which is just as important as the research that is produced (Deen and Harder 1999):

- A clearly articulated mission from which a strategic focus and research priorities can be ascertained;
- An institutional structure that provides for complete scientific independence from outside influences;
- A credible and openly competitive process for soliciting and evaluating research proposals based on merit review;
- A rigorous standard for evaluating research products;
- A mechanism for widely disseminating research findings and for involving a wide array of stakeholders; and
- An ability to obtain competent staff and to secure a stable funding source.

The Advisory Board reviewed the organizational structures of four leading cooperative research programs: HEI,[1] EPA's Science to Achieve Results Program (STAR),[2] NCHRP, and the Transit Cooperative Research Program (TCRP).[3] Summaries of these programs are included in Appendix B. On the basis of this review, the following specific program elements appear to be most important for success:

- *Core partners*—entities that should contribute to the overall governance of the program, the primary customers and recipients of the research products.[4] Three categories of core partners should be considered when forming a surface transportation environmental cooperative research program: public entities, the private sector, and nongovernmental/nonprofit organizations.
- *Institutional arrangement*—establishment of the research program in a setting that provides for independence and credibility. A partnership between industry and the public sector enhances a cooperative research program's ability to create a cohesive, integrated research environment and should offer the added attraction of securing private investments while

[1] See www.healtheffects.org.

[2] See es.epa.gov/ncerqa/ncqwelc.html.

[3] Interviews were conducted with Chris Jenks, Senior Program Manager, TCRP; Ronald McCready, Senior Program Manager, NCHRP; Peter Preuss, EPA, Manager of the STAR program; and Robert Reilly, Transportation Research Board, Division Director and Manager of NCHRP and TCRP.

[4] For purposes of this report, core partners are classified as sponsors, a separate and distinct category from stakeholders.

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establishing a firewall of independence around the program. Representatives from nongovernmental organizations can form the third leg of the partnership, thereby differentiating the model from that of HEI.[5]

- *Strategic focus*—program direction, as established by the core partners and stakeholders of the program and guided by the national research agenda. To ensure that all core partners and relevant stakeholders are in agreement on the priorities of the cooperative research program, a mechanism is needed for formulating, articulating, and periodically updating the program's strategic focus areas. HEI and STAR, for example, develop multiyear strategic plans.
- *Solicitation and evaluation of research proposals*—the ability to exercise vital quality control mechanisms through open competition and merit review. Establishing clear criteria aids in the selection of the most appropriate research projects, thereby ensuring a selection process that is transparent, fair, and subject to open competition. HEI, STAR, NCHRP, and TCRP all use clear selection criteria in addition to insisting that the selected research projects undergo external merit review. Although the merit review processes differ among the four programs, each incorporates the fundamental elements of both external and internal merit review, as well as open competition.
- *Evaluation of research*—peer review and other approaches designed to ensure the validity and credibility of both the research and the operating functions of the cooperative research program. In addition to evaluating specific research projects upon completion, periodic programmatic evaluations can serve to increase confidence in the operations of the program (NRC 1999) and may be important when a significant number of end users/customers/stakeholders are to be satisfied.
- *Dissemination of research*—mechanisms for effectively disseminating research findings. Too often, the research process ends with the publication of findings. Unless research programs make a concerted effort to inform other researchers and research institutions, practicing professionals, decision makers, and the general populace about those findings, a system of fragmented, uncoordinated research initiatives will persist.

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[5] The primary drawback associated with creating a new institution is the customary lag time between the creation of a new entity and its full implementation. This problem can be solved by either establishing the cooperative research program in an existing independent, nonprofit entity with appropriate capabilities for managing such a program, or by simply incorporating the lag time into the initial strategic planning stage and communicating clear expectations to all involved in the partnership.

- *Funding*—stable funding that enables support of long-term basic and applied research (see below).
- *Competency and availability of staff*—the ability to attract and retain highly skilled and independent staff. Next to stable and sufficient funding, the support of competent staff is the most crucial element in achieving a successful program. If the program is to avail itself of the best and most experienced representatives of the multiple disciplines needed for the research efforts, long-term stable arrangements and flexible contracting processes must be offered with established and emerging institutions that can demonstrate the ability to assemble appropriate teams and complete the tasks assigned. The staffs and institutions involved must also be shielded from political interests and undue influence from key stakeholders and core partners; that is, they must be granted full independence so they can apply the highest standards of scientific rigor to their work (NRC 1999).
- *Stakeholder involvement/communication*—mechanisms for providing for meaningful stakeholder involvement in the selection, evaluation, and coordination of the research.[6] To maintain stakeholder confidence, the process for determining research priorities, selecting and structuring studies, and reviewing the final research products must be clearly understood and readily transparent. All four of the research programs reviewed share common features for actively soliciting stakeholder involvement. Stakeholders are invited to participate in the formulation of the program's strategic plan and strategic focus areas, to submit research proposals, to participate in merit reviews of the research proposals, to participate in workshops at which ongoing research is presented, and to participate in peer reviews of the research products. They are also apprised of the research findings and recommendations.

In summary, the structure and characteristics of a cooperative research program designed to improve the quality and credibility of research in the surface transportation arena should have the following elements:

- Core partners
  - Public partners
  - Private partners
  - Nonprofits

[6] For purposes of this report, stakeholders are defined as all entities, excluding core partners, who demonstrate an interest in the work of the cooperative research program or are fundamental to the successful completion of the program's work.

- Board of directors
  - Formed by core partners
  - Solicits stakeholder input
  - Develops strategic focus
  - Manages priority setting
- Proposal solicitation
  - Request for proposals
  - Open competition
  - Merit review—project selection criteria
  - Stakeholder involvement
- Evaluation of research proposals
  - Expert peer review
  - Publication of final report with reviewers' comments
- Dissemination of research results
  - Set-aside funds for distribution of reports
  - Internet, professional databases, libraries, and so forth
  - One-page summaries of reports for the nonscientific community
  - Presentations of research at workshops
- Periodic program evaluation (measures of success)
- Stakeholder involvement
  - Strategic plan
  - Open solicitation of research proposals
  - Merit review of research proposals
  - Research presentations at workshops
  - Peer review of final research
  - Dissemination of research reports

FUNDING

Adequate and stable funding must be available for the proposed program on a multiyear basis to support administrative, contracting, and sponsorship activities, including the ability to enter into partnerships with other public and private entities; to support long-term research, both basic and applied; and to sponsor workshops and demonstrations of implementation.

Congress first established a continuing commitment to transportation research beyond the budget of the then Bureau of Public Roads of the Department of Agriculture through the Hayden-Cartwright Act of 1934, enabling the

states to use federal transportation funds for surveys, planning, and engineering investigations in support of future highway improvements (FHWA 1976). The scope of this commitment was subsequently expanded to encompass broader planning and research activities. In these early years, the development of fundamental science and engineering knowledge to support transportation improvements and operations was essential.

The Federal-Aid Highway Act of 1962 (Public Law 87-866) first enabled the states to pool funds collaboratively to further research interests. NCHRP was established to conduct research in acute problem areas that affected highway planning, design, construction, operation, and maintenance nationwide. In 1991, the Intermodal Surface Transportation Efficiency Act increased funding for planning and research to 2 percent of the funding for certain federal-aid highway program categories and required that at least 25 percent of those funds (now known as State Planning and Research Funds) be spent for research. These funds, along with limited direct apportionments to DOT, remain the principal source of transportation research support today.

With passage of the National Environmental Policy Act of 1969, transportation agencies were given broader responsibilities and required to coordinate with environmental organizations. However, no funding commensurate with such responsibilities was ever identified. Nor was any mechanism created to further collaborative approaches rather than regulatory research initiatives. While transportation-derived funding remains one of the largest sources of investment in many environmental research areas, most of the activity associated with this funding is tied directly to individual transportation projects instead of to the development of knowledge that would assist in enhancing the overall condition of the environment. Also, little research into the effects of past projects and current operations is undertaken, the focus being primarily on new endeavors.

Because transportation–environment research has been underfunded during the past 30 years, a significant investment is now needed to address both the backlog of issues requiring attention and the issues that continue to arise. Current programs are not designed to address the full range of pressing research needs in surface transportation and the environment. HEI focuses on only one such issue—the health effects of air pollution. NCHRP and TCRP focus on their respective surface transportation modes, and while the scope of both programs includes topics in planning, economics, and environmental protection, program resources are devoted each year primarily to modal concerns. NCHRP research dollars are used mainly for the design and

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construction of highway structures and pavements, and on issues related to safety and operations; TCRP focuses on transit concerns. In contrast, the transportation–environment research agenda proposed in this report would address all surface transportation modes (highways, transit, and rail) and would cover the full range of environmental impacts, with research spanning the six priority areas identified above. Both research addressing short-term needs and longer-term efforts aimed at uncovering fundamental relationships and devising basic new approaches to transportation and the environment would be funded.

While a precise budgetary estimate has not been developed, it is the judgment of the Advisory Board that full implementation of the agenda proposed in this report would necessitate a multiyear investment of well over a $100 million. In reviewing the NCHRP, TCRP, and HEI programs, the Advisory Board ascertained that the minimum operating budget of each was $8 million. The multiyear investment envisioned for the proposed transportation–environment research agenda would be an important complement to these other expenditures. Indeed, by developing new knowledge and helping to put that knowledge into practice, a focused, coordinated investment in transportation–environment research would enhance the efficacy of these existing programs.[7]

A large-scale research program requires a careful startup phase and review of success before a sustainable and effective annual level of research activity can be determined. Thus it is prudent to anticipate that full implementation of the proposed program should and will be phased in over several years. However, there is little reason for growth of the program to be constrained by a lack of funding. At current federal funding levels, as little as 0.05 percent of annual authorizations of certain federal-aid program categories produces approximately $150 million. While a precise annual budgetary estimate for the eventual surface transportation cooperative research program cannot be established until after the startup phase, it is the Advisory Board's opinion that the budget will not exceed such a small fraction of the overall federal transportation program. A national commitment of this scale would not pose a significant financial challenge to the federal transportation program, and given the importance of the environmental issues at stake in the proposed research program, could be expected to produce benefits many times as large.

[7] The transportation–environment research agenda also would complement the proposed Future Strategic Highway Research Program, which includes proposals for applied, short-term work on planning and the environment as one of its components (see TRB 2001).

IMPLEMENTATION

The Advisory Board envisions that representatives from appropriate federal government agencies would establish a relationship with an independent entity capable of implementing and managing a national surface transportation environmental cooperative research program having the characteristics of a successful program outlined above. The implementing organization would be directed to report the program's activities each year to the appropriate federal agency representatives and to Congress.

INCREASED COOPERATION, COORDINATION, AND COMMUNICATION

The proposed surface transportation environmental cooperative research program could serve as a coordinating body for many entities involved in such research. Such entities might include federal agencies conducting environmental and transportation research, universities, the private sector, nongovernmental organizations, state transportation and environmental agencies, international bodies, and other research institutions. Specifically, the program could be tasked with (*a*) annually surveying the research being conducted in the area both domestically and internationally; (*b*) providing specific recommendations for enhancing coordination, eliminating duplication, and identifying research gaps and priorities, with particular attention to long-term research needs; (*c*) enabling and supporting ongoing information sharing and collaborative debate; (*d*) sponsoring demonstrations and operational tests of promising research findings in cooperation with other parties; (*e*) soliciting stakeholder input to the management and evaluation of the program; and (*f*) fostering further education and capacity building in both research and professional practice.

REFERENCES

Abbreviations

FHWA	Federal Highway Administration
GAO	General Accounting Office

NRC	National Research Council
TRB	Transportation Research Board

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APPENDIX A

RESEARCH PRIORITIES WORKSHOP: SUMMARY REPORT

On September 26–27, 2000, in Washington, D.C., the Surface Transportation Environmental Cooperative Research Program Advisory Board (Advisory Board) convened a broad spectrum of transportation and environmental professionals for a focused 2-day workshop designed to identify future research priorities for the surface transportation community. Prior to the "Research Priorities Workshop," the Advisory Board members identified six critical research areas and outlined three pertinent questions for each area. Panelists and audience members were invited to respond to these questions. The critical research areas were selected on the basis of the Advisory Board's mission to produce a national research agenda of energy, environment, and planning research for the surface transportation community.

CRITICAL RESEARCH AREAS

The six critical research areas selected for discussion during the Research Priorities Workshop were as follows:

- *Human health,* as defined by transportation's impact on the environment and the potential adverse effects on human health related to, for example, air quality, water quality, and safety;
- *Ecosystem health,* specifically, transportation's impact on the environment and the resulting health of the ecosystem;

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- *Climate change,* namely the effects of patterns of demand on fuel consumption and greenhouse gas emissions, and the role for alternative fuels, new vehicles, and other strategies;
- *Land use and the built environment,* focusing on the relationship between patterns of growth and land consumption and surface transportation;
- *Design and management of research programs,* soliciting recommendations for how to effectively structure a research program that will address the intersection between the environment and transportation; and
- *Institutions, governance, and capacity-building.* The Advisory Board queried participants during this segment of the workshop to consider how research can be structured to best aid agencies and institutions that develop and deliver surface transportation.

Each panelist and invited workshop participant was requested to respond to the following three questions, tailored to the individual critical research areas:

- What should be the priority for future research in the area of human health?
- What organizational arrangements may be needed to meet these new priorities?
- What areas in human health research are currently underresearched or inadequately addressed via traditional research programs?

Mission of the Surface Transportation Environmental Cooperative Research Program Advisory Board

> (c) ADVISORY BOARD.—
> ESTABLISHMENT.—In consultation with the Secretary of Energy, the Administrator of the Environmental Protection Agency, and the heads of other appropriate Federal departments and agencies, the Secretary shall establish an advisory board to recommend environmental and energy conservation research, technology, and technology transfer activities related to surface transportation. [Transportation Equity Act for the 21st Century (TEA-21), Sec. 5107]

On the basis of the legislative mandate contained in TEA-21, the Federal Highway Administration (FHWA) contracted with the Transportation Research Board (TRB) to create the Advisory Board. The National Research Council

appointed a group of preeminent experts to the Advisory Board and placed them under the leadership of Elizabeth Deakin in 1999. Members of the Advisory Board represent a broad spectrum of the transportation and environmental communities, including academia, state departments of transportation, state environmental protection agencies, metropolitan planning organizations (MPOs), transit organizations, environmental groups, and industry.

The Advisory Board is formally charged with recommending a national agenda of energy, environment, and planning research for the surface transportation community. It should be noted that the Advisory Board members determined that in order to recommend a viable agenda for environment and energy conservation research related to surface transportation, the concept of "planning" would have to be integrated into the agenda. It remains the contention of the Advisory Board members that unless environmental and energy conservation concerns are factored into the transportation planning process, the secondary and cumulative effects of system-level transportation decisions on larger-scale environmental systems will continue to remain insufficiently addressed in the early stages of the transportation planning process. The Advisory Board's emphasis in the planning area specifically focuses on the overlap between planning processes and environmental issues and focuses on theme areas such as land use and transportation, distributional impacts, and the creation of an integrated, user-oriented, systems approach to transportation and the environment.

The Advisory Board members also believe that the identification of research priorities will only be a productive exercise if existing research programs are structured to implement the new priorities. Therefore, the Advisory Board members identified institutions and institutional structures along with the design and management of research programs as two of the six critical research areas. In its final report the Advisory Board intends to outline a national research agenda, which will be accompanied by recommendations for structuring and managing research programs and institutions.

Research and Technology Partnership Forum

The Research and Technology Partnership Forum was created by FHWA, TRB, and the American Association of State Highway and Transportation Officials to promote an awareness of research and technology activities in the surface transportation arena and to create more efficient and effective partnerships. TRB is serving as the "secretariat" for the Forum. The Forum is composed of

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five working groups: safety, infrastructure renewal, policy analysis and system monitoring, operations and mobility, and environment and planning. As the Advisory Board's scope of work overlaps with the mission of the environment and planning workgroup, namely to create a national agenda for environment and planning research, it was agreed by all pertinent parties that the Advisory Board would assume the responsibilities for that workgroup. Therefore, the Research Priorities Workshop was created for two purposes. First, the workshop served as an efficient means for the Advisory Board to gather broad input from transportation and environmental professionals regarding the appropriate research priorities for surface transportation. The input received will serve as a foundation to the Advisory Board's report scheduled for completion in October 2001, outlining a national agenda for anticipated use by Congress, federal agencies, and other pertinent stakeholders in establishing environmental, energy, and planning research priorities. Second, the workshop served as a forum for promoting the goals of the Research and Technology Partnership Forum. During the workshop the Advisory Board solicited and received input from individuals representing the following organizations and constituencies: FHWA, EPA, the Department of Housing and Urban Development, the National Environmental Respiratory Center, the Health Effects Institute, the American Lands Alliance, the Institute for Ecosystem Studies, the American Council for an Energy-Efficient Economy, Oak Ridge National Laboratory, Sky Trust International, People in Defense of Earth Resources, Natural Resources Defense Council, Arcadia Land Company, Honda Motor Company, Defenders of Wildlife, and various academics and university research centers. A list of participants is provided in Appendix B.

Structure of Workshop Summary

The Advisory Board determined that a summary highlighting the key points associated with each critical research area would be a more productive and beneficial tool for both the Advisory Board and for other interested parties. Therefore, transcripts or summaries of each presenter's dialogue will not be given in the summary.

Human Health Panel

Presenters: Dr. Joe Mauderly, National Environmental Respiratory Center; Dr. Patricia Waller, formerly Director of the University of Michigan Trans-

portation Research Institute; Dr. Jane Warren, Director of Science, Health Effects Institute.

Summary: "The continued evolution of the national transportation infrastructure and the strategic planning, technological developments, and regulatory decisions shaping this evolution will be driven in significant part by health concerns" according to Dr. Joe Mauderly. Therefore, the ability to properly assess transportation's impact on human health and to accurately evaluate alternative transportation proposals in their proper context becomes critical. The issue of whether current research methodologies and programs are currently being designed and managed to accomplish this goal was a focal point for discussion. A key theme emerging from this dialogue centered on the need to integrate research into a systems management approach. Both Dr. Mauderly and Dr. Warren provided examples in their presentations illustrating the need to shift the current research paradigm of examining and evaluating the effects of individual air pollutants on human health to a paradigm in which all sources contributing to a particular health burden are considered. Presenters and participants acknowledged that, to date, research on pollutant mixtures has been largely underfunded and avoided because of the inherent complexity of the task. The issue of risk and the need to reconcile the total risk with the total health burden was also identified as requiring further consideration under a national research agenda.

The second key theme that emerged from the workshop discussion was the overall concept of community and connectivity. Dr. Waller eloquently made the case for broadening the Advisory Board's working definition of human health (i.e., air quality, water quality, and safety) to encompass both community health and social well-being along with individual quality-of-life indicators. The issue of tracking human incapacity rates resulting from transportation-related causes was an area cited as an example of a quality-of-life issue requiring additional research along with access issues for the elderly, the poor, and the traditionally disenfranchised communities.

Considering transportation as an integral component of a larger system appeared to resonate with the majority of participants and presenters. When asked how to shift the current research culture to one of an integrated, collaborative system, presenters and participants suggested that a concerted effort should be made to expand the network of traditional transportation partners. The transportation community needs to consider the impacts of transportation on the global community and to develop institutions and structures that are capable of factoring and filtering the needs of different cultures, regulatory structures, and decision-making processes.

ECOSYSTEM HEALTH PANEL

Presenters: Dr. John Bissonette, Utah State University; Dr. Gene Likens, Institute of Ecosystem Studies; Dr. Faith Campbell, American Lands Alliance; Daniel Smith, University of Florida.

Summary: According to Dr. Gene Likens, "The health of an ecosystem is based on its structure and function, and how these change with time and in response to natural and anthropogenic impacts." The presenters during this session began their presentations by briefly outlining the most pervasive ecological impacts, both direct and indirect, of transportation systems.[1] First, the construction of roadways may disrupt natural hydrologic flowpaths and increase erosion, air pollution, and surface water runoff. Second, roadways may also facilitate the rapid spread of invasive species and contribute to increased wildlife mortality rates through wildlife–automobile collisions. Third, roadways can serve as effective barriers to wildlife movement, altering natural migratory patterns; this in turn may result in habitat fragmentation, whereby certain species become at risk for genetic isolation.

The list of ecological impacts is wide-ranging. While the presenters were not charged with enumerating or elaborating on specific ecological impacts associated with transportation, they effectively conveyed an overarching theme of the need to incorporate ecological considerations into the transportation planning and maintenance processes. Many of the presenters and participants concurred, and echoed the need to focus future research efforts on the various intersection points between transportation systems and habitat networks.

Presenters and participants also acknowledged that a considerable number of studies have already been conducted and documented regarding the ecological effects of transportation. To date, however, substantial progress has not been made in monitoring long-term ecosystem responses to anthropogenic stressors, nor has there been a concerted effort to comprehensively assess certain ecological impacts on a countrywide, continentwide, or even statewide basis. For example, while large animal mortality rates frequently receive considerable attention, no comprehensive databases have been established to track these rates on a countrywide basis. Even more important, many of the presenters and participants articulated the need to develop databases that would provide for experimental manipulations on a systems level, such as measuring the

[1] The discussion primarily centered on the impacts associated with roads and roadside ecological issues.

impacts of various deicing agents on aquatic and terrestrial ecosystems, or quantifying the effects of highway infrastructure on ecosystem integrity. The concept of collecting data and conducting systemwide analysis emerged as the second primary theme of the session.

Climate Change/Sustainable Transportation Panel

Presenters: Dr. John DeCicco, The American Council for an Energy-Efficient Economy; Dr. David Greene, Oak Ridge National Laboratory; Rafe Pomerance, Sky Trust International.

Summary: Water vapor, carbon dioxide (CO_2), ozone, methane, nitrous oxide, and chlorofluorocarbons constitute the primary "greenhouse gases," all of which are naturally occurring and are essential to regulating the atmospheric temperature. Since 1990, total U.S. greenhouse gas emissions have risen by 11.1 percent.[2] The primary greenhouse gas emitted as a result of human activities is CO_2; fossil fuel combustion constitutes the largest source of CO_2 and is the leading source of overall greenhouse gas emissions in the United States. While scientists and other professionals agree that concentrations of CO_2 in the atmosphere have increased, significant disagreement persists concerning the resulting impact on the atmosphere. Several panelists and workshop participants, therefore, concluded that a fundamental step toward rectifying the global climate change problem is to clearly delineate the issue, the potential impacts, and the necessary solutions before, for example, seeking customer acceptance of new vehicular technologies. Discussion also centered on the need to research various aspects of social marketing and market penetration in order to close the gap between the supply and the demand for "greener" products. In addition, transportation professionals must be informed of the potential impacts of global climate change on the nation's transportation infrastructure so they can anticipate needed changes.

The majority of presenters and panelists agreed on the need for conducting further research to comprehensively evaluate the existing array of strategies for reducing greenhouse gas emissions, emphasizing economic and social costs, secondary benefits, and societal acceptance. It was noted that strategies should be researched and evaluated in light of their ability to hold society "harmless." The issue of using alternative fuels as a strategy for reducing greenhouse gas

[2] Year of measurement 1997; baseline of 1990.

emissions received considerable attention. Some participants asserted that research on alternative fuels should be curtailed until a corresponding infrastructure is established; in particular, mass-market sales of such fuels may not occur as long as alternative-fuel vehicles are restricted to niche markets.

In conclusion, the overarching theme expressed during this session was the need to incorporate social marketing research into existing and future programs designed to explore reduction strategies for greenhouse gas emissions. The technical strategies necessary for accomplishing emissions reductions are fairly well understood and incorporated into traditional research programs; the next step will be to connect these technologies to broader societal goals. Several participants recommended the formation of new institutions that would link global and local initiatives; incorporate the activities of government, industry, and nongovernmental organizations; and have the forethought and capability to create "value" for sustainable technologies and systems.

Land Use/Built Environment Panel

Presenters: Susan Wachter, Department of Housing and Urban Development; Susana Almanza, People in Defense of Earth Resources; Dr. David Goldstein, Natural Resources Defense Council; Dr. Susan Handy, University of Texas at Austin; Christopher Leinberger, Arcadia Land Company.

Summary: Dr. Handy began the discussion by grouping transportation and land use research into two primary categories: (*a*) the influence of transportation investments on land use and (*b*) the influence of land use patterns on travel behavior. While both categories have been extensively researched, additional questions remain concerning causal relationships and the role public policies can and will play vis-à-vis other factors. The linkage between transportation and land use, according to Dr. Handy, needs to be assessed at both the macro and micro levels and in both the short and the long term. Christopher Leinberger concurred with Dr. Handy, observing that to date research conducted on land use has not been very effective since it has not addressed long-term land use problems or focused on changing public attitudes. Land use research needs to take a 20-year perspective. Dr. Wachter noted that between 2000 and 2025, jobs and capacity in the United States will grow by 25 percent, and 50 percent of the current built environment will be replaced. Where this development occurs will affect many environmental and societal issues. Susana Almanza also commented that long-term research is needed to realistically

determine future land uses that will be compatible with the unique cultural and behavioral characteristics of all affected communities. For example, research should be conducted to assess which communities will benefit from land use decisions and which communities will be left behind or negatively affected.

According to Dr. Goldstein, future long-term transportation research should also explore the impacts of location efficiency and the development of least cost planning templates for transportation investments. For example, long-term research in these areas could explore the potential directions of causality, such as the extent to which the ability to access transit leads to higher density, and what is the actual price elasticity for gasoline, holding other variables constant.

The key theme that emerged from the panelists' presentations was the need to connect research to both current and future policy decisions. Workshop participants and panelists expressed a need to close the gap between research and current practice. To close this gap and to work within funding constraints, Dr. Handy suggested that the following questions be considered when prioritizing research needs:

- What research has been done and to what end? Some of the questions have been largely answered; for others, much research has been conducted, but few answers have been generated; and for the remainder, very little is known.
- What is the relative importance of the remaining questions, and what makes a question important? One criterion is the frequency with which the question is asked. Another is the implications of the answer—what difference it will make in decisions about transportation and land use policy.

Design and Management of Research Programs

Presenters: Dr. Ray Chamberlain, former Vice President of the American Trucking Associations, former Executive Director of the Colorado Department of Transportation; Dr. Randy Erickson, formerly Technical Director, 3M Traffic Control Materials Division; Dr. William C. Harris, President and Executive Director, Columbia University's Biosphere 2 Center.

Summary: All three presenters were asked to provide their recommendations for successfully designing and managing research programs. Several key factors for success emerged from the discussion. First, the institutions that house the research programs must provide the requisite administrative support, that is, the space, equipment, and staff time needed to implement the research program

effectively for an extended time. Second, a support system must be created within the institution to provide for the encouragement and motivation of staff, appropriate peer reviews, and a positive work environment for scientists. Third, vision statements and clear expectations for the research programs must be developed and communicated to both internal and external customers. Finally, all three presenters strongly advocated that discretionary funding be provided to research scientists, arguing that the scientists must have the flexibility to conduct research that is not necessarily linked to customer-driven needs.

The primary barrier to effectively designing and managing research programs identified by the presenters centered on funding. The presenters noted that to accomplish timely research, secure funding sources must be identified. It was also noted that frequently many research projects require multiple sources of funding and that oftentimes these sources may not be working on the same time schedules, leaving the coordination of funding to the research institution—which may not be equipped to serve as the "banker." Several presenters also noted that research institutions must secure sufficient funding to attract top researchers and to complete complex research projects.

When asked to provide recommendations for establishing or redesigning existing research programs to more fully address the intersection between transportation and the environment, several of the presenters commented that it would be a mistake to refocus existing programs. Rather, they suggested that the Advisory Board recommend the formation of a new program utilizing new funding sources. The concept of research centers, modeled after the National Science Foundation centers, was recommended. Many presenters and workshop participants noted that researchers and transportation policymakers must do a better job communicating to citizens the need for transportation research. People must be motivated to solve problems and work with a team approach. New research programs must be cognizant of this need when soliciting funding. Finally, any new research program that is developed must have champions associated with its establishment.

Institutions, Governance, and Capacity-Building Panel

Presenters: Alex Taft, Executive Director, Association of Metropolitan Planning Organizations; Carole Whiteside, President, Great Valley Center.

Summary: Alex Taft began his presentation by outlining the need to establish a National Cooperative Metropolitan Planning Organization Research

Program (NCMPORP). The primary need for such an organization, according to Mr. Taft, stems from the fact that after Congress increased the role of MPOs in TEA-21, MPOs were viewed by many constituencies as the venue for multimodal planning and transportation/land use planning. Mr. Taft also noted that MPOs are increasingly becoming the avenue for local citizen groups and environmental interests to address their transportation-related equity issues and environmental concerns.

While no clear consensus was reached concerning the formation of NCMPORP, both panelists and several workshop participants concurred with the need to develop an approach or system whereby solutions to transportation planning issues are truly multimodal in scope. In other words, the current practice of "stovepiping" research or decision-making processes by modes or planning functions needs to be rectified.

Carole Whiteside provided a synopsis of the problems facing the Great Valley Region of California and in so doing identified several critical questions facing the structure and functioning of institutions. What methods can be used to increase the collaboration of a multitude of jurisdictions and independent local governments, particularly as commute corridors and transit routes are extended beyond traditional boundaries and in many directions at once? What are the potentially useful models of government? What will the process be for governing interjurisdictional and interregional projects?

While none of the workshop participants had an obvious answer to these questions, most concurred with the concept that the "bigger picture" in transportation needs to be articulated by policymakers and understood by the general public. For example, all too often, policymakers and planners are focused on and concerned with only one piece of a much larger regional project. Therefore, the range of impacts and alternatives associated with a particular project are oftentimes not identified or assessed from a systems-level perspective prior to the decision-making process. Many participants also commented that existing models are not scaled or scoped to identify the full range of alternatives hindering the "bigger picture" approach.

The concluding sentiment and overarching theme of this session appeared to center on the concept of connectivity. While new institutions and new analytical tools may be warranted, it was the view of many that the current problems associated with the environment–transportation interface will not be solved until the public feels a connection to the issue and demands a solution. In other words, regional cooperation may not emerge until the public forces the political will.

APPENDIX B

MATRIX OF COOPERATIVE RESEARCH PROGRAMS

Program	Core Partners	Strategic Focus	Solicitation and Evaluation of Research Proposals	Evaluation of Research Product
Health Effects Institute (HEI)	Automotive industry and U.S. Environmental Protection Agency (EPA)	Priorities are guided by a 5-year strategic plan. Plan is reviewed and updated annually	The Research Committee identifies program areas and openly solicits proposals. Proposals are reviewed for scientific quality and overall integration into the research program. Board of Directors reviews recommended proposals for procedure, independence, and quality of the selection process	The Health Review Committee evaluates all HEI-funded studies on the basis of scientific quality and the study's contribution to unresolved scientific questions. Each draft final report is peer-reviewed by scientists with appropriate technical expertise

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EPA's Science to Achieve Results program (STAR)	EPA Partnerships are formed with other agencies for particular projects	Strategic plan establishes priorities for research and development using a risk-based process	Competition for Request for Applications (RFAs) is announced through the *Federal Register*, the Internet, universities, and so forth. RFAs are awarded after an external peer review and an internal relevancy review (merit review)	No evaluation of final research product
National Cooperative Highway Research Program (NCHRP)	State departments of transportation, Transportation Research Board (TRB), and American Association of State Highway and Transportation Officials (AASHTO)	Priorities are set on an annual basis by the primary customers of the program—state departments of transportation	Problem statements are solicited from individual states and AASHTO standing committees. Problem statements are selected by a merit-based review. Research proposals are selected for funding on the basis of an expert panel review	No formal evaluation of final research product. If panel review committees are not satisfied with the work of the researcher, the final report will not be published
Transit Cooperative Research Program (TCRP)	TRB, American Public Transportation	Priorities are set on an annual basis by the pri-	Problem statements are openly solicited and are	No formal evaluation of final research product. If panel

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Program	Core Partners	Strategic Focus	Solicitation and Evaluation of Research Proposals	Evaluation of Research Product
	Association (APTA), Federal Transit Administration	mary customers of the program—transit operators	selected on the basis of a merit-based review. Research proposals are selected for funding on the basis of an expert panel review	review committees are not satisfied with the work of the researcher, the final report will not be published

Program	Research Dissemination	Funding Sources	Competence and Independence of Staff	Stakeholder Involvement
HEI	Research reports are distributed to EPA, industry sponsors, the scientific community, public interest groups, and appropriate libraries. A one-page statement is written for nonscientists	EPA and the automotive industry	HEI employs a small, highly skilled technical staff. A firewall is established between staff serving as liaisons to the Research Committee (proposal selection) and staff serving as liaisons to the	HEI's Board of Directors consists of public and private figures in science and policy. HEI routinely consults with interested parties on the development of the HEI strategic plan and in determining

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	summarizing the key findings of the report		Review Committee (project evaluation)	research priorities. Stakeholders also have the opportunity to attend annual workshops, where research results are presented
STAR	Final reports are distributed via the National Technical Information Service and the EPA website. Summaries of reports are provided in both scientific and nonscientific formats	EPA's Office of Research and Development (ORD) contributes about $110 million; federal partners contribute about $20 million	Through ORD's intramural and technical support program, ORD scientists are assigned to areas of highest risk/priority. A firewall is established between staff who administer the independent peer review and staff who write or select RFAs	The STAR program follows the federal guidelines for public comment and involvement. In addition, stakeholders are invited to workshops to hear updates on research in progress. Finally, stakeholder participation is solicited in the writing of RFAs when STAR forms a partnership with a private entity

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Program	Research Dissemination	Funding Sources	Competence and Independence of Staff	Stakeholder Involvement
NCHRP	Final reports are published and distributed via the TRB website, and copies of the reports are mailed to the program subscribers	State departments of transportation. The program is voluntarily funded from a percentage of the federal-aid highway funds of the state departments of transportation. These funds are projected for several years, providing a consistent funding base	NCHRP hires staff experienced in the areas of research undertaken by the program. No firewall is established between staff selecting and administering the program	The AASHTO Standing Committee on Research determines the priorities for the program. The Federal Highway Administration is provided an opportunity to propose projects. Expert panels are selected to conduct merit reviews of the problem statements
TCRP	Funding is set aside for TCRP to contract with APTA to distribute and market research reports	Funding is specifically earmarked for TCRP through the appropriation process. Funding has not kept pace with inflation and has recently been subject to earmarks	TCRP hires staff experienced in the areas of research undertaken by the program. No firewall is established between staff selecting and administering the program	The Transit Development Corporation's Board of Directors serves as the Board of Directors for TCRP. Expert panels are selected to conduct merit reviews of the problem statements

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STUDY COMMITTEE BIOGRAPHICAL INFORMATION

Elizabeth Deakin, *Chair,* is Director of the University of California Transportation Center and a professor in the Department of City and Regional Planning at the University of California at Berkeley. She also holds faculty appointments in the Energy and Resources Group and in the Master of Urban Design Program at Berkeley. She received S.B. and S.M. degrees in political science and civil engineering/transportation from Massachusetts Institute of Technology and a law degree from Boston College Law School. Her areas of expertise include transportation planning and policy, land use planning and administration, and environmental policy. She has authored or coauthored more than 150 journal articles and technical reports as well as a book and six book chapters. She served as Chair of the Transportation Research Board (TRB) Committee on Transportation and Land Development from 1992 to 1998. She is the California Senate's appointee to the state's Vehicle Inspection Maintenance Review Committee and has served on a number of local government commissions. She currently sits on the board of three nonprofit environmental organizations.

F. Kaid Benfield is an environmental attorney and director of transportation and smart growth policy for the Natural Resources Defense Council (NRDC) in Washington, D.C. He has also served the organization as director of its land program, director of its forestry and agriculture projects, and legal affairs coordinator. Before coming to NRDC, he worked at the U.S. Department of Justice and in private legal practice. He is a graduate of Emory University and Georgetown University Law Center and the author of numerous publications related to environmental law and policy, including the books *Solving Sprawl* (with Jutka Terris and

Nancy Vorsanger) and *Once There Were Greenfields* (with Mathew D. Raimi and Donald D. T. Chen). He is a member of several steering committees and boards relating to transportation and smart growth.

Kenneth J. Button is currently Professor of Public Policy at George Mason University. He received a B.A. in economics from the University of East Anglia, an M.A. in economics from the University of Leeds, and a Ph.D. in economics from Loughborough University. He has been elected a Fellow of the Institute of Logistics and Transport, Fellow of the Institution of Highways and Transportation, and Fellow of the Chartered Institute of Transport. His areas of expertise include transport economics, travel demand modeling, environmental economics, and international transport policy. He has authored or coauthored more than 80 books and hundreds of articles and papers pertaining to various aspects of transportation policy. Currently, he is the Editor-in-Chief for *Transportation Research D, Transportation and Environment,* and the *Journal of Air Transport Management.* He serves on numerous committees and in 1996 cochaired the European Science Foundation/National Science Foundation Joint Initiative on Transport Research.

Judith M. Espinosa is the director of the Alliance for Transportation Research Institute at the University of New Mexico. She received a B.A. in nursing from the University of New Mexico; a master's degree in public health administration from the University of California, Los Angeles; and a doctor of jurisprudence from the University of New Mexico. She was recently nominated by President Clinton and confirmed by the U.S. Senate to serve as a Trustee on the Morris K. Udall Foundation for Scholarship and Excellence in National Environmental Policy, and she chairs the Good Neighbor Environmental Board, a federal advisory committee on U.S.–Mexico environmental and infrastructure issues. She served for 4 years as New Mexico's Secretary of Environment and for 2 years as its Secretary of Transportation. She currently is a member of the following boards: the National Wildlife Federation, the Environmental Leadership Program, the Surface Transportation Policy Project, the Energy Foundation, and the Clean Air Action Corporation. She has written several articles on transportation and the environment.

Richard T. T. Forman is Professor of Advanced Environmental Studies in Landscape Ecology at Harvard University. He received a B.S. from Haverford College, a Ph.D. from the University of Pennsylvania, an honorary A.M. from Harvard University, an honorary doctor of humane letters from

Miami University, and an honorary doctor of science from Florida International University. His interests and research include the principles of landscape and regional ecology, forest ecology, the spatial meshing of nature and people, and the ecology of road systems. He has authored numerous articles, and his books include *Landscape Ecology Principles in Landscape Architecture and Land Use Planning* and the award-winning *Land Mosaics: The Ecology of Landscapes and Regions*. He has served as President of the Torrey Botanical Society and as Vice President of the Ecological Society of America. In 1992 he was named Distinguished Landscape Ecologist, and he has received medals and awards in eight countries. He is the lead author of a forthcoming book, *Road Ecology: Science and Solutions*.

Fred Hansen is the General Manager of the Tri-County Metropolitan Transportation District of Oregon (Tri-Met). He assumed this position in 1998. Previously he served for 4 years as the Deputy Administrator for the U.S. Environmental Protection Agency (EPA) in Washington, D.C., where he managed EPA's day-to-day operations and was involved in all major policy issues. Before joining EPA, Hansen directed the Oregon Department of Environmental Quality for more than 10 years. He also served as Oregon's Deputy State Treasurer as well as in previous positions in Washington, D.C., where he worked as Executive Officer of the Peace Corps and Chief of Staff to a member of Congress from Oregon. He received a bachelor's degree from the University of Oregon (Phi Beta Kappa) and a master's degree from McMaster University, and he completed a year of doctoral work at The Johns Hopkins University.

Edwin E. Herricks is Professor of Environmental Biology in the Department of Civil Engineering at the University of Illinois at Urbana-Champaign. He received a B.A. in biology and English from the University of Kansas, an M.S. in engineering from The Johns Hopkins University, and a Ph.D. in biology from Virginia Polytechnic Institute and State University. His areas of expertise include aquatic ecology, biomonitoring, and stream ecosystem management, and he has broad experience in the identification, assessment, and restoration of the adverse effects of man's activities on streams, rivers, lakes, and their watersheds. Recent research has focused on stormwater toxicity, stream restoration, climate change impact, and environmental management systems integration. He has authored or coauthored three books; his most recent book, *Stormwater Runoff in Receiving Streams: Impact, Monitoring, Management,* was published in 1995. He has authored more than 140 articles and reports. He has recently served on National

Research Council (NRC) panels addressing river navigation and nuclear waste issues, and he is presently a member of the Panel on Methods and Techniques of Corps of Engineers Project Analysis. Herricks is an advisor to local, state, and federal agencies and has participated in educational and management programs in the United Kingdom, Yugoslavia, France, Germany, Japan, and Taiwan.

Wayne W. Kober has more than 28 years of multimodal transportation and environmental management experience for both the public and private sectors. He has a B.S. degree in environmental resource management from Penn State University. He is nationally recognized as an innovative leader in the field of transportation project development and environmental management. His broad span of experience at successfully integrating environmental analysis, agency/public involvement, and context-sensitive design aspects into a systematic decision-making process has enabled him to play a prominent role in advancing Pennsylvania's multimodal transportation improvement programs. In addition, he has worked at the regional and national levels in leading the development of environmental streamlining and stewardship legislation, policies, and practices. He is in private practice and currently serves as a Senior Transportation and Environmental Management Specialist for the American Association of State Highway and Transportation Officials (AASHTO).

Alan J. Krupnick is Senior Fellow at Resources for the Future and Director of its Quality of the Environment Division. He received his Ph.D. in economics from the University of Maryland. His research interests include the analysis of environmental issues, with a particular focus on air pollution, cost–benefit analysis, and the design of environmental policies, including their intersection with transportation policies. He recently cochaired a federal advisory committee that provided counsel to EPA on implementing its new ozone and particulate standards. In 1994 Dr. Krupnick served as a senior staff economist for environment and natural resources on the President's Council of Economic Advisers. He served on TRB's Committee for a Review of the Highway Cost Allocation Study and its Committee for the Evaluation of the Congestion Mitigation and Air Quality Improvement Program, and he is currently a member of NRC's Committee on Research and Peer Review in EPA.

Martin Lee-Gosselin is currently Professor of Planning at Laval University, Quebec, Canada. He received a Ph.D. in urban, technological, and environmental planning from the University of Michigan, as well as master's

and bachelor's degrees in interdisciplinary fields from Michigan State University and the University of Bristol, England. He specializes in survey and analysis methods to investigate travel behavior both as it exists now and in response to future changes in policy or the availability of alternative fuel, vehicle, and telecommunications technologies. He is the principal investigator of a major network research program, involving seven Canadian universities, on the behavioral foundations of integrated land use, transport, and environmental impact models. Before joining Laval in 1990, he was a SERC Visiting Research Fellow at London and Oxford Universities. He spent 20 years in university research, state government, and the private sector, including 7 as Research Director for the Office of the Secretary of State of Michigan. He has served on various international bodies for the Organization for Economic Cooperation and Development, the World Health Organization, and the European Community; on the Japanese institute IATSS; on five TRB committees; and on the Board of the International Association for Travel Behaviour Research. He has coedited several books, including *Understanding Travel Behaviour in an Era of Change* (1997) with Peter Stopher, and has published numerous articles on the travel behavior, energy, environmental, and safety aspects of transportation.

Ysela Llort is the State Transportation Planner for the Florida Department of Transportation. In this capacity, she oversees the statewide and systems planning function for the Department of Transportation. Among her primary responsibilities are executive level policy formulation and interpretation, as well as working with the numerous transportation partners, including metropolitan planning organizations, to obtain consensus on needs and priorities for the state. Prior to her work with the Florida Department of Transportation, Ms. Llort served 9 years with the Virginia Department of Transportation as Assistant District Engineer for Planning and Operations in Northern Virginia, adjacent to Washington, D.C. Ms. Llort is a graduate of Duke University, where she earned a degree in economics; she holds master's degrees from Clemson University in both city and regional planning and transportation engineering.

C. Ian MacGillivray is Director of the Engineering Division for the Iowa Department of Transportation. He is responsible for the department's traffic and transportation safety programs along with general coordination and management of research, technology transfer, and the department's engineering staff/process development programs. He served as the Director of the Planning and Research Division from 1977 to 1993. Mr. MacGillivray

received a bachelor of science degree in civil engineering from the University of Alberta and a master of science degree in civil engineering from Purdue University. He currently serves on the AASHTO Standing Committee on Research; chairs the National Cooperative Highway Research Program's (NCHRP) Project Panel 20-05: Synthesis of Information Related to Highway Problems; serves as Vice Chair of AASHTO's Special Committee on International Activity Coordination; and serves on various other TRB, AASHTO, and NCHRP committees.

Jane T. Nishida has been Maryland's Secretary of the Environment since 1995. She received a B.A. in international relations from Lewis and Clark College and a doctor of jurisprudence degree from Georgetown University Law Center. She currently serves on the following committees: Governor's Council on the Chesapeake Bay, Governor's Pesticide Council, Lead Hazard Advisory Committee, State Soil Conservation Committee, Northeast Ozone Transport Commission, Smart Growth and Neighborhood Conservation Subcabinet, Western Maryland Economic Development Task Force, and the World Trade Center Institute. She also chairs the Smart Growth Task Force of the Environmental Council of the States.

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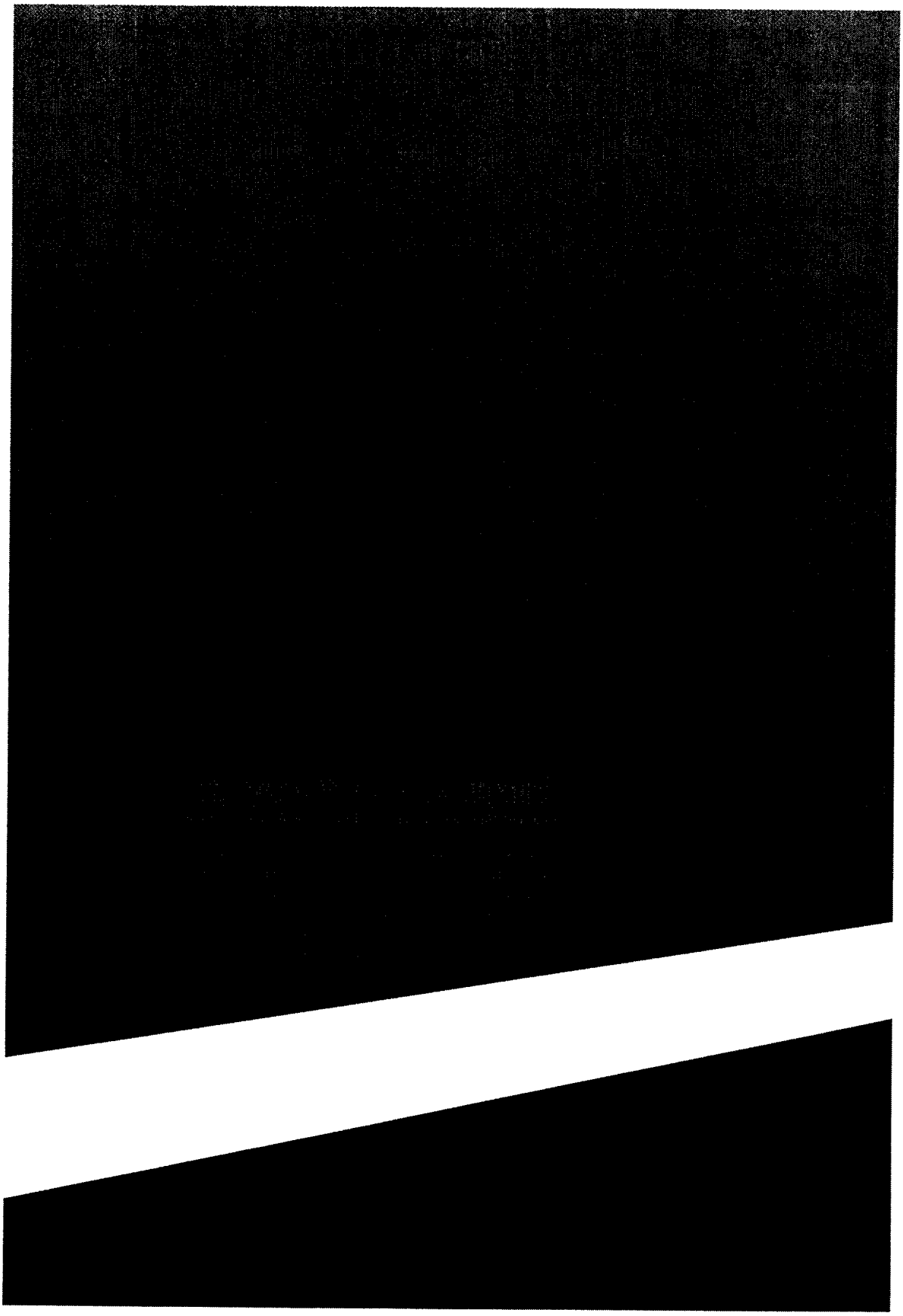
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at the Georgia Institute of Technology. She received an undergraduate degree from Kent State University and master's and Ph.D. degrees in regional planning from Cornell University. Her areas of expertise include planning theory and policy analysis, transportation planning, impact assessment, disaster planning, urban revitalization, environmental planning, and public participation. She has written numerous articles and research reports on various aspects of transportation planning. She is a member of the TRB Executive Committee, the Urban Land Institute, the Urban Affairs Association, the American Planning Association, the Planners Network, the Association of Collegiate Schools of Planning, the Sigma Xi, the National Scientific Research Society, the Women's Transportation Seminar, and the Conference of Minority Transportation Officials.

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ROADS AND THEIR MAJOR ECOLOGICAL EFFECTS

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KEY WORDS: animal movement, material flows, population effects, roadside vegetation, transportation ecology

ABSTRACT

A huge road network with vehicles ramifies across the land, representing a surprising frontier of ecology. Species-rich roadsides are conduits for few species. Roadkills are a premier mortality source, yet except for local spots, rates rarely limit population size. Road avoidance, especially due to traffic noise, has a greater ecological impact. The still-more-important barrier effect subdivides populations, with demographic and probably genetic consequences. Road networks crossing landscapes cause local hydrologic and erosion effects, whereas stream networks and distant valleys receive major peak-flow and sediment impacts. Chemical effects mainly occur near roads. Road networks interrupt horizontal ecological flows, alter landscape spatial pattern, and therefore inhibit important interior species. Thus, road density and network structure are informative landscape ecology assays. Australia has huge road-reserve networks of native vegetation, whereas the Dutch have tunnels and overpasses perforating road barriers to enhance ecological flows. Based on road-effect zones, an estimated 15–20% of the United States is ecologically impacted by roads.

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INTRODUCTION

Roads appear as major conspicuous objects in aerial views and photographs, and their ecological effects spread through the landscape. Few environmental scientists, from population ecologists to stream or landscape ecologists, recognize the sleeping giant, road ecology. This major frontier and its applications to planning, conservation, management, design, and policy are great challenges for science and society.

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This review often refers to The Netherlands and Australia as world leaders with different approaches in road ecology and to the United States for especially useful data. In The Netherlands, the density of main roads alone is 1.5 km/km^2, with traffic density of generally between 10,000 and 50,000 vehicles per commuter day (101). Australia has nearly 900,000 km of roads for 18 million people (66). In the United States, 6.2 million km of public roads are used by 200 million vehicles (85). Ten percent of the road length is in national forests, and one percent is interstate highways. The road density is 1.2 km/km^2, and Americans drive their cars for about 1 h/day. Road density is increasing slowly, while vehicle kilometers (miles) traveled (VMT) is growing rapidly.

The term road corridor refers to the road surface plus its maintained roadsides and any parallel vegetated strips, such as a median strip between lanes in a highway (Figure 1; see color version at end of volume). "Roadside natural strips" of mostly native vegetation receiving little maintenance and located adjacent to roadsides are common in Australia (where road corridors are called road reserves) (12, 39, 111). Road corridors cover approximately 1% of the United States, equal to the area of Austria or South Carolina (85). However, the area directly affected ecologically is much greater (42, 43).

Theory for road corridors highlights their functional roles as conduits, barriers (or filters), habitats, sources, and sinks (12, 39). Key variables affecting processes are corridor width, connectivity, and usage intensity. Network theory, in turn, focuses on connectivity, circuitry, and node functions (39, 71).

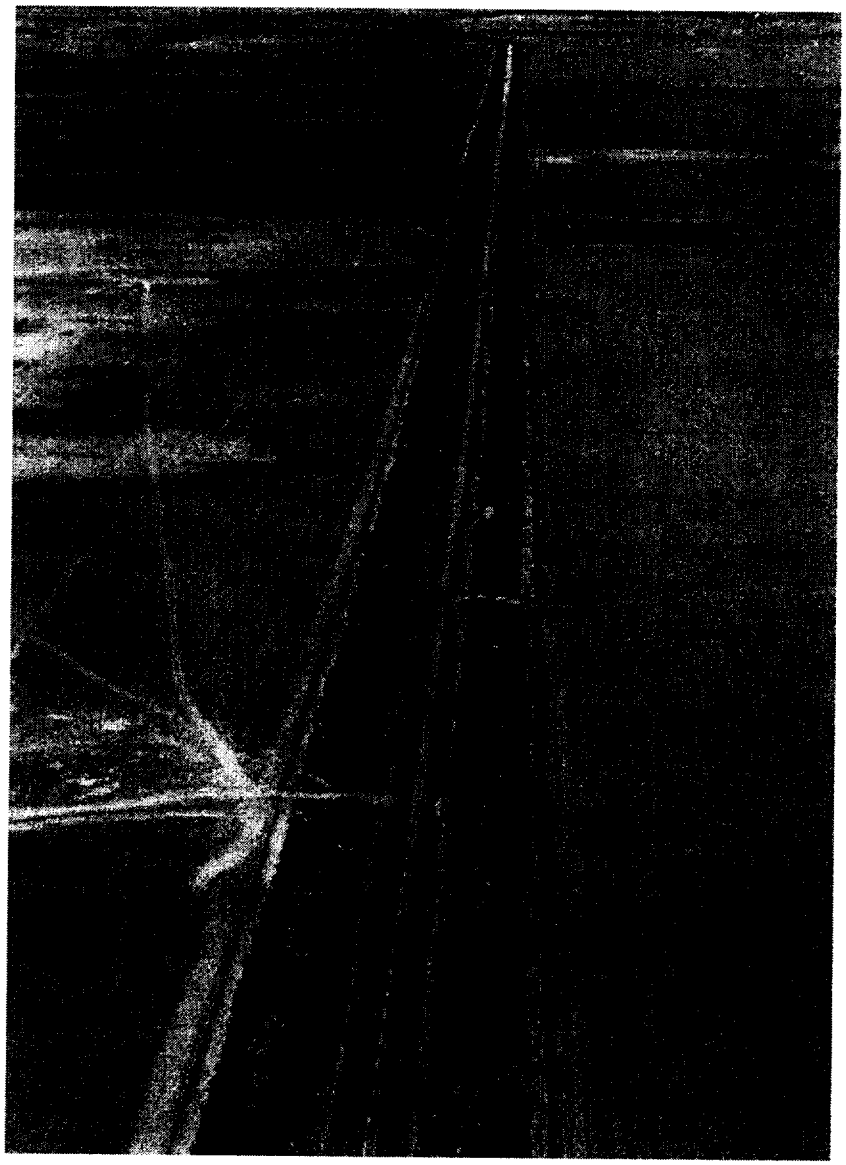
This review largely excludes road-construction-related activities, as well as affiliated road features such as rest stops, maintenance facilities, and entrance/exit areas. We also exclude the dispersed ecological effects of air pollution emissions, such as greenhouse gases, nitrogen oxides (NOX), and ozone, which are reviewed elsewhere (85, 135). Bennett's article (12) plus a series of books (1, 21, 33, 111) provide overviews of parts of road ecology.

Gaping holes in our knowledge of road ecology represent research opportunities with a short lag between theory and application. Current ecological knowledge clusters around five major topics: (*a*) roadsides and adjacent strips; (*b*) road and vehicle effects on populations; (*c*) water, sediment, chemicals, and streams; (*d*) the road network; and (*e*) transportation policy and planning.

Figure 1 Road corridor showing road surface, maintained open roadsides, and roadside natural strips. Strips of relatively natural vegetation are especially characteristic of road corridors (known as road reserves) in Australia. Wheatbelt of Western Australia. Photo courtesy of BMJ Hussey. See color version at end of volume.

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ROADSIDE VEGETATION AND ANIMALS

Plants and Vegetation

"Roadside" or "verge" refers to the more-or-less intensively managed strip, usually dominated by herbaceous vegetation, adjacent to a road surface (Figure 1). Plants on this strip tend to grow rapidly with ample light and with moisture from road drainage. Indeed, management often includes regular mowing, which slows woody-plant invasion (1, 86). Ecological management may also maintain roadside native-plant communities in areas of intensive agriculture, reduce the invasion of exotic (non-native) species, attract or repel animals, enhance road drainage, and reduce soil erosion.

Roadsides contain few regionally rare species but have relatively high plant species richness (12, 139). Disturbance-tolerant species predominate, especially with intensive management, adjacent to highways, and exotic species typically are common (19, 121). Roadside mowing tends to both reduce plant species richness and favor exotic plants (27, 92, 107). Furthermore, cutting and removing hay twice a year may result in higher plant species richness than does mowing less frequently (29, 86). Native wildflower species are increasingly planted in dispersed locations along highways (1).

Numerous seeds are carried and deposited along roads by vehicles (70, 112). Plants may also spread along roads due to vehicle-caused air turbulence (107, 133) or favorable roadside conditions (1, 92, 107, 121, 133). For example, the short-distance spread of an exotic wetland species, purple loosestrife (*Lythrum salicaria*), along a New York highway was facilitated by roadside ditches, as well as culverts connecting opposite sides of the highway and the median strip of vegetation (133). Yet few documented cases are known of species that have successfully spread more than 1 km because of roads.

Mineral nutrient fertilization from roadside management, nearby agriculture, and atmospheric NOX also alter roadside vegetation. In Britain, for example, vegetation was changed for 100–200 m from a highway by nitrogen from traffic exhaust (7). Nutrient enrichment from nearby agriculture enhances the growth of aggressive weeds and can be a major stress on a roadside native-plant community (19, 92). Indeed, to conserve roadside native-plant communities in Dutch farmland, fertilization and importing topsoil are ending, and in some places nutrient accumulations and weed seed banks are reduced by soil removal (86; H van Bohemen, personal communication).

Woody species are planted in some roadsides to reduce erosion, control snow accumulation, support wildlife, reduce headlight glare, or enhance aesthetics (1, 105). Planted exotic species, however, may spread into nearby natural ecosystems (3, 12). For example, in half the places where non-native woody species were planted in roadsides adjacent to woods in Massachusetts (USA), a species had spread into the woods (42).

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Roadside management sometimes creates habitat diversity to maintain native ecosystems or species (1, 86, 131). Mowing different sections along a road, or parallel strips in wide roadsides, at different times or intervals may be quite effective (87). Ponds, wetlands, ditches, berms, varied roadside widths, different sun and shade combinations, different slope angles and exposures, and shrub patches rather than rows offer variety for roadside species richness.

In landscapes where almost all native vegetation has been removed for cultivation or pasture, roadside natural strips (Figure 1) are especially valuable as reservoirs of biological diversity (19, 66). Strips of native prairie along roads and railroads, plus so-called beauty strips of woodland that block views near intensive logging, may function similarly as examples. However, roadside natural strips of woody vegetation are widespread in many Australian agricultural landscapes and are present in South Africa (11, 12, 27, 39, 66, 111). Overall, these giant green networks provide impressive habitat connectivity and disperse "bits of nature" widely across a landscape. Yet they miss the greater ecological benefits typically provided by large patches of natural vegetation (39, 41).

In conclusion, roadside vegetation is rich in plant species, although apparently not an important conduit for plants. The scattered literature suggests a promising research frontier.

Animals and Movement Patterns

Mowing, burning, livestock grazing, fertilizing, and planting woody plants greatly impact native animals in roadsides. Cutting and removing roadside vegetation twice a year in The Netherlands, compared with less frequent mowing, results in more species of small mammals, reptiles, amphibians, and insects (29, 86). However, mowing once every 3–5 y rather than annually results in more bird nests. Many vertebrate species persist better with mowing after, rather than before or during, the breeding period (86, 87). The mowing regime is especially important for insects such as meadow butterflies and moths, where different species go through stages of their annual cycle at different times (83). Roadsides, especially where mowed cuttings are removed, are suitable for ~80% of the Dutch butterfly fauna (86).

Planting several native and exotic shrub species along Indiana (USA) highways resulted in higher species richness, population density, and nest density for birds, compared with nearby grassy roadsides (105). Rabbit (*Sylvilagus*) density increased slightly. However, roadkill rates did not differ next to shrubby versus grassy roadsides.

In general, road surfaces, roadsides, and adjacent areas are little used as conduits for animal movement along a road (39), although comparisons with null models are rare. For example, radiotracking studies of wildlife across the landscape detect few movements along or parallel to roads (35, 39, 93). Some exceptions are noteworthy. Foraging animals encountering a road sometimes

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move short distances parallel to it (10, 106). At night, many large predator species move along roads that have little vehicular or people traffic (12, 39). Carrion feeders move along roads in search of roadkills, and vehicles sometimes transport amphibians and other animals (11, 12, 32). Small mammals have spread tens of kilometers along highway roadsides (47, 60). In addition, migrating birds might use roads as navigational cues.

Experimental, observational, and modeling approaches have been used to study beetle movement along roadsides in The Netherlands (125–127). On wide roadsides, fewer animals disappeared into adjacent habitats. Also, a dense grass strip by the road surface minimized beetle susceptibility to roadkill mortality (126, 127). Long dispersals of beetles were more frequent in wide (15–25 m) than in narrow (<12 m) roadsides. Nodes of open vegetation increased, and narrow bottlenecks decreased, the probability of long dispersals. The results suggest that with 20–30-m-wide roadsides containing a central suitable habitat, beetle species with poor dispersal ability and a good reproductive rate may move 1–2 km along roadsides in a decade (127).

Adjacent ecosystems also exert significant influences on animals in corridors (39). For example, roadside beetle diversity was higher near a similar patch of sandy habitat, and roadsides next to forest had the greatest number of forest beetle species (127). In an intensive-agriculture landscape (Iowa, USA), bird-nest predation in roadsides was highest opposite woods and lowest opposite pastures (K Freemark, unpublished data). Finally, some roadside animals also invade nearby natural vegetation (37, 47, 54, 60, 63, 127).

The median strip between lanes of a highway is little studied. A North Carolina (USA) study found no difference in small-mammal density between roadsides on the median and on the outer side of the highway (2). This result was the same whether comparing mowed roadside areas or unmowed roadside areas. Also, roadkill rates may be affected by the pattern of wooded and grassy areas along median strips (10).

In conclusion, some species move significant distances along roadsides and have major local impacts. Nevertheless, road corridors appear to be relatively unimportant as conduits for species movement, although movement rates should be better compared with those at a distance and in natural-vegetation corridors.

ROAD AND VEHICLE EFFECTS ON POPULATIONS

Roadkilled Animals

Sometime during the last three decades, roads with vehicles probably overtook hunting as the leading direct human cause of vertebrate mortality on land. In addition to the large numbers of vertebrates killed, insects are roadkilled in prodigious numbers, as windshield counts will attest.

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Estimates of roadkills (faunal casualties) based on measurements in short sections of roads tell the annual story (12, 39, 123): 159,000 mammals and 653,000 birds in The Netherlands; seven million birds in Bulgaria; five million frogs and reptiles in Australia. An estimated one million vertebrates per day are killed on roads in the United States.

Long-term studies of roadkills near wetlands illustrate two important patterns. One study recorded >625 snakes and another >1700 frogs annually roadkilled per kilometer (8, 54). A growing literature suggests that roads by wetlands and ponds commonly have the highest roadkill rates, and that, even though amphibians may tend to avoid roads (34), the greatest transportation impact on amphibians is probably roadkills (8, 28, 34, 128).

Road width and vehicle traffic levels and speeds affect roadkill rates. Amphibians and reptiles tend to be particularly susceptible on two-lane roads with low to moderate traffic (28, 34, 57, 67). Large and mid-sized mammals are especially susceptible on two-lane, high-speed roads, and birds and small mammals on wider, high-speed highways (33, 90, 106).

Do roadkills significantly impact populations? Measurements of bird and mammal roadkills in England illustrate the main pattern (56, 57). The house sparrow (*Passer domesticus*) had by far the highest roadkill rate. Yet this species has a huge population, reproduces much faster than the roadkill rate, and can rapidly recolonize locations where a local population drops. The study concluded, based on the limited data sets available, that none of the >100 bird and mammal species recorded had a roadkill rate sufficient to affect population size at the national level.

Despite this overall pattern, roadkill rates are apparently significant for a few species listed as nationally endangered or threatened in various nations (~9–12 cases) (9, 39, 43; C Vos, personal communication). Two examples from southern Florida (USA) are illustrative. The Florida panther (*Felis concolor coryi*) had an annual roadkill mortality of approximately 10% of its population before 1991 (33, 54). Mitigation efforts reduced roadkill loss to 2%. The key deer (*Odocoileus virginianus clavium*) has an annual roadkill mortality of ~16% of its population. Local populations, of course, may suffer declines where the roadkill rate exceeds the rates of reproduction and immigration. At least a dozen local-population examples are known for vertebrates whose total populations are not endangered (33, 39, 43).

Vehicles often hit vertebrates attracted to spilled grain, roadside plants, insects, basking animals, small mammals, road salt, or dead animals (12, 32, 56, 87). Roadkills may be frequent where traffic lanes are separated by impermeable barriers or are between higher roadside banks (10, 106).

Landscape spatial patterns also help determine roadkill locations and rates. Animals linked to specific adjacent land uses include amphibians roadkilled

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near wetlands and turtles near open-water areas (8). Foraging deer are often roadkilled between fields in forested landscapes, between wooded areas in open landscapes, or by conservation areas in suburbs (10, 42, 106). The vicinity of a large natural-vegetation patch and the area between two such patches are likely roadkill locations for foraging or dispersing animals. Even more likely locations are where major wildlife-movement routes are interrupted, such as roads crossing drainage valleys in open landscapes or crossing railway routes in suburbs (42, 106).

In short, road vehicles are prolific killers of terrestrial vertebrates. Nevertheless, except for a small number of rare species, roadkills have minimal effect on population size.

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Vehicle Disturbance and Road Avoidance

The ecological effect of road avoidance caused by traffic disturbance is probably much greater than that of roadkills seen splattered along the road. Traffic noise seems most important, although visual disturbance, pollutants, and predators moving along a road are alternative hypotheses as the cause of avoidance.

Studies of the ecological effects of highways on avian communities in The Netherlands point to an important pattern. In both woodlands and grasslands adjacent to roads, 60% of the bird species present had a lower density near a highway (102, 103). In the affected zone, the total bird density was approximately one third lower, and species richness was reduced as species progressively disappeared with proximity to the road. Effect-distances (the distance from a road at which a population density decrease was detected) were greatest for birds in grasslands, intermediate for birds in deciduous woods, and least for birds in coniferous woods.

Effect-distances were also sensitive to traffic density. Thus, with an average traffic speed of 120 km/h, the effect-distances for the most sensitive species (rather than for all species combined) were 305 m in woodland by roads with a traffic density of 10,000 vehicles per day (veh/day) and 810 m in woodland by 50,000 veh/day; 365 m in grassland by 10,000 veh/day and 930 m in grassland by 50,000 veh/day (101–103). Most grassland species showed population decreases by roads with 5000 veh/day or less (102). The effect-distances for both woodland and grassland birds increased steadily with average vehicle speed up to 120 km/h and also with traffic density from 3000 to 140,000 veh/day (100, 102, 103). These road effects were more severe in years when overall bird population sizes were low (101).

Songbirds appear to be sensitive to remarkably low noise levels, similar to those in a library reading room (100, 102, 103). The noise level at which population densities of all woodland birds began to decline averaged 42 decibels (dB), compared with an average of 48 dB for grassland species. The most sensitive

woodland species (cuckoo) showed a decline in density at 35 dB, and the most sensitive grassland bird (black-tailed godwit, *Limosa limosa*) responded at 43 dB. Field studies and experiments will help clarify the significance of these important results for traffic noise and birds.

Many possible reasons exist for the effects of traffic noise. Likely hypotheses include hearing loss, increase in stress hormones, altered behaviors, interference with communication during breeding activities, differential sensitivity to different frequencies, and deleterious effects on food supply or other habitat attributes (6, 101, 103, 130). Indeed, vibrations associated with traffic may affect the emergence of earthworms from soil and the abundance of crows (*Corvus*) feeding on them (120). A different stress, roadside lighting, altered nocturnal frog behavior (18). Responses to roads with little traffic may resemble behavioral responses to acute disturbances (individual vehicles periodically passing), rather than the effects of chronic disturbance along busy roads.

Response to traffic noise is part of a broader pattern of road avoidance by animals. In the Dutch studies, visual disturbance and pollutants extended outward only a short distance compared with traffic noise (100, 103). However, visual disturbance and predators moving along roads may be more significant by low-traffic roads.

Various large mammals tend to have lower population densities within 100–200 m of roads (72, 93, 108). Other animals that seem to avoid roads include arthropods, small mammals, forest birds, and grassland birds (37, 47, 73, 123). Such road-effect zones, extending outward tens or hundreds of meters from a road, generally exhibit lower breeding densities and reduced species richness compared with control sites (32, 101). Considering the density of roads plus the total area of avoidance zones, the ecological impact of road avoidance must well exceed the impact of either roadkills or habitat loss in road corridors.

Barrier Effects and Habitat Fragmentation

All roads serve as barriers or filters to some animal movement. Experiments show that carabid beetles and wolf spiders (*Lycosa*) are blocked by roads as narrow as 2.5 m wide (73), and wider roads are significant barriers to crossing for many mammals (11, 54, 90, 113). The probability of small mammals crossing lightly traveled roads 6–15 m wide may be $<10\%$ of that for movements within adjacent habitats (78, 119). Similarly, wetland species, including amphibians and turtles, commonly show a reduced tendency to cross roads (34, 67).

Road width and traffic density are major determinants of the barrier effect, whereas road surface (asphalt or concrete versus gravel or soil) is generally a minor factor (34, 39, 73, 90). Road salt appears to be a significant deterrent to amphibian crossing (28, 42). Also, lobes and coves in convoluted outer-roadside boundaries probably affect crossing locations and rates (39).

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The barrier effect tends to create metapopulations, e.g. where roads divide a large continuous population into smaller, partially isolated local populations (subpopulations) (6, 54, 128). Small populations fluctuate more widely over time and have a higher probability of extinction than do large populations (1, 88, 115, 122, 123). Furthermore, the recolonization process is also blocked by road barriers, often accentuated by road widening or increases in traffic. This well-known demographic threat must affect numerous species near an extensive road network, yet is little studied relative to roads (6, 73, 98).

The genetics of a population is also altered by a barrier that persists over many generations (73, 115). For instance, road barriers altered the genetic structure of small local populations of the common frog (*Rana temporaria*) in Germany by lowering genetic heterozygosity and polymorphism (97, 98). Other than the barrier effect on this amphibian and roadkill effects on two southern Florida mammals (20, 54), little is known of the genetic effects of roads.

Making roads more permeable reduces the demographic threat but at the cost of more roadkills. In contrast, increasing the barrier effect of roads reduces roadkills but accentuates the problems of small populations. What is the solution to this quandary (122, 128)? The barrier effect on populations probably affects more species, and extends over a wider land area, than the effects of either roadkills or road avoidance. This barrier effect may emerge as the greatest ecological impact of roads with vehicles. Therefore, perforating roads to diminish barriers makes good ecological sense.

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WATER, SEDIMENT, CHEMICALS, STREAMS, AND ROADS

Water Runoff

Altering flows can have major physical or chemical effects on aquatic ecosystems. The external forces of gravity and resistance cause streams to carve channels, transport materials and chemicals, and change the landscape (68). Thus, water runoff and sediment yield are the key physical processes whereby roads have an impact on streams and other aquatic systems, and the resulting effect-distances vary widely (Figure 2).

Roads on upper hillslopes concentrate water flows, which in turn form channels higher on slopes than in the absence of roads (80). This process leads to smaller, more elongated first-order drainage basins and a longer total length of the channel network. The effects of stream network length on erosion and sedimentation vary with both scale and drainage basin area (80).

Water rapidly runs off relatively impervious road surfaces, especially in storm and snowmelt events. However, in moist, hilly, and mountainous terrain, such

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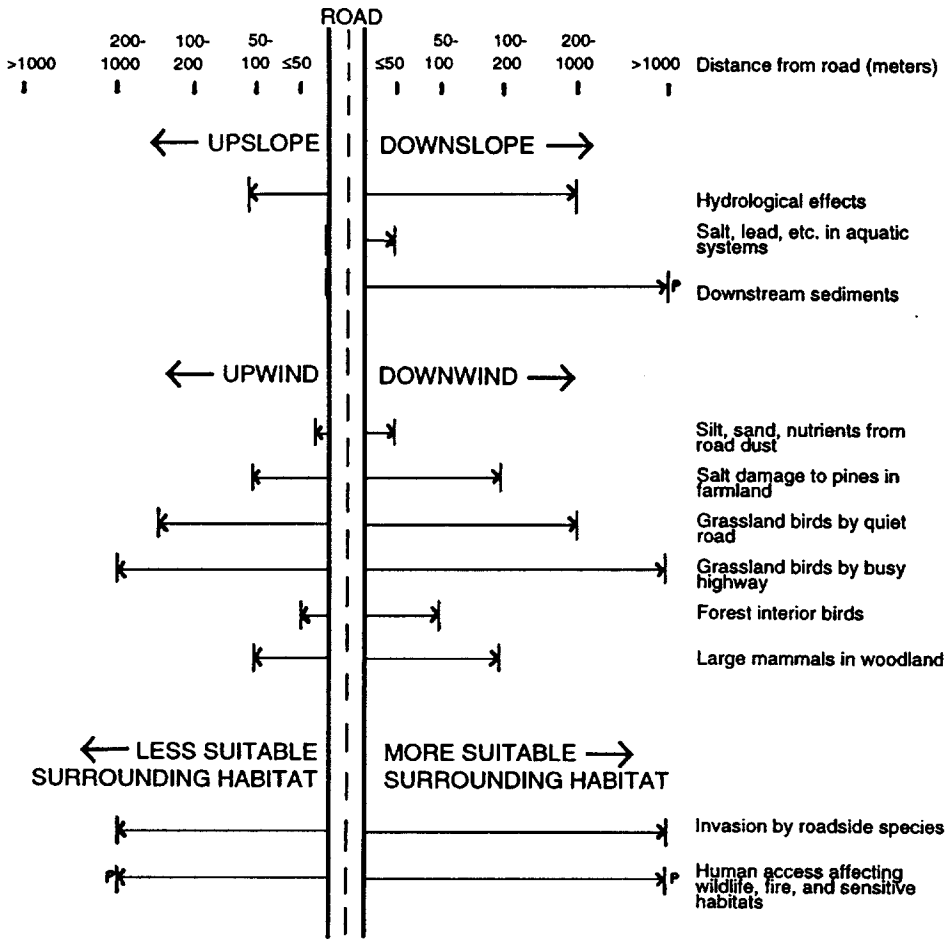


Figure 2 Road-effect zone defined by ecological effects extending different distances from a road. Most distances are based on specific illustrative studies (39); distance to left is arbitrarily half of that to right. (*P*) indicates an effect primarily at specific points. From Forman et al (43).

runoff is often insignificant compared with the conversion of slow-moving groundwater to fast-moving surface water at cutbanks by roads (52, 62, 132). Surface water is then carried by roadside ditches, some of which connect directly to streams while others drain to culverts with gullies incised below their outlets (132). Increased runoff associated with roads may increase the rates and extent of erosion, reduce percolation and aquifer recharge rates, alter channel morphology, and increase stream discharge rates (13, 14). Peak discharges or

floods then restructure riparian areas by rearranging channels, logs, branches, boulders, fine-sediment deposits, and pools.

In forests, the combination of logging and roads increases peak discharges and downstream flooding (62, 132). Forest removal results in lower evapotranspiration and water-storage capabilities, but roads alone may increase peak discharge rates (62). Also, flood frequency apparently correlates with the percentage of road cover in a basin (52, 62, 110).

Roads may alter the subsurface flow as well as the surface flow on wetland soils (116). Compacted saturated or nearly saturated soils have limited permeability and low drainage capacity. Wetland road crossings often block drainage passages and groundwater flows, effectively raising the upslope water table and killing vegetation by root inundation, while lowering the downslope water table with accompanying damage to vegetation (116, 118).

Streams may be altered for considerable distances both upstream and downstream of bridges. Upstream, levees or channelization tend to result in reduced flooding of the riparian zone, grade degradation, hydraulic structural problems, and more channelization (17). Downstream, the grade change at a bridge results in local scouring that alters sedimentation and deposition processes (17, 49). Sediment and chemicals enter streams where a road crosses, and mathematical models predict sediment loading in and out of reaches affected by stream crossings (5). The fixed stream (or river) location at a bridge or culvert reduces both the amount and variability of stream migration across a floodplain. Therefore, stream ecosystems have altered flow rates, pool-riffle sequences, and scour, which typically reduce habitat-forming debris and aquatic organisms.

Sediment

The volume of sediment yield from a road depends on sediment supply and transport capacity (5). Sediment yield is determined by road geometry, slope, length, width, surface, and maintenance (5, 51), in addition to soil properties and vegetation cover (59). Road surfaces, cutbanks, fillslopes, bridge/culvert sites, and ditches are all sources of sediment associated with roads. The exposed soil surfaces, as well as the greater sediment-transport capacity of increased hydrologic flows, result in higher erosion rates and sediment yields (99).

Road dust as a little-studied sediment transfer may directly damage vegetation, provide nutrients for plant growth, or change the pH and vegetation (109). Effect-distances are usually <10–20 m but may extend to 200 m downwind (Figure 2). In arid land, soil erosion and drainage are common road problems (61).

Arctic roads also are often sources of dust. Other ecological issues include change in albedo, flooding, erosion and thermokarst, weed migration, waterfowl and shorebird habitat, and altered movement of large mammals (129).

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Landsliding or mass wasting associated with roads may be a major sediment source (13, 117). Some of this sediment accumulates on lower slopes and is subject to subsequent erosion. The rest reaches floodplains or streams, where it alters riparian ecosystems, channel morphology, or aquatic habitat. Although gradual sediment transport and episodic landslides are natural processes affecting streams, elevated levels caused by roads tend to disrupt aquatic ecosystems. Indeed, logging roads commonly produce more erosion and sediment yield, particularly by mass wasting, than do the areas logged (45, 51, 104, 117).

Buffer strips between roads and streams tend to reduce sediments reaching aquatic ecosystems (77, 91). Buffers may be less effective for landslides than for arresting water and sediment from culverts and roadside ditches. Good road location (including avoiding streamsides and narrow floodplains for many ecological reasons), plus good ecological design of roadsides relative to slope, soil, and hydrology, may be a better strategy than depending on wide buffers to absorb sediment.

Water from road ditches tends to deposit finer sediment in streams, whereas landslides generally provide coarser material. Fine sediment increases turbidity (51), which disrupts stream ecosystems in part by inhibiting aquatic plants, macro-invertebrates, and fish (14, 16, 31, 99). Coarse deposits such as logs and boulders help create deep pools and habitat heterogeneity in streams. During low-flow periods, fine-sediment deposits tend to fill pools and smooth gravel beds, hence degrading habitats and spawning sites for key fish (13, 14, 31). During high-discharge events, accumulated sediment tends to be flushed out and redeposited in larger water bodies.

In short, roads accelerate water flows and sediment transport, which raise flood levels and degrade aquatic ecosystems. Thus, local hydrologic and erosion effects along roads are dispersed across the land, whereas major impacts are concentrated in the stream network and distant valleys.

Chemical Transport

Most chemical transport from roads occurs in stormwater runoff through or over soil. Runoff pollutants alter soil chemistry, may be absorbed by plants, and affect stream ecosystems, where they are dispersed and diluted over considerable distances (16, 50, 66, 137, 138). Deicing salt and heavy metals are the two main categories of pollutants studied in road runoff.

The primary deicing agent, NaCl, corrodes vehicles and bridges, contaminates drinking water supplies, and is toxic to many species of plants, fish, and other aquatic organisms (4, 16, 84). Calcium magnesium acetate (CMA) is a more effective deicer, less corrosive, less mobile in soil, biodegradable, and less toxic to aquatic organisms (4, 84, 89). Also, CaCl used to decrease dust may inhibit amphibian movement (28).

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Airborne NaCl from road snowplowing may cause leaf injury to trees (e.g. *Pinus strobus*) up to 120 m from a road, especially downwind and downslope (58, 84). Trees seem to be more sensitive to chloride damage than are common roadside shrubs and grasses. Sodium accumulation in soils, mainly within 5 m of a road, alters soil structure, which affects plant growth (84). Road salt has facilitated the spread of three coastal exotic plants as much as 150 km in The Netherlands (1).

Deicing agents tend to increase the mobility of chemical elements in soil, such as heavy metals (by NaCl) and Na, Cl, Ca, and Mg (by CMA) (4). This process facilitates contamination of groundwater, aquifers, and streams. Because of dilution, the chemical effects of road runoff on surface water ecosystems may be primarily confined to small streams, particularly where they run adjacent to roads (36, 84).

Heavy metals are relatively immobile and heterogeneously distributed in roadsides, especially due to drainage ditch flows (15, 55, 80). Soils adjacent to the road surface typically contain the greatest mass (136). Elevated concentrations in grass tissue may occur within 5–8 m of a road, although high lead levels have been found in soil out to 25 m (30, 65, 82). Elevated lead concentrations were found in tissue of several small-mammal species in a narrow zone by roads, with higher lead levels by busy roads (48).

Highway roadsides of 5–15-m width next to traffic densities of 11,000–124,000 veh/day in The Netherlands had somewhat higher heavy-metal accumulations on the downwind side, but no correlation with traffic density was found (30). All average levels of Pb, Cd, Zn, Cr, Ni, and As in cut grass (hay) from these roadsides were below the Dutch maximum-acceptable-levels for livestock fodder and "clean compost." Only Zn in some roadsides studied exceeded the maximum for "very clean compost."

Many other chemicals enter roadsides. Herbicides often kill non-target plants, particularly from blanket applications in drifting air. For polycyclic aromatic hydrocarbons from petroleum (136), the preliminary conclusion for the Dutch highways was that levels in roadside hay "do not seem to give cause for alarm" (30). Fertilizer nutrients affect roadside vegetation (19, 86, 92), and nitrogen from vehicular NOX emission altered vegetation up to 100–200 m from a highway in Britain (7). Acidic road runoff may have impacts on stream ecosystems (36, 81). Of the hazardous materials transported on roads, e.g. >500,000 shipments moved each day in the United States, a small fraction is spilled, although occasional large spills cause severe local effects (85).

Typical water-quality responses to road runoff include altered levels of heavy metal, salinity, turbidity, and dissolved oxygen (16, 23, 81). However, these water-quality changes, even in a wetland, tend to be temporary and localized due to fluctuations in water quantity (23). Road runoff is a major source of heavy

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metals to stream systems, especially Pb, Zn, Cu, Cr, and Cd (16, 50, 64, 137). Fish mortality in streams has been related to high concentrations of Al, Mn, Cu, Fe, or Zn, with effects on populations reorded as far as 8 km downstream (81). Both high traffic volume and high metal concentration in runoff have correlated with mortality of fish and other aquatic organisms (59). Floodplain soil near bridges may have high heavy-metal concentrations (138). Although highway runoff generally has little adverse effect on vegetation or plant productivity, it may change the species composition of floodplain plant communities, favoring common species (138).

Overall, terrestrial vegetation seems to be more resistant than aquatic organisms to road impacts (59, 138). Drainage of road runoff through grassy channels greatly reduces toxic solid- and heavy-metal concentrations (59). Furthermore, dense vegetation increases soil infiltration and storage. Therefore, instead of expensive detention ponds and drainage structures to reduce runoff impacts, creative grassland designs by roads, perhaps with shrubs, may provide both sponge and biodiversity benefits. The wide range of studies cited above lead to the conclusion that chemical impacts tend to be localized near roads.

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THE ROAD NETWORK

New Roads and Changing Landscape Pattern

Do roads lead to development, or does development lead to roads? This timeless debate in the transportation community has greater ramifications as environmental quality becomes more important in the transportation–land-use interaction (114). For example, new roads into forested landscapes often lead to economic development as well as deforestation and habitat fragmentation (22).

At the landscape scale, the major ecological impacts of a road network are the disruption of landscape processes and loss of biodiversity. Interrupting horizontal natural processes, such as groundwater flow, streamflow, fire spread, foraging, and dispersal, fundamentally alters the way the landscape works (40, 53). It truncates flows and movements, and reduces the critical variability in natural processes and disturbances. Biodiversity erodes as the road network impacts interior species, species with large home ranges, stream and wetland species, rare native species, and species dependent on disturbance and horizontal flows.

A new road system in the Rondonia rainforest of Brazil illustrates such effects. By 1984, road construction and asphalt paving had stimulated a major influx of people and forest clearing (25). A regular pattern of primary roads plus parallel secondary roads 4 km apart was imposed on the land. Commonly, small forest plots of ~5 ha were gradually converted to grass and joined with neighboring plots to form large pastures (26). Simulation models of this typical scenario were compared with models of a worst-case scenario and an "innovative

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farming" scenario with perennial crops and essentially no fire or cattle (25, 26). Species requiring a large area and having poor "gap-crossability" disappeared in all model scenarios after road construction. Species with moderate requirements for area and gap-crossability persisted only in the innovative farming scenario. Reestablishing the connectivity of nature with a network of wildlife corridors was proposed as a solution to maintain the first group of species, which are of conservation importance.

The closure and removal of some roads in the grid is an alternative ecological approach. Natural landscape processes and biodiversity are both inhibited by a rigid road grid. Closing and eliminating some linkages would permit the reestablishment of a few large patches of natural rainforest (39, 41, 43). Such a solution helps create a road network with a high variance in mesh size. Large natural-vegetation patches in areas remote from both roads and people are apparently required to sustain important species such as wolf, bear, and probably jaguar (*Canis lupus, Ursus, Felis onca*) (39, 76). Temporary road closures could, for example, enhance amphibian migration during the breeding phase (67). In contrast, road closure and removal could eliminate motorized vehicle use, thus reducing numerous disturbance effects on natural populations and ecosystems.

A general spatial-process model emphasizes that roads have the greatest ecological impact early in the process of land transformation (39, 41). They dissect the land, leading to habitat fragmentation, shrinkage, and attrition. Forest road networks may also create distinctive spatial patterns, such as converting convoluted to rectilinear shapes, decreasing core forest area, and creating more total edge habitat by roads than by logged areas (79, 96).

Forest roads as a subset of roads in general are characterized as being narrow, not covered with asphalt, lightly traveled, and remote (98). Among the wide range of ecological effects of roads (39, 95), forest roads have a distinctive set of major ecological effects: (*a*) habitat loss by road construction, (*b*) altered water routing and downstream peak flows, (*c*) soil erosion and sedimentation impacts on streams, (*d*) altered species patterns, and (*e*) human access and disturbance in remote areas (43, 45, 62, 132). Thus, an evaluation of logging regimes includes the ecological effects of both the road network and forest spatial patterns (45, 69). In conclusion, a road network disrupts horizontal natural processes, and by altering both landscape spatial pattern and the processes, it reduces biodiversity.

Road Density

Road density, e.g. measured as km/km^2, has been proposed as a useful, broad index of several ecological effects of roads in a landscape (39, 43, 44, 95). Effects are evident for faunal movement, population fragmentation, human access, hydrology, aquatic ecosystems, and fire patterns.

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A road density of approx. 0.6 km/km^2 (1.0 mi/mi^2) appears to be the maximum for a naturally functioning landscape containing sustained populations of large predators, such as wolves and mountain lions (*Felis concolor*) (43, 76, 124). Moose (*Alces*), bear (*Ursus*) (brown, black, and grizzly), and certain other populations also decrease with increasing road density (11, 43, 72). These species are differentially sensitive to the roadkill, road-avoidance, and human-access dimensions of road density. Species that move along, rather than across, roads presumably are benefitted by higher road density (12, 39).

Human access and disturbance effects on remote areas tend to increase with higher road density (39, 72, 76). Similarly, human-caused fire ignitions and suppressions may increase, and average fire sizes decrease (111).

Aquatic ecosystems are also affected by road density. Hydrologic effects, such as altered groundwater conditions and impeded drainage upslope, are sensitive to road density (116, 118). Increased peak flows in streams may be evident at road densities of 2–3 km/km^2 (62). Detrimental effects on aquatic ecosystems, based on macro-invertebrate diversity, were evident where roads covered 5% or more of a watershed in California (75). In southeastern Ontario, the species richness of wetland plants, amphibians/reptiles, and birds each correlated negatively with road density within 1–2 km of a wetland (38).

Road density is an overall index that averages patterns over an area. Its effects probably are sensitive to road width or type, traffic density, network connectivity, and the frequency of spur roads into remote areas. Thus network structure, or an index of variance in mesh size, is also important in understanding the effect of road density (39, 76, 79, 96). Indeed, although road density is a useful overall index, the presence of a few large areas of low road density may be the best indicator of suitable habitat for large vertebrates and other major ecological values.

TRANSPORTATION POLICY AND PLANNING

Environmental Policy Dimensions

Ecological principles are increasingly important in environmental transportation policy, and Australia, The Netherlands, and the United States highlight contrasting approaches. Australian policy has focused on biodiversity, including wildflower protection. An enormous network of road reserves with natural-vegetation strips 10–200 m wide (Figure 1) stands out in many agricultural landscapes (66, 92, 111). Public pressure helped create this system, which "helps to prevent soil erosion" and "where wildflowers can grow and flourish in perpetuity" (111). Diverse experimental management approaches involve burning, weed control, planting native species, and nature restoration. Ecological

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scientists commonly work side by side with civil engineers in transportation departments at all levels of government.

In contrast, Dutch policy has focused on the open roadside vegetation, roadkills, animal movement patterns, and nature restoration (1, 21, 29, 86). This approach reflects the stated national objectives of (*a*) recreating "nature, including natural processes and biodiversity; and (*b*) enhancing the national ecological network," mainly composed of large natural-vegetation patches and major wildlife and water corridors (1, 46). An impressive series of mitigation overpasses, tunnels, and culverts provide for animal and water movement where interrupted by road barriers (24, 43, 44, 86). Environmental activities in transportation revolve around a group of environmental scientists in the national Ministry of Transport who work closely with engineers and policy-makers at both local and national levels.

In the United States, environmental transportation policy focuses on vehicular pollutants, as well as engineering solutions for soil erosion and sedimentation (85). A few states have built wildlife underpasses and overpasses to address local roadkill or wildlife movement concerns. A 1991 federal law—the Intermodal Surface Transportation Efficiency Act (ISTEA)—establishes policy for a transportation system that is "economically efficient and environmentally sound," considers the "external benefits of reduced air pollution, reduced traffic congestion and other aspects of the quality of life," considers transportation in a region-wide metropolitan area, and links ecological attributes with the aesthetics of a landscape (43). Thus, US transportation policy largely ignores biodiversity loss, habitat fragmentation, disruption of horizontal natural processes, natural stream and wetland hydrology, streamwater chemistry, and reduction of fish populations, a range of ecological issues highlighted in the transportation community in 1997 (85).

Of course, many nations use ecological principles in designing transportation systems (21, 33, 63, 95, 134), and environmental scientists, engineers, and policy-makers in Europe have united to "conserve biodiversity and reduce ...fauna casualties" at the international level (21; H van Bohemen, personal communication). The successful removal of lead from petroleum led to less lead in roadside ecosystems worldwide. Nevertheless, the huge Australian road-reserve system and the Dutch mitigation system for animal and water flows are especially ambitious and pioneering.

Spatial Planning and Mitigation

Most existing roads were built before the explosion in ecological knowledge, and many are poorly located ecologically (43). Yet the Dutch have developed a promising transportation planning process for the movement of both people and natural processes across the land (40, 44, 86). In essence, the ecological network, consisting of large natural-vegetation patches plus major corridors for

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water and wildlife movement, is mapped. The road network is then superimposed on the ecological network to identify bottlenecks. Finally, mitigation or compensation techniques are applied to eliminate designated percentages of bottlenecks in a time sequence. The earlier such spatial planning begins, the greater its effect (41).

Compensation is proposed where bottlenecks apparently cannot be overcome by mitigation. The principle of no-net-loss has been used internationally for wetlands with varying success (46, 94), whereas no-net-loss of natural processes and biodiversity by roads is a concept only beginning to be applied (1, 24, 46, 86). The loss, e.g. of biodiversity or groundwater flow, is compensated by increasing an equivalent ecological value nearby. Options include protection of an equivalent amount of high-quality habitat, reestablishment of another wildlife corridor, or creation of new habitat. Mitigation, on the other hand, attempts to minimize detrimental ecological impacts and is illustrated by the varied wildlife passages (tunnels, pipes, underpasses, overpasses) operating for animal movement (21, 86).

Diverse tunnel designs focus on small and mid-sized animals. Amphibian tunnels, generally 30–100 cm wide and located where roads block movement to breeding ponds or wetlands, are widespread in Europe and rare in the United States (33, 43, 67). "Ecopipes," or badger tunnels, are pipes ~40 cm in diameter mainly designed for movement of mid-sized mammals across Dutch roads, and located where water can rarely flow through (9, 44, 46, 86). In contrast, Dutch wildlife culverts are ~120 cm wide, with a central channel for water flow between two raised 40-cm-wide paths for animal movement. "Talus tunnels" are designed for a mid-sized mammal that lives and moves in rock talus slopes in Australia (74).

Wildlife underpasses, generally 8–30 m wide and at least 2.5 m high, have been built for large mammals in southern Florida and scattered locations elsewhere in the United States, Canada, and France (33, 43, 54, 63, 93, 113). Wildlife overpasses, also designed for large mammals, range in width up to 200 m and are scarce: approximately 6 in North America (New Jersey, Utah, Alberta, British Columbia) (33, 43; BF Leeson, personal communication) and 17 in Europe (Germany, France, The Netherlands, Switzerland) (44, 46, 63, 86, 134). The minimum widths for effectiveness may be 30–50 m in the center and 50–80 m on the ends (33, 46, 86). The two Swiss overpasses of 140-m and 200-m width remind us that ultimately the goal should be "landscape connectors" that permit all horizontal natural processes to cross roads (43, 44).

These mitigation structures are normally combined with fencing and vegetation to enhance animal crossing (86). Almost all such passages are successful in that the target species crosses at least occasionally, and most are used by many other species. Florida underpasses are used by the Florida panther (*Felis concolor coryi*), nearly the whole local terrestrial fauna, and groundwater as

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well (33, 54). Underpasses and overpasses are used by almost all large mammal species of a region. Yet, little information exists on crossing rates relative to population sizes, movement rates away from roads, predation rates, home range locations, and so forth. Nevertheless, mitigation passages are effective in perforating road barriers to maintain horizontal natural processes across the land.

The Road-Effect Zone

Roads and roadsides cover 0.9% of Britain and 1.0% of the United States, while road reserves (Figure 1) cover 2.5% of the State of Victoria, Australia (12, 85, 131). Yet how much of the land is ecologically impacted by roads with vehicles?

The road-effect zone is the area over which significant ecological effects extend outward from a road and typically is many times wider than the road surface plus roadsides (Figure 2) (39, 95, 101, 134). The zone is asymmetric with convoluted boundaries, reflecting the sequence of ecological variables, plus unequal effect-distances due to slope, wind, and habitat suitability on opposite sides of a road (40, 43). Knowing the average width of the road-effect zone permits us to estimate the proportion of the land ecologically affected by roads (43). For example, based on the traffic noise effect-distances of sensitive bird species described above, road-effect zones cover ~10–20% of The Netherlands (101).

Finally, a preliminary calculation for the United States was made based on nine water and species variables in Massachusetts (USA), plus evidence from the Dutch studies (42). An estimated 15–20% of the US land area is directly affected ecologically by roads. These estimates reemphasize the immensity and pervasiveness of ecological road impacts. Moreover, they challenge science and society to embark on a journey of discovery and solution.

ACKNOWLEDGMENTS

Virginia H Dale, Robert D Deblinger, Malcolm L Hunter, Jr, and Julia A Jones provided terrific reviews, which we deeply appreciate.

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Annu. Rev. Ecol. Syst. 1998.29:207-231. Downloaded from arjournals.annualreviews.org
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Wetlands

SECOND EDITION

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VNR VAN NOSTRAND REINHOLD
NEW YORK

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Library of Congress Catalog Card Number 92-36129
ISBN 0-442-00805-8

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Printed in the United States of America

Van Nostrand Reinhold
115 Fifth Avenue
New York, NY 10003

International Thomson Publishing
Berkshire House
168-173 High Holborn
London WC1V7AA, England

Thomas Nelson Australia
102 Dodds Street
South Melbourne 3205
Victoria, Australia

Nelson Canada
1120 Birchmount Road
Scarborough, Ontario
M1K 5G4, Canada

16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Library of Congress Cataloging in Publication Data

Mitsch, William J.
Wetlands / William J. Mitsch and James G. Gosselink. —2nd ed.
p. cm.
Includes bibliographical references (p.) and index.
ISBN 0-442-00805-8
1. Wetland ecology—United States. 2. Wetlands—United States.
3. Wetland conservation—United States. I. Gosselink, James G.
II. Title
QH104.M57 1993
574.5'26325'0973—dc20 92-36129
CIP

Preface

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Values and Valuation of Wetlands

15

Wetlands provide many services and commodities to humanity. At the population level, wetland-dependent fish, shellfish, fur animals, waterfowl, and timber provide important and valuable harvests and millions of days of recreational fishing and hunting. At the ecosystem level, wetlands moderate the effects of floods, improve water quality, and have aesthetic and heritage value. They also contribute to the stability of global levels of available nitrogen, atmospheric sulfur, carbon dioxide, and methane.

The valuation of these services and commodities for purposes of wetland management is complicated by the difficulty of comparing by some common denominator the various values of wetlands against human economic systems; by the conflict between a private owner's interest in the wetlands and the values that accrue to the public at large; and by the need to consider the value of a wetland as a part of an integrated landscape. Valuation techniques include the nonmonetized scaling and weighting approaches for comparing different wetlands or different management options for the same wetland, and common denominator approaches that reduce the various values to some common term such as dollars or embodied energy. These common denominator methodologies can include willingess to pay, opportunity costs, replacement value, and energy analysis. None of these approaches is without problems, and no universal agreement about their use has been reached.

The term *value* imposes an anthropocentric orientation on a discussion of wetlands. The term is often used in an ecological sense to refer to functional processes, as, for example, when we speak of the "value" of primary production

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in providing the food energy that drives the ecosystem. But in ordinary parlance, the word connotes something worthy, desirable, or useful to humans. The reasons that wetlands are often legally protected have to do with their value to society, not with the abstruse ecological processes that occur in wetlands; this is the sense in which the word *value* is used in this chapter. Perceived values arise from the functional ecological processes described in previous chapters but are determined also by human perceptions, the location of a particular wetland, the human population pressures on it, and the extent of the resource. Regional wetlands are integral parts of larger landscapes—drainage basins, estuaries. Their functions and their values to people in these landscapes depend on both their extent and their location. Thus the value of a forested wetland varies. If it lies along a river, it probably plays a greater functional role in stream water quality and downstream flooding than if it were isolated from the stream. If situated at the headwaters of a stream, a wetland would function in ways different from those of a wetland located near the stream's mouth. The fauna it supports depend on the size of the wetland relative to the home range of the animal. Thus to some extent each wetland is ecologically unique. This complicates the measurement of its "value." References for this subject are found in several literature reviews and annotated bibliographies (e.g., Reppert et al., 1979; Larson, 1982; Adamus, 1983; Sather and Smith, 1984; Shabman and Batie, 1988; Costanza et al., 1989; Leitch and Ekstrom, 1989; Reeder and Mitsch, 1990; Folke, 1991) and in a series of reports of the "Wetlands Are Not Wastelands" joint project of Wildlife Habitat Canada, Environment Canada, and Canadian Wildlife Service (see Manning et al., 1990).

WETLAND VALUES

Wetland values can conveniently be considered from the perspective of three hierarchical levels—population, ecosystem, and global.

Populations

The easiest values of wetlands to identify are the populations that depend on wetland habitats for their survival.

Animals Harvested for Pelts

Fur-bearing mammals and the alligator are harvested for their pelts (Fig. 1
In contrast to most other commercially important wetland species, these
typically have a limited range and spend their lives within a short dist
their birthplaces. The most abundant are the muskrats (*Ondatra zibethi*
about 10 million pelts harvested each year (Fig. 15–1b) out of a total o
lion for all species (Fig. 15–1a). Muskrats (Fig. 15–2, top) are found in
throughout the United States except, strangely, the south Atlantic Co

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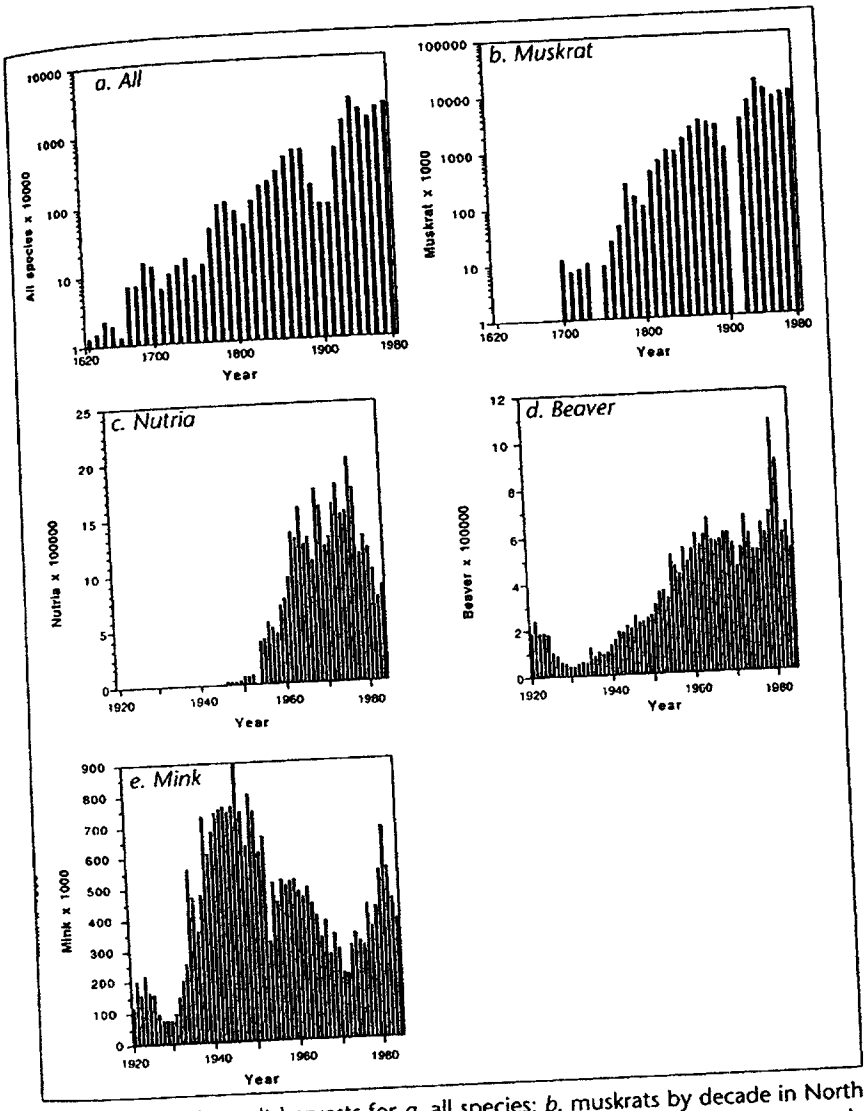


Figure 15–1. Fur pelt harvests for *a.* all species; *b.* muskrats by decade in North America; *c.* nutria in United States, post-1934; *d.* beaver and *e.* mink in Canada and United States, post-1934. (*Data from Novak et al., 1987*)

prefer fresh inland marshes, but along the northern Gulf Coast are more abundant in brackish marshes. About 50 percent of the nation's harvest is from the Midwest and 25 percent from along the northern Gulf of Mexico, mostly Louisiana (Chabreck, 1979).

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The nutria (*Myocastor coypus*) is the next most abundant species. It is very much like a muskrat but is larger and more vigorous (Figs. 15-1c; 15-2; Kinler et al., 1987). This species was imported from South America to Louisiana and escaped from captivity in 1938, spreading rapidly through the state's coastal marshes. It is now abundant in freshwater swamps and in coastal marshes from which it may have displaced muskrats to more brackish locations. Ninety-seven percent of the U.S. nutria harvest occurs in Louisiana. In order of decreasing abundance (but not dollar value), other harvested fur animals are beaver (Fig. 15–1d), mink (Fig. 15–1e), and otter. Raccoons are also taken commercially and in the north-central states are second only to muskrats. Beavers are associated with forested wetlands, especially in the Midwest. Minnesota harvests 27 percent of the nation's catch.

The alligator represents a dramatic success story of a return from the edge of extinction to a healthy population (at least in the central Gulf states) that is now harvested under close regulation in Florida and Louisiana. The species was threatened by severe hunting pressure, not by habitat loss. When that pressure was removed, its numbers increased rapidly. Alligators are abundant in fresh and slightly brackish lakes and streams and build nests in adjacent marshes and swamps. The Louisiana harvest in 1979 was worth about $1.7 million (Office of Technology Assessment, 1984). In Louisiana, the industry was worth over $16 million in 1992, for both wild and farm-raised animals (G. Linscombe, La. Dept. Wildlife and Fisheries, personal communication).

Waterfowl and Other Birds

Eighty percent of America's breeding bird population and more than 50 percent of the 800 species of protected migratory birds rely on wetlands (Wharton et al., 1982). Wetlands, which are probably known best for their waterfowl abundance, also support a large and valuable recreational hunting industry. We use the term "industry" because hunters spend large sums of money in the local economy (estimated at $58 million for the Mississippi flyway alone) for guns, ammunition, hunting clothes, travel to hunting spots, food, and lodging. Most of the birds hunted are hatched in marshes in the far North, sometimes above the Arctic Circle, but are shot during their winter migrations to the southern United States and Central America. There are exceptions—the wood duck (*Aix sponsa*) breeds locally throughout the continent—but the generalization holds for most species. Different groups of geese and ducks have different habitat preferences and these preferences change with the maturity of the duck and the season. Therefore, a broad diversity of wetland habitat types is important for waterfowl success. The freshwater prairie potholes of North America are the prime breeding place for waterfowl. There an estimated 50 to 80 percent of the continent's main game species are produced (Batt et al., 1989). Wood ducks use forested wetlands, however. During the winter, diving ducks (*Aythya* spp.)





Figure 15–2. (top) the musk coypus). (Photo reprinted with Department of W

pintail, redhead, and canvasback (Table 15–1). Habitat degradation, both in the northern breeding grounds and in wintering areas, is considered a major cause of the decline (Harris, 1989). Gadwall populations, in contrast, have increased 22 percent over the 1955–1991 average (Bortner et al., 1991).

Hunting is closely regulated and tailored to the local region. The mallard makes up about one-third of the U.S. total of harvested ducks. About 50 percent are shot in wetlands; most of the rest are shot in agricultural fields. In Louisiana, one-third of the mallard population is killed each year. The percentage is lower for other species—about 8–13 percent. The vast flocks of geese that used to be so abundant along the Eastern Seaboard and the Gulf Coast are smaller now but are still abundant and are considered to be important as hunted species in some areas.

Fish and Shellfish

Over 95 percent of the fish and shellfish species that are harvested commercially in the United States are wetland-dependent (Feierabend and Zelanzy, 1987). The fishing industry contributed $1.7 billion to the U.S. gross national product in 1988. The degree of dependence on wetlands varies widely with species and with the type of wetland. Some important species are permanent residents; others are merely transients that feed in wetlands when the opportunity arises. Some shallow wetlands, which may exhibit several other wetland "values," may be virtually devoid of fish, whereas other types of deepwater and coastal wetlands may serve as important nursery and feeding areas. Table 15–2 lists some of the major nektonic species associated with wetlands. Table 8–6 shows dollar value of coastal fisheries. Virtually all of the freshwater species are dependent to some degree on wetlands, often spawning in marshes bordering lakes or in riparian forests during spring flooding. These species are primarily recreational, although some small local commercial fisheries exploit them. The saltwater species tend to spawn offshore, move into the coastal marsh "nursery" during their juvenile stages, and then emigrate offshore as they mature. They are often important for both commercial and recreational fisheries. The menhaden is caught only commercially, but competition between commercial and sport fishermen for shrimp, blue crab, oyster, catfish, seatrout, and striped bass can be intensive and acrimonious. Anadromous fish probably use wetlands less than the other two groups. Their most intensive use is probably by young fry that sometimes linger in estuaries and adjacent marshes on their migrations to the ocean from the freshwater streams in which they were spawned.

The relationship between the area of marsh or the marsh-water interface of coastal wetlands and the production of commercial fisheries has been illustrated for shrimp and fish harvests in Louisiana and worldwide (R. E. Turner, 1982; Gosselink, 1984; Costanza et al., 1989), blue crab production in western Florida (Lynn et al., 1981), and oyster production in Virginia (Batie and Wilson, 1978). In one example, R. E. Turner (1977, 1982) showed a direct relationship be-

breeding grounds for insects, birds, turtles, and snakes. The hole itself is a place where the alligator can wait out the dry period until the winter rains. It also provides a refuge for dense populations of fish and shellfish (up to 1,600/m^2). These organisms, in turn, attract top carnivores, and so the gator holes are sites of concentrated biological activity that may be important for the survival of many species.

The slackwater darter (*Etheostoma boschungi*) is an example of the specificity sometimes required by wetland species. This small fish, found in small and moderate creeks in Alabama and Tennessee, migrates 1 to 5 km upstream at certain times of the year to spawn in small marshy areas associated with water seeps. It requires shallow (2–8 cm) water and deposits its eggs on a single species of rush (*Juncus acuminatus*) in spite of the presence of other species. The larvae remain in the vicinity of these marshes for four to six weeks before returning to their home streams (Williams and Dodd, 1979).

Ecosystem Values

At the level of the whole ecosystem, wetlands have value to the public for flood mitigation, storm abatement, aquifer recharge, water-quality improvement, aesthetics, and general subsistence. Some of the ecosystem values of wetlands vary from year to year or from season to season. For example, Figure 15–6 illustrates several of the potential ecosystem values of riparian forested wetlands during flooding (spring) and dry (summer) seasons.

Flood Mitigation

Chapter 4 dealt with the importance of hydrology in determining the character of wetlands. Conversely, wetlands influence regional water-flow regimes. One way they do this is to intercept storm runoff and store storm waters, thereby changing sharp runoff peaks to slower discharges over longer periods of time (Fig. 15–7). Because it is usually the peak flows that produce flood damage, the effect of the wetland area is to reduce the danger of flooding (Novitzki, 1979; Verry and Boelter, 1979). Riverine wetlands are especially valuable in this regard. On the Charles River in Massachusetts, the floodplain wetlands were deemed so effective for flood control by the U.S. Army Corps of Engineers that they purchased them rather than build expensive flood-control structures to protect Boston (U.S. Army Corps of Engineers, 1972). The study on which the Corp's decision was made is a classic in wetland hydrologic values. It demonstrated that if the 3,400 hectares of wetlands in the Charles River Basin were drained and leveed off from the river, flood damages would increase by $17 million per year.

Bottomland hardwood forests along the Mississippi River before European settlement stored floodwater equivalent to about 60 days' river discharge. Storage capacity has now been reduced to only about 12 days (Gosselink et al.,

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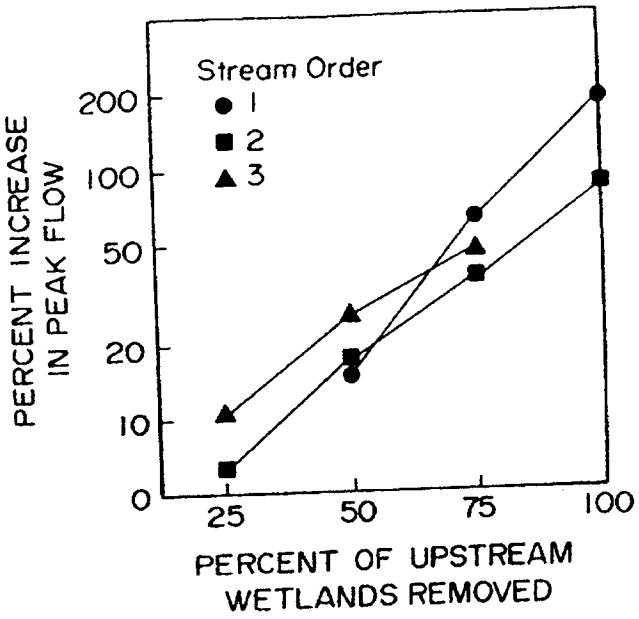


Figure 15–9. Hydrologic model simulation results showing relationships between increase in peak flood streamflow and percent wetland removal for Massachusetts watershed. Results are for various stream orders for 130-year flood. (*After Ogawa and Male, 1983*)

has not been well documented. Some hydrologists believe that although some wetlands recharge groundwater systems, most wetlands do not (Carter et al., 1979; Novitzki, 1979; Carter, 1986; Carter and Novitzki, 1988). The reason for the absence of recharge is that soils under most wetlands are impermeable (Larson, 1982). In the few studies available, recharge occurred primarily around the edges of wetlands and was related to the edge:volume ratio of the wetland. Thus recharge appears to be relatively more important in small wetlands such as prairie potholes than in large ones. These small wetlands can contribute significantly to recharge of regional groundwater (Weller, 1981). Heimburg (1984) found significant radial infiltration from cypress domes in Florida and concluded that the rate of infiltration was relative to the area of the wetland and the depth of the surficial water table. He also concluded that these wetlands represent hydrologic "highs" in the surface water table and are therefore "closely coupled to groundwater." There did not appear to be any direct percolation to deep aquifers, however.

Water Quality

Wetlands, under favorable conditions, have been shown to remove organic and inorganic nutrients and toxic materials from water that flows across them. The con-

cept of wetlands as sinks for chemicals was discussed in detail in Chapter 5. Wetlands have several attributes that cause them to exert major influences on chemicals that flow through them, whether the chemicals are naturally added or artificially applied (Sather and Smith, 1984). These attributes include the following:

1. A reduction in water velocity as streams enter wetlands, causing sediments and chemicals sorbed to sediments to drop out of the water column;
2. A variety of anaerobic and aerobic processes in close proximity, promoting denitrification, chemical precipitation, and other chemical reactions that remove certain chemicals from the water (see Chap. 5);
3. The high rate of productivity of many wetlands that can lead to high rates of mineral uptake by vegetation and subsequent burial in sediments when the plants die;
4. A diversity of decomposers and decomposition processes in wetland sediments;
5. A high amount of contact of water with sediments because of the shallow water, leading to significant sediment-water exchange;
6. The accumulation of organic peat in many wetlands, which causes the permanent burial of chemicals.

There have also been a number of reports of efficient primary, secondary, and tertiary treatment of sewage wastewater as it flows through wetlands. More details about wetlands as wastewater and nonpoint sources of pollution control are given in Chapter 17. Where environmental circumstances are appropriate, waste organic compounds are rapidly decomposed and nitrogen is denitrified and lost to the air. Nonvolatile pollutants such as heavy metals and phosphorus accumulate under favorable conditions. When those materials saturate the ecosystem, they may begin to increase in the effluent. For these elements, permanent long-term storage depends in part on whether the wetland is accreting vertically (and thus sequestering materials in deep sediments).

Aesthetics

A real but difficult aspect of a wetland to capture is its aesthetic value, often hidden under the dry term "nonconsumptive use values," which simply means that people enjoy being out in wetlands. There are many aspects of this kind of wetland use. Wetlands are excellent "biological laboratories" where students in elementary, secondary and higher education can learn natural history first hand. Wetlands are a rich source of information about cultural heritage. The remains of prehistoric Native American villages and mounds of shells or middens have contributed to our understanding of Native American cultures and of the history of the use of our wetlands. Smardon (1979) described wetlands as visually and educationally rich environments because of their ecological interest and diversity. Their complexity makes them excellent sites for research. Many artists—the Georgia poet Sidney Lanier, the painters John Constable and John Singer

Sargent, and many others who paint and photograph wetlands—have been drawn to them. Many visitors to wetlands use hunting and fishing as excuses to experience the wildness and its solitude, expressing that frontier pioneering instinct that may lurk in all of us.

Subsistence Use

In many regions of the world, including Alaska, Canada, and several developing nations, the subsistence use of wetlands is extensive. There wetlands provide the primary resources on which village economies are based. Those societies have adapted to the local ecosystems over many generations and are integrated into them. For those cultures few alternative life-styles exist (Ellanna and Wheeler, 1986; see also Chap. 1).

Regional and Global Values

The wetlands function of maintaining water and air quality is discharged on a much broader scale than that of the wetland ecosystem itself. Wetlands may be significant factors in the global cycles of nitrogen, sulfur, methane, and carbon dioxide.

Nitrogen Cycle

The natural supply of ecologically useful nitrogen comes from the fixation of atmospheric nitrogen gas (N_2) by a small group of plants and microorganisms that can convert it into organic form. The current production of ammonia from N_2 for fertilizers is about equal to all natural fixation (Delwiche, 1970). Wetlands may be important in returning a part of this "excess" nitrogen to the atmosphere through denitrification. As discussed in Chapter 5, denitrification requires the close proximity of an aerobic and a reducing environment such as the surface of a marsh, and the denitrification rate seems to increase with the supply of nitrate. Because most temperate wetlands are the receivers of fertilizer-enriched agricultural runoff and are ideal environments for denitrification, it is likely that they are important to the world's available nitrogen balance.

Sulfur Cycle

Sulfur is another element whose cycle has been modified by humans. The atmospheric load of sulfate has been greatly increased by fossil fuel burning. It is about equally split between anthropogenic sources (104×10^{12} g/yr), chiefly caused by fossil fuel burning; and natural biogenic sources (103×10^{12} g/yr) of which salt marshes account for about 25 percent (Cullis and Hirschler, 1980; Andreae and Raembonck, 1983; Gosselink and Maltby, 1990). When sulfates are washed out of the atmosphere by rain, they acidify oligotrophic lakes and streams. When sulfates are washed into marshes, however, the intensely reduc-

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NC-CREWS FACT SHEET

North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS)

* **What is NC-CREWS?** NC-CREWS is the name of the procedure that DCM uses to assess the functions of wetlands shown on its wetland type maps. NC-CREWS is a watershed based GIS wetland functional assessment model.

* NC-CREWS evaluates only the wetlands that are detailed on DCM's Wetland Type Maps. If the wetlands are not on DCM's Wetland Type Maps then they are not evaluated.

* NC-CREWS evaluates 3 main wetland functions: Water Quality Functions, Wildlife Habitat Functions, and Hydrology Functions. NC-CREWS also evaluates Potential Risk. Potential Risk is an estimation of the relative risk to watershed integrity posed by a specific wetland's loss.

* NC-CREWS rates 39 different parameters for each and every wetland identified on the DCM maps. Of these 39 parameters, 21 measure landscape characteristics and 18 measure internal characteristics of the wetland itself.

Structure

* NC-CREWS uses a hierarchical structure in which individual parameters are rated and successively combined until the wetland's overall functional significance is determined.

* There are four levels of ratings: 1. Overall Wetland Rating, 2. Specific Function And Potential Risk Ratings, 3. Subfunction ratings, and 4. Parameter and Sub-parameter Ratings.

Ratings

* NC-CREWS has three relative rating scores. They are Beneficial Significance, Substantial Significance, and Exceptional Significance.

* Functional assessment ratings for individual functions, subfunctions, parameters, and sub-parameters can be looked at independently. (This is used for identifying the most significant wetlands that perform the specified function, subfunction, parameter or sub-parameter).

Verification

* The NC-CREWS procedure is based on the best wetland science available in the scientific literature and on extensive review by a team of wetland scientists.

* An advisory panel of Wetland Scientists and State and Federal Agencies has reviewed every step of the procedure's development.

* Field visits to nearly 400 wetland sites were made to gather data on functional indicators used in the procedure.

* NC-CREWS has been approved by the EPA as an acceptable GIS method for assessing wetland functions.

NC-CREWS - Overall Wetland Functional Significance Rating Definitions

The Overall Wetland Rating (OWR) for wetlands is based on each wetland's ability and opportunity to provide (1) Water Quality, (2) Hydrologic, and (3) Wildlife Habitat functions.

Exceptional Functional Significance:
A wetland is rated exceptional for its overall functional significance when it performs water quality, hydrologic and/or wildlife habitat functions at well above normal levels. Specifically, a wetland is rated Exceptional when any two of the primary wetland functions (water quality, hydrology, and habitat) are rated Exceptional. Salt or Brackish marshes, estuarine scrub-shrub wetlands; estuarine forested wetlands; unique natural ecosystems or special wildlife habitat areas, wetlands located adjacent to primary nursery areas, and wetlands that contain threatened or endangered species are also rated Exceptional.

Substantial Functional Significance:
A wetland is rated Substantial when the wetland performs the three primary wetland functions at normal or slightly above normal levels. A wetland is also rated Substantial if it is a buffer to a wetland rated Exceptional.

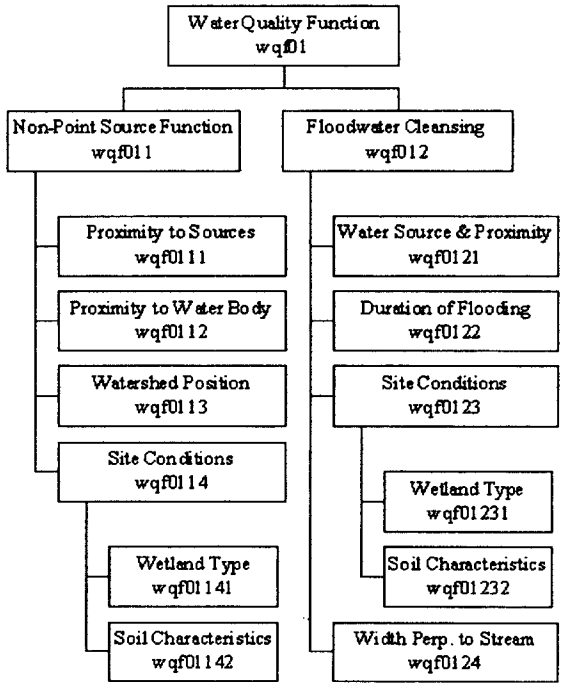
Beneficial Functional Significance:
A wetland is rated Beneficial when it performs the three primary wetland functions at below normal levels or, in some cases, not at all. Although most wetlands perform a variety of wetland functions, all wetlands do not provide all functions. A wetland is rated Beneficial when any two of the primary wetland functions are rated low and none are rated high. Some jurisdictional wetlands may not perform some functions due to degradation or alteration, but may provide other functions at below normal levels.

Non-Wetland:
Places in the coastal zone, considered upland, they are generally agriculture or bare land. Non-wetlands are not rated by NC-CREWS.

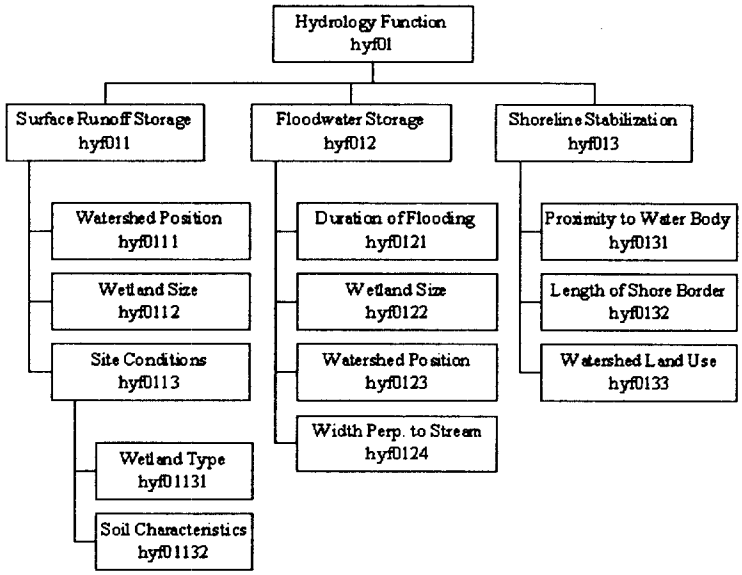
Unable to Evaluate:
Potential wetland areas that are not rated in the NC-CREWS model because satellite imagery indicates that they have been recently altered. Most of these areas were forested wetlands in 1988 but have been cleared according to 1994 satellite imagery.

Potential Risk:
Potential Risk is a measure of the relative risk to watershed and landscape functional integrity posed by the loss of a wetland's functions. Potential Risk is not used to determine a wetland's functional significance. Nevertheless, potential risk is useful when identifying the most significant wetlands within a watershed.

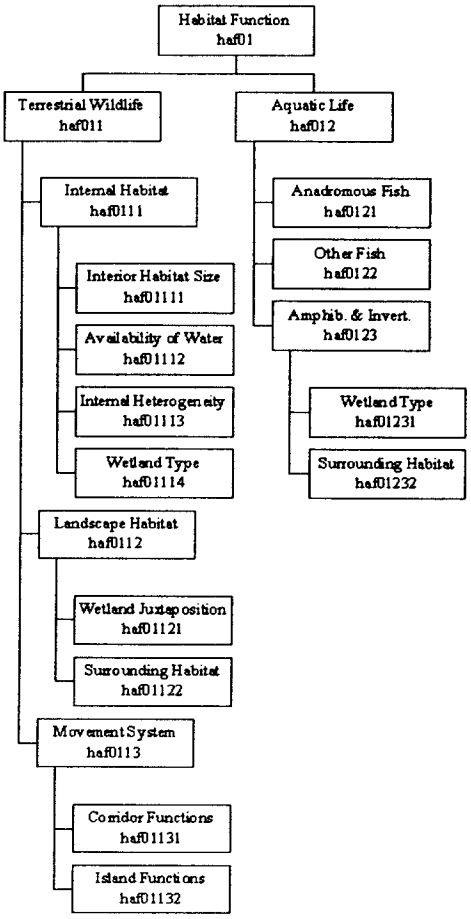
NC-CREWS Water Quality Function



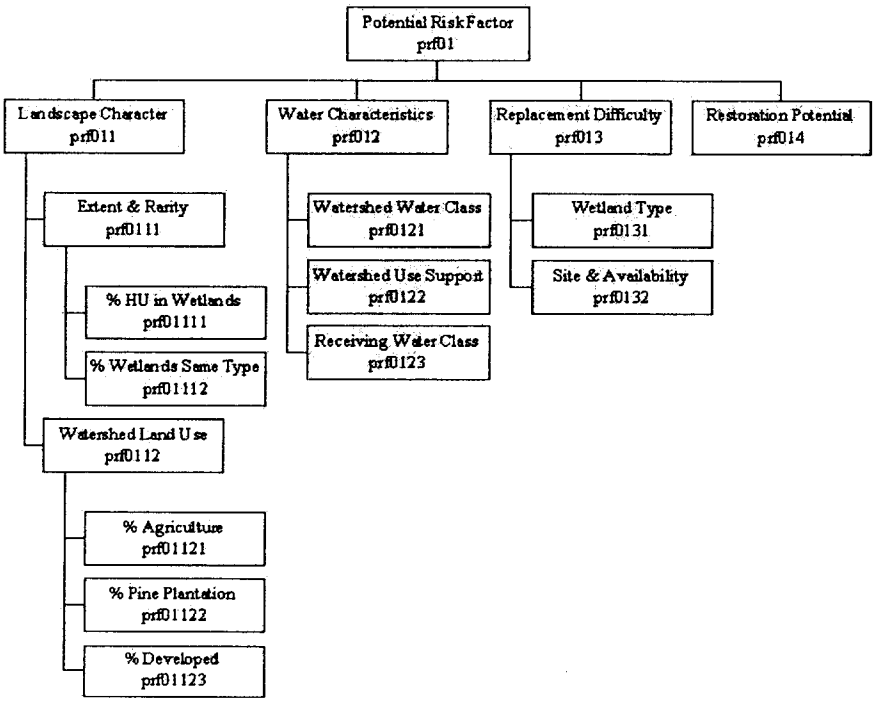
NC-CREWS Hydrology Function



NC-CREWS Habitat Function



NC-CREWS Potential Risk Function



Wetlands Ecology and Management 12: 519–529, 2004.
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Sensitivity analysis of transportation corridor location in wetland areas: a multiobjective programming and GIS approach

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Received 19 July 2002; accepted in revised form 12 October 2003

Key words: Clean Water Act, GIS, Integer Programming, NC-CREWS, North Carolina, Road location

Abstract

A multiobjective programming approach for locating transportation corridors through areas containing wetlands is presented. The approach uses a geographic information system in combination with multiple objectives for environment and construction costs, and the North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS) program. The multiobjective function is a weighted combination of wetland values and construction cost. The objective minimizes total cost of construction and wetland impacts resulting from a specific transportation corridor. The transportation designer specifies starting and ending points of the desired corridor. The model then finds the best path given the weights placed on each individual objective (i.e. habitat quality, water quality, hydrology, and construction expense). By varying the weight set, several different paths can be found. The approach is tested on a watershed in Carteret County North Carolina using a benchmarking procedure. One benchmark minimizes a combined wetland significance loss (cost). This path avoids crossing wetlands. The other benchmark minimizes construction expense. Varying the weight placed on each of the objective function components generates additional paths. The approach is useful in locating alternative road corridor paths in attempts to satisfy conflicting societal interests.

Introduction

Wetlands provide a variety of beneficial functions. Some functions pertain to water quality, such as non-point source pollutant removal and floodwater cleansing. Other functions address hydrologic regimes, such as surface runoff storage, floodwater storage, and shoreline stabilization. More functions relate to habitats for both terrestrial and aquatic wildlife (Sutter and Wuenscher 1997). This diversified set of functions is the reason society places significant value on wetland areas. In order to comply with regulations governing development in wetland areas in the United States of America, ground transportation planners are required to consider wetland impacts when designing transportation corridors. In the United States wetland lost from transportation projects must be mitigated, usually by restoration of degraded wetland areas. In order to acquire a Clean Water Act Section 404 permit to develop within a wetland, the United States Army Corp of Engineers (COE), which administers the process, requires: (1) that effort be made to avoid wetland area; (2) if not possible to avoid wetlands, effort must be made to minimize impact to wetlands; and (3) compensatory mitigation of the wetland loss. It is our observation that these requirements are quantifiable through a combination of mathematical programming techniques, a wetland functional evaluation methodology, and information contained within a geographic information system (GIS) model of a landscape.

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This paper presents a logical approach to fulfilling the first two COE requirements: (1) that effort be made to avoid wetlands, and (2) if not possible to avoid wetlands, effort must be made to minimize impact to wetlands. It should be noted that Gainey (1998), in a similar effort, addresses the third COE requirement of compensatory mitigation of wetland loss. In that effort, Gainey quantified the mitigation site selection process by a logical combination of a wetland functional evaluation program (North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS), GIS watershed data, and an Integer Programming mathematical technique. The objective in Gainey's research was to minimize the cost of mitigation in order to replace all wetland functions lost by development.

It is difficult to estimate the value of a wetland and correspondingly the loss of wetland functions caused by a development project. The North Carolina Division of Coastal Management created and is using an automated wetland evaluation system called NC-CREWS (Sutter and Wuenscher 1997). This is an GIS-based method that produces a functional evaluation for individual wetlands within a landscape. Within this program (NC-CREWS) the estimated value of each wetland is a function of its unique condition and its relative position to other land types within a watershed.

The project that we describe attempts to compute the optimal placement of transportation corridors. Optimality is defined as the minimum weighted sum of construction costs and negative wetland impacts. The NC-CREWS wetland rating system is used in practice and used here to estimate wetland value. NC-CREWS is not the focus of this paper. Any method that can quantitatively estimate wetland values over large watersheds would be applicable. This project integrates information with the purpose of evaluating the feasibility of an automated tool for locating transportation corridors that balances construction costs and wetland loss.

The NC-CREWS method is a practical application of wetland functional assessment. It uses the hydrogeomorphic (HGM) method (Brinson 1995; Rheinhardt et al. 1997), functional indicators within wetland subclasses, and GIS technology to predict the wetland functional significance that would be determined by a site-specific method (Sutter and Wuenscher 1997). This method is designed around a hierarchical structure. The procedure divides the wetland's overall ecological significance into four functions: (1) water quality, (2) hydrologic, (3) habitat, and (4) risk to the watershed. Each of these four functions consists of subfunctions. In turn, these subfunctions are broken down into parameters that represent measurable wetland characteristics. Using parameter values, the procedure produces ratings of high, medium or low for each subfunction. The subfunction ratings are then evaluated by conditional logic to determine the function rating and overall ecological significance rating of each area (Sutter and Wuenscher 1997).

For an example of the Water Quality Function, a subfunction is the "Non-point Source Removal Function". This subfunction is evaluated based on the measurable parameters: proximity to sources, proximity to water bodies, watershed position, wetland type and soil type. For a second example, the Wildlife Habitat rating is based on ratings of Terrestrial Habitat and Aquatic Habitat. In turn, sub-functions are rated according to parameter ratings. Terrestrial Habitat is a combination of Internal Habitat, Landscape Habitat, and Movement System Value functions. The fourth and final layer in this hierarchy consists of measurable parameters. The methodology of combining measurable parameters and working up the hierarchy to reach a final function rating is not discussed in this paper, but let it suffice to say that it is a complex process. For a more detailed explanation of NC-CREWS see Sutter and Wuenscher (1997).

In the following sections, we discuss the development and use of the model for analyzing placement of roads within wetlands. This includes the mathematical formulation of the problem and an example of how the formulation works. This is followed by a description of the computer program used to perform the analysis and some sample results of analysis using an actual watershed. Finally, test results using different objective weighting schemes are presented.

Methods

Analytic model description

Multiobjective programming is a generalization of single-objective approaches to planning problems.

Using multiple objectives achieves three major improvements to planning: promotes and integrates dissimilar points of view of diverse participants, a wider range of alternative solutions are typically identified, and models (or analysts) are not required to make important value judgments that they are not in a good position to articulate (Cohon 1978).

The multiobjective function represents the total cost of development within an area that contains wetlands. There are two general components of cost: construction costs and wetland impact costs. The construction cost component consists of a baseline cost and a wetland incremental cost. The baseline cost represents the per unit area construction costs. Direct costs such as materials, labor, and equipment depreciation are assumed to be included in the per unit area cost, dollars per square foot in this case. The incremental cost represents the per unit area cost, over and above the baseline cost, that is expended when development proceeds through a particular type of wetland. These costs are associated with (1) implementing management practices[1] that minimize wetland degradation, (2) complying with US government regulations requiring mitigation and post-development monitoring[2], and (3) additional road structures (e.g. bridges) (National Research Council 2001). It is assumed that these costs can be expressed for each individual wetland type existing in the development area.

The wetland impact cost is a necessary component of the model. As used here, wetland impact cost is not monetary. It is the loss of wetland functions. Wetland cost has three parts: habitat, hydrology, and water quality. For these parts, "cost" is defined as loss of "wetland functional value". To quantify this we use NC-CREWS's functional significance rating for each wetland.

Wetland rating scale interval

Once site specific information has been gathered, the NC-CREWS program can rate a wetland (or potential restoration sites) on the significance of that wetland's ability to provide a particular set of ecological and sociological functions to the watershed. A wetland can receive a rating of 1 (beneficial function for the watershed), 2 (substantial function for the watershed), or 3 (significant function for the watershed) (Sutter and Wuenscher 1997). The analytic model uses these ratings to represent the cost of losing a particular wetland area. This cost represents the functional value lost. For example, if a wetland provided habitat related functions to a watershed that were rated beneficial (1), hydrologic functions that were rated substantial (2), and water quality functions that were rated significant (3), then the total impact cost would be 6 (1 + 2 + 3). From the literature, it is not clear how much more consequential a rating of substantial is compared to a rating of beneficial or how much more consequential a rating of significant is compared to substantial. To allow for transportation planners to have some flexibility in these ratings, the analytic model employs adjustable rating interval coefficients. These coefficients represent the level of significance between each rating, and in the implementation are set by the user using a sliding scale. For instance, to show that a jump to a significant rating from a Substantial rating is much larger than a jump to a substantial rating from a beneficial rating, the two rating interval coefficients could be set at 50 and 10, respectively. The wetland impact cost for the same example stated above would now be 73 ([1 + (1 + 10) + (1 + 10 + 50)]). With this method the quantification of wetland impact cost (functional value) is increased due to the increase in the value spectrum employed, a 0–50 range as compared to a 0–3. This method gives the manager, analyst or transportation planner flexibility in how to quantify wetland ratings. Managers need flexibility, so that they do not get locked into a single interpretation of the wetland rating. Even though at this time the literature does not answer the question of how much better significant is than substantial or substantial is than beneficial, in the future a quantitative rating may be developed.

Objective function weights

The objective function needs a mechanism for weighting each of the cost components. The model incorporates separate weight parameters for each of the wetland functions of water quality, habitat, and hydrology, along with a weight

[1]Best Management Practices have been developed for construction projects that disturb the soil in order to comply with the North Carolina Sedimentation and Pollution Control Act of 1973.

[2]USA Clean Water Act Section 404.

parameter for construction cost. The analytic model multiobjective function employs four weight parameters, three for wetland impact costs and one for construction cost. Since the different objectives have different units attached to them, the weights are not meant to imply any relative value between objectives. These weights are simply used to locate alternative efficient paths through the landscape. The mathematical representation of the model is an attempt to express all the concepts and relationships in NC-CREWS and objectives discussed above in a symbolic form while at the same time being able to find the mathematically optimal corridor given a weight set. Changing the weights allows a transportation planner to find alternative corridors.

Mathematical formulation

The mathematical formulation is shown in Figure 1. This formulation is designed to minimize the multiple objective costs of building a road from point A to point B. It is an integer programming formulation (Bradely et al. 1977). It is integer because a variable, X_i, is either part of the road corridor or not. Logically the variables must take on values of zero or one. Integer programming formulations are commonly used in natural resource management (Schuster et al. 1993). Equation (1), in Figure 1, is a mathematical expression of the objective to minimize the weighted sum of all costs, financial and environmental, associated with the road project. Equation (2) sums baseline costs and incremental cost for different wetlands to get total financial cost of construction. Equations (3)–(5) define each of the wetland function values. Equation (3) represents habitat value lost if wetland i is included in the road corridor. It is the sum of the rating interval coefficients from 1 to the number indicated by the NC-CREWS habitat rating for each cell. Equation (4) represents hydrology value lost if wetland i is included in the road corridor. It is the sum of the rating interval coefficients from 1 to the number indicated by the NC-CREWS hydrology rating for each cell. Equation (5) is for the cost of losing the wetland water quality function. It is the sum of the rating interval coefficient from 1 to the number indicated by the NC-CREWS water quality rating for each cell.

Equations (6)–(9) constrain the solution to be a set of contiguous cells from point A to point B. The evaluation process finds the least cost path, which begins at the cell with point A and ends at the cell with point B. Equations (8) and (9) restrict the path to include cell A and B. Progression from point A to point B is insured by equation (6). For Equation (6), the watershed is cut by a series of non-intersecting planes, which must be crossed by the road corridor. "layer$_{ik}$" = 1 for each cell i cut by the plane (layer) k. Thus, equation (6) force the road corridor to include at least one cell in each plane. A corridor can cross a plane any number of times but it must be crossed at least once. Connectivity of the corridor is insured by equation (7). If cell i is included in the corridor, then two cells adjacent to i must also be in the corridor (i.e. once cell coming into i and one cell going out of i.) "adj$_{ij}$" = 1 if cell i is adjacent to cell j. These relations are based on a method similar to, but significantly less complex, then that used by Guignard and Wang (1994). In an effort to plan a wildlife corridor in a forested reserve through time, they used a series of subset grids (layers) and trigger variables to codify contiguousness, adjacency, and starting and ending points. Our methodology is simpler because the road corridor is located only once. Their problem was to maintain a connected corridor that can change position through time. A cell can only be a part of the final path if both its routing decision variable (X_i) and its adjacency coefficient (adj$_{ij}$) are equal to 1. Line 10 limits the decision variables to the values of 0 or 1. Line 11 states that adjacency of two cells is signified by 1 and nonadjacency is 0. Line 12 states that cells contained in layer k all have a coefficient of 1 in the layer k constraint.

Example formulation

To illustrate the mechanics of the mathematical formulation, a small example problem is given. Figure 2 shows the grid used. In this problem we assume that cells 2, 7, 9, 12, 14, 17, 19, and 24 all contain high value wetland and all other cells have lesser value. The subscripted number in each cell represents a hypothetical composite of the multiobjective function coefficients. Figure 3 displays the mathematical formulation for the example problem. In Figure 3, equation (13) is the objective function. Equations (14)–(22) insure that the road will go from A to B and are comparable to

$$MIN \sum_{i=1}^{n} (W_c C_i + W_{ha} HA_i + W_{hy} HY_i + W_{wq} WQ_i) X_i \quad (1)$$

Subject To:

$$C_i = BCCa + WCC_i a \quad (2)$$

$$HA_i = \sum RIC_r \quad \forall r = 1 \text{ to } HAR_i \quad (3)$$

$$HY_i = \sum RIC_r \quad \forall r = 1 \text{ to } HYR_i \quad (4)$$

$$WQ_i = \sum RIC_r \quad \forall r = 1 \text{ to } WQR_i \quad (5)$$

$$\sum_{i=2}^{n-1} X_i layer_{ik} \geq 1 \quad \forall k = 1 \text{ to } L \quad (6)$$

$$2X_i - \sum_{j=1}^{n} X_j adj_{ij} \leq 0 \quad \forall i = 2 \text{ to } n-1 \quad (7)$$

$$X_B = 1 \quad (8)$$

$$X_A = 1 \quad (9)$$

$$X_i \in [0,1] \quad (10)$$

$$adj_{ij} \in [0,1] \quad (11)$$

$$layer_{ik} \in [0,1] \quad (12)$$

where X_i = [0,1] decision variable segment of corridor utilizing cell i. X_i = 1 if included, 0 otherwise. X_A is the starting cell and X_B is the ending cell of the road corridor.

adj_{ij} = [0,1] if cell i is adjacent to cell j then adj_{ij} = 1, 0 otherwise. This is a coefficient generating function for adjacency. It is not a variable.

$layer_{ik}$ = [0,1]. Coefficient generating function for cutting plain constraint (6), if cell i is cut by plain k then $layer_{ik}$ = 1, 0 otherwise.

n = the number of cells in a grid which spans the study area.

L = the number of plains through which the path must pass between A to B.

a = area of each square cell in the grid.

C_i = total construction cost for one unit area expressed in dollars for cell i.

BCC = baseline construction cost for one unit area.

WCC_i = Wetland type-related incremental construction cost for cell i.

HAR_i = Habitat functional rating, produced by NC-CREWS, for the wetland to which cell i belongs.

HYR_i = Hydrology functional rating, produced by NC-CREWS, for the wetland to which cell i belongs.

WQR_i = Water quality functional rating, produced by NC-CREWS, for the wetland to which cell i belongs.

HA_i = Habitat value associated with cell i

HY_i = Hydrology value associated with cell i.

WQ_i = Water quality value associated with cell i.

RIC_r = Rating interval constant used to express quantitative difference between each NC-CREWS rating.

W_c = objective function weight given to construction related cost.

W_{ha} = objective function weight given to habitat related cost.

W_{hy} = objective function weight given to hydrology related cost.

W_{wq} = objective function weight given to water quality cost.

Figure 1. Mathematical formulation used in analysis of multiobjective corridor location problem.

equations (6), (8) and (9) in Figure 1. Equations (23)--(45) insure a contiguous road and are comparable to equation 7 in Figure 1. You may notice that equations (23)-(26) do not have a coefficient of 2 attached to the positive variable. This is simply for shortening the equations since the full expression is not necessary, because to get to cell 2 or 6 you must come from cell 1 which has already been

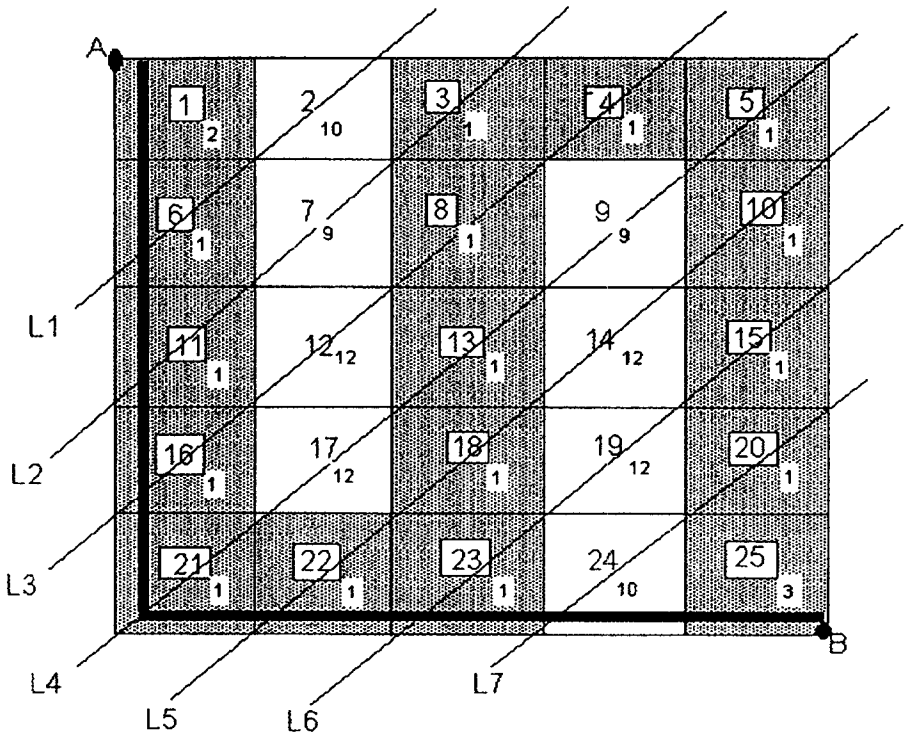


Figure 2. A 25-cell grid that illustrates the methodology. "A" is the entry point and "B" is the destination point. Large numbers in each cell are the cell labels and subscript numbers are the objective function coefficients for each cell. L1 through L7 are the cutting planes that the corridor must pass through. White cells contain high value wetlands.

selected (equation 14), and once in cell 20 or 24 your only choice is cell 25 which has already been selected (equation 22).

When solving the equations presented in Figure 3, the path shown by shaded squares in Figure 2 results. The objective weights used in this example were 1 for habitat, hydrology, and water quality objectives but 0 for road construction. The selected path effectively avoids crossing the areas with high wetland values. Next, to show the effect of the multiobjective formulation, we increased the weight on construction costs to 1. For the example problem this had the effect of increasing all the coefficients equally except for cell 4, which because of a hypothetical water crossing had its coefficient go up by three times the others. In other words, the effect was that all the coefficients remain the same except for the coefficient for cell 4, which changes from one to three. The path shown by the bold line in Figure 2 is the resulting corridor. Changing the weights and therefore the coefficients can result in many different paths through the grid. Figure 4 shows results of 4 different objective weighting combinations through an actual watershed. We shall now discuss the application to an actual watershed.

Computer program description and analysis

To test the formulation, a program was built using GIS software[3]. The program is a menu driven software application, which generates the optimal (least cost) path between two points for a given set

[3]ESRI, Inc. ARC/INFO GIS software using the Macro Language (AML).

$$Min 2x_1 + 10x_2 + x_3 + x_4 + x_5 + x_6 + 9x_7 + x_8 + 9x_9 + x_{10} + x_{11} + 12x_{12} + x_{13} + 12x_{14} + x_{15} + x_{16} + 12x_{17} + x_{18} + 12x_{19} + x_{20} + x_{21} + x_{22} + x_{23} + 10x_{24} + 3x_{25} \quad (13)$$

Subject to:

$$x_1 = 1 \quad (14)$$

$$x_2 + x_6 \geq 1 \quad (15)$$

$$x_3 + x_7 + x_{11} \geq 1 \quad (16)$$

$$x_4 + x_8 + x_{12} + x_{16} \geq 1 \quad (17)$$

$$x_5 + x_9 + x_{13} + x_{17} + x_{21} \geq 1 \quad (18)$$

$$x_{10} + x_{14} + x_{18} + x_{22} \geq 1 \quad (19)$$

$$x_{15} + x_{19} + x_{23} \geq 1 \quad (20)$$

$$x_{20} + x_{24} \geq 1 \quad (21)$$

$$x_{25} = 1 \quad (22)$$

$$x_2 - x_3 - x_7 \leq 0 \quad (23)$$

$$x_6 - x_{11} - x_7 \leq 0 \quad (24)$$

$$x_{20} - x_{15} - x_{19} \leq 0 \quad (25)$$

$$x_{24} - x_{23} - x_{19} \leq 0 \quad (26)$$

$$2x_3 - x_2 - x_4 - x_8 \leq 0 \quad (27)$$

$$2x_4 - x_3 - x_5 - x_9 \leq 0 \quad (28)$$

$$2x_5 - x_4 - x_{10} \leq 0 \quad (29)$$

$$2x_7 - x_2 - x_6 - x_8 - x_{12} \leq 0 \quad (30)$$

$$2x_8 - x_3 - x_7 - x_9 - x_{13} \leq 0 \quad (31)$$

$$2x_9 - x_4 - x_8 - x_{10} - x_{14} \leq 0 \quad (32)$$

$$2x_{10} - x_5 - x_9 - x_{15} \leq 0 \quad (33)$$

$$2x_{11} - x_6 - x_{12} - x_{16} \leq 0 \quad (34)$$

$$2x_{12} - x_7 - x_{11} - x_{13} - x_{17} \leq 0 \quad (35)$$

$$2x_{13} - x_8 - x_{12} - x_{14} - x_{18} \leq 0 \quad (36)$$

$$2x_{14} - x_9 - x_{13} - x_{15} - x_{19} \leq 0 \quad (37)$$

$$2x_{15} - x_{10} - x_{14} - x_{20} \leq 0 \quad (38)$$

$$2x_{16} - x_{11} - x_{12} - x_{16} \leq 0 \quad (39)$$

$$2x_{17} - x_{12} - x_{16} - x_{18} - x_{22} \leq 0 \quad (40)$$

$$2x_{18} - x_{13} - x_{17} - x_{19} - x_{23} \leq 0 \quad (41)$$

$$2x_{19} - x_{14} - x_{18} - x_{20} - x_{24} \leq 0 \quad (42)$$

$$2x_{21} - x_{16} - x_{22} \leq 0 \quad (43)$$

$$2x_{22} - x_{17} - x_{21} - x_{23} \leq 0 \quad (44)$$

$$2x_{23} - x_{18} - x_{22} - x_{24} \leq 0 \quad (45)$$

$$x_i = \{0,1\} \; \forall i = 1,...25$$

Figure 3. Mathematical formulation for the simple example problem over a 5 × 5 grid (Figure 2).

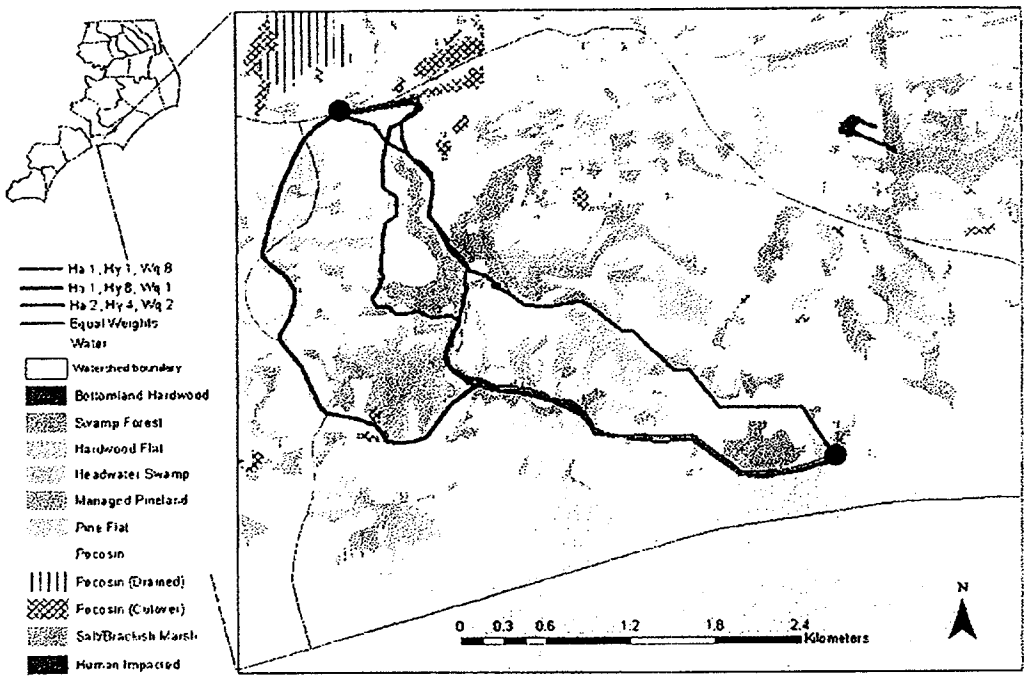


Figure 4. Example output from OptiCor showing alternative paths generated by changing weights on habitat, hydrology, and water quality functions. Construction costs were weighted zero. Each path connects the entry point to the destination point. The colored polygons represent wetland areas. The white polygons represent non-wetland areas. The location map in the upper left corner is the coastal region of North Carolina.

of weights. The result is a potential road corridor drawn on the wetland study area map. The program also reports estimated construction costs, wetland function loss and total wetland acreage impacted. The output represents a potential transportation corridor that balances both construction cost and negative impacts to wetlands. We call this program Optimal Corridor (OptiCor). OptiCor allows a user to control the weights (W_c, W_{ha}, W_{hy}, W_{wq}) on the various cost components in the multiobjective function (Figure 1). This ability gives the user the power to generate alternative corridors that minimize various objective combinations.

A visual example of the output, with 4 alternative road corridors, is shown in Figure 4. Changing the weight combination in equation (1), (Figure 1) creates each alternative. For example, the corridor labeled "Ha1, Hy1, Wq8" uses weights ($W_{ha} = 1$, $W_{hy} = 1$, $W_{wq} = 8$) in equation (1). In other words, this corridor is the result when eight times more emphasis is placed on loss of water quality. The resulting corridor is the red line. On the other hand, the blue line is the corridor resulting when all three objectives have equal weights ($W_{ha} = 1$, $W_{hy} = 1$, $W_{wq} = 1$). The other corridors shown have other weight combinations. The weight for construction cost was zero in this instance.

The input data required to run the model is the NC-CREWS wetland rating data produced by the North Carolina Division of Coastal Management (a short description of the rating process can be found in the introduction to this paper). A detailed description can be found in Sutter and Wuenscher (1997). The program runs on one watershed at a time. A single watershed GIS data set (including NC-CREWS ratings) is input into the program. The vector data are converted into a raster data

set. All optimization is accomplished while the data are in raster form. Once the optimal path is determined, the data are converted back into vector format for display. In raster format, the watershed map is characterized as a grid. Each cell within the grid takes on the attributes of the overlaying polygon. Consequently, each of the cells has four different costs associated with the location. Each cost represents the NC-CREWS wetland rating function and construction cost if that cell is included within the road corridor. To calculate the total cost of routing a corridor through a particular cell, each of the four corresponding cost components are multiplied by the user set weight values, the products are summed, and the result is stored as part of the cell attribute data. This calculation is performed for each cell in the raster representation of the watershed. Once the total weighted costs are produced, they are used as input to the objective function. The mathematical programming model seeks to minimize the sum of total costs associated with a set of contiguous cells that connect point A to point B.

In order to test the formulation, multiple optimization runs of OptiCor were made. First, benchmark runs, where all weights are set to zero except for one, were run for each objective, giving four possible paths representing the least cost path for each objective. Then several iterations were made that explore variations in weights for one objective at a time. The test runs, shown in Figure 4, are all based on one watershed in Carteret County, North Carolina, between the White Oak River 9 miles to the west, Morehead City to 5 miles the east, and Bogue Sound to the south (the Natural Resource Conservation Service references the watershed as number 234).

Results

The numerical results of several runs are summarized in Table 1. Each row in Table 1 has a corresponding, but not necessarily unique, path through the watershed. The first four rows are the benchmark runs, where only one objective is minimized. The next 11 rows display the results of increasing the weight on the habitat function in NC-CREWS from 0 to 10. The next 11 rows are for the hydrology function, then the water quality function and

Table 1. Summary of multiobjective optimizations of road locations through wetland areas.

Weights				Objective values			
Hab	Hydro	WQ	Const.	Hab	Hydro	WQ	Const
1	0	0	0	1230	15 887	9826	$1 60 843
0	1	0	0	12 569	1471	8870	$1 44 285
0	0	1	0	14 426	15 026	729	$1 29 816
0	0	0	1	11 613	10 108	5083	$8062
0	1	1	1	11 441	9630	5066	$8244
1	1	1	1	9274	9900	4993	$8197
2	1	1	1	9274	9900	4993	$8197
3	1	1	1	9274	9900	4993	$8190
4	1	1	1	9272	9899	4992	$8180
5	1	1	1	9300	10 844	5133	$8409
6	1	1	1	9278	10 805	5136	$8418
7	1	1	1	9276	10 803	5134	$8398
8	1	1	1	9279	10 806	5137	$8425
9	1	1	1	9281	10 808	5138	$8424
10	1	1	1	9277	10 804	5135	$8408
1	0	1	1	9352	9978	5017	$8211
1	1	1	1	9274	9900	4993	$8197
1	2	1	1	11 442	9631	5066	$8247
1	3	1	1	11 442	9631	5066	$8247
1	4	1	1	11 439	9628	5064	$8219
1	5	1	1	11 401	9592	5070	$8256
1	6	1	1	11 403	9593	5070	$8263
1	7	1	1	11 399	9589	5067	$8234
1	8	1	1	11 402	9593	5070	$8263
1	9	1	1	11 509	9741	5166	$8460
1	10	1	1	10 901	9709	5147	$8410
1	1	0	1	9274	9900	4993	$8197
1	1	1	1	9274	9900	4993	$8197
1	1	2	1	9274	9900	4993	$8197
1	1	3	1	9274	9900	4993	$8193
1	1	4	1	9272	9898	4993	$8173
1	1	5	1	9274	9900	4991	$8197
1	1	6	1	9274	9900	4993	$8197
1	1	7	1	9274	9899	4993	$8188
1	1	8	1	9274	9900	4992	$8197
1	1	9	1	9275	9900	4993	$8193
1	1	10	1	9273	9899	4992	$8189
1	1	1	0	12 316	15 811	9757	$16 063
1	1	1	1	9274	9900	4993	$8197
1	1	1	2	11 443	9633	5070	$8252
1	1	1	3	11 443	9631	5069	$8234
1	1	1	4	11 443	9633	5070	$8252
1	1	1	5	11 442	9628	5065	$8251
1	1	1	6	11 443	9634	5072	$8247
1	1	1	7	11 442	9632	5068	$8251
1	1	1	8	11 441	9631	5068	$8233
1	1	1	9	11 440	9632	5069	$8219
1	1	1	10	11 442	9632	5069	$8240

Hab – habitat quality objective, Hydro – hydrology objective, WQ – water quality objective, Const – construction cost objective (×1000). The first four rows are the benchmark runs.

finally construction costs. The most noticeable result is that when one of the functions is not considered (weight = 0), the loss in that function jumps up. As soon as it is considered (weight = 1), the functional loss decreases dramatically. Further increases in weight lead to smaller changes in the functional value.

Discussion and conclusions

The primary objective of these tests was to demonstrate that this approach to road corridor location could be a useful tool for evaluating the trade off between environmental damage and the financial costs of road construction. The results in Table 1 and Figure 4 hopefully illustrate that a multiobjective approach to road locations through a wetland is a potentially useful tool for transportation planning. Much of the utility comes from being able to develop rapidly and evaluate alternative road locations. It is interesting to note that the paths generated with single objectives (the benchmark runs) are all quite unique, with low losses for the effective objective, but high costs in the other objectives. However, when all objectives are considered, paths are not nearly so unique. In fact, 25% of the non-benchmark paths are repeated at least once, and all multiobjective paths have significant overlaps.

The greatest potential use of this methodology is in the design phase of a transportation project. In the preliminary design phase transportation engineers, real estate specialist, regulating agencies, politicians, and other appropriate parties could use the program to scope out a range of alternative routes. Using the power of a GIS each route could be displayed visually with associated costs and environmental impacts. The selection of a preferred route will most likely be a compromise between objectives (a political decision). A compromise will always have a degree of subjectivity, but with the alternative routes and their relative impacts as evidence subjectivity can be reduced to political values. Of course, there is still uncertainty in the impacts of the location decision. Cost estimates have error. Land classifications have error. Wetland value estimates are uncertain. As great as the error and uncertainty of using this methodology at least we have integrated all the information that we do know into a logical framework for decision making. Other options have the same difficulty but without the logical framework.

In subsequent phases of the design process the program can be revisited. For example, if on closer on the ground examination a planned segment of the corridor turns out to be unavailable for political, environmental, or engineering reasons, this area could be eliminated from the set of possible areas and the problem run again yielding a new set of solutions.

A tool such as described in this paper will enhance road location decision making by bringing together what we know about wetland functions, road construction methods, land classification, and the political process into a logical framework that visually displays alternatives.

Acknowledgements

This research was supported in part by the North Carolina State University Center for Transportation and the Environment and the North Carolina Agricultural Research Service.

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USDA Natural Resources Conservation Service

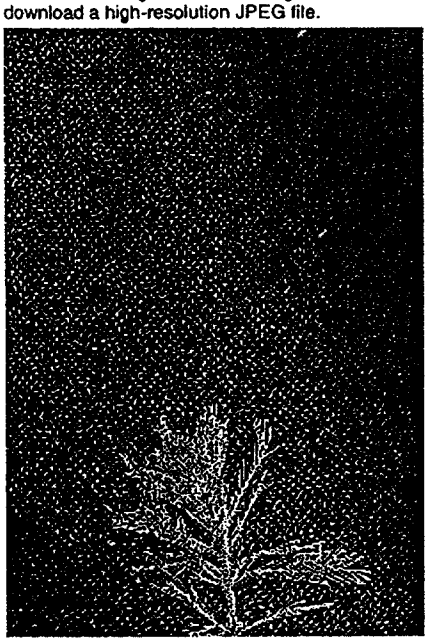
PLANTS Profile

Myriophyllum aquaticum (Vell.) Verdc.

parrot feather watermilfoil

Symbol:	MYAQ2
Group:	Dicot
Family:	Haloragaceae
Growth Habit:	Forb/herb
Duration:	Perennial
U.S. Nativity:	Introduced

Click on the image below to enlarge it and download a high-resolution JPEG file.



Myriophyllum brasiliense

Robert H. Mohlenbrock. USDA NRCS. 1995. *Northeast wetland flora: Field office guide to plant species.* Northeast National Technical Center, Chester, PA. Courtesy of USDA NRCS Wetland Science Institute. Usage Guidelines.

Printer-Friendly Version

Classification Distribution Images Invasive Links More Info Noxious Related Taxa Synonyms Wetland

Plant Images:

View all *Myriophyllum* thumbnails at the PLANTS Gallery

More Information About parrot feather watermilfoil

Plant classification

Plant source & reference

Plant Synonyms:

MYAQ2 *Myriophyllum aquaticum* (Vell.) Verdc.

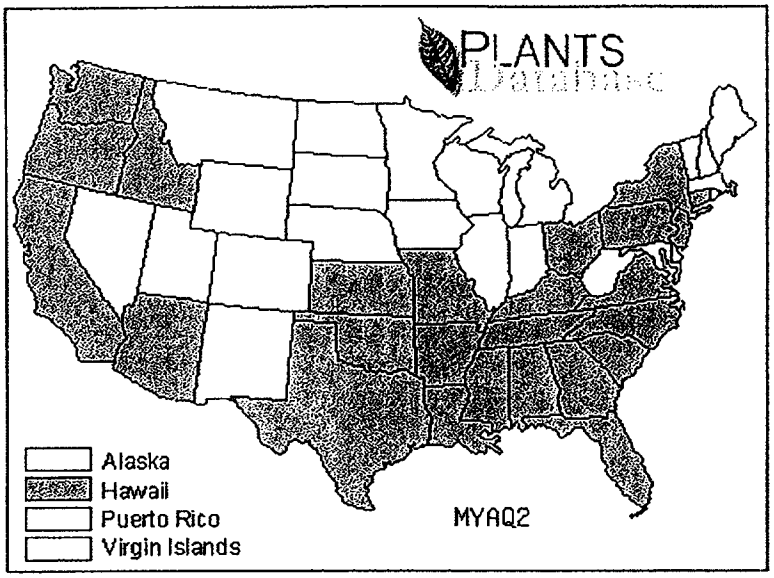
ENAQ *Enydria aquatica* Vell.

MYBR *Myriophyllum brasiliense* Camb.

MYPR2 *Myriophyllum proserpinacoides* Gillies ex Hook. & Arn.

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Plant Distribution by State



© Image generated using gd 1.8

Myriophyllum aquaticum (Vell.) Verdc.

MYAQ2

See county distributions for the following states by clicking on them below or on the map.

AR	CA	FL*
GA	KY	MO
NC	SC	TN*
VA		

* Offsite source.

Alabama	Florida	Kentucky	New York	Pennsylvania	Washington
Arizona	Georgia	Louisiana	North Carolina	South Carolina	
Arkansas	Hawaii	Mississippi	Ohio	Tennessee	
California	Idaho	Missouri	Oklahoma	Texas	
Connecticut	Kansas	New Jersey	Oregon	Virginia	

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Related Taxa:
Myriophyllum aquaticum (Vell.) Verdc.

View 4 genera in Haloragaceae, 13 species in *Myriophyllum*

«Back to Top»

Classification:
Myriophyllum aquaticum (Vell.) Verdc.

Click on a scientific name below to expand it in the PLANTS Classification Report.

Kingdom	Plantae – Plants
Subkingdom	Tracheobionta – Vascular plants
Superdivision	Spermatophyta – Seed plants
Division	Magnoliophyta – Flowering plants
Class	Magnoliopsida – Dicotyledons
Subclass	Rosidae –
Order	Haloragales –
Family	Haloragaceae – Water Milfoil family
Genus	*Myriophyllum* L. – watermilfoil
Species	*Myriophyllum aquaticum* (Vell.) Verdc. – parrot feather watermilfoil

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Noxious Weed Information:
Myriophyllum aquaticum (Vell.) Verdc.

This plant is listed by the U. S. federal government or a state. Common names are from state and federal lists. Click on a place name to get a complete noxious weed list for that location.

Alabama:	
parrotfeather, watermilfoil	Class C noxious weed
Maine:	
parrot feather	Invasive aquatic plant
Vermont:	
parrot feather	Class A noxious weed
Washington:	
parrotfeather	Class B noxious weed
parrotfeather	Wetland and aquatic weed quarantine

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Invasive Information:
Myriophyllum aquaticum (Vell.) Verdc.

parrot feather
watermilfoil

This plant is considered invasive by the authoritative sources noted below. This plant may be known by one or more common names in different places, and some are listed above. Click on an acronym to view each invasive plant list, or click here for a composite list of Invasive Plants of the U.S.

STATE	Assorted authors. 200_. **State Noxious Weed Lists for 43 States**. State agriculture or natural resource departments.
CalEPPC	California Exotic Pest Plant Council. 1999. **Exotic Plant Pest List** (http://www.caleppc.org/info/plantlist.html, October 19, 1999). California Exotic Pest Plant Council. California.
SEEPPC	Southeast Exotic Pest Plant Council. 1996. **Invasive Exotic Pest Plants in Tennessee** (http://webriver.com/tn-eppc/exlist.htm, October 19, 1999). Research Committee of the Tennessee Exotic Pest Plant Council. Tennessee.

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Introduced Information:
Myriophyllum aquaticum (Vell.) Verdc.

This plant is introduced to the United States from another country or countries. Click on link below for a partial or complete list of U.S. introduced plants.

Scientific Name = A| B| C| D| E| F| G| H| I| J| K| L| M| N| O| P| Q| R| S| T| U| V| W| X| Y| Z| all

Common Name = A| B| C| D| E| F| G| H| I| J| K| L| M| N| O| P| Q| R| S| T| U| V| W| X| Y| Z| all

Note: The complete introduced plant report is 1.4 MB. Download and display times may take 3 to 12 minutes depending on

your internet connection, internet traffic, your computer and browser. It may appear your computer has locked up. Task manager may report that Netscape is 'Not Responding'. Typically, Netscape is formatting the report for display, and if you are patient, the final report will appear.

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Wetland Indicator Status:*
Myriophyllum aquaticum (Vell.) Verdc.

MYBR: *Myriophyllum brasiliense* Camb.

Nat. Ind.	Reg. 1	Reg. 2	Reg. 3	Reg. 4	Reg. 5	Reg. 6	Reg. 7	Reg. 8	Reg. 9	Reg. 0	Reg. A	Reg. C	Reg. H
OBL	OBL	OBL	OBL	NO	OBL	OBL	OBL	NO	OBL	OBL	NO	NO	OBL

*for this plant and/or its synonyms

Interpreting wetland indicator status

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Other Species Accounts and Images:
Myriophyllum aquaticum (Vell.) Verdc.

View species account from USF Atlas of Florida Vascular Plants.
View species account from ARS Germplasm Resources Information Network (GRIN).
View taxonomic account from Integrated Taxonomic Information System (ITIS) for ITIS Taxonomic Serial Number 503904.
View species account from The Kemper Center for Home Gardening.
View photographs from University of Tennessee Herbarium.

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Related Web Sites:
Myriophyllum aquaticum (Vell.) Verdc.

Aquatic, Wetland and Invasive Plant Info. System: abstract & image
Cornell University Biological Control
NC-Aquatic Weed Fact Sheet (NCSU)
Serious aquatic weeds of Western Australia: large photographs
TX-Submerged Plants (TAES)
VA-Invasive Alien Plant Species of Virginia
WA-King County Noxious Weeds
WA-NonNative Freshwater Plants
Western Aquatic Plant Management Society

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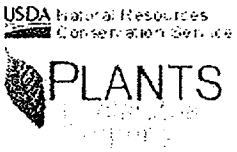
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Vascular Plants

PLANTS' vascular plant nomenclature, most phytogeography, and core attribute data for the United States and its Caribbean territories are provided under a cooperative agreement with John Kartesz and his staff at the Biota of North America Program (BONAP).

Pacific Basin vascular plant checklists, excluding Hawaii, are being developed by Warren L. Wagner, Department of Botany, Smithsonian Institution, and George Staples, The Bishop Museum, Honolulu. Longterm maintenance of the Pacific Basin checklist is being done by Dr. Wagner. All users of Pacific Basin vascular PLANTS data should acknowledge the contributions made by the Smithsonian and Bishop museums.

Contents

Nonvascular Plants

Lichens

Robert Egan (U. Nebraska at Omaha) and Theodore Esslinger (North Dakota State University) assembled the lichen checklist in PLANTS, which is based upon the North American lichen checklist published periodically in the *Bryologist*. Roger Rosentreter of the Bureau of Land Management provided some of our lichen common names from an unpublished manuscript.

Mosses

Marshall Crosby of the Missouri Botanical Garden is currently updating our moss checklist in association with botanists working on bryophytes for the *Flora of North America*. Lewis Anderson and Molly McMullen of Duke University developed the original list.

Liverworts and hornworts

Ray Stotler and Barbara Crandall-Stotler of Southern Illinois University, Carbondale developed these checklists.

Contents

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WATER PURIFICATION

(Fact sheet 6 of 10 on Wetland Values and Functions. Return to Introduction)

Plants and soils in wetlands play a significant role in purifying water. High levels of nutrients such as phosphorous and nitrogen, commonly associated with agricultural run-off, are effectively removed by wetlands. This is important in preventing eutrophication further downstream, a process that leads to rapid plant and algal growth followed by depleted oxygen levels that affect other species. It can also be important in preventing high concentrations of these nutrients reaching groundwater supplies or other water sources that may be used for drinking water.

Wetlands can be highly effective in dealing with these high levels of nutrients – in Florida's cypress swamps, 98% of all nitrogen and 97% of all phosphorous entering the wetlands from waste water were removed before this water entered the groundwater.

Many wetland plants have the capacity to remove toxic substances that have come from pesticides, industrial discharges and mining activities. Some wetland plants have been found to accumulate heavy metals in their tissues at 100,000 times the concentration in the surrounding water and so can detoxify certain kinds of effluent. *Eichhornia crassipes* (water hyacinth), some *Typha* and *Phragmites* species have been used to treat effluents from mining areas that contain high concentrations of heavy metals such as cadmium, zinc, mercury, nickel, copper and vanadium. (*Eichhornia crassipes*, a native of South America, is a "Jekyll and Hyde" of the wetland world, helpfully removing toxic materials in some wetlands and proving to be a costly adversary in others because of its phenomenal growth rate.)

In Brief.....

- ***Plants and soils in wetlands play a significant role in purifying water, removing high levels of nitrogen and phosphorous and, in some cases, removing toxic chemicals.***
- ***New York City recently avoided spending US$ 3-8 billion on new waste water treatment plants by investing US$ 1.5 billion in buying land around the reservoirs upstate as well as instituting other watershed protective measures.***
- ***Florida's cypress swamps removed 98% of all nitrogen and 97% of all phosphorous entering the wetlands from waste water before this water entered the groundwater.***
- ***The 8,000-hectare East Calcutta marshes, a patchwork of tree-fringed canals, vegetable plots, rice paddies and fish ponds, along with the assistance of 20,000 people, daily transform one third of the city's sewage and most of its domestic refuse into 20 tonnes of fish and 150 tonnes of vegetables.***
- ***In the Chesapeake Bay one million oysters have been seeded in a tributary to "clean" the water before it reaches the Bay***

In West Bengal, India, 430 members of a Fisherman's Cooperative harvest one tonne of fish a day from ponds that receive 23 million litres of polluted water daily from



Photo: WWF/UNEP/TOPHAM/Ezequiel Becerra

both industrial and domestic sources. *Eichhornia crassipes* is used here to remove the heavy metals while other wetland plants remove grease and oil. Mercury levels, although high in incoming water, cannot be detected in the outflow, and the wetland plants remove 99.9% of the faecal coliform bacteria.

Some wetland animal species are also proving to be useful in this regard. In the Chesapeake Bay in the USA, one million oysters are being re-seeded in a tributary feeding into the Bay in an effort to "clean-up" the pollutants in the water before they reach the Bay.

Of course nature has its limitations, and it would be wrong to consider that wetlands can deal with whatever waste concentrations we humans can produce. The environmental catastrophes associated with mining wastes in the past two years are testimony to this - in Southern Spain in 1999, when more than 5 million cubic metres of heavy metal-laden sludge poured into the Guadiamar river and part of Coto Doñana wetlands; and in Romania in January 2000, when 100,000 cubic metres of cyanide and heavy metal-contaminated wastewater flowed into three rivers and devastated 1,000 km of river ecosystems in Romania, Hungary, Yugoslavia, and Bulgaria.

The value of the purification function of wetlands is significant: New York City recently found that it could avoid spending US $3-8 billion on new waste water treatment plants (with US$ 700 million annual operating costs) by investing just US$ 1.5 billion in buying land around the reservoirs upstate as well as instituting other protective measures to protect the watershed that will do the job of purifying the water supply for free.

Using this purification capacity of wetlands, Calcutta has pioneered a system of sewage disposal that is both efficient and environmentally friendly. Built to house one million people, Calcutta is now home to over 10 million, many living in slums and creating a sanitation nightmare. But the 8,000-hectare East Calcutta marshes, a patchwork of tree-fringed canals, vegetable plots, rice paddies and fish ponds, along with the assistance of 20,000 people, daily transform one third of the city's sewage and most of its domestic refuse into 20 tonnes of fish and 150 tonnes of vegetables. Mobilising people and wetlands here dispenses with the need for costly engineered sewage systems, brings great benefit to many local people, and solves at least part of the sanitation problem in the city.

For further information about the Ramsar Convention on Wetlands, please contact the **Ramsar Convention Bureau**, Rue Mauverney 28, CH-1196 Gland, Switzerland (tel +41 22 999 0170, fax +41 22 999 0169, e-mail ramsar@ramsar.org). Posted 21 December 2000, Sandra Hails, Ramsar.

Home

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News

FOR RELEASE
05/09/2003 (Friday)
No. 03-21

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Surface Transportation Board Votes To Authorize Construction of "Bayport Loop" Line To Provide Additional Rail Service in Houston Area

Surface Transportation Board (Board) Chairman Roger Nober announced that the Board, at its open voting conference held today, voted to authorize construction of the "Bayport Loop" project, which will give certain Houston, Texas-area shippers access to an additional railroad to provide competitive service. The Board voted to impose mitigation measures to address the minor and negligible environmental impacts identified in an Environmental Impact Statement (EIS) and concerns raised by the local community.

In announcing the Board's vote, Chairman Nober said,

"This decision will provide BNSF the opportunity to serve chemical companies in the Bayport Loop. Permitting railroads to construct new lines to reach customers is the right way to promote rail-to-rail competition."

Commenting on the environmental review process, Chairman Nober remarked,

"I am proud that we completed such a thorough environmental review and reached a decision on the merits in only 17 months, which sounds like a long time to most of us,

but is rather expeditious in the world of environmental review of transportation projects."

Commission Morgan commented,

"Our approval today is the culmination of a process that I believe has achieved the proper balance between the need for a full and fair review of environmental matters and the need for a timely review of projects that can enhance the Nation's rail transportation infrastructure and the service that it provides. This decision represents good government, and I wholeheartedly endorse it."

In accordance with the regulations of the President's Council on Environmental Quality implementing the National Environmental Policy Act at Section 1506.10(b) of Title 40, *Code of Federal Regulations* [40 CFR 1506.10(b)], the Board set the deadline for filing administrative appeals in this case as 30 days from the date on which notice of the Final EIS is published in the *Federal Register*. The Board's final decision here will not become effective until that date.

The Board's decision in this case, entitled *San Jacinto Rail Limited Construction Exemption and The Burlington Northern and Santa Fe Railway Company Operation Exemption -- Build-Out to the Bayport Loop Near Houston, Harris County, TX*, STB Finance Docket No. 34079, is being issued today. Commissioner Morgan commented. Printed copies will be available for a fee by contacting **Dā 2 Dā Legal Copy Service, Suite 405, 1925 K Street, N.W., Washington, DC 20006, telephone (202) 293-7776**, or via **da2dalegal@earthlink.net.** The decisions also will be available for viewing and downloading under "Decisions & Notices" on the Board's website at www.stb.dot.gov. A fact sheet is attached.

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ATTACHMENT

FACT SHEET

In August 2002, the Board examined the transportation aspects of a proposal for the

construction by San Jacinto Rail Limited and operation by The Burlington Northern and Santa Fe Railway Company (collectively, "BNSF") of a 12.8-mile line of railroad serving petrochemical industries in the Bayport Loop industrial district area of Houston. The line would connect the Bayport Loop with the former Galveston, Henderson and Houston Railroad line (or GH&H line), now owned by Union Pacific Railroad Company (UP). BNSF would operate over the GH&H via trackage rights imposed as a condition of the 1996 merger between UP and Southern Pacific Transportation Company. Currently, UP is the only railroad serving the Bayport Loop.

In its August decision, the Board tentatively concluded that the proposal should be allowed because it would promote the Rail Transportation Policy by providing an alternative rail service option to shippers in the Bayport Loop, but reserved making a final decision until completion of the environmental review process.

Today's vote follows the issuance of an Environmental Impact Statement (EIS) that accounted for the more than 600 comments received after extensive public outreach conducted by the Board's Section of Environmental Analysis (SEA). The EIS indicates that the proposal would have only minor or negligible environmental impacts. Furthermore, it indicates that the environmental impacts that would occur can be effectively mitigated by BNSF's voluntary mitigation measures, as well as additional environmental conditions that SEA developed.

The EIS considers various alternative routings for the proposed project. Consistent with the EIS, the Board today voted to identify Alternative "1C"--which was designed to avoid potential impacts on aviation--as the preferred route, although it finds that all of the route alternatives considered in the EIS are fully acceptable environmentally and therefore authorizes petitioners to construct and operate any one of them. Additional information on the EIS was provided in a fact sheet attached to a news release issued on May 2, 2003.

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Traffic World September 20, 2004, Monday

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Traffic World

September 20, 2004, Monday

SECTION: RAIL; Pg. 25

LENGTH: 729 words

HEADLINE: Shippers' Eminent Rivals;
Fight for lines in Houston comes down to BNSF's ability to win eminent domain rights for tracks

BYLINE: BY JOHN GALLAGHER

BODY:
Copyright 2004, Traffic World, Inc. Burlington Northern Santa Fe Railway is locking horns with the City of Houston over the right of eminent domain in a legal battle that chemical shippers say is hindering their ability to compete.

Although the battle was supposedly ended by a Surface Transportation Board decision last year, the city is erecting legal barriers to BNSF's ability to link up with the shippers. That has the railroad and its customers raising important questions about how far local communities can go to block federal rulings on interstate commerce, questions the shippers believed were settled by the STB.

"If municipalities can have a say on interstate commerce, it would be an impediment to rail transportation nationwide," said David Harpole, a spokesman for Lyondell Chemicals, one of the shipper partners in the disputed project. "It comes down to the fundamental issues of the railroad's ability to serve the country."

The STB last year approved BNSF's San Jacinto Rail, an $85 million shipper-carrier project that would bring rail competition to four chemical shippers captive to Union Pacific Railroad in the Bayport, Texas Industrial District in southeast Houston. STB Chairman **Roger Nober,** the only member of the board at the time, reasoned that competition resulting from the 13-mile rail buildout promoted national transportation policy.

"In short, we determined that BNSF's proposed line would result in an additional service option for Bayport shippers and require BNSF and UP to compete for their traffic," the STB said in its decision. "We found these goals to be fully consistent with the public interest."

But after initial appeals by environmental groups to the 5th U.S. Circuit Court of Appeals were dropped, the City of Houston filed an appeal to the 14th District Texas Court of Appeals to block the sale of land BNSF needed. The two sides went to mediation last month in an effort to work out their differences.

Nober, who met with Houston city officials last week, says government and business officials "are very much focused on the outcome."

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"The opposition believes there are already too many rail lines and don't want another built. But (the STB's) interest is not in the San Jacinto project per se, but the viability of build-ins as a competitive option. If (municipalities) make it harder to construct build-ins, it's less likely people will be willing to see them as viable and be willing to spend the money on applying for them. STB sees build-ins as a market based means of competition to single served areas."

The STB filed a "friend of the court" brief with the Texas court objecting to rulings that prevent BNSF from exercising its right of eminent domain. "BNSF has the authority from us, but they need the land, and the court is preventing that," Nober said. "And Houston won't sell it to them, so they're stuck."

Houston's chemical shippers said the BNSF line would drastically reduce their rates. "We've stated on many occasions that in chemical facilities where there's no competition, rates are often twice what it costs to ship the same product to the same end user," said David Harpole, a spokesman for Lyondell Chemicals, one of the shipper partners in the San Jacinto project. "This prevents us from competing in a global market."

Area officials say they would prefer that BNSF and rival UP work out a deal to allow BNSF access to UP's existing line, eliminating the need for a costly second line. Toyota and BNSF were able to use such leverage against UP in San Antonio last year, when the parties threatened to create a local rail district in order to **build-out** to UP to dual rail access for Toyota. Instead, BNSF and UP worked out a trackage rights arrangement.

Exercising political pull, however, can be expensive. "We ended up spending $170,000 of taxpayers' money for the first phase of building the short line railroad, which included filing at the STB and hiring consultants to conduct environmental analysis," said Bruce Flohr, chairman of the Bexar County, Texas, Rail District.

"When the other guy wants something badly enough, you open your swap list and trade for something along another part of your system," he said. "But you're not going to get the railroads to agree outright on something like this, especially when you're talking about arch rivals."

LOAD-DATE: September 22, 2004

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Railway Age May 1, 2004

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May 1, 2004

SECTION: No. 5, Vol. 205; Pg. 6; ISSN: 0033-8826

IAC-ACC-NO: 117188655

LENGTH: 282 words

HEADLINE: Will court rulings discourage rail investment; industry outlook; Brief Article

BODY:
Court rulings delaying two rail construction projects approved by the Surface Transportation Board could discourage investment in rail expansion, STB Chairman **Roger Nober** told attendees of the National Industrial Transportation League's spring forum. According to Nober, the U.S. Court of Appeals for the Eighth Circuit sent back for further proceedings a portion of the Board's decision approving Dakota, Minnesota & Eastern Railroad Corp.'s new line to Wyoming's Powder River Basin. The court was primarily concerned about the environmental effects of an increase in coal consumption. For the first time, Nober said, the ruling "raised the possibility that the agency would need to examine the effects of transporting a certain commodity carried by the regulated business." The court denied an appeal for a rehearing. Nober also described a delay in a rail construction project approved by the Board for BNSF subsidiary San Jacinto Rail Ltd. and four chemical shippers for a 12.8-mile line near Houston, Texas, with BNSF providing service over it. Some of the line's property must be obtained through the state's eminent domain statutes, but a Texas state court ruled that those statutes preclude taking the land. The ruling is under appeal. "Stepping back," concluded Nober, "I am concerned about the larger implications that these rulings may have on the decisions of railroads and shippers to try to improve their competitive positions by building-in. Since these types of projects are privately-funded, I worry that companies may decide that it is too risky tie up capital on a **build-in** project and no longer look to these as private-sector solutions to railroad competition."

IAC-CREATE-DATE: June 7, 2004

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Traffic World October 20, 2003, Monday

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Traffic World

October 20, 2003, Monday

SECTION: RAIL; Pg. 29

LENGTH: 1037 words

HEADLINE: Undone Deals;
Shippers find themselves sidelined by local opposition to rail projects

BYLINE: BY JOHN GALLAGHER

BODY:
Copyright 2003, Traffic World, Inc. For the second time in a week a local court knocked down a decision by the Surface Transportation Board on environmental grounds, leaving rail shippers out in the cold.

On Oct. 8, a county court judge blocked San Jacinto Rail Ltd.'s attempt to build a 13-mile rail line in the Bayport Industrial District in southeast Houston. Burlington Northern Santa Fe Railway, a partner in San Jacinto Rail, was to operate the $85 million line on behalf of San Jacinto's other partners, four chemical and plastics shippers within the district and captive to Union Pacific Railroad.

That came five days after a federal appeals court in North Dakota found the STB did not adequately address environmental issues in approving the Dakota, Minnesota & Eastern Railroad's proposed rail line extension into the Powder River Basin in Wyoming. That project, which would involve building about 280 miles of new track and upgrading 600 miles of existing track at a cost of roughly $2 billion, would allow another railroad to compete with UP and BNSF for low-sulfur coal.

That was a stinging rebuke for the STB, the railroads and their customers because the 8th U.S. Circuit Court of Appeals agreed with the Sierra Club's assertion that the STB failed to consider the effects of increased coal shipping

on air quality. For the railroads, it raised the possibility of new and higher hurdles to expansion.

"The question in my mind is, which is the entity to go to with these kinds of things if it's not the STB?" said National Industrial Transportation League President John Ficker. "If anybody along the way can stop (projects), then there's a real problem. It slows down the whole process.""The question in my mind is, which is the entity to go to with these kinds of things if it's not the STB?" said National Industrial Transportation League President John Ficker. "If anybody along the way can stop (projects), then there's

Harris County, Texas, officials did not make available immediately a copy of the dismissal in the San Jacinto case and STB Chairman **Roger Nober** was cautious about drawing larger

conclusions. "Until we see what the judge says and what they base it on, we don't know the situation," said Nober. "But obviously we want to be sure that the authority to build and provide competitive service is still a viable option. We think competitive service in this area is a good thing and one that will help carriers and shippers in that part of the world."

The court in Texas dismissed a lawsuit by BNSF to condemn 240 acres that would have been used for the San Jacinto line's right of way.

San Jacinto Rail filed with the STB in August 2001 and the board approved the project in May following release by the STB's Section of Environmental Analysis of its Final Environmental Impact Study. The STB concluded that the line would promote federal rail transportation policy in the area by increasing competition and providing an alternative rail service option to shippers in the Bayport.

"Obviously we are disappointed," said BNSF spokesman Joe Faust. "The route we had presented we felt was best not just for BNSF but for the community as well. We plan to explore our legal options, which includes an appeal."

DM&E is concerned about the impact of the Wyoming case. Rail industry experts believe it could impede financing opportunities for the railroad because anything that slows down approval processes is seen as a negative by potential investors. DM&E President Kevin Schieffer was not available for comment.

Nober said he was "concerned" about certain aspects of the federal court's decision in the DM&E case and is considering how the STB will proceed.

The court cited DM&E's argument that because federal clean air regulations mandate reductions in pollutant emissions, those emissions will "definitely fall to the mandated level, (reducing) whatever effect the emissions will have on global warming." The court responded that such an assumption says nothing about how the project will affect pollutants not subject to statutory caps. "For the most part, (the board) has completely ignored the effects of increased coal consumption, and it has made no attempt to fulfill the requirements laid out in the (Council of Environmental Quality) regulations," the court said.

But according to transportation industry insiders, such a requirement would be a setback for rail competition because it would erect new barriers to new service. "From a rail shipper and freight standpoint, I'm not aware of any other case where the STB has been asked to look not only at the transportation effects but at the commodity being transported," said a Department of Transportation official who declined to be identified. "That would be a very dangerous and disturbing precedent if that stands and becomes the norm."

In the San Jacinto Rail case, "If the Sierra Club had come in and used the same argument there, and the court agreed, the STB would have to go back and redo the environmental impact of moving more chemicals to every location for four chemical plants."

It's hardly academic for the railroads. The DOT official pointed to a rail infrastructure improvement project under way in Chicago involving six Class 1 railroads. "The board would have to be able to model all the different commodities flowing through Chicago and measure the effects that more efficient service would have on those flows," said the official. "If the STB had to do that kind of analysis in every case, it would make their environmental task much more difficult, and shippers would be denied the benefit of getting more competitive options."

If such "nimby" issues do become more prevalent in the rail industry, shippers said they would turn to Congress. "At this point right now, about the only outlet (rail shippers) have for relief is through build-ins or **build-outs**" to competing rail lines, said Curt Warfel, manager

for customer service and logistics at Eka Chemicals Inc. and second vice chairman at NITL. "And if the courts are going to remove that for environmental reasons, I think it makes it that much more important that we get some sort of legislative relief."

LOAD-DATE: October 20, 2003

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THIS INDENTURE, Made and entered into this 22 day of December, 1949, by and between the CAROLINAS CEMENT AND LIME COMPANY, a corporation under the laws of the State of Delaware, party of the first part, and the ATLANTIC COAST LINE RAILROAD COMPANY, a corporation under the laws of the State of Virginia, party of the second part, WITNESSETH:

That the party of the first part, for and in consideration of One Dollar to it in hand paid by the party of the second part, receipt of which is hereby acknowledged, hereby grants to the party of the second part, its successors and assigns, a non-exclusive easement or right of way for the purpose of operating trains, locomotives and equipment over that certain railroad track of the party of the first part at Giant (near Harleyville) County of Dorchester, State of South Carolina, the location of the center line of which track is described as follows:

> Beginning at a point at the southerly end of the main track of the Atlantic Coast Line Railroad Company's Pregnall Branch as now constructed, said point being in the center line of said main track and at Station 1818 plus 28.4, of the chainage of said Pregnall Branch, the southerly end of said main track being distant 2734.7 feet southwardly from the southerly edge of Four Holes Swamp, measurements being along the center line of the track; running thence southwardly along the center line of the old roadbed of the Atlantic Coast Line Railroad Company's former Pregnall Branch a distance of 2592.8 feet to the northerly end of the track of the Carolina Giant Cement Company, which northerly end is at Station 1844 plus 21.2 of said chainage; also beginning at said point at Station 1818 plus 28.4 and running northeastwardly on a curve to the right, tangent to the center line of the portion of the track of the party of the first part above described, 381.4 feet; the track, over which said non-exclusive easement is hereby conveyed, having a total length of 2974.2 feet and the center line thereof being shown in green on the blue print attached hereto and made a part hereof.

TO HAVE AND TO HOLD the said non-exclusive easement or right of way unto the said party of the second part, its successors and assigns, so long as the party of the second part, its successors or assigns, shall use the same for railroad purposes; it being understood and agreed that no forfeiture or reversion shall take effect unless and until the party of the second part herein, its successors or assigns, shall abandon the use of said easement for railroad purposes; it being further understood that, so long as the party of the second part shall use said track for its purposes, said track shall be maintained by it without cost to said party of the first part.

IN WITNESS WHEREOF the party of the first part has caused these presents to be signed in its name and behalf by its President and its corporate seal to be affixed and the same to be attested by its Secretary.

Signed, sealed and delivered in the presence of:

CAROLINAS CEMENT AND LIME COMPANY

By J. Ross Marshall
President

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