Attachment 10

Subsurface Investigation Report – Aldinger 2012

GEOTECHNICAL MEMORANDUM
FOR THE PROPOSED
BLACKSTONE RIVER FISH LADDER
PASSAGE IMPROVEMENTS
PAWTUCKET, RHODE ISLAND

Prepared for:

EA Engineering, Science & Technology
2374 Post Road
Warwick, Rhode Island 02886

Prepared by:

Paul B. Aldinger & Associates, Inc.
860A Waterman Avenue, Suite 9
East Providence, Rhode Island 02914

PBA No. 11081
February 2012

PAUL B. ALDINGER & ASSOCIATES, INC.
Consulting in Geotechnical Engineering & Groundwater Hydrology
860A Waterman Avenue, Suite 9 East Providence, R.I. 02914 (401) 435-5570

February 9, 2012

Mr. Thomas Cook, P.E.
EA Engineering, Science & Technology, Inc.
2374 Post Road
Warwick, Rhode Island 02886

Re: Geotechnical Engineering Report
Blackstone Fish Passage
Pawtucket, Rhode Island
PBA No. 11081

Dear Mr. Cook:

Paul B. Aldinger & Associates, Inc. (PBA) is pleased to provide EA Engineering, Science & Technology, Inc. (EA) with this geotechnical engineering report for the above referenced project. This report is subject to the limitations that are outlined in Appendix A.

1.00 INTRODUCTION/PROJECT DESCRIPTION

The project site is located on the Blackstone River in Pawtucket, Rhode Island. The proposed project consists of the construction of two fish ladders to facilitate both upstream and downstream fish access through two dams, the Main Street Dam and the Slater Pond Dam. Figure 1, Site Vicinity Plan, provides the approximate location of the site. Based on the plan titled "Existing Conditions Plan" developed by EA, the water is flowing from the east to the west over the two dams, with the Slater Mill Dam located upstream of the Main Street Dam. The proposed project consists of the construction of a Denil fish ladder at each dam location to facilitate both upstream and downstream fish access through the dams.

The objectives of our engineering services were to plan and monitor a subsurface exploration program, perform geotechnical engineering analyses, develop an engineering report with specific earthwork and foundation design recommendations for the proposed fish ladder, and provide assistance to EA with the design and construction monitoring of the new facilities.

2.00 GEOLOGY

Surficial Geology - The 1946 *Ground-water Map of the Pawtucket Quadrangle, Rhode Island* by William B. Allen and the 1949 *Surficial Geology Map of the Pawtucket Quadrangle, Rhode Island* by Newton E. Chute were reviewed to obtain site geology information. The surficial geology in the vicinity of the site reportedly consists of outwash deposits. The eastern side of the project is mapped as Outwash Plains consisting of sand and gravel plains and low alluvial fans deposited along valley floors by glacial meltwater streams. The western side of the project is mapped as River Terrace

Alluvium, which is described as alluvium on terraces formed by river erosion. A small area of bedrock outcropping is also indicated in the immediate vicinity of the proposed project.

Bedrock Geology - The 1949 *Bedrock Geologic Map of the Pawtucket Quadrangle, Rhode Island*, Alonzo W. Quinn, R.G. Ray, and W.L. Seymour indicates the bedrock underlying the project site is Pondville Conglomerate and Rhode Island Formation. This rock reportedly consists of gray to black sedimentary rocks, including beds of conglomerate, sandstone, shale, black shale, and coaly material. In addition, information presented on the *Ground-water Map of the Pawtucket Quadrangle, Rhode Island* indicates the anticipated bedrock elevation within the vicinity of the site is approximately between elevations -8 and +36 feet mean sea level.

3.00 SUBSURFACE INVESTIGATION PROGRAM

A subsurface investigation consisting of two drilled test borings was completed for the project. One boring was completed on the left abutment of the Slater Mill Dam and one boring was completed through the bridge deck of the Main Street Bridge. An attempt was made to complete a boring with the use of a floating drill rig on the river. However, given the swift current at the time, this effort was abandoned in favor of coring through the bridge deck.

The boring locations are indicated on Figures 2 and 3, Subsurface Exploration Plan. The borings were completed by New Hampshire Boring Company of Brockton, Massachusetts on October 14, 2011, between November 29 and 30, 2011, and on January 17, 2012.

One test boring (B-1) was drilled on land, just to the south of the Slater Mill Dam crest. The second boring (B-2) was completed by drilling through the Main Street Bridge deck and seating the casing in the bedrock at the base of the river. The boring locations are presented on Figure 2, Subsurface Exploration Plan. The ground surface elevations provided on the boring logs were approximated from the "Existing Conditions Plan" developed by EA and reference mean sea level. The test borings were observed and logged by an engineering technician from PBA and the logs are included in Appendix B.

The borings were advanced with casing using the wash and drive method of drilling to depths of 18 and 16 feet below the ground surface, respectively. Standard split spoon soil samples were obtained at intervals of 5 feet using a 1⅜-inch inside diameter split spoon sampler in substantial conformance with ASTM D1586, the Standard Penetration Test (SPT). The standard ASTM method of driving the sampler was employed using a 140-pound hammer falling 30 inches. The number of blows required to drive the sampler for each 6 inches of penetration was recorded. The number of blows required to drive the sampler from 6 to 18 inches of penetration is the SPT blow count (N-value), a commonly-used indicator of soil density. A 10-foot rock core samples was obtained from boring B-1 between depths of 8 and 18 feet below grade. In boring B-2 a 15-foot rock core sample was obtained between depths of 1 and 16 feet.

4.00 SUBSURFACE CONDITIONS

Generalized soil conditions encountered in the subsurface explorations include the following strata from the ground surface downward. Refer to the boring logs in the Appendix B for more detailed descriptions of the conditions encountered.

4.10 Soil Conditions

- **Topsoil** - Approximately 6 inches of topsoil was encountered at the ground surface in boring B-1. This stratum was underlain by;

- **Glacial Outwash** - The glacial outwash consisted of a medium dense, brown fine to coarse SAND and GRAVEL with trace amounts of silt, and cobbles. This stratum extended to a depth of approximately 7 to 8 feet below grade and was underlain by;

- **Bedrock** - In boring B-1 the bedrock was described as slightly fractured, layered gray SHALE and SANDSTONE. In boring B-2, bedrock was the first stratum encountered. The rock sample from B-2 was also described as SHALE. These types of rock are consistent with the formations described as part of the Rhode Island Formation. A 10-foot rock core was obtained from boring B-1 in two five-foot sections. Approximately 90 percent recovery and 75 percent RQD was recorded for each sample from B-1. A 15-foot rock core was obtained from boring B-2 in three five-foot sections. Recovery of the samples ranged from 87 to 100 percent and the RQD was measured at 70, 87, and 93 percent for the three core samples.

4.20 Groundwater Conditions

Water was introduced into the soil as a result of the drilling process at B-1, therefore accurate readings of groundwater level were not obtained within the explorations. The groundwater level is likely to be near and slightly above the level observed in the river. Boring B-2 was completed within the waterway. It should be noted that fluctuations in the levels of the groundwater will likely occur due to variations in tide, rainfall, temperature, and other factors occurring.

5.00 GEOTECHNICAL DESIGN RECOMMENDATIONS

Based upon the design plans which EA provided to us, we understand that the footing inverts for the fish ladder at the Slater Mill Dam will be located between approximate elevations +14.1 and +17.5 feet (mean sea level). At the Main Street Dam, we understand that the footing inverts will be located between approximate elevations -1.0 and -12.5 feet (mean sea level). Based upon our review of the site geology and the results of the test borings, it is likely that bedrock will be encountered above the planned footing inverts at both fish ladder locations. It is our understanding that blasting of rock will not be allowed.

The cores obtained of this bedrock indicate that the rock is of good to excellent rock quality. Since the planned footing inverts will be located within the encountered bedrock, the rock will be able to adequately support the proposed loadings. Support of both new fish ladders with rock anchors will be feasible. We understand that your design requires rock anchors be included to provide between 30 and 150 kip loadings in tension.

Based upon our review of the boring results and our engineering analyses, we have developed the following recommendations for use in the project design.

5.10 Rock Anchor Design

Rock anchors consisting of an all-thread bar with a minimum diameter of 1.375 inches can be used to stabilize the proposed fish passage-way. The threaded bar would be installed into the bedrock within a PVC sleeve with a resin placed in annular space around the bar. An anchor plate with sealing cap and nut would extend up from the threaded bar into the cast-in-place concrete which comprises the fish passage-way. Rock anchors with a capacity of 150 kips would need a bond length which extends a minimum of 25 feet into the rock. For up to a 60 kip anchor capacity, the minimum bond length would be 10 feet into the rock. We have assumed that the drill hole diameter of the bond zone would be a minimum of 4 inches in diameter and the upper limit of this bond zone would be located at a minimum of 15 feet below the top of bedrock in order to develop the required anchor capacity. The ultimate bond stress between the bedrock and grout was assumed to be 100 psi based upon the recommended values published in the Post Tensioning Institute design manual. Our analysis utilized a factor of safety of 2 for this calculation.

5.20 Corrosion Protection System

In order to ensure that the service life of the rock anchor will not be impacted by its corrosive environment, the anchors should have a Class I corrosion protection system incorporated into the design. Within the unbonded anchor length, the Class I protection system consists of installing the reinforcing bar within a grout-filled sheath which is then protected by an additional smooth sheath and grout within the unbonded zone. Within the bond zone, the corrosion protection consists of encapsulation of the reinforcing bar within a corrugated sheath and grout. A minimum of 0.5 inches of grout cover must be provided over the corrugated sheath. A watertight permanent seal is provided between the unbonded and bonded lengths of the anchor.

Corrosion protection of the anchor head can be provided by using a plastic cover filled with grease or grout over the anchor head or embedding the anchor head in concrete with a minimum cover of 2 inches. The bearing plate should be coated with bitumen or other protective compound on both sides. A grout-filled trumpet is also attached to the underside of the bearing plate with a watertight connection and extends to the unbonded zone. The trumpet consists of either steel or PVC-pipe and extends from the bearing plate to a minimum distance of 4 inches into the unbonded zone.

5.30 Rock Anchor Installation

It is our understanding that the support piers for the new fish passage will be constructed of pre-cast concrete blocks. The blocks should be cast with a sleeve to allow for the anchor to be installed from the top of the pier and extend down into the bedrock. Since the piers will be constructed of pre-cast concrete blocks, an extension to the rock anchor will be utilized to reach the top of the pier and this will assist in interlocking the block elements. Construction of a temporary work platform may be required in order to position the drilling equipment at the top of the pier to allow for the installation of the anchors.

In order to adequately prepare the site for the pier construction, leveling of the bedrock surface will be required. We anticipate that only a limited amount of rock will be excavated mechanically and blasting will not be permitted at the site. Therefore, we understand that you intend to provide a level base for the new piers by placing grout on the bedrock surface prior to constructing the new piers.

5.40 Anchor Testing Requirements

One rock anchor at each fish ladder should be performance tested. All other anchors should be proof tested to demonstrate that the anchor meets the design requirements. Anchor testing is conducted by incrementally loading the anchor to a maximum load of 1.33 times the design load. Upon completion of the anchor test loading sequence, the anchor is locked off at the design load. Anchor testing should not occur until the grout has been allowed to cure to its full design strength.

The Contractor should be required by specification to submit a detailed plan of the intended load testing program for the project which includes, as a minimum, the intended loading sequence, test load hold times, a listing of the equipment proposed for use along with appropriate calibration records, anchor lock-off load and intended load lock-off procedure.

5.50 Dewatering/River Diversion

It is our understanding that the flow of the Blackstone River will be partially diverted during the construction of the fish passage. We understand that based upon the geometry of the work area and the measured volume of water which traverses this location, it will not be possible to completely divert the river flow. In addition, dewatering of the project area during construction would be extremely difficult. We anticipate that the work will be completed at a time of low flow and that it may be necessary for the Contractor to construct a temporary work platform to support the drilling equipment required for construction. It may also be possible to complete the work from a barge. We recommend that the Contractor be required to submit a detailed plan which outlines his intended method of construction prior to the mobilization of equipment to the site.

Specifications should also require that the contractor provide for proper diversion of surface water runoff away from any excavations so that structures, embankments, and compacted fill are not

undermined. During periods of heavy rainfall, diversion of trapped surface water may also be a significant problem.

6.00 FINAL DESIGN & CONSTRUCTION MONITORING

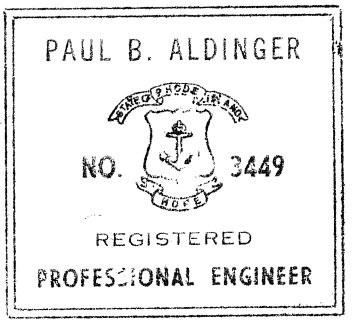
It is recommended that PBA be provided the opportunity to review foundation design plans and prepare or review project earthwork and rock anchor specifications to ensure that our recommendations have been properly interpreted. In addition, it is recommended that a geotechnical engineer be present during earthwork construction, to observe the excavation of the bedrock surface and to monitor rock anchor installation and testing.

We appreciate the opportunity to have been of service to EA Engineering, Science & Technology, Inc. and we trust that the information contained in this report is adequate for your needs at this time. Please contact the undersigned if there are questions on these recommendations or if you need additional information.

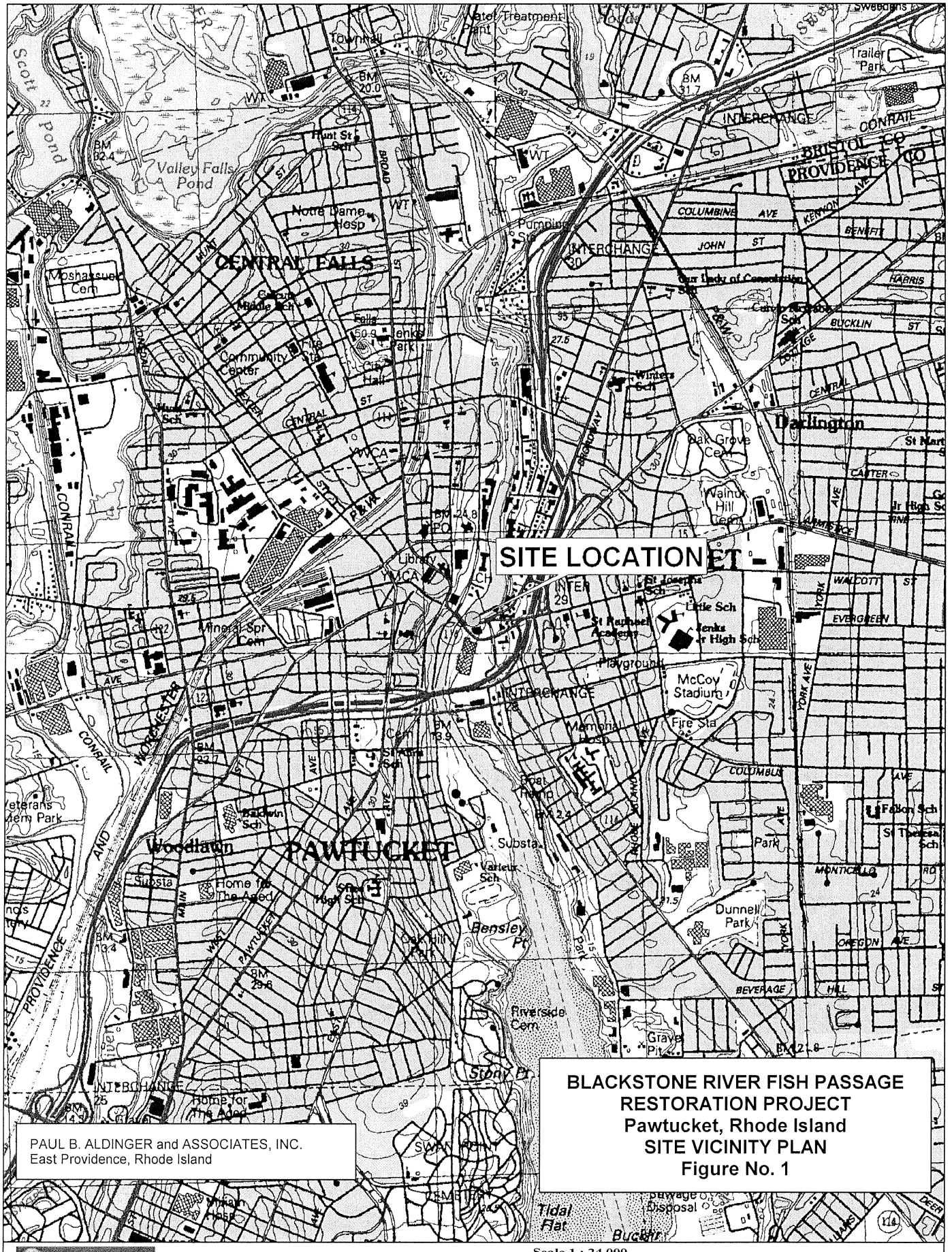
Very truly yours,

PAUL B. ALDINGER & ASSOCIATES, INC.

Paul B. Aldinger, Ph.D., P.E.
Chief Engineer



FIGURES



BLACKSTONE RIVER FISH PASSAGE RESTORATION PROJECT
Pawtucket, Rhode Island
SITE VICINITY PLAN
Figure No. 1

PAUL B. ALDINGER and ASSOCIATES, INC.
East Providence, Rhode Island

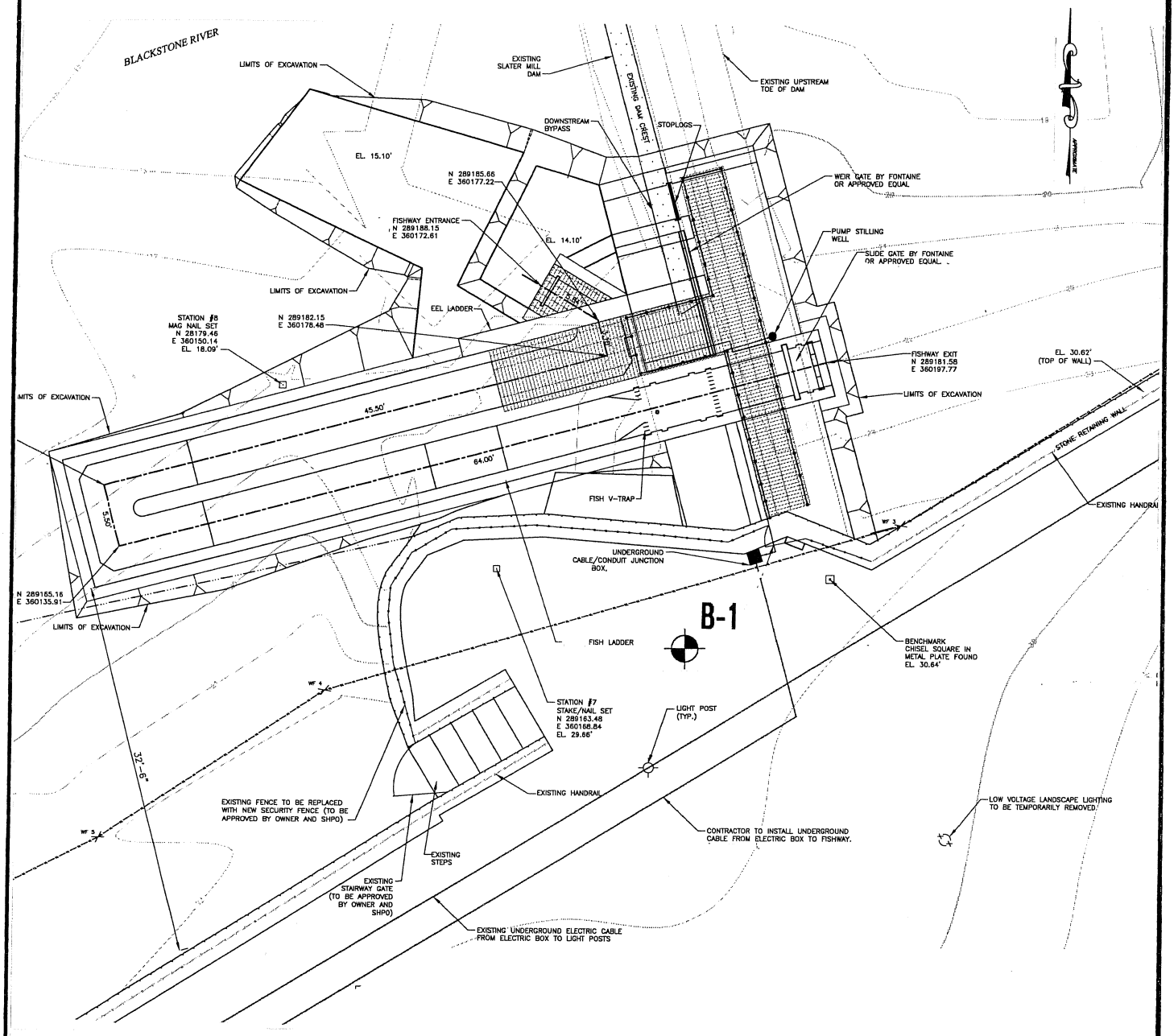
DeLORME

Zoom Level: 13-0 Datum: WGS84

Scale 1 : 24,000
1" = 2,000 ft

0 800 1600 2400 3200 4000 ft
0 200 400 600 800 1000 m

TN
MN
15.4°W



LEGEND

B-1 BORING BY NEW HAMPSHIRE BORING, INC.
MONITORED BY PAUL B. ALDINGER & ASSOCIATES, INC.
ON OCTOBER 14, 2011.

GRAPHIC SCALE IN FEET

NOTE

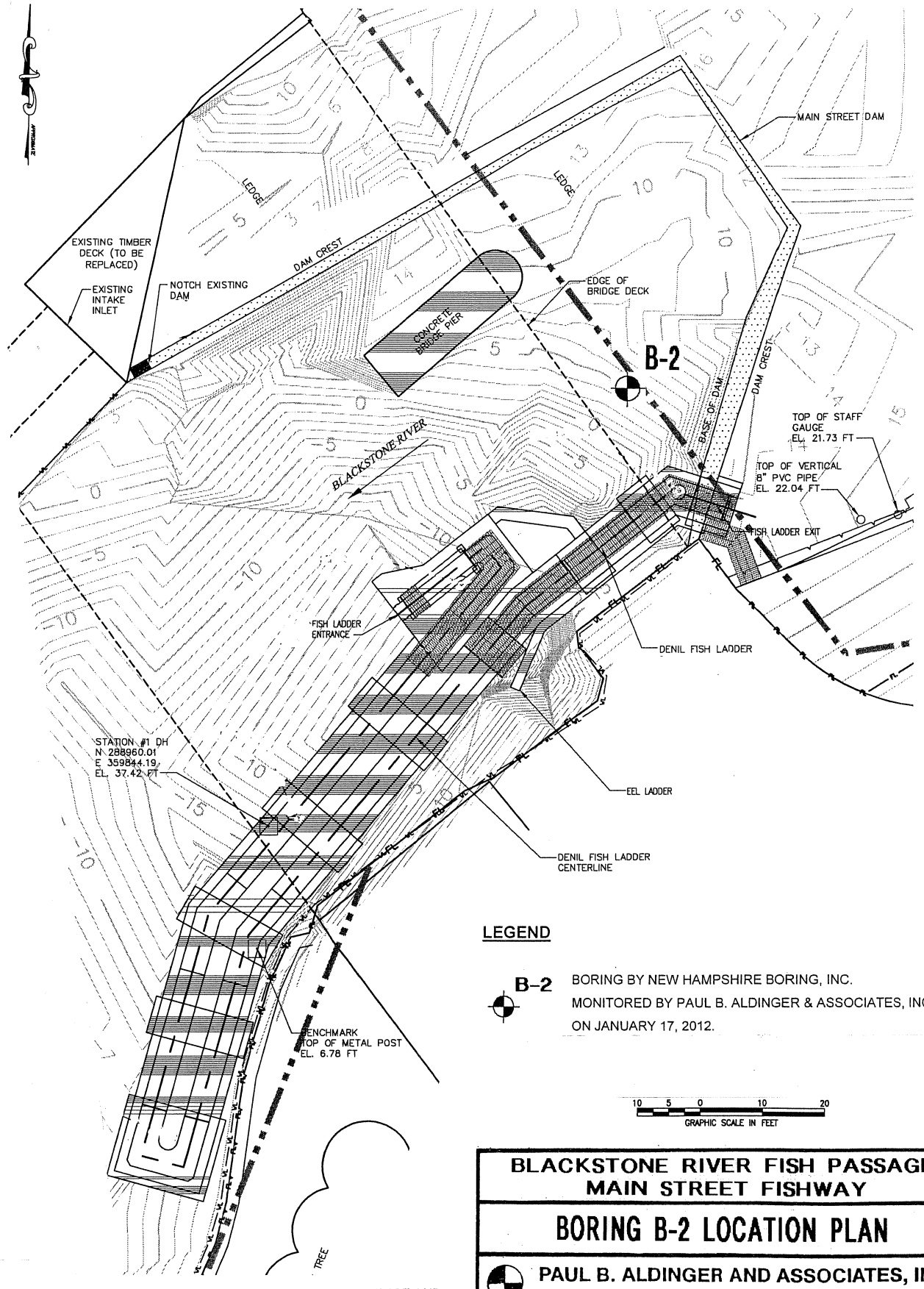
1. BASE PLAN DEVELOPED FROM PLAN BY EA ENGINEERING, SCIENCE AND TECHNOLOGY, TITLED "PROPOSED SITE PLAN, BLACKSTONE RIVER FISH PASSAGE RESTORATION PROJECT, SLATER MILL FISHWAY, PAWTUCKET, RHODE ISLAND", DATED APRIL 2011.

BLACKSTONE RIVER FISH PASSAGE SLATER MILL FISHWAY

BORING B-1 LOCATION PLAN

PAUL B. ALDINGER AND ASSOCIATES, INC.
Consulting in Geotechnical Engineering and Geohydrology

SCALE:	DATE:	FIGURE NO.
Graphic	Feb 2012	2



LEGEND

B-2 BORING BY NEW HAMPSHIRE BORING, INC.
MONITORED BY PAUL B. ALDINGER & ASSOCIATES, INC.
ON JANUARY 17, 2012.

10 5 0 10 20
GRAPHIC SCALE IN FEET

NOTE

1. BASE PLAN DEVELOPED FROM PLAN BY EA ENGINEERING, SCIENCE AND TECHNOLOGY, TITLED "PROPOSED SITE PLAN, BLACKSTONE RIVER FISH PASSAGE RESTORATION PROJECT, MAIN STREET FISHWAY, PAWTUCKET, RHODE ISLAND", DATED APRIL 2011.

BLACKSTONE RIVER FISH PASSAGE MAIN STREET FISHWAY

BORING B-2 LOCATION PLAN

PAUL B. ALDINGER AND ASSOCIATES, INC.
Consulting in Geotechnical Engineering and Geohydrology

SCALE:	DATE:	FIGURE NO.
Graphic	Feb 2012	3

APPENDIX A

LIMITATIONS

APPENDIX A

LIMITATIONS

A. Explorations

1. The analyses and recommendations submitted in this report are based in part upon the data obtained from subsurface explorations. The nature and extent of variations between these explorations may not become evident until construction. If variations then appear evident, it will be necessary to reevaluate the recommendations of this report.

2. The generalized soil profiles described in the text and shown on the figures are intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and have been developed by interpretations of widely spaced explorations and samples; actual soil transitions are probably more erratic. For specific information, refer to the boring logs.

3. Water level readings have been made in the drill holes at times and under conditions stated on the boring logs. These data have been reviewed and interpretations have been made in the text of this report; however, it must be noted that fluctuations in the level of the groundwater may occur due to variations in rainfall, temperature, tide and other factors occurring since the time measurements were made.

B. Review

1. In the event that any changes in the nature, design, or location of the proposed structures are planned, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report are modified or verified in writing by Paul B. Aldinger & Associates, Inc. It is recommended that this firm be provided the opportunity for a general review of final design and specifications, in order that earthwork and foundation recommendations may be properly interpreted and implemented in the design and specifications.

C. Construction

1. It is recommended that this firm be retained to provide soil engineering services during construction of the excavation and foundation phases of the work. This is to observe compliance with the design concepts, specifications, or recommendations and to allow design changes in the event that subsurface conditions differ from those anticipated prior to the start of construction.

D. Use of Report

1. This report has been prepared for the exclusive use of EA Engineering, Science & Technology for specific application to the proposed Blackstone River Fish Passage Improvements in Pawtucket, Rhode Island in accordance with generally accepted soil and foundation engineering practices. No other warranty, express or implied, is made.

2. This report may contain comparative cost estimates for the purpose of evaluating alternative construction schemes. These estimates may also involve approximate quantity evaluations. It should be noted that quantity estimates may not be accurate enough for construction bids. Since Paul B. Aldinger & Associates, Inc. has no control over labor and materials cost and design, the estimates of construction costs have been made on the basis of experience. We cannot guarantee the accuracy of cost estimates as compared to contractors' bids for construction costs.

APPENDIX B

TEST BORING LOGS

Client Name	New Hampshire Boring, Inc.	Sheet 1 of 1	**Boring No.** B - 1
P.B. Aldinger Associates	1215 West Chestnut St. Brockton, MA 02301	NHB JOB NUMBER: 22667	
City/Town: Pawtucket, RI		PROJECT NAME: Blackstone Fish Ladder	

Location: Main Street	Date & Time Started	Date & Time Completed	Total Hours Worked
Groundwater Depth (Feet): Date & Time: 10/14/11	10/14/2011	10/14/2011	
DRILLER: Todd Penticost	HELPER: Tyler Lancaster		
Ground Elevation: ± 29.0	Inspector's Name (Print): E. Dessert	Inspector's Company: P.B. Aldinger Assoc.	

Sample Number	Depth Range (Feet)	Blow Counts per 6 Inches 0-6	6-12	12-18	18-24	Recovery (inches)	Field Description	Strata Changes
S-1	0-2	Push				24/8	6" Topsoil, grass/brown, FINE TO COARSE SAND and GRAVEL (FILL)	
S-2	4-6	5	10	22	9	24/12	Medium dense, brown, FINE TO COARSE SAND and GRAVEL, Cobbles, Boulders (FILL)	7.5'
							(Rollerbit 7.5' to 8' into rock)	
C-1	8-13				5 min	60/52	Slightly fractured, layered, gray SHALE and SANDSTONE BEDROCK	
					5 min		Recovery = 87% RQD = 76.7%	
					5 min			
					7 min			
					7 min			
C-2	13-18				5 min	60/54	Slightly fractured, layered, gray SHALE and SANDSTONE BEDROCK	
					6 min		Recovery = 90% RQD = 75%	
					6 min			
					7 min			
					6 min			
							BOE 18'	

Remarks:

AUGER SIZE:

CASING SIZE: HW

SPLIT SPOON SIZE: 4"

DRILL RIG TYPE: D50 Remote

Penetration Resistance (N) Guide

Cohesionless Soils (Sands, Gravels)		Cohesive Soils (Silts, Clays)	
Relative Density	Penetration Resistance	Consistency	Penetration Resistance
Very Loose	0 - 4	Very Soft	0 - 2
Loose	4 - 10	Soft	2 - 4
Medium Dense	10 - 30	Medium Stiff	4 - 8
Dense	30 - 50	Stiff	8 - 15
Very Dense	Over 50	Very Stiff	15 - 30
		Hard	Over 30

N = Sum of Second and Third 6" Blow Counts

Terms Used for Second Entry of Descriptions: and = 40-50%, some = 10-40%, trace = 10% or less

Client Name	New Hampshire Boring, Inc. 1215 West Chestnut St. Brockton, MA 02301	Sheet 1 of 1	**Boring No. B - 2**
P.B. Aldinger Associates		NHB JOB NUMBER: 22667	
City/Town: Pawtucket, RI		PROJECT NAME: Blackstone Fish Ladder	

Location: Main Street	Date & Time Started	Date & Time Completed	Total Hours Worked
Groundwater Depth (Feet): Date & Time: 01/17/12	1/17/2012	1/17/2012	
DRILLER: Peter Rosinha	HELPER: James Olney		
Ground Elevation: ± 5.5	Inspector's Name (Print): E. Dessert	Inspector's Company: P.B. Aldinger Assoc.	

Sample Number	Depth Range (Feet)	Blow Counts per 6 Inches 0-6	6-12	12-18	18-24	Recovery (inches)	Field Description	Strata Changes
							Rollerbit 0-1' into rock	
C-1	1-6				6 min	60/52	Slightly fractured, gray, SANDSTONE BEDROCK	
					7 min			
					7 min		Recovery = 87% RQD = 70%	
					7 min			
					6 min			5.5'
C-2	6-11				6 min	60/60	Slightly fractured, reddish/gray, SHALE BEDROCK	
					6 min			
					6 min		Recovery = 100% RQD = 87.5%	
					7 min			
					6 min			
C-3	11-16				6 min	60/60	Slightly fractured, reddish/gray, SHALE BEDROCK	
					6 min			
					6 min		Recovery = 100% RQD = 93.3%	
					7 min			
					7 min			
					6 min			
							BOE 16'	
							NOTES:	
							1. Top of bridge sidewalk ±El.37.5. Top of rock 32' below(±El. 5.5)	
							2. Cored through bridge sidewalk with 6" thinwall (± 8" thick)	
							3. Extended 4" casing to top of rock	

Remarks:

AUGER SIZE:

CASING SIZE: HW

SPLIT SPOON SIZE: 4"

DRILL RIG TYPE: D50 M

Penetration Resistance (N) Guide

Cohesionless Soils (Sands, Gravels)		Cohesive Soils (Silts, Clays)	
Relative Density	Penetration Resistance	Consistency	Penetration Resistance
Very Loose	0 - 4	Very Soft	0 - 2
Loose	4 - 10	Soft	2 - 4
Medium Dense	10 - 30	Medium Stiff	4 - 8
Dense	30 - 50	Stiff	8 - 15
Very Dense	Over 50	Very Stiff	15 - 30
		Hard	Over 30

N = Sum of Second and Third 6" Blow Counts

Terms Used for Second Entry of Descriptions: and = 40-50%, some = 10-40%, trace = 10% or less