

Bowers & Harris Pond

SEDIMENT ANALYSIS STUDY



August 2013

Prepared for:

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1.0 Introduction

Bowers Pond and Harris Pond are drinking water reservoirs located in series in southern New Hampshire, straddling the border between the towns of Merrimack and Nashua. These two drinking water reservoirs provide the primary storage volume of a riverine reservoir pond system in series, consisting of Holts Pond, Bowers Pond, and Harris Pond. The drinking water reservoirs were created in the late 1800s as a result of damming portions of Pennichuck Brook and are currently operated by Pennichuck Water Works, Inc. in Merrimack, New Hampshire. The upper Pennichuck Brook watershed is mainly rural in nature, becoming more developed closer to the ponds, with a highly developed corridor consisting of commercial, industrial, and high density residential development running through portions of Amherst, Merrimack and Nashua. A major state highway, the Everett Turnpike, also runs through the lower watershed and intersects Bowers Pond. An ortho-photo of the Pennichuck Brook sub-watershed, revealing the setting of the ponds within the surrounding watershed is presented in Appendix A and is titled “Pennichuck Brook Subwatershed Ortho-photo.”

A sediment impact study was completed in November 2012 by Comprehensive Environmental Inc. (CEI) to evaluate sediment accumulation between 2000 and 2010. The results of the investigation showed that sediments measured in 2000 had moved around in the pond system and new sediment accumulations were also evident, including formation of a sediment ‘island’. Recommendations were made to evaluate whether the sediment is accumulating faster than expected, the source of the sediment accumulation and responses needed to reduce and/or prevent sediment accumulation from continuing. This sediment investigation study was initiated to perform the recommended evaluations.

This project included the following scope:

1. Estimate expected sediment loadings over time based on land uses, standard sanding factors, algal die-off and stream channel deposition
2. Identification of locations for collection of sediment cores
3. Collect sediment core samples
4. Install sediment sampling gages
5. Report Findings & Accumulation Estimates

The Pennichuck Brook watershed was separated into 21 sub-watershed areas to complete modeling for the Watershed Restoration Plan and to differentiate between areas of interest throughout this sediment study. A subwatershed map titled “Pennichuck Brook Model Subwatershed Map” is provided in Appendix A which details this watershed breakdown.

2.0 Data Collection and Field Work

2.1 Sediment Core Collection

CEI subcontracted the company Soil Exploration to perform soil sediment borings from a floating barge at 13 pre-determined locations along Harris and Bowers Pond. Using the 2010 Sediment Depth map prepared by CEI, these locations were chosen near incoming tributaries,



and in existing sediment deltas within multiple sections of both ponds. These locations were selected to represent incoming sediments and those that have accumulated over the long-term based on where sediment deltas have settled. Sediment core samples were retrieved at each of the thirteen locations, at 4-foot depth intervals to a maximum depth of 12 feet. These intervals began at the soil/water interface and terminated when substantial amounts of clay, mud, or solid sand was encountered. Reaching refusal, or when the slide hammer could no longer advance the sample tube into the underlying soils, was assumed to represent the original hardened sediment river bottom prior to the construction of the dams. This assumption is based on the fact that smaller sediments and organic material were located above these sediment layers.

The boring process began by using a slide hammer to drive a sampling tube down to a depth of four feet to collect the first core sample. The clear, hollow, plastic sampling tubes have an approximate diameter of 1.5 inches and collected material as they were driven into the underlying soils. Once the sample tube was extracted, a metal casing with an approximate diameter of 3 inches was driven down to the same depth and a device was lowered to wash the inside diameter of the casing out. This was done to widen the borehole for easy entry for the next interval and to ensure that the first four feet of extracted material would not be disturbed by a potential collapse of the surrounding material. This process was repeated for every subsequent soil sample until “native” material or refusal was reached. Refusal was encountered only when hard sediment or other obstruction prevented the slide hammer from advancing the boring deeper into the soil beneath.

Once a boring was completed, the metal casings were extracted and an orange marking pole was placed in the borehole to permanently mark its location. The marking poles extend a few inches above the water’s surface so that the exact sampling locations can be easily located in the future in order to annually monitor sediment movement and accumulations. The coordinates for each borehole were also recorded using a handheld GPS unit. A map identifying the borehole locations across Bowers and Harris ponds, titled “Sediment Measurements” is located in Figure 1.0 of this report. Figures 2.0 and 3.0 provide boring profiles and material compositions for the soil encountered during the boring exploration for Bowers and Harris Ponds, respectively. A large scale map detailing these boring profiles is provided at the end of this report.

2.2 Sediment Core Analysis

The Core sample compositions were visually inspected and analyzed to determine the probable sources of the soil deposits. The amount of recovery for each 4-foot sampling section varied based on the type of sediment encountered. Soft organic and sandy material, for example, was heavily compressed during the boring process and the resulting core sample often measured far less than four feet in length. This compression was later accounted for during the analysis of the samples. During most of the borings, the sampled material had been compressed to approximately 50% of the total length of the core. A table titled “Pond Sediment Cores,” is located in Appendix B and contains the complete record of the sediment core samples taken from Harris and Bowers Pond including elevations, depths, and locations. Photos depicting each segment of the sediment cores are provided in Appendix A and titled “Sediment Core Photos”.



To expand upon the visual analysis of pond core samples, CEI contacted Dr. Clark Alexander, Professor at Skidaway Institute of Oceanography and Director of Applied Coastal Research Laboratory at Georgia Southern University in Savannah, GA for his expertise in sediment tracing. Dr. Alexander performed a Gamma Spectroscopy analysis on a select pond sediment core, which examines the aging characteristics of the collected material through radionuclide testing. Fallout radionuclides are present in most soils and can be natural and/or anthropogenic, depending on location. They are useful for tracing physical processes, such as soil mixing, erosion, and sedimentation as well as geochemical processes occurring at the earth's surface on timescales of years to decades ¹. Detection of fallout radionuclides is based on their half-life and rate of decay.

Gamma spectroscopy is a proven and reliable analytical method to detect and quantify unknown radionuclides in sample media ². The radionuclides tested for in the select soil samples included Caesium-137, Lead-210, and Beryllium-7. The presence of any of these three radionuclides in soil samples will likely present a “timeline” of when soil was deposited in a particular location over an extended period of time. This analysis is important in determining the rate of sediment buildup in the Pennichuck drinking water reservoirs.

Caesium-137 (Cs-137) is the radionuclide that has been most widely used as a sediment tracer. It is a man-made radionuclide, with a half-life of 30.2 years. Cs-137 was produced mainly from atmospheric testing of thermonuclear weapons, which ranged from the mid-1950s to the 1960s. Global fallout of Cs-137 began in 1954, peaked in the early 1960s, and reached near zero levels in the mid-1980s. Nuclear power station accidents, such as the Chernobyl disaster in 1986 have also contributed to Cs-137 fallout. Today, if Cs-137 is detected in a soil sample, it can be used to trace when sediment was deposited based on its concentration and rate of decay.

Lead-210 (Pb-210) and Beryllium-7 (Be-7) are both fallout radionuclides of natural origin. Unlike Cs-137, these two radionuclides can be treated as essentially constant over time. Lead-210 has a half-life of 22.2 years and is derived from the decay of gaseous Rn-222. Lead-210 is commonly termed “unsupported” or “excess” Pb-210 when incorporated into soils and sediments, to distinguish it from the Pb-210 produced in situ by the decay of Ra-226. Pb-210 is measureable in soil for roughly 100 years (5 times its half-life). Be-7 has an extremely short half-life of 53 days and is produced by the bombardment of the Earth's atmosphere by cosmic rays and is subsequently deposited as fallout ³. As with Cs-137 and Pb-210, Be-7 can be used to trace sediment based on its concentration and rate of decay.

Prior to laboratory analysis, the entire sediment core was sliced along its cross-section into ten, 3-inch long sub-samples at areas of interest along the core to be sent in for analysis. Sub-samples were selected based on changes in material composition and where the highest concentrations of radionuclides might be located. Many factors were taken into consideration in

¹ Center for Applied Isotope Studies at the University of Georgia. Center for Applied Isotope Studies, n.d. Web. 1 June 2013. <http://cais.uga.edu/programs_applications/nuclear_monitoring/gamma_spectroscopy.php>.

² Dartmouth College Department of Earth Sciences. Dartmouth College, 6 Sept. 2011. Web. 2 June 2013. <<http://www.dartmouth.edu/~earthsci/labs/cosmolab.html>>.

³ Walling, Des E. "Using Environmental Radionuclides to Trace Sediment Mobilisation and Delivery in River Basins as an Aid to Catchment Management." *Proceedings of the Ninth International Symposium on River Sedimentation*. Exeter, UK: Department of Geography, University of Exeter, 2004. 121-35. [Print](#).



determining which core sample should be sent in for analysis. The boring at location (TB-9) in Bowers Pond was tested for these traces of fallout radionuclides due to both its unique composition and location near the Everett Turnpike, which was constructed in 1955. The boring at location TB-9 was a particularly interesting candidate for the radionuclide testing because it was anticipated that large quantities of sand found in the boring sample were a direct result of the construction of the Turnpike. Small, dark bands of material were also visible throughout this particular core, making it unique to most other cores. Lastly, this core sample presented clear transitions between different materials throughout its length. There were other cores located throughout the ponds that had similar composition to this location, so TB-9 was selected as the representative sample.

3.0 Sediment Load Calculations & Analysis

Desktop calculations were performed to estimate expected sediment loads from the surrounding watershed and their potential sources, including roadway sanding, surrounding land uses, channel deposition, and algal die-off.

The Pennichuck Brook watershed is currently comprised of five towns, which are as follows: Amherst, Hollis, Merrimack, Nashua, and Milford. Each town was asked to provide their best estimates regarding yearly sand usage, as well as the amount of lane miles that the town is responsible for maintaining. It is important to note that the amount of sand used varies annually based on storm frequency and severity. Seasonal state and private road sanding volumes have also been estimated and used to calculate a total volume of sand used in the Pennichuck Brook watershed.

Sediment loadings from surrounding land uses and stream bank erosion were also estimated. The surrounding watershed land uses contribute sediment to the water supply reservoirs as stormwater runoff erodes surfaces. During storm events of ranging severities, erosion of stream banks (channel deposition) can also cause sediment to accumulate in the reservoir ponds.

3.1 Sediment Observations

The thirteen sediment borings showed a layer of black, organic material was prevalent near the surface of almost every core. This organic material represents decaying plant matter that accumulates each year as lily pads, grass, cyanobacteria, forest debris, and other organic materials die and settle to the bottom of the ponds. This soft, dark material accounted for approximately 1-3 inches of the cores and a relatively small portion of the overall recovered material from the borings taken in Bowers and Harris ponds. Underneath the organic material, however, most of the cores revealed a transition to sand or silty sand. Some of the borings contained sand continuously throughout the sample, whereas others were underlain by larger sediments and finally clay or mud. Dark organic bands were also visible in some of the collected samples, including the boring sample that was tested for radionuclides (TB-9).

CEI sent ten soil samples from soil core TB-9, three inches in length, to S.W. Cole Engineering, Inc. for a laboratory gradation analysis. The results of this analysis confirmed that the samples consisted of mostly sand and fines (particles passing the #200 sieve). A table titled “Soil



Gradation Testing” is located in Appendix A and identifies each sample sent in for analysis, followed by the results of the gradation analysis. A series of boring logs titled “Sediment Core Boring Logs” are provided in Appendix A and detail the material composition of each core taken in the ponds. This information was used to generate profile views of the thirteen borings including their compositions and depths using AutoCAD. Profile drawings of the pond cores are detailed in Figures 2.0 and 3.0 and depict a scaled representation of the borings horizontally, as well as vertically across Bowers and Harris ponds respectively.

3.2 Expected Sediment Load Analysis

Sediment loads from roadway sanding operations were estimated using sanding rates obtained from town highway/winter operations departments, and using extrapolated sanding application rates for state and private roads. For example, it was assumed that state-owned roads receive less sand than town-owned roads, but are subject to a heavier salt loading. Privately owned roads were assumed to receive more sand than other roads, but are much less numerous than state and town-owned roads. GIS was used to differentiate between and quantify town, state, and private roads. The sand volumes used were divided between the number of lanes and lane miles in each sub-watershed area to determine the volume of sand that would theoretically reach the reservoir ponds. This information was used to determine an estimated volume of sand accumulating each year within each sub-watershed from the combined sanding of town, state, and private roads. A spreadsheet containing a summary of the calculated yearly sand loadings from town, state, and private roads within these 21 sub-watersheds is titled “Seasonal Sand Usage” and is located in Appendix B of this report. A breakdown of the yearly sand usage for town, state, and private roads within each of the 21 sub-watershed areas is included in the spreadsheet.

Land use coefficients and the acreage of land for each land use category were used to determine estimated Total Suspended Solids (TSS) contributions for each sub-watershed area. TSS quantities were relatively small when compared to the calculated sand use volumes per sub-watershed area, but still represent a major contribution to the pond sediment accumulation. TSS results, titled “Total Suspended Solids Loadings” can be found in Appendix B of this report.

Estimates of stream bank erosion loadings were calculated using a “Lateral Erosion Rate” formula ($LER=aQ^{0.6}$) which accounts for many factors, such as flow, % developed land, curve number, k-factor, animal density, an empirical constant, and average slope of the contributing subwatershed to a specific stream segment. A model, “Equations for estimating bankfull-channel geometry and discharge for streams in the northeastern United States” (Gardner C. Bent, USGS) was used to determine bankfull stream width, depth, cross-sectional area, and discharge for a given subwatershed, which was necessary to determine a volume of erosion for various tributaries in the Pennichuck Brook watershed. Lateral erosion rates were calculated for sub-watershed areas that contained major tributaries in the Pennichuck Brook watershed, namely Witches Brook and Pennichuck Brook. These sub-watersheds were divided up between three monitoring locations (12-PEN, 01-WCH, and 09T-PEN) along Pennichuck Brook, Witches Brook, and through Holts Pond. Using this equation, a total estimated value of stream bank erosion was calculated for each sub-watershed area containing tributaries that flow through the three monitoring locations. Common obstacles that would normally be identified during field



observations such as rocks, culvert pipes, and tree roots were not factors that could be accounted for using this particular formula.

Using the USGS bankfull stream bank erosion analysis resulted in an overestimation in the volume of sediment that was being contributed to the ponds. The calculated volume produced approximately 99,400 yd³/yr of stream bank eroded sediment. This loading did not correlate when compared to the calculated combined loading of sand usage and TSS, which is approximately 3,400 yd³/yr. Therefore, a relatively small amount of sediment erodes from stream banks and actually reaches the reservoir ponds on a yearly basis. General observations showed that common obstacles such as culvert pipes, tree roots, and rocks prevent eroded stream bank material from reaching the reservoirs all at once during common storm events. A detailed stream morphology assessment of the contributing streams would be necessary to determine a representative amount of stream bank erosion and resulting annual sediment accumulation to the reservoir ponds. This assessment could provide information regarding the amount of time that it takes for a certain volume of eroded sediment to reach the ponds from various locations along the stream. A summary of roadway sand, stream bank, and land use contributions to the watershed is presented in Table 1.0 in this report and is titled “Total Watershed Loading Estimates.”

3.3 Sediment Accumulation Using Gamma Spectroscopy

The Gamma Spectroscopy analysis performed on sediment core TP-9 was used to identify a range of possible accumulation rates based on the length of the core sub-sample and presence of radionuclides. Based on the amount of sediment recovery in this core sample compared to the depth of the boring, a compaction rate of 50% was used for every core sample obtained.

Beryllium-7 (Be-7) was not detected in any of the 10 sub-samples. Be-7 has a very short half-life (approximately 53 days) and its absence indicates that there has been little, if any, sediment accumulation to this area of Bowers Pond in the last six months.

Caesium-137 (Cs-137) was present above detection limits only in the first core interval, representing the top 6 inches (15.24 centimeters) of sediment in the pond at this location. Since 1954 was the first year Cs-137 was introduced into the atmosphere and 2012 was the year the sample was taken, a conservative accumulation rate of 0.26 cm/yr was calculated (15.24 cm over 58 years).

Lead-210 (Pb-210) results indicated that Pb-210 was present above detection limits only in some of the top core intervals, representing roughly 12-33 inches (a maximum of 85 cm) of sediment in the pond at this location. Since Pb-210 decays over a period of approximately 112 years, its decay profile should be captured in the material that was present during the time period of the construction of the dams and reservoir ponds. Using the obtained radiochemical data results for Pb-210, a more conservative accumulation rate of 0.85 cm/yr was calculated (approximately 85 cm over 100 years). Copies of Dr. Alexander’s results and conclusive report can be found in Appendix D of this report.



3.4 Summary of Findings

The two sediment accumulation rates produced by the radiochemical analysis may represent the upper and lower limits of a possible range of accumulation rates. Sediment may have accumulated at a faster rate several years ago or been the result of a specific contribution, such as construction of the Everett Turnpike crossing, and then slowed down when construction slowed down. Based on the limited number of samples analyzed, the decay profiles of Cs-137 and Pb-210 could not provide an exact accumulation rate for the particular section (TP-9) in Bowers Pond.

However, subsequent comparison of the radiochemical results with the estimated sediment loadings from the watershed does yield useful information. The surface area of each pond was delineated from the 2010 Bathymetry Map and then multiplied by each sediment accumulation rate to obtain a range of yearly sedimentation volumes. According to the radiochemical data and 2010 Bathymetry Map, sediment accumulation rates range from about 1,750 yd³/yr (0.26 cm/yr) to 5,730 yd³/yr (0.85 cm/yr). The estimated watershed sediment loadings determined through land use calculation were about 3,420 yd³/yr. This falls within the range predicted by the Gamma Spectroscopy results, indicating these accumulation estimates are consistent for this pond. Despite this correlation, there are still potential sources of sediment that could contribute to the higher accumulation rate (e.g. stream bank erosion and sediment migration).

The sediment core analyzed for radiochemical contents represents the sediment accumulation rate for only one specific area in Bowers Pond at TP-9. Accumulation rates vary from pond to pond due to varying land uses and restrictions (e.g., culverts, dams, wetlands) in each contributing drainage area. Holts Pond is the first receiving water body in the Pennichuck Brook water supply system and has the largest direct contributing area without significant upstream attenuation through pond settling, essentially serving as a detention basin to the downstream ponds. This would suggest that Holts Pond contains the most amount of sediment, followed by Bowers Pond, and finally Harris Pond.

To summarize the radiochemical analysis results, Cs-137 was introduced to the atmosphere, mainly during the 1950's, as a result of thermonuclear weapons testing in the western United States. The resulting radionuclide's widespread deposit has made it possible to aid in determining the aging characteristics of the underlying soils since the time of its introduction and rate of decay is known. The detection of Cs-137 at a depth of 6 inches results in a lower accumulation rate of 0.26 cm/yr (1,750 yd³/yr) for the ponds over a 50-60 year period. This was determined by detecting and partially capturing the Cs-137 radionuclide's decay profile during the radiochemical analysis. The resulting accumulation of 1,750 yd³/yr was determined by spreading the 0.26 cm/yr accumulation over the surface area of the bottom of the ponds.

Pb-210 is a fallout radionuclide of natural origin and can be treated as essentially constant over time. Like Cs-137, Pb-210's decay profile can be captured in soils, but can be detected for up to approximately 100 years. The detection of Pb-210 found at a maximum depth of 33 inches results in a higher accumulation rate of 0.85 cm/yr (5,730 yd³/yr) for the ponds over a 100-120 year period. The resulting accumulation of 5,730 yd³/yr was determined by spreading the 0.85 cm/yr accumulation over the surface area of the bottom of the ponds.



The constant accumulation of Pb-210 also helps aid in determining soil aging characteristics since it is detectable in soils for a longer period of time than Cs-137. Since the decay profiles of each radionuclide had not been fully captured during the radiochemical analysis, two different accumulation rates had been calculated, which has been treated as the upper and lower bounds of possible accumulation rates. By comparing the lower (1,750 yd³/yr from Cs-137) and upper (5,730 yd³/yr from Pb-210) annual accumulation rates from the radiochemical analysis to the empirical calculations for land use and roadway maintenance activities; the predicted estimated annual loading rate can be confirmed. The approximate rate of 3,420 yd³/yr falls between the radiochemical accumulation rates and could be used as accurate prediction rate for estimating reservoir storage loss over time.

The approximate storage capacity of Bowers and Harris Ponds are 891,146 yd³ and 1,683,277 yd³, respectively. The surface areas of Bowers and Harris Ponds were delineated from the 2010 Bathymetry Map and used to calculate an accumulated sediment volume. Using the lower accumulation rate of 0.26 cm/yr produced by the Cs-137 analysis and extrapolating over 120 years (approximate time period of construction of the dams), an estimated 108,912 yd³ of sediment has accumulated in Bowers Pond. Over this time period, approximately 12% of the original drinking water storage capacity has been filled by sediment. When using the larger accumulation rate of 0.85 cm/yr produced by the Pb-210 analysis over 120 years, an estimated 355,877 yd³ of sediment has accumulated in Bowers Pond. This would account for almost 40% of the original drinking water storage capacity.

Using the lower accumulation rate of 0.26 cm/yr produced by the Cs-137 analysis and extrapolating over 120 years for Harris Pond, an approximate sediment volume of 94,396 yd³ has accumulated. This would account for approximately 5.6% of the original storage capacity of the reservoir. Using the larger accumulation rate of 0.85 cm/yr produced by the Pb-210 analysis over 120 years, an estimated 308,447 yd³ of sediment has accumulated in Harris Pond. This volume of sediment would account for approximately 18% of the original storage capacity of Harris Pond.

The above calculations assume that the pond volumes and delineated surface area of both ponds using the 2010 Bathymetry Map are representative of the original reservoir pond conditions and that sediment accumulations are distributed evenly across the entire surface area of each pond. This data would suggest that there is a concern regarding the sediment accumulation rates to each pond. Since the construction of the dams, Bowers Pond has lost 12% to 40% of its original drinking water capacity and Harris Pond has lost 5.6% to 18% of its original drinking water capacity.

Based on results from the previous sediment study completed in November of 2012, the sediment in Bowers and Harris Ponds has accumulated and migrated to different areas and has not spread evenly over time. It should be noted that the calculated sediment accumulations and storage capacity losses are assuming the accumulation of sediment has been evenly spread over the entire surface area of the pond bottoms, resulting in an average sediment depth through-out the ponds. This assumption could also provide a more conservative estimate of storage loss.



Visual observations were made during the recent soil exploration of sediment deltas and sediment “islands” forming in portions of Bowers Pond that appeared deeper than what was noted in the latest 2010 sediment mapping. Other core locations revealed less accumulation than previously noted in both 2000 and 2010, further confirming movement of sediment from some areas and the addition of sediment in others. Visual inspection of soil cores taken at these locations revealed material compositions that would support these results, however, without radiochemical analysis this cannot be confirmed. It is possible that large portions of the ponds do have deeper sediment depths resulting from higher accumulation rates compared to those analyzed at core location TB-9 and the conservative estimates for loss of storage could be accurate representing an average depth of sediment over the entire reservoir system.

As a result of these calculations, it is clear that further analyses need to be conducted to further refine the results. The range of sediment accumulation rates produced by the radiochemical analysis support the calculated accumulation rates produced by roadway maintenance sand usage and general land use TSS loadings over the entire watershed. This is true using data from one pond core sample from a single location. To obtain accurate sediment accumulation rates in each pond, more of the completed borings would need to be analyzed for radionuclides or more shallow cores taken at different locations throughout the reservoir ponds. This will provide useful information specific to each area and will be comparable to the data that has already been obtained. Comparing the compositions of the collected cores is helpful in determining probable accumulation rates relative core TB-9, but further radiochemical analyses would also be needed to accurately present those rates throughout each pond.

This would help confirm whether the accumulation results are accurate throughout the ponds, as well as provide additional “time stamps” on the sediment accumulation to determine if pond filling is occurring faster or slower than anticipated. Further analysis may also provide a more detailed sediment accumulation time period and rate rather than assuming the ponds have gradually filled over a 100-120 year period at a consistent rate. It is more likely the sediment accumulation has sped up in more recent years with increased watershed development. Additional time stamp data from radiochemical analysis could confirm this assumption.

Likewise, further analysis of stream bank erosion will need to be conducted to determine how much more sediment is contributing to the reservoir ponds from eroding tributaries. Although these estimates were not included in this report, it would be useful to know how much sediment erodes from the stream banks and what portion of that volume reaches the ponds on an annual basis. This resulting amount could provide clarification that the accumulation rate and loss of storage is closer to the upper end that was predicted from the radiochemical analysis, rather than be near the average of the two. The stream bank erosion and resulting sediment loading could make up the difference between the land use loading predictions and the storage loss due to the higher accumulation rate of 0.85 cm/yr.

4.0 Recommendations

To develop a more accurate representation of the actual sediment accumulation rate it is recommended that borings of up to 3 feet in length be taken, preferably by hand, in “ponded” locations in each reservoir. It is now known that the detectable radionuclide concentrations



reside within approximately 1 to 2 feet of the existing surface material and taking sediment samples by hand would provide a more representative sample of in situ conditions. By collecting samples in this manner, it is likely that a more accurate decay profile will be captured, giving much more insight as to what the actual accumulation rates may be.

Obtaining sediment accumulation rates in area(s) of each reservoir will not only reveal contributing sediment quantities from directly contributing watershed areas, but will also help determine how much sediment is passing over each dam. The cores that were sampled as part of this study could also be submitted for radiochemical analysis; however the half-lives of some of the radionuclides that could provide a more current detailed time stamp may not be detectable in the older samples. This will also provide a starting point for known accumulation sediment locations and depths to be further monitored through the sediment accumulation monitoring at each of the permanent boring location.

It is also recommended that secchi disk and echo-sounding procedures be conducted at each of the permanent boring locations once a year and once every 5 years, respectively, to closely monitor sediment accumulations. These recommended procedures were provided in the November 2012 sediment study completed by CEI. Water clarity can easily be recorded by using a secchi disk and the Acoustic Echo-sounding Method is a reliable technique frequently used to determine water depth.

The Acoustic Echo-sounding Method should be used to measure sediment depth at each of the permanent boring locations to record sediment movement and accumulations. This is done by first determining a fixed reference point, such as a spillway elevation. The current water level and its difference to the fixed reference point should be measured and recorded. Permanent staff gauges should be installed at each spillway to record the water level prior to performing echo sounding procedures.

At each permanent measurement point location, a secchi disk reading and depth to sediment (or pond bottom) should be obtained from the sonar unit and recorded in the logs that were provided in the November 2012 sediment study. Once this has been completed, the data should be inputted for processing by GIS to develop an elevation model. This will provide an annual comparison to determine the difference in sediment depths over time. By consistently measuring water clarity and depth, sediment migrating into the ponds and resulting accumulation rates can be continually monitored.

To further expand on the sediment accumulation mapping, GPS units with sonar capabilities can be used to measure pond depths and tied into the permanent boring locations as bench marks to cross reference and check newly acquired data points. Point by point depths using the sonar and GPS unit attached to an electrically powered boat could be obtained and used to take spatially accurate GPS points with invert elevations of the pond bottoms to create accurate bathymetric maps of the migrating sediment. Sampling could be done in a grid fine enough to yield a map of resolution similar to the baseline information, but could be updated on an annual basis to track sediment accumulation in some areas and sediment migration throughout the reservoir system. This process would be far less time consuming and cost effective compared to the transect



methods previously used. Measurements could also be more accurately cross referenced using newly acquired baseline information.

This data could not only be used to track accumulation over time, but also identify locations where sediment accumulation is the greatest, providing a prioritized map of locations that could be permitted and developed as permanent dredging locations for routine maintenance as sediment settles in the area.



Table 1: Total Watershed Loading Estimates

Sub-Watershed	Area (acres)	Roadway Loading				Streambank Loading (yd³/yr)	Land Use Loading (yd³/yr)	Total Loading (yd³/yr)	Roadway Loading				Streambank Loading (tons/yr)	Land Use Loading (tons/yr)	Totals (tons/yr)
		State (yd³/yr)	Town (yd³/yr)	Private (yd³/yr)	Totals (yd³/yr)				State (tons/yr)	Town (tons/yr)	Private (tons/yr)	Totals (tons/yr)			
3	662	39.2	31.4	14.7	85.3	5359.5	19.7	5464.4	52.9	42.4	19.8	115.1	7235.3	26.6	7377.0
4	233	9.2	4.9	6.0	20.1	3315.9	15.3	3351.2	12.4	6.6	8.1	27.1	4476.4	20.6	4524.1
5	19	0.9	0.5	0.0	1.4	68.6	0.1	70.1	1.2	0.6	0.0	1.8	92.7	0.1	94.6
6	1406	30.8	76.3	72.6	179.7	29292.7	54.8	29527.1	41.6	103.0	98.0	242.6	39545.1	73.9	39861.6
7	461	10.0	15.0	15.8	40.8	810.1	34.8	885.7	13.5	20.2	21.3	55.1	1093.7	47.0	1195.7
8	1088	2.0	36.5	73.0	111.5	4957.2	46.5	5115.3	2.7	49.3	98.6	150.5	6692.2	62.8	6905.6
9	960	20.2	177.6	17.7	215.5	20064.6	43.1	20323.2	27.3	239.7	23.9	290.9	27087.3	58.2	27436.3
10	491	0.0	82.9	0.7	83.6	2898.8	10.0	2992.4	0.0	111.9	0.9	112.9	3913.4	13.5	4039.8
11	665	0.0	173.7	1.7	175.4	1231.1	8.2	1414.6	0.0	234.4	2.3	236.7	1662.0	11.0	1909.7
12	939	0.0	114.3	7.4	121.7	1211.2	10.0	1342.8	0.0	154.3	10.0	164.3	1635.1	13.4	1812.8
13	1768	0.0	304.9	3.0	307.9	3756.9	21.2	4086.0	0.0	411.6	4.1	415.7	5071.8	28.6	5516.1
14	1338	17.0	219.0	4.8	240.8	786.0	11.1	1037.9	23.0	295.7	6.5	325.1	1061.1	14.9	1401.2
15	26	0.0	4.0	1.3	5.3	246.1	0.3	251.8	0.0	5.4	1.8	7.2	332.3	0.4	339.9
16	34	0.0	0.0	0.0	0.0	2033.3	1.3	2034.6	0.0	0.0	0.0	0.0	2745.0	1.7	2746.7
17	1373	22.4	384.4	5.4	412.2	4404.9	37.9	4854.9	30.2	519.0	7.2	556.4	5946.6	51.1	6554.2
18	951	23.1	185.9	11.4	220.4	7347.6	36.3	7604.3	31.2	251.0	15.4	297.6	9919.2	49.1	10265.8
19	337	0.0	82.0	1.3	83.3	926.5	7.8	1017.6	0.0	110.6	1.8	112.4	1250.8	10.5	1373.7
20	686	12.9	51.3	12.5	76.7	2397.9	27.0	2501.6	17.4	69.3	16.9	103.5	3237.1	36.4	3377.1
21	105	0.5	14.6	0.0	15.1	2212.3	6.4	2233.8	0.7	19.8	0.0	20.4	2986.6	8.7	3015.7
22	1326	12.8	170.0	3.2	186.0	2122.5	16.3	2324.8	17.3	229.5	4.3	251.1	2865.4	22.0	3138.5
23	1686	7.2	318.5	6.9	332.6	3614.0	22.2	3968.8	9.7	430.0	9.3	449.1	4878.9	30.0	5357.9
24	741	0.7	60.4	3.2	64.2	360.8	12.2	437.2	0.9	81.5	4.3	86.7	487.1	16.4	590.3
Totals		2,979.45				99,418.52	442.23	cy / yr	Totals				134,215.01	597.01	ton / yr
		Total Roadway & Land Use Loadings					3,421.68	cy / yr	Total Roadway & Land Use Loadings					4,619.27	ton / yr
		Total of All Loadings					102,840.21	cy / yr	Total of All Loadings					138,834.28	ton / yr

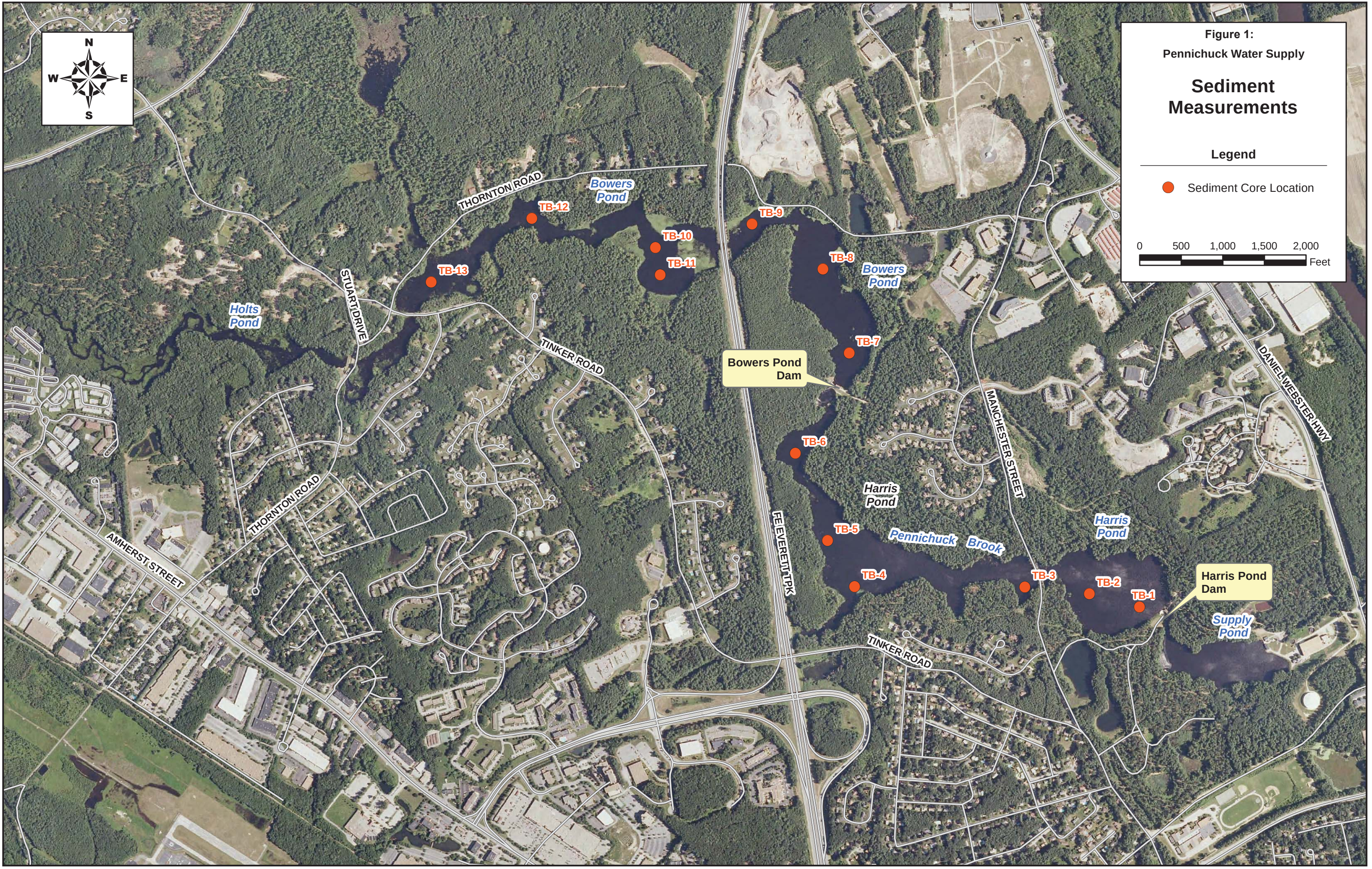
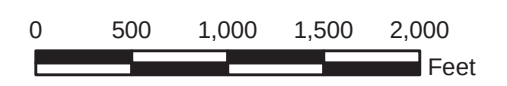
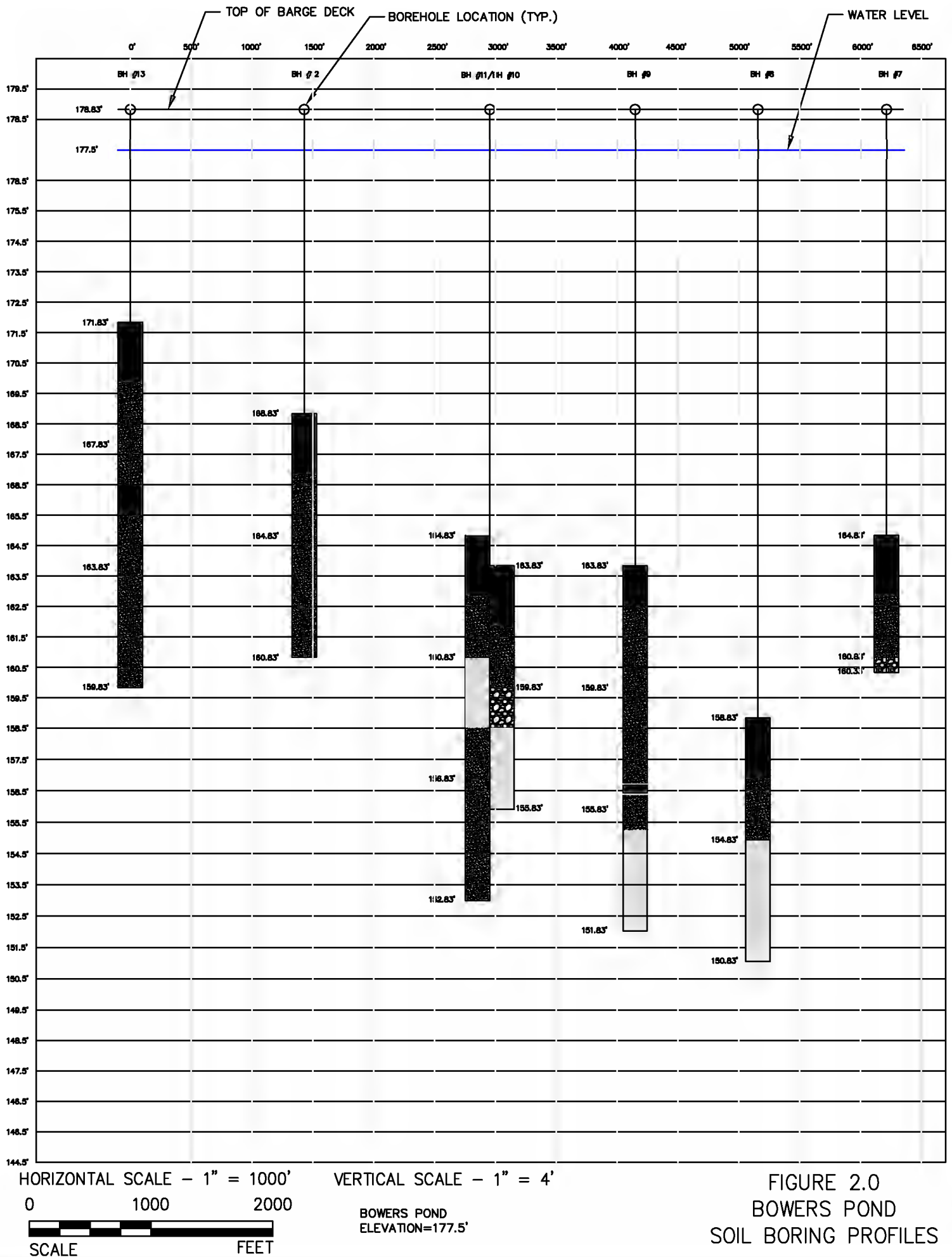


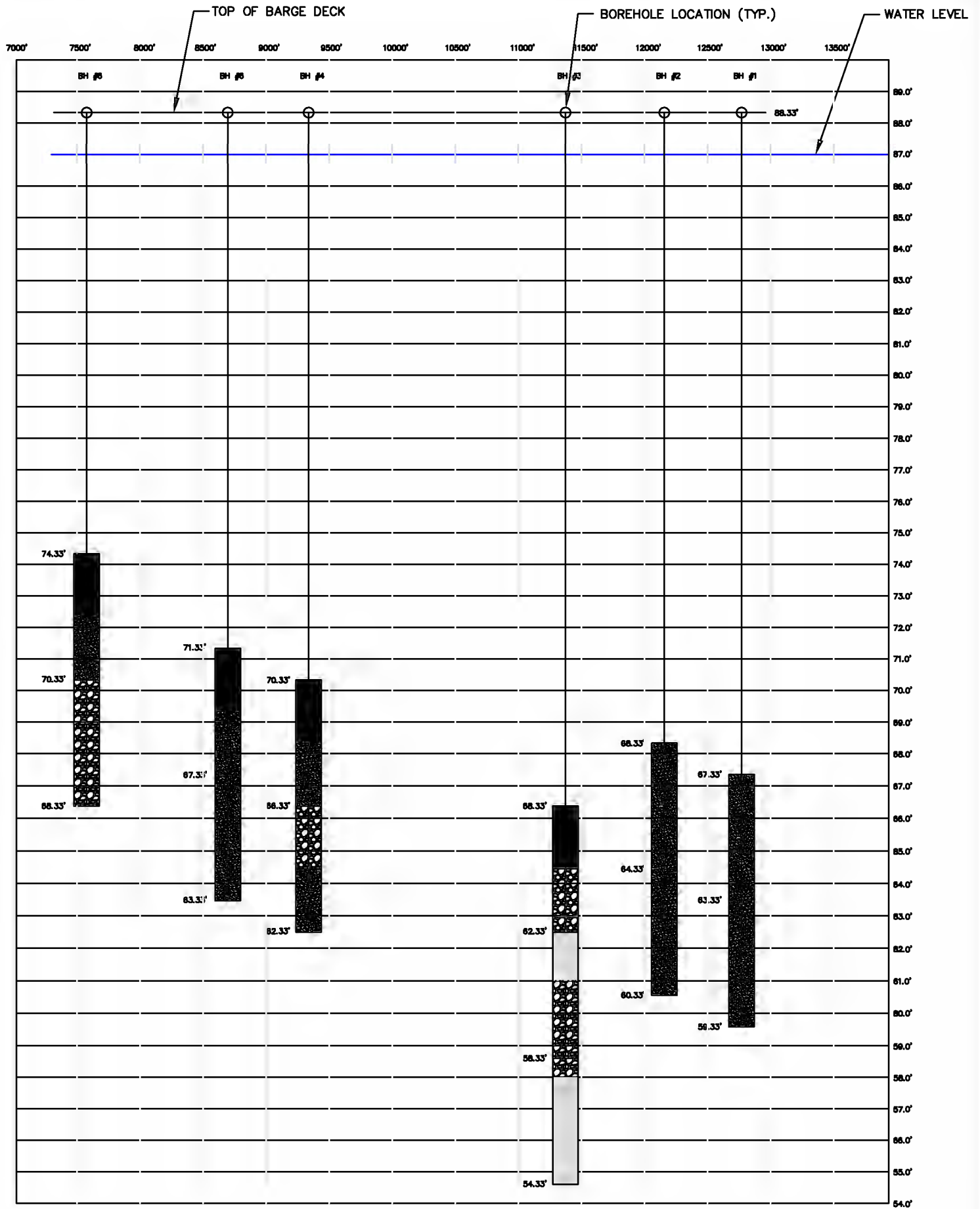
Figure 1:
Pennichuck Water Supply
**Sediment
Measurements**

Legend

- Sediment Core Location







HORIZONTAL SCALE - 1" = 1000'

0 1000 2000

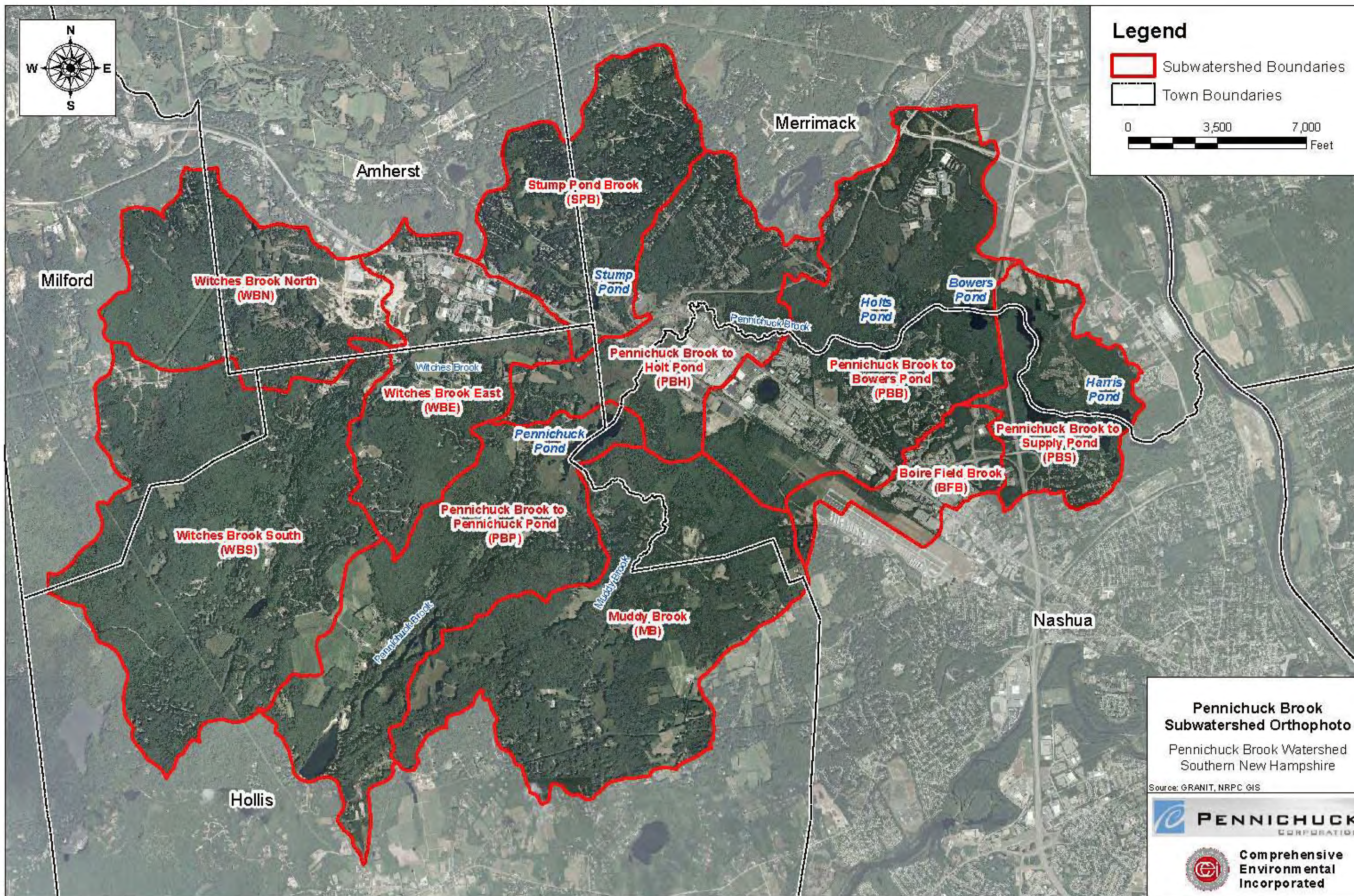
SCALE FEET

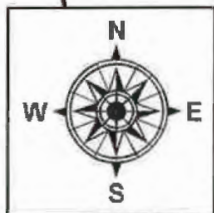
VERTICAL SCALE - 1" = 4'

HARRIS POND
ELEVATION=90.5'

FIGURE 3.0
HARRIS POND
SOIL BORING PROFILES

Appendix A

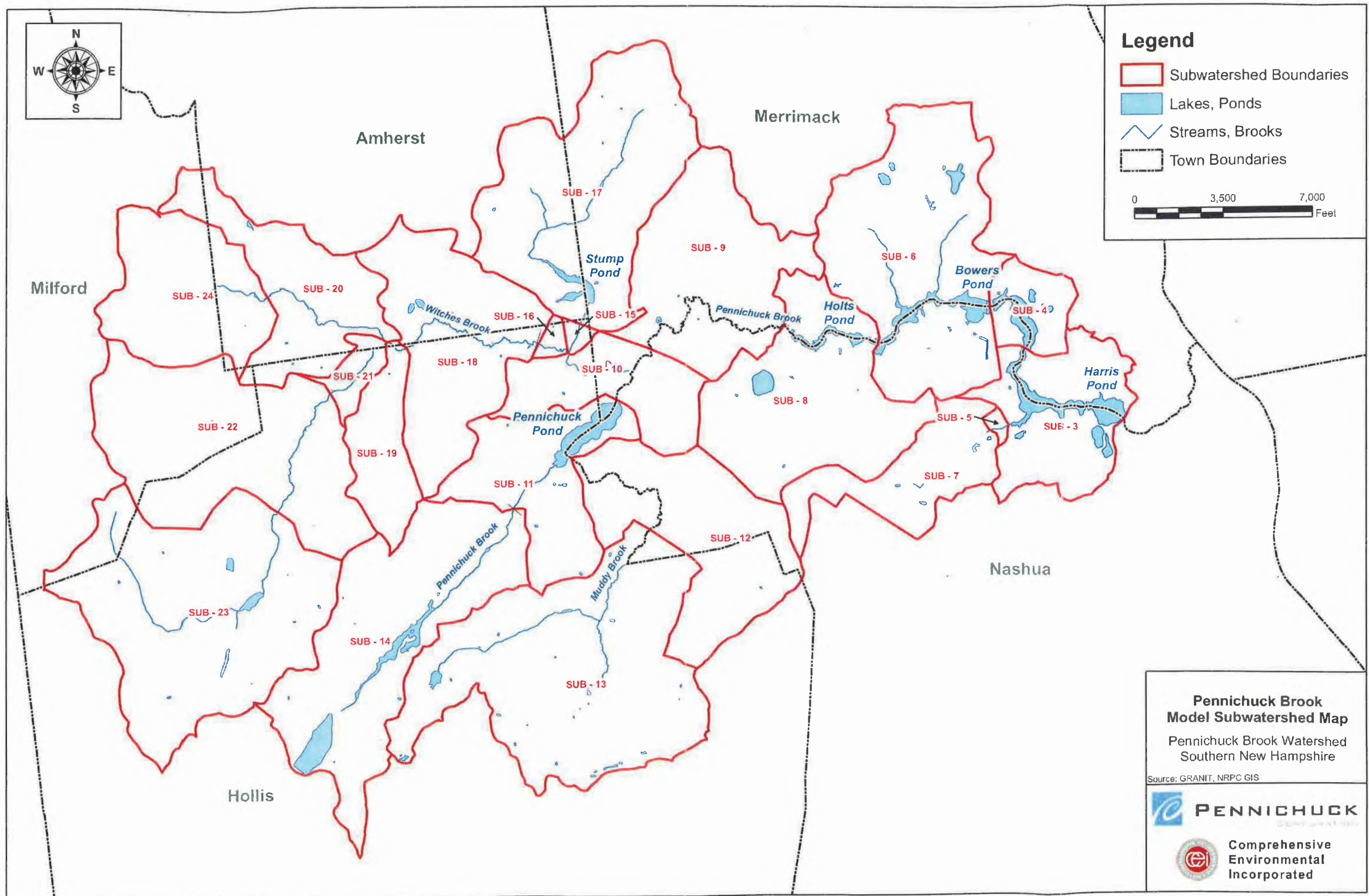




Legend

- Subwatershed Boundaries
- Lakes, Ponds
- Streams, Brooks
- Town Boundaries

0 3,500 7,000 Feet



**Pennichuck Brook
Model Subwatershed Map**

Pennichuck Brook Watershed
Southern New Hampshire

Source: GRANIT, NRPC GIS

PENNICHUCK

**Comprehensive
Environmental
Incorporated**

Appendix B

Pond Sediment Cores (Soil Exploration)

Soil Borings completed by: Brian and Rich (Soil Exploration, Leominster, MA)

Location	Point #	Sample #	Photo ID	T	Lab ID	Date	Time	H ₂ O Depth	Deck Height	H2O Depth	Local	Boring Depth		Elevation (top of deck)	Calculated Sample		Sample
								to Top of Deck			Datum Water Elevation	Interval (top of deck)	Elevations		Recovery (in)		
Harris Pond (elev.=87')	2	1	Harris TB2	T	2 - 1	10/3/2012	1:30 PM	20' 1"	16"	18' 9"	87.0	20'-24'	20	24	88.33	68.33 - 64.33	15.00
	2	2	Harris TB2	B	2 - 2		2:30 PM				87.0	24'-28'	24	28	88.33	64.33 - 60.33	26.25
	1	1	Harris TB1	T	1 - 1	10/4/2012	8:30 AM	20' 10"	16"	19' 6"	87.0	21'-25'	21	25	88.33	67.33 - 63.33	15.00
	1	2	Harris TB1	B	1 - 2		9:15 AM				87.0	25'-29'	25	29	88.33	63.33 - 59.33	27.75
	3	1	Harris TB3	T	3 - 1	10/4/2012	2:00 PM	22' 0"	16"	20' 8"	87.0	22'-26'	22	26	88.33	66.33 - 62.33	8.25
	3	2	Harris TB3	M	3 - 2		2:30 PM				87.0	26'-30'	26	30	88.33	62.33 - 58.33	12.00
	3	3	Harris TB3	B	3 - 3		3:00 PM				87.0	30'-34'	30	34	88.33	58.33 - 54.33	8.25
	4	1	Harris TB4	T	4 - 1	10/5/2012	8:00 AM	18' 0"	16"	16' 8"	87.0	18'-22'	18	22	88.33	70.33 - 66.33	7.75
	4	2	Harris TB4	B	4 - 2		8:30 AM				87.0	22'-26'	22	26	88.33	66.33 - 62.33	17.25
	5	1	Harris TB5	T	5 - 1	10/5/2012	10:30 AM	17' 0"	16"	15' 8"	87.0	17'-21'	17	21	88.33	71.33 - 67.33	16.25
	5	2	Harris TB5	B	5 - 2		11:00 AM				87.0	21'-25'	21	25	88.33	67.33 - 63.33	27.25
	6	1	Harris TB6	T	6 - 1	10/5/2012	12:30 PM	14' 0"	16"	12' 8"	87.0	14'-18'	14	18	88.33	74.33 - 70.33	16.25
	6	2	Harris TB6	B	6 - 2		1:30 PM				87.0	18'-22'	18	22	88.33	70.33 - 66.33	6.25
Bowers Pond (elev.=177.5')	7	1	Bowers TB7	T	7 - 1	10/9/2012	10:00 AM	14' 0"	16"	12' 8"	177.5	14'-18'	14	18	178.83	164.83 - 160.83	7.00
	7	2			-		10:30 AM				177.5	18'-18' 6"	18	18.5	178.83	160.83 - 160.33	No Sample
	8	1	Bowers TB8	T	8 - 1	10/9/2012	11:45 AM	20' 0"	16"	18' 8"	177.5	20'-24'	20	24	178.83	158.83 - 154.83	21.25
	8	2	Bowers TB8	B	8 - 2		12:35 PM				177.5	24'-28'	24	28	178.83	154.83 - 150.83	24.50
	9	1	Bowers TB9	T	9 - 1	10/9/2012	2:00 PM	15' 0"	16"	13' 8"	177.5	15'-19'	15	19	178.83	163.83 - 159.83	24.75
	9	2	Bowers TB9	M	9 - 2		2:20 PM				177.5	19'-23'	19	23	178.83	159.83 - 155.83	26.00
	9	3	Bowers TB9	B	9 - 3		2:40 PM				177.5	23'-27'	23	27	178.83	155.83 - 151.83	25.50
	10	1	Bowers TB10	T	10 - 1	10/9/2012	3:15 PM	15' 0"	16"	13' 8"	177.5	15'-19'	15	19	178.83	163.83 - 159.83	15.50
	10	2	Bowers TB10	B	10 - 2		3:45 PM				177.5	19'-23'	19	23	178.83	159.83 - 155.83	14.00
	11	1	Bowers TB11	T	11 - 1	10/10/2012	8:15 AM	14' 0"	16"	12' 8"	177.5	14'-18'	14	18	178.83	164.83 - 160.83	24.75
	11	2	Bowers TB11	M	11 - 2		8:30 AM				177.5	18'-22'	18	22	178.83	160.83 - 156.83	13.00
	11	3	Bowers TB11	B	11 - 3		9:00 AM				177.5	22'-26'	22	26	178.83	156.83 - 152.83	14.75
	12	1	Bowers TB12	T	12 - 1	10/10/2012	9:50 AM	10' 0"	16"	8' 8"	177.5	10'-14'	10	14	178.83	168.83 - 164.83	17.75
	12	2	Bowers TB12	B	12 - 2		10:30 AM				177.5	14'-18'	14	18	178.83	164.83 - 160.83	29.50
	13	1	Bowers TB13	T	13 - 1	10/10/2012	11:05 AM	7' 0"	16"	5' 8"	177.5	7'-11'	7	11	178.83	171.83 - 167.83	18.50
	13	2	Bowers TB13	M	13 - 2		11:30 AM				177.5	11'-15'	11	15	178.83	167.83 - 163.83	18.25
	13	3	Bowers TB13	B	13 - 3		12:00 PM				177.5	15'-19'	15	19	178.83	163.83 - 159.83	25.75

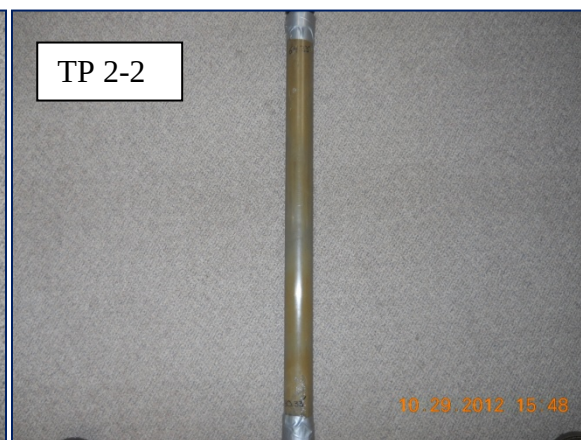
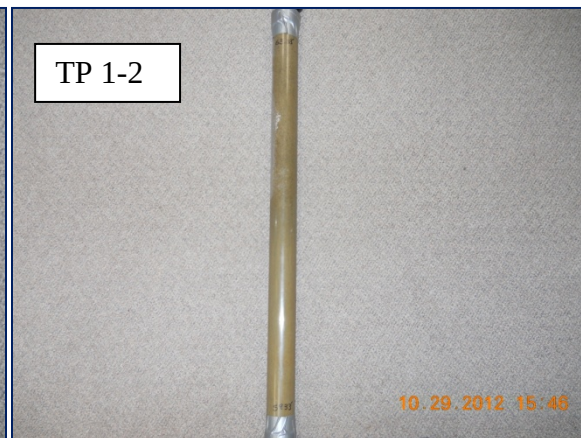
Pond Sediment Cores (Soil Exploration)

Soil Borings completed by: Brian and Rich (Soil Exploration, Leominster, MA)

Description	Photo ID	Lab ID	USGS		Boring		Elevation	Calculated Sample
			Assumed	Water	Interval	Depth		
			elevation		(top of		(top of	Elevations
					deck)		deck)	
sand/minimal organic material	Harris TB2	T 2 - 1	168.0		20'-24'	20	24	169.33 149.33 - 145.33
solid sand	Harris TB2	B 2 - 2	168.0		24'-28'	24	28	169.33 145.33 - 141.33
sand/minimal organic material-not many leaves; all pine	Harris TB1	T 1 - 1	168.0		21'-25'	21	25	169.33 148.33 - 144.33
very solid sand/minimum organic material	Harris TB1	B 1 - 2	168.0		25'-29'	25	29	169.33 144.33 - 140.33
soft/some organics to hard sediment	Harris TB3	T 3 - 1	168.0		22'-26'	22	26	169.33 147.33 - 143.33
slight organic material (soft) to sediment (hard)	Harris TB3	M 3 - 2	168.0		26'-30'	26	30	169.33 143.33 - 139.33
very solid sediment to silt	Harris TB3	B 3 - 3	168.0		30'-34'	30	34	169.33 139.33 - 135.33
Little silt; sandy; soft(organic sand)	Harris TB4	T 4 - 1	168.0		18'-22'	18	22	169.33 151.33 - 147.33
some sediment to sand; minimal organic material	Harris TB4	B 4 - 2	168.0		22'-26'	22	26	169.33 147.33 - 143.33
organic material to sand	Harris TB5	T 5 - 1	168.0		17'-21'	17	21	169.33 152.33 - 148.33
good sand/some organic bands	Harris TB5	B 5 - 2	168.0		21'-25'	21	25	169.33 148.33 - 144.33
organic/dark brown sand	Harris TB6	T 6 - 1	168.0		14'-18'	14	18	169.33 155.33 - 151.33
sandy gravel (hard); river bottom cobble	Harris TB6	B 6 - 2	168.0		18'-22'	18	22	169.33 151.33 - 147.33
light silt to solid sand	Bowers TB7	T 7 - 1	177.5		14'-18'	14	18	178.83 164.83 - 160.83
Refusal at 18' 6"-river bottom		-	177.5		18'-18' 6"	18	18.5	178.83 160.83 - 160.33
soft silt into soft sand	Bowers TB8	T 8 - 1	177.5		20'-24'	20	24	178.83 158.83 - 154.83
soft dark silt to grey silt	Bowers TB8	B 8 - 2	177.5		24'-28'	24	28	178.83 154.83 - 150.83
soft/dark silt to sand (soft)	Bowers TB9	T 9 - 1	177.5		15'-19'	15	19	178.83 163.83 - 159.83
sand into soft silt/some organic bands	Bowers TB9	M 9 - 2	177.5		19'-23'	19	23	178.83 159.83 - 155.83
soft silt to gravel (hard) at 26'	Bowers TB9	B 9 - 3	177.5		23'-27'	23	27	178.83 155.83 - 151.83
soft organic material to sand (soft)	Bowers TB10	T 10 - 1	177.5		15'-19'	15	19	178.83 163.83 - 159.83
gravel to silty sand	Bowers TB10	B 10 - 2	177.5		19'-23'	19	23	178.83 159.83 - 155.83
soft organic material to sand (soft)	Bowers TB11	T 11 - 1	177.5		14'-18'	14	18	178.83 164.83 - 160.83
silty sand to sand (soft)	Bowers TB11	M 11 - 2	177.5		18'-22'	18	22	178.83 160.83 - 156.83
sand (soft)	Bowers TB11	B 11 - 3	177.5		22'-26'	22	26	178.83 156.83 - 152.83
soft/dark organic material to sand (soft)	Bowers TB12	T 12 - 1	177.5		10'-14'	10	14	178.83 168.83 - 164.83
sand (soft)	Bowers TB12	B 12 - 2	177.5		14'-18'	14	18	178.83 164.83 - 160.83
soft/dark silt to sand (soft)	Bowers TB13	T 13 - 1	177.5		7'-11'	7	11	178.83 171.83 - 167.83
soft sand with organic bands	Bowers TB13	M 13 - 2	177.5		11'-15'	11	15	178.83 167.83 - 163.83
sand (soft)	Bowers TB13	B 13 - 3	177.5		15'-19'	15	19	178.83 163.83 - 159.83

Sediment Core Photos:

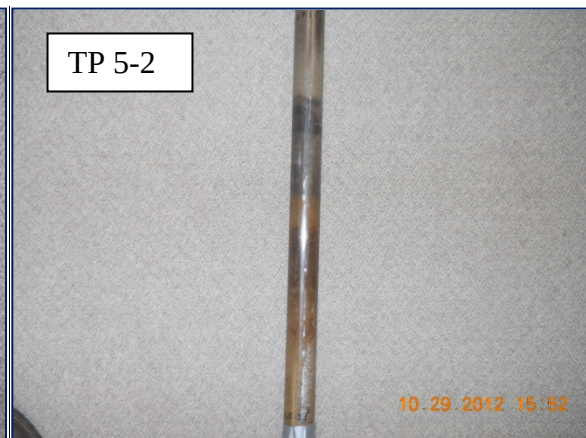
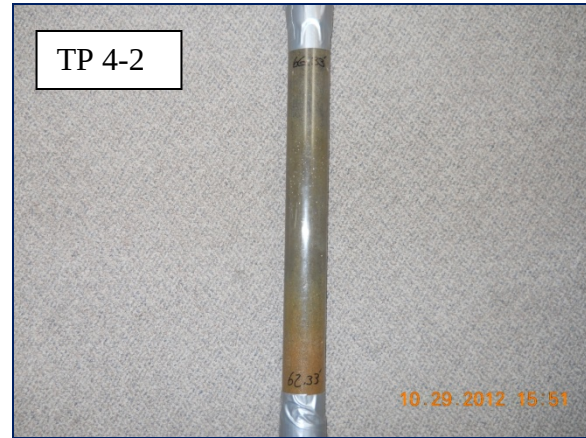
Harris Pond Core Samples



Harris Pond Core Samples:



Harris Pond Core Samples:



Harris Pond Core Samples:



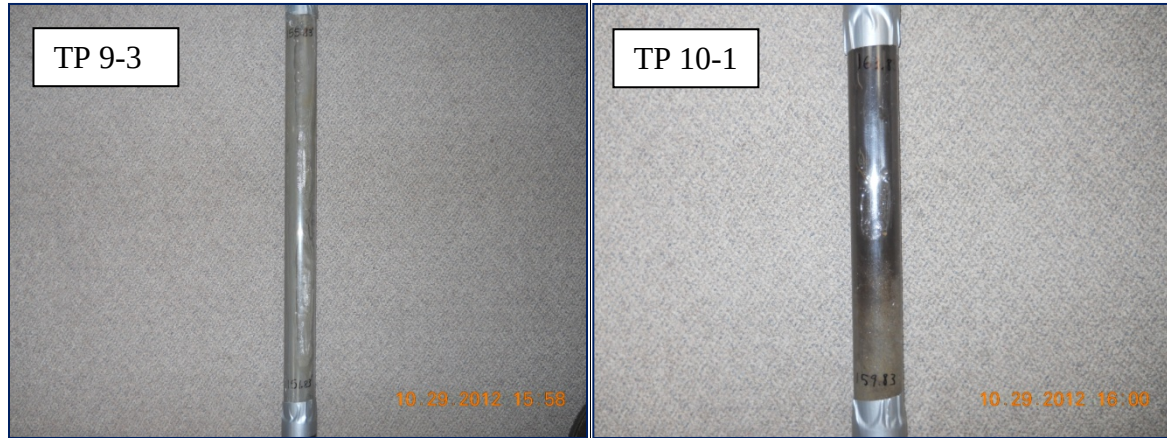
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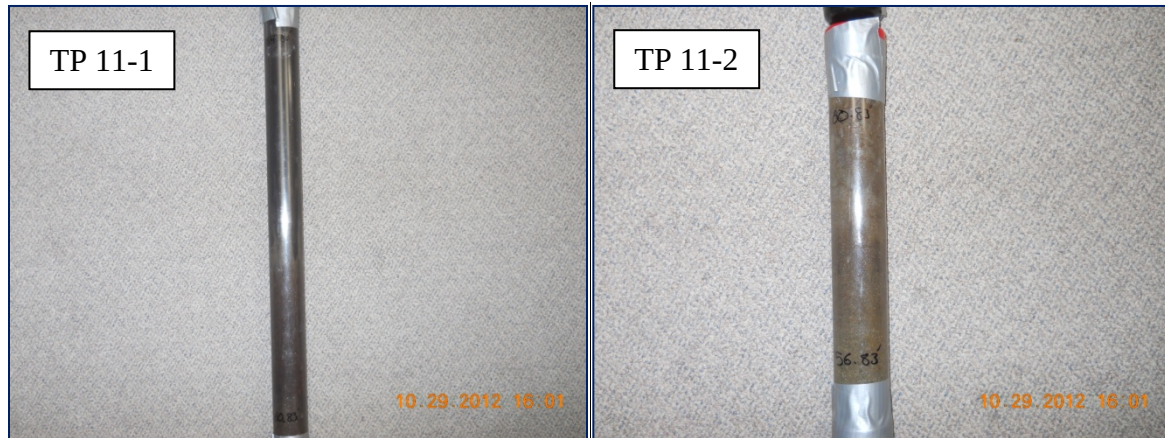
Bowers Pond Core Samples:



Bowers Pond Core Samples:



Bowers Pond Core Samples:



Bowers Pond Core Samples:



Soil Gradation Testing

	Sample ID	Location	Length
Sample 1	S1	1-2	2.25"
Sample 2	S2	2-3	2.75"
Sample 3	S3	3-4	3.00"
Sample 4	S4	4-5	4.50"
Sample 5	S5	5-6	2.75"
Sample 6	S6	6-7	3.25"
Sample 7	S7	7-8	2.50"
Sample 8	S8	8-9	2.50"
Sample 9	S9	9-10	3.00"
Sample 10	S10	10-end	3.50"

** Location: Samples sent for gradation were taken between the samples sent in for Gamma Spectroscopy Analysis



LETTER OF TRANSMITTAL

Project Name Merrimack NH - Pennichuck Source Testing

Project Number 13-0019

Project Manager Scott Harmon

Client Comprehensive Environmental, Inc,

Date 1/9/2013

Comprehensive Environmental, Inc,
William Devore
21 Depot Street
Merrimack, NH 03054

Phone 603-424-8444

Results Being Reported

GRAIN SIZE (WET SIEVE) - ASTM C117, C136/AASHTO T11, T27

Copy To

Notes:

S. W. COLE ENGINEERING, INC.

BY: 



Report of Gradation

ASTM C-117 & C-136

Project Name MERRIMACK NH - PENNICHUCK SOURCE TESTING

Project Number 13-0019

Client COMPREHENSIVE ENVIRONMENTAL, INC,

Lab ID 108M

Date Received 1/8/2013

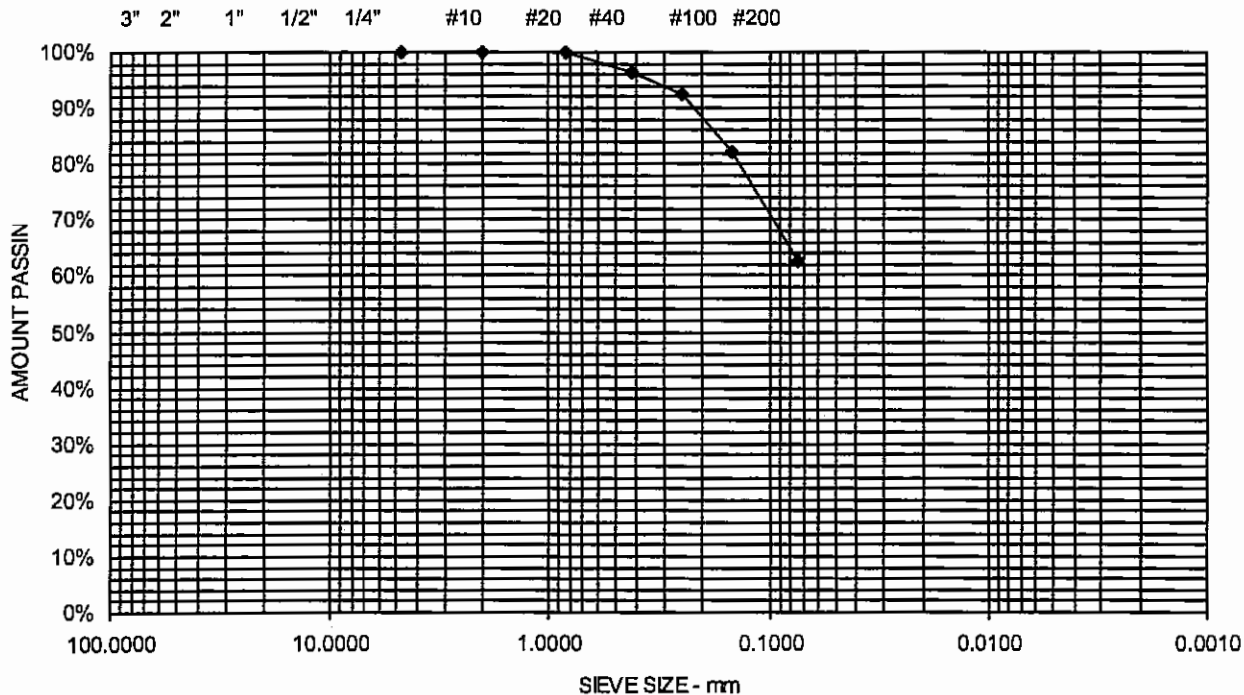
Material Source S-1

Date Completed 1/9/2013

Tested By CHRISTOPHER WILDES

<u>STANDARD DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
4.75 mm	No. 4	100	0% Gravel
2.00 mm	No. 10	100	
850 μm	No. 20	100	
425 μm	No. 40	97	37.4% Sand
250 μm	No. 60	92	
150 μm	No. 100	82	62.6% Fines
75 μm	No. 200	62.6	

SANDY SILT



Comments:

Sheet



Report of Gradation

ASTM C-117 & C-136

Project Name MERRIMACK NH - PENNICHUCK SOURCE TESTING

Project Number 13-0019

Client COMPREHENSIVE ENVIRONMENTAL, INC,

Lab ID 109M

Date Received 1/8/2013

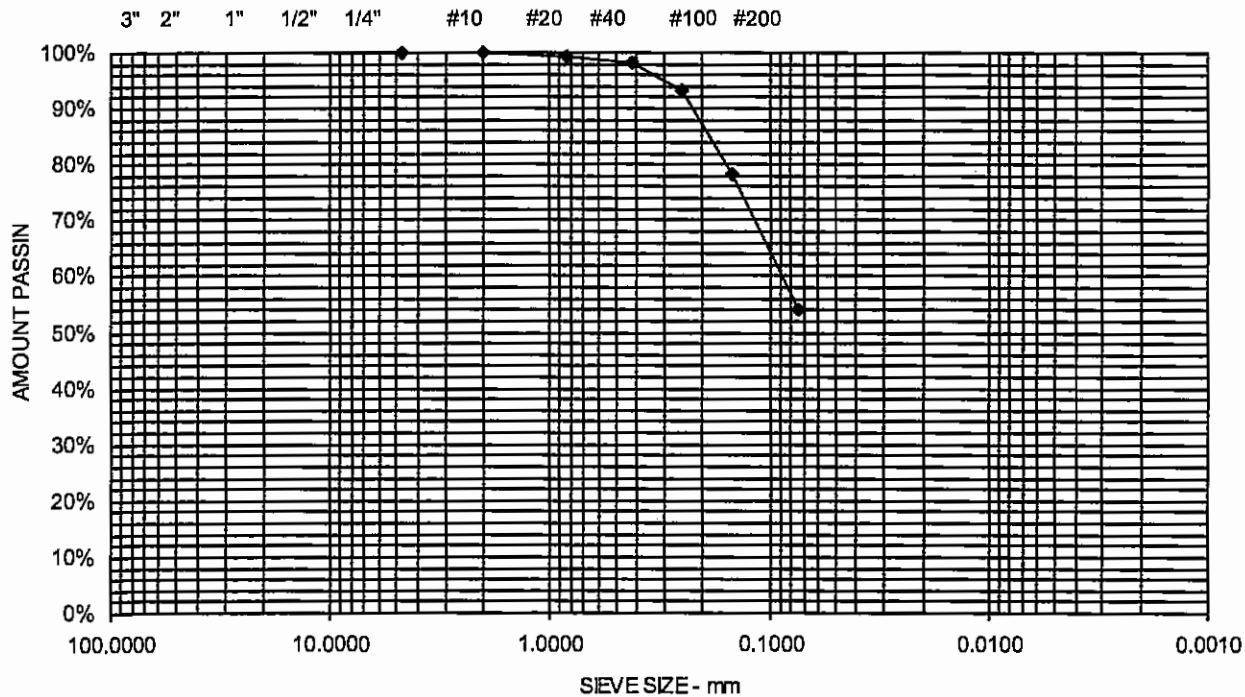
Date Completed 1/9/2013

Material Source S-2

Tested By CHRISTOPHER WILDES

<u>STANDARD</u> <u>DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
4.75 mm	No. 4	100	0% Gravel
2.00 mm	No. 10	100	
850 μm	No. 20	99	
425 μm	No. 40	98	45.9% Sand
250 μm	No. 60	93	
150 μm	No. 100	78	54.1% Fines
75 μm	No. 200	54.1	

SANDY SILT



Comments:

Sheet



Report of Gradation

ASTM C-117 & C-136

Project Name MERRIMACK NH - PENNICHUCK SOURCE TESTING

Project Number 13-0019

Client COMPREHENSIVE ENVIRONMENTAL, INC,

Lab ID 110M

Date Received 1/8/2013

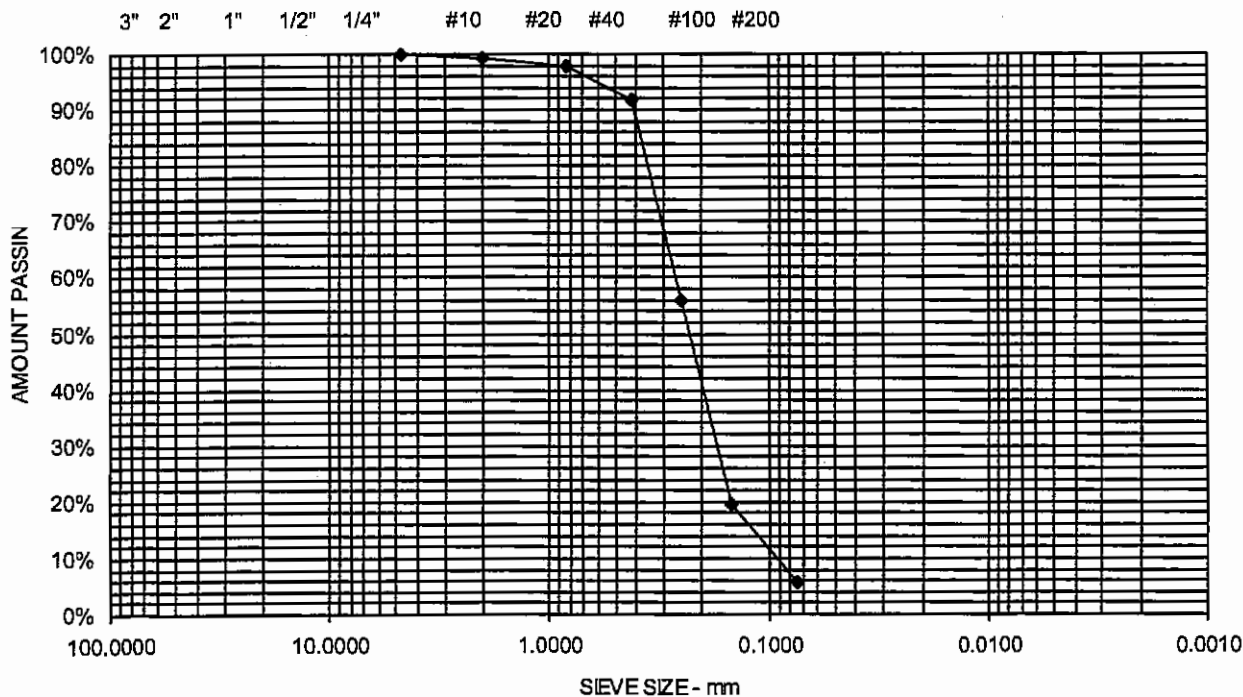
Date Completed 1/9/2013

Material Source S-3

Tested By CHRISTOPHER WILDES

<u>STANDARD DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
4.75 mm	No. 4	100	0% Gravel
2.00 mm	No. 10	99	
850 μm	No. 20	98	
425 μm	No. 40	92	94.5% Sand
250 μm	No. 60	56	
150 μm	No. 100	20	
75 μm	No. 200	5.5	5.5% Fines

MEDIUM TO FINE SAND



Comments:

Sheet



Report of Gradation

ASTM C-117 & C-136

Project Name MERRIMACK NH - PENNICHUCK SOURCE TESTING

Project Number 13-0019

Client COMPREHENSIVE ENVIRONMENTAL, INC,

Lab ID 111M

Date Received 1/8/2013

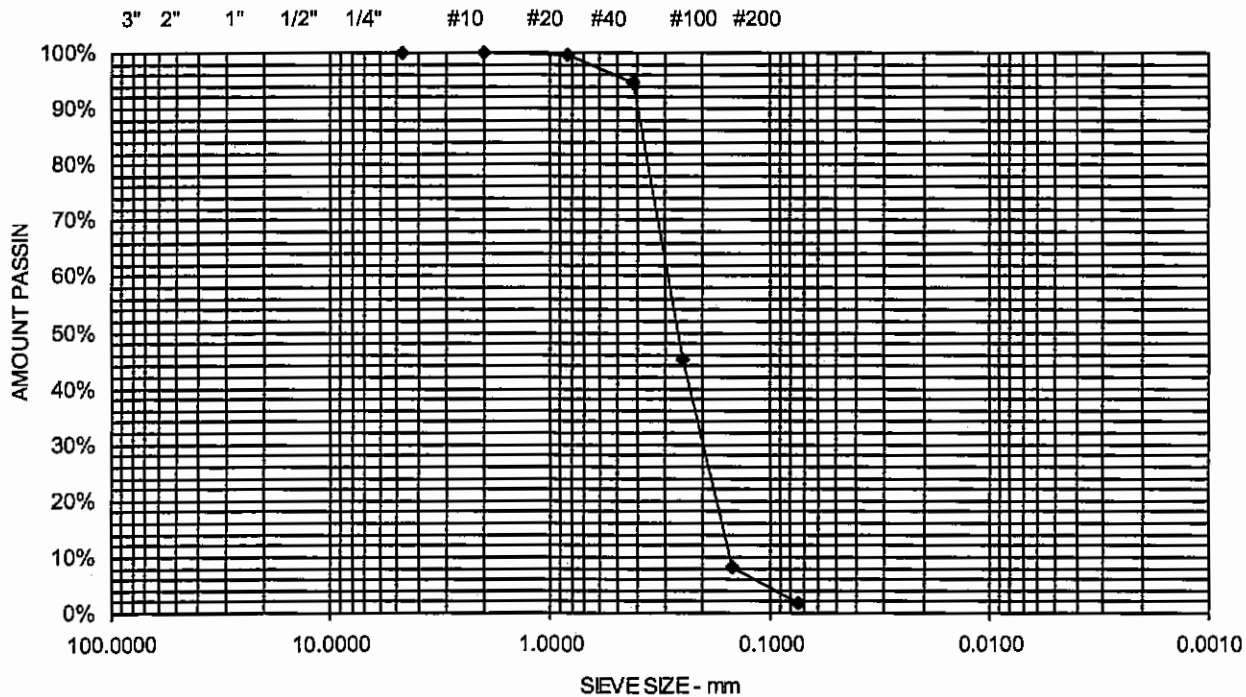
Material Source S-4

Date Completed 1/9/2013

Tested By CHRISTOPHER WILDES

<u>STANDARD DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
4.75 mm	No. 4	100	0% Gravel
2.00 mm	No. 10	100	
850 μm	No. 20	100	
425 μm	No. 40	95	98.1% Sand
250 μm	No. 60	45	
150 μm	No. 100	8	
75 μm	No. 200	1.9	1.9% Fines

FINE MEDIUM SAND



Comments:

Sheet



Report of Gradation

ASTM C-117 & C-136

Project Name MERRIMACK NH - PENNICHUCK SOURCE TESTING

Project Number 13-0019

Client COMPREHENSIVE ENVIRONMENTAL, INC,

Lab ID 112M

Date Received 1/8/2013

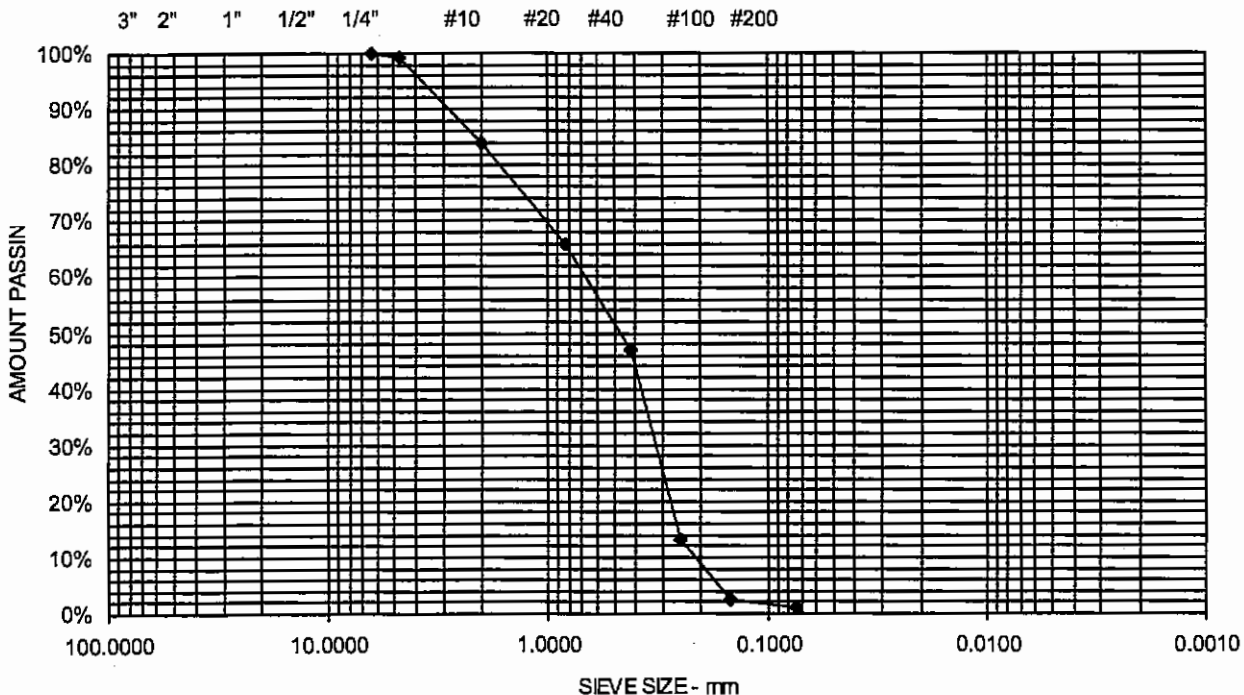
Date Completed 1/9/2013

Material Source S-5

Tested By CHRISTOPHER WILDES

<u>STANDARD DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
6.3 mm	1/4"	100	
4.75 mm	No. 4	99	0.7% Gravel
2.00 mm	No. 10	84	
850 μm	No. 20	66	
425 μm	No. 40	47	98.3% Sand
250 μm	No. 60	13	
150 μm	No. 100	2	
75 μm	No. 200	1.0	1% Fines

COARSE TO MEDIUM SAND



Comments:

Sheet



Report of Gradation

ASTM C-117 & C-136

Project Name MERRIMACK NH - PENNICHUCK SOURCE TESTING

Project Number 13-0019

Client COMPREHENSIVE ENVIRONMENTAL, INC,

Lab ID 113M

Date Received 1/8/2013

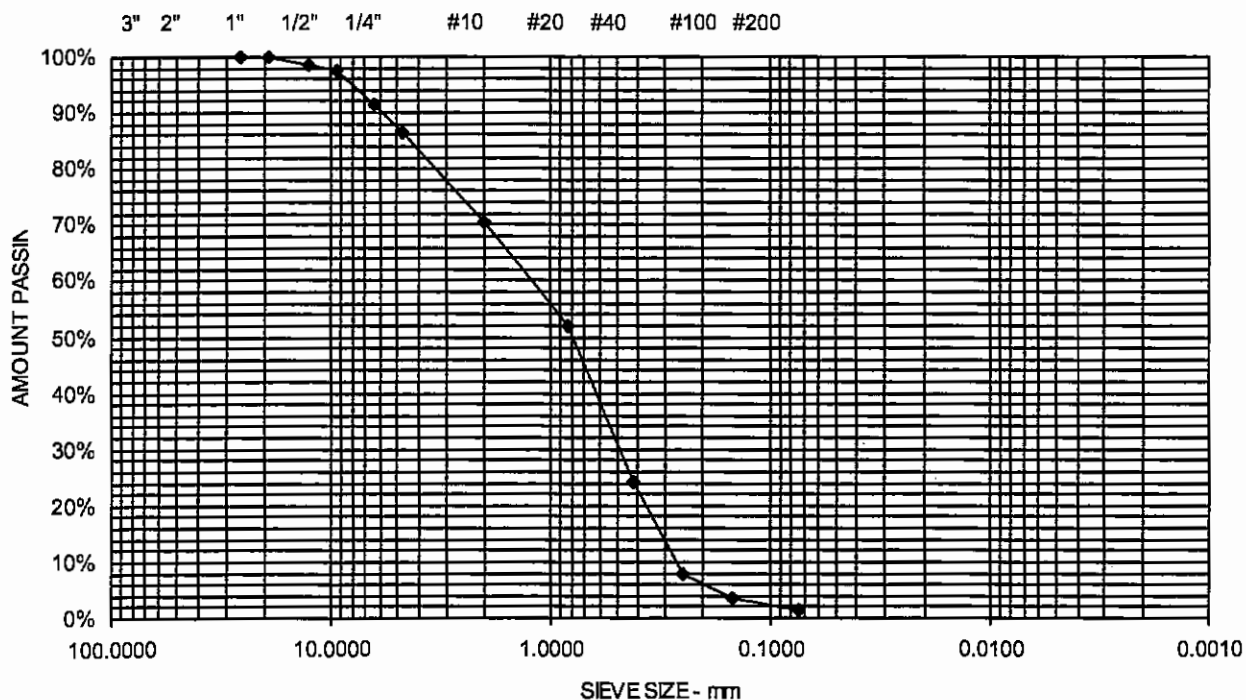
Date Completed 1/9/2013

Material Source S-6

Tested By CHRISTOPHER WILDES

<u>STANDARD DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
25.0 mm	1"	100	
19.0 mm	3/4"	100	
12.5 mm	1/2"	99	
9.5 mm	3/8"	98	
6.3 mm	1/4"	92	
4.75 mm	No. 4	86	13.5% Gravel
2.00 mm	No. 10	70	
850 μm	No. 20	52	
425 μm	No. 40	24	85.1% Sand
250 μm	No. 60	8	
150 μm	No. 100	3	
75 μm	No. 200	1.3	1.3% Fines

SAND WITH LITTLE FINE GRAVEL



Comments:

Sheet

Report of Gradation

ASTM C-117 & C-136

Project Name MERRIMACK NH - PENNICHUCK SOURCE TESTING

Project Number 13-0019

Client COMPREHENSIVE ENVIRONMENTAL, INC.,

Lab ID 114M

Date Received 1/8/2013

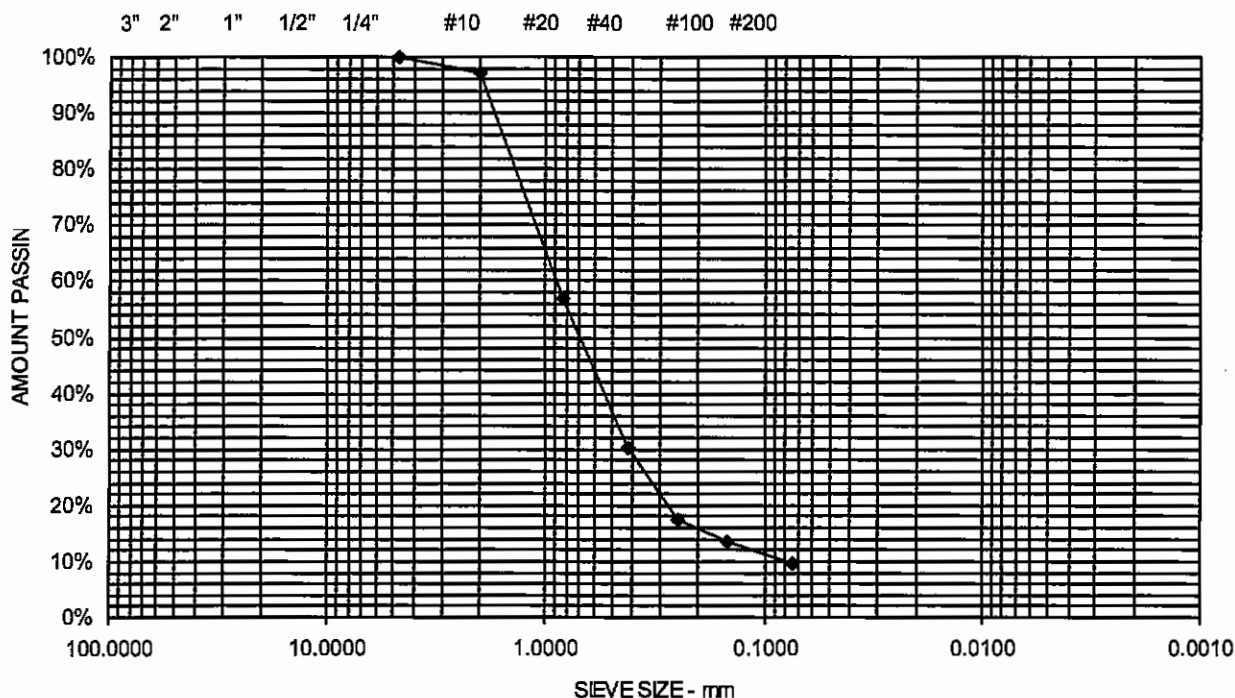
Material Source S-7

Date Completed 1/9/2013

Tested By CHRISTOPHER WILDES

<u>STANDARD DESIGNATION (mm/um)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
4.75 mm	No. 4	100	0% Gravel
2.00 mm	No. 10	97	
850 um	No. 20	57	
425 um	No. 40	30	90.6% Sand
250 um	No. 60	17	
150 um	No. 100	13	
75 um	No. 200	9.4	9.4% Fines

FINE TO MEDIUM SAND WITH LITTLE SILT



Comments:

Sheet

Report of Gradation

ASTM C-117 & C-136

Project Name MERRIMACK NH - PENNICHUCK SOURCE TESTING

Project Number 13-0019

Client COMPREHENSIVE ENVIRONMENTAL, INC.

Lab ID 115M

Date Received 1/8/2013

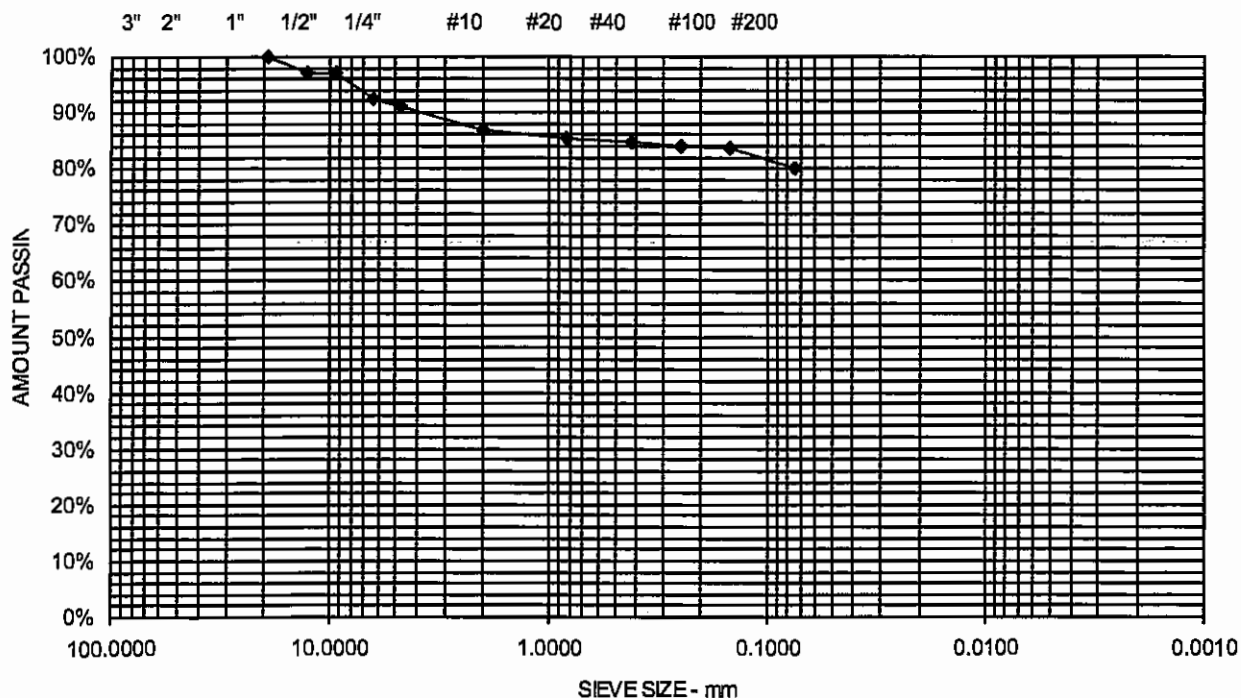
Date Completed 1/9/2013

Material Source S-8

Tested By CHRISTOPHER WILDES

<u>STANDARD DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
19.0 mm	3/4"	100	
12.5 mm	1/2"	97	
9.5 mm	3/8"	97	
6.3 mm	1/4"	93	
4.75 mm	No. 4	91	9% Gravel
2.00 mm	No. 10	87	
850 μm	No. 20	85	
425 μm	No. 40	85	11% Sand
250 μm	No. 60	84	
150 μm	No. 100	84	
75 μm	No. 200	80.0	80% Fines

SILT AND CLAY WITH SAND AND FINE GRAVEL



Comments:

Sheet

Report of Gradation

ASTM C-117 & C-136

Project Name MERRIMACK NH - PENNICHUCK SOURCE TESTING

Project Number 13-0019

Client COMPREHENSIVE ENVIRONMENTAL, INC,

Lab ID 116M

Date Received 1/8/2013

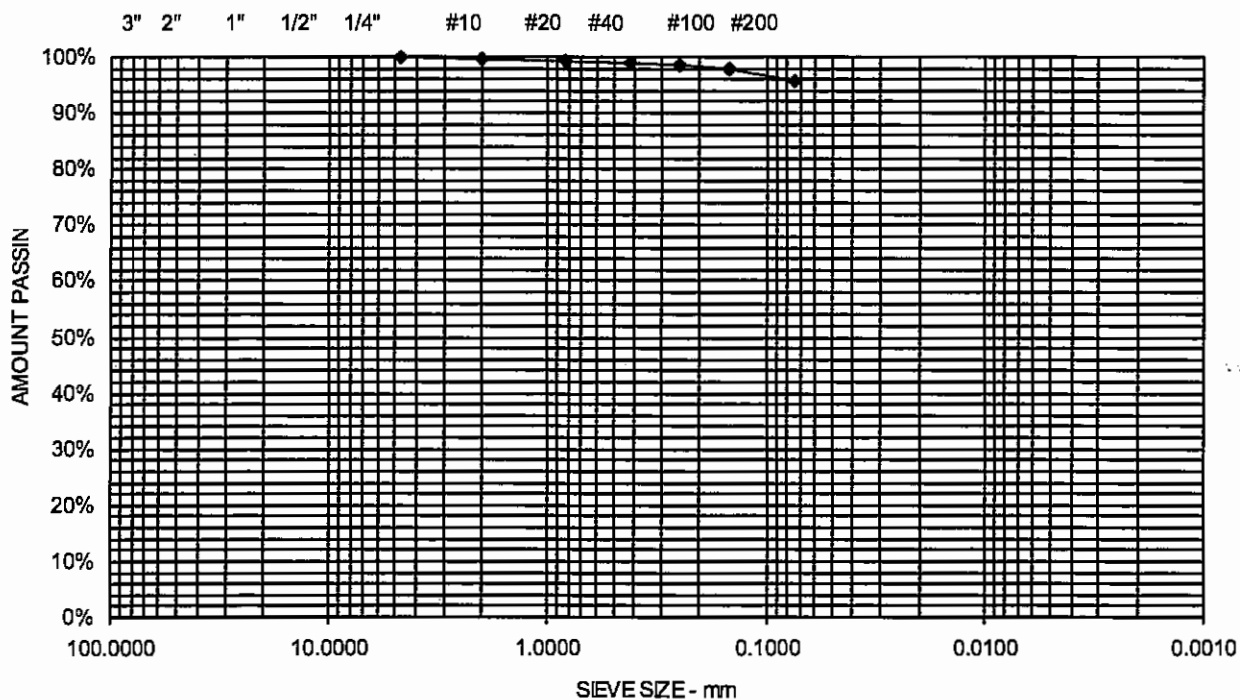
Material Source S-9

Date Completed 1/9/2013

Tested By CHRISTOPHER WILDES

<u>STANDARD DESIGNATION (mm/um)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
4.75 mm	No. 4	100	0% Gravel
2.00 mm	No. 10	100	
850 um	No. 20	99	
425 um	No. 40	99	4.2% Sand
250 um	No. 60	98	
150 um	No. 100	98	
75 um	No. 200	95.8	95.8% Fines

SILT AND CLAY



Comments:

Sheet

Report of Gradation

ASTM C-117 & C-136

Project Name MERRIMACK NH - PENNICHUCK SOURCE TESTING

Project Number 13-0019

Client COMPREHENSIVE ENVIRONMENTAL, INC.,

Lab ID 117M

Date Received 1/8/2013

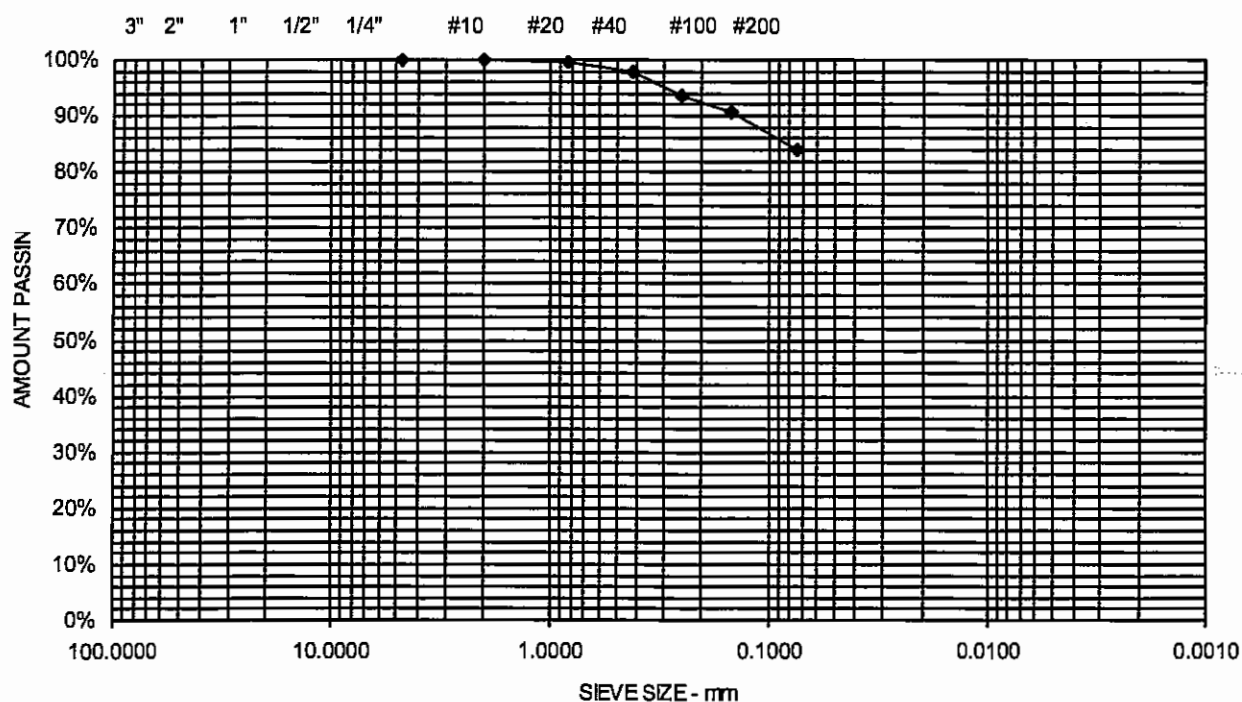
Date Completed 1/9/2013

Material Source S-10

Tested By CHRISTOPHER WILDES

<u>STANDARD DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
4.75 mm	No. 4	100	0% Gravel
2.00 mm	No. 10	100	
850 μm	No. 20	100	
425 μm	No. 40	98	16% Sand
250 μm	No. 60	94	
150 μm	No. 100	91	
75 μm	No. 200	84.0	84% Fines

SILT AND CLAY WITH FINE SAND



Comments:

Sheet

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-1		
				LOCATION: Harris Pond		
				DATE: 10/4/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Ground Surface			
	5					
	10					
	15					
	20					
	25		sand/minimal organic material (all pine; no leaves)			sample recovery: ≈1.25'
	30		very solid sand/minimal organic material			sample recovery: ≈2.31'
	35					
	40					

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-2		
				LOCATION: Harris Pond		
				DATE: 10/4/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Water Surface			
	5					
	10					
	15					
	20		sand/minimal organic material			sample recovery: ≈1.25'
	25		solid sand			sample recovery: ≈2.19'
	30					
	35					
	40					

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-3		
				LOCATION: Harris Pond		
				DATE: 10/4/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Ground Surface			
	5					
	10					
	15					
	20					
	25		soft/some organics to hard sediment			sample recovery: ≈0.69'
	30		slight organic material (soft) to sediment (hard)			sample recovery: ≈1.00'
	35		very solid sediment to silt			sample recovery: ≈0.69'
	40					

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-4		
				LOCATION: Harris Pond		
				DATE: 10/5/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Ground Surface			
	5					
	10					
	15					
	20		Little silt, sandy, soft organic sand			sample recovery: ≈0.65'
	25		sediment to sand/minimal organic material			sample recovery: ≈1.44'
	30					
	35					
	40					

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-5		
				LOCATION: Harris Pond		
				DATE: 10/5/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Ground Surface			
	5					
	10					
	15					
	20		organic material to sand			sample recovery: ≈1.35'
	25		good sand/some organic bands			sample recovery: ≈2.27'
	30					
	35					
	40					

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054

[illegible]

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-7		
				LOCATION: Bowers Pond		
				DATE: 10/9/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Ground Surface			
	5					
	10					
	15		light silt to solid sand			sample recovery: ≈0.58'
			no recovery-river bottom			none
	20					
	25					
	30					
	35					
	40					

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-8		
				LOCATION: Bowers Pond		
				DATE: 10/9/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Ground Surface			
	5					
	10					
	15					
	20		soft silt into soft sand			sample recovery: ≈1.77'
	25		soft dark silt to grey silt			sample recovery: ≈2.04'
	30					
	35					
	40					

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-9		
				LOCATION: Bowers Pond		
				DATE: 10/9/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Ground Surface			
	5					
	10					
	15		soft/dark silt to soft sand			sample recovery: ≈2.06'
	20		sand into soft silt/some organic bands			sample recovery: ≈2.17'
	25		soft silt to hard gravel at 26'			sample recovery: ≈2.13'
	30					
	35					
	40					

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-10		
				LOCATION: Bowers Pond		
				DATE: 10/9/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Ground Surface			
	5					
	10					
	15		soft dark organic material to soft sand			sample recovery: ≈1.29'
	20		gravel to silty sand			sample recovery: ≈1.17'
	25					
	30					
	35					
	40					

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-11		
				LOCATION: Bowers Pond		
				DATE: 10/10/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Ground Surface			
	5					
	10					
	15		soft/dark organic material to soft sand			sample recovery: ≈2.06'
	20		silty sand to soft sand			sample recovery: ≈1.08'
	25		soft sand			sample recovery: ≈1.23'
	30					
	35					
	40					

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-12		
				LOCATION: Bowers Pond		
				DATE: 10/10/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Ground Surface			
	5					
	10		soft/dark organic material to soft sand			sample recovery: ≈1.48'
	15		soft sand			sample recovery: ≈2.46'
	20					
	25					
	30					
	35					
	40					

Sediment Core Boring Log

Comprehensive Environmental
Incorporated
21 Depot Street
Merrimack, NH 03054



PROJECT: Pennichuck Water Works-Pond Sediment Borings				BORING/TP: TB-13		
				LOCATION: Bowers Pond		
				DATE: 10/10/2012	SCALE: 1 inc = 0.5"	
ELEV	Depth	Symbol	Description of Materials	BPF	WL	Remarks
0	0	GS	Ground Surface			
	5					
	10		soft dark silt to soft sand			sample recovery: ≈1.54'
	15		soft sand with organic bands			sample recovery: ≈1.52'
	20		soft sand			sample recovery: ≈2.15'
	25					
	30					
	35					
	40					

Appendix C

Seasonal Sand Usage

Sand Weight & Volume Used per Season per Town (varies per year)			
Town	Weight (tons)	Volume (yd ³)	Total Town Road/Lane Miles
Amherst:	4,050	3,000	130
Hollis:	5,400	4,000	82
Merrimack:	5,000	3,700	160
Nashua:	1,450	1,075	700
Milford:	1,950	1,445	81

Miles

Miles

Miles

Lane Miles

Miles

Assumptions:

1 cubic foot of sand weighs 100 lbs; 1 cubic yard of sand weighs 2700 lbs

Sanding in all areas of the watershed is done at a consistent rate and evenly distributed across all lanes of road

Road and lane miles, as well as average volume of sand used per season obtained from each town is accurate

State and Private road sand loadings were estimated

Sand Usage Loading Summary

Watershed	Lane Length Total (mi)			Loading / Year			Loading / Year			Loading / Year			Loading / Year		
	State	Town	Private	State	Town	Private	State	Town	Private	State	Town	Private	Total	Total	Total
	(mi)	(mi)	(mi)	(yd3/yr)	(yd3/yr)	(yd3/yr)	(lbs/yr)	(lbs/yr)	(lbs/yr)	(tons/yr)	(tons/yr)	(tons/yr)	(yd3/yr)	(lbs/yr)	(tons/yr)
3	7.83	12.64	2.94	78.3	31.4	14.7	211,410	84,894	39,690	105.7	42.4	19.8	124.4	335,994	168.0
4	1.84	0.42	1.2	18.4	4.9	6.0	49,680	13,125	16,200	24.8	6.6	8.1	29.3	79,005	39.5
5	0.18	0.3	0	1.8	0.5	0.0	4,860	1,243	0	2.4	0.6	0.0	2.3	6,103	3.1
6	6.16	10.33	14.52	61.6	76.3	72.6	166,320	205,981	196,020	83.2	103.0	98.0	210.5	568,321	284.2
7	2	9.77	3.16	20.0	15.0	15.8	54,000	40,476	42,660	27.0	20.2	21.3	50.8	137,136	68.6
8	0.4	17.12	14.6	4.0	36.5	73.0	10,800	98,575	197,100	5.4	49.3	98.6	113.5	306,475	153.2
9	4.04	18.63	3.54	40.4	177.6	17.7	109,080	479,451	47,790	54.5	239.7	23.9	235.7	636,321	318.2
10	0	4.28	0.14	0.0	82.9	0.7	0	223,846	1,890	0.0	111.9	0.9	83.6	225,736	112.9
11	0	7.12	0.34	0.0	173.7	1.7	0	468,878	4,590	0.0	234.4	2.3	175.4	473,468	236.7
12	0	5.21	1.48	0.0	114.3	7.4	0	308,540	19,980	0.0	154.3	10.0	121.7	328,520	164.3
13	0	13.12	0.6	0.0	304.9	3.0	0	823,271	8,100	0.0	411.6	4.1	307.9	831,371	415.7
14	3.4	8.98	0.96	34.0	219.0	4.8	91,800	591,366	12,960	45.9	295.7	6.5	257.8	696,126	348.1
15	0	0.26	0.26	0.0	4.0	1.3	0	10,893	3,510	0.0	5.4	1.8	5.3	14,403	7.2
17	4.48	33.25	1.07	44.8	384.4	5.4	120,960	1,037,922	14,445	60.5	519.0	7.2	434.6	1,173,327	586.7
18	4.62	10.9	2.28	46.2	185.9	11.4	124,740	501,972	30,780	62.4	251.0	15.4	243.5	657,492	328.7
19	0	3.36	0.26	0.0	82.0	1.3	0	221,268	3,510	0.0	110.6	1.8	83.3	224,778	112.4
20	2.58	4.22	2.5	25.8	51.3	12.5	69,660	138,511	33,750	34.8	69.3	16.9	89.6	241,921	121.0
21	0.1	0.6	0	1.0	14.6	0.0	2,700	39,512	0	1.4	19.8	0.0	15.6	42,212	21.1
22	2.56	9.523	0.64	25.6	170.0	3.2	69,120	459,045	8,640	34.6	229.5	4.3	198.8	536,805	268.4
23	1.44	13.06	1.38	14.4	318.5	6.9	38,880	860,049	18,630	19.4	430.0	9.3	339.8	917,559	458.8
24	0.14	6.25	0.63	1.4	60.4	3.2	3,780	163,065	8,505	1.9	81.5	4.3	64.9	175,350	87.7
Totals	41.77	189.343	52.5	417.7	2508.1	262.5	1,127,790	6,771,882	708,750	563.9	3385.9	354.4	3188.3	8,608,422	4304.2

Sand Loading Calculations

Watershed Town Name Number of Lanes			Road Length per Lane (mi)			Lane Length Total (mi)			Loading / Year			Loading / Year			Loading / Year			Loading / Year Watershed Summary				
			Owner			Owner			Owner			Owner			Owner							
			State	Town	Private	State	Town	Private	State	Town	Private	State	Town	Private	State	Town	Private	State	Town	Private		
			(mi)	(mi)	(mi)	(mi)	(mi)	(mi)	(yd3/yr)	(yd3/yr)	(yd3/yr)	(lbs/yr)	(lbs/yr)	(lbs/yr)	(tons/yr)	(tons/yr)	(tons/yr)	Watershed	State	Town	Private	Totals
3	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3	yd3/yr	yd3/yr	yd3/yr	yd3/yr	
	Hollis	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		78.3	31.4	14.7	124.4	
	Merrimack	2	0	0.6	1.41	0	1.2	2.82	0.0	13.9	14.1	0.0	37500.0	38070.0	0.0	18.8		19.0	(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Nashua	1	0.76	0	0	0.76	0	0	7.6	0.0	0.0	20520.0	0.0	0.0	10.3	0.0		0.0	105.7	42.4	19.8	168.0
	Nashua	2	2.1	5.72	0.06	4.2	11.44	0.12	42.0	17.6	0.6	113400.0	47394.3	1620.0	56.7	23.7		0.8				
	Nashua	3	0.89	0	0	2.67	0	0	26.7	0.0	0.0	72090.0	0.0	0.0	36.0	0.0		0.0				
	Nashua	5	0.04	0	0	0.2	0	0	2.0	0.0	0.0	5400.0	0.0	0.0	2.7	0.0		0.0				
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0				
			Totals			7.83	12.64	2.94	78.3	31.4	14.7	211410.0	84894.3	39690.0	105.7	42.4	19.8					
4	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4	yd3/yr	yd3/yr	yd3/yr	yd3/yr	
	Hollis	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		18.4	4.9	6.0	29.3	
	Merrimack	1	0	0	0.52	0	0	0.52	0.0	0.0	2.6	0.0	0.0	7020.0	0.0	0.0		3.5	(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Merrimack	2	0.41	0.21	0.34	0.82	0.42	0.68	8.2	4.9	3.4	22140.0	13125.0	9180.0	11.1	6.6		4.6	24.8	6.6	8.1	39.5
	Nashua	2	0.51	0	0	1.02	0	0	10.2	0.0	0.0	27540.0	0.0	0.0	13.8	0.0		0.0				
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0				
			Totals			1.84	0.42	1.2	18.4	4.9	6.0	49680.0	13125.0	16200.0	24.8	6.6	8.1					
5	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	yd3/yr	yd3/yr	yd3/yr	yd3/yr	
	Hollis	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.8	0.5	0.0	2.3	
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)	
	Nashua	1	0.14	0	0	0.14	0	0	1.4	0.0	0.0	3780.0	0.0	0.0	1.9	0.0		0.0	2.4	0.6	0.0	3.1
	Nashua	2	0.02	0.15	0	0.04	0.3	0	0.4	0.5	0.0	1080.0	1242.9	0.0	0.5	0.6		0.0				
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0				
			Totals			0.18	0.3	0	1.8	0.5	0.0	4860.0	1242.9	0.0	2.4	0.6	0.0					
6	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6	yd3/yr	yd3/yr	yd3/yr	yd3/yr	
	Hollis	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		61.6	76.3	72.6	210.5	
	Merrimack	1	0.53		0.16	0.53	0	0.16	5.3	0.0	0.8	14310.0	0.0	2160.0	7.2	0.0		1.1	(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Merrimack	2	1.06	2.53	2.52	2.12	5.06	5.04	21.2	58.6	25.2	57240.0	158125.0	68040.0	28.6	79.1		34.0	83.2	103.0	98.0	284.2
	Merrimack	4	0.43	0.24	0.93	1.72	0.96	3.72	17.2	11.1	18.6	46440.0	30000.0	50220.0	23.2	15.0		25.1				
	Merrimack	5	0.31			1.55	0	0	15.5	0.0	0.0	41850.0	0.0	0.0	20.9	0.0		0.0				
	Nashua	1		0.01		0	0.01	0	0.0	0.0	0.0	0.0	41.4	0.0	0.0	0.0		0.0				
	Nashua	2	0.12	2.15	2.8	0.24	4.3	5.6	2.4	6.6	28.0	6480.0	17814.3	75600.0	3.2	8.9		37.8				
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
			Totals			6.16	10.33	14.52	61.6	76.3	72.6	166320.0	205980.7	196020.0	83.2	103.0	98.0					
7	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7	yd3/yr	yd3/yr	yd3/yr	yd3/yr	
	Hollis	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		20.0	15.0	15.8	50.8	
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)	
	Nashua	1	0.52	0.12	0	0.52	0.12	0	5.2	0.2	0.0	14040.0	497.1	0.0	7.0	0.2		0.0	27.0	20.2	21.3	68.6
	Nashua	2	0.56	3.55	1.58	1.12	7.1	3.16	11.2	10.9	15.8	30240.0	29414.3	42660.0	15.1	14.7		21.3				
	Nashua	3	0	0.08	0	0	0.24	0	0.0	0.4	0.0	0.0	994.3	0.0	0.0	0.5		0.0				
	Nashua	4	0.09	0	0	0.36	0	0	3.6	0.0	0.0	9720.0	0.0	0.0	4.9	0.0		0.0				
	Nashua	5	0	0.33	0	0	1.65	0	0.0	2.5	0.0	0.0	6835.7	0.0	0.0	3.4		0.0				
	Nashua	6	0	0.11	0	0	0.66	0	0.0	1.0	0.0	0.0	2734.3	0.0	0.0	1.4		0.0				
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
			Totals			2	9.77	3.16	20.0	15.0	15.8	54000.0	40475.7	42660.0	27.0	20.2	21.3					
8	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	yd3/yr	yd3/yr	yd3/yr	yd3/yr	
	Hollis	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		4.0	36.5	73.0	113.5	
	Merrimack	2	0.2	0.51	0	0.4	1.02	0	4.0	11.8	0.0	10800.0	31875.0	0.0	5.4	15.9		0.0	(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Nashua	1	0	0.69	0.48	0	0.69	0.48	0.0	1.1	2.4	0.0	2858.6	6480.0	0.0	1.4		3.2	5.4	49.3	98.6	153.2
	Nashua	2	0	4.55	7.06	0	9.1	14.12	0.0	14.0	70.6	0.0	37700.0	190620.0	0.0	18.9		95.3				
	Nashua	4	0	0.79	0	0	3.16	0	0.0	4.8	0.0	0.0	13091.4	0.0	0.0	6.5		0.0				
	Nashua	5	0	0.63	0	0	3.15	0	0.0	4.8	0.0	0.0	13050.0	0.0	0.0	6.5		0.0				
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0				
			Totals			0.4	17.12	14.6	4.0	36.5	73.0	10800.0	98575.0	197100.0	5.4	49.3	98.6					

9	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Hollis	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		40.4	177.6	17.7	235.7
	Merrimack	1	0	0	0.08	0	0	0.08	0.0	0.0	0.4	0.0	0.0	1080.0	0.0	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Merrimack	2	1.07	7.42	1.32	2.14	14.84	2.64	21.4	171.8	13.2	57780.0	463750.0	35640.0	28.9	231.9		54.5	239.7	23.9	318.2
	Merrimack	5	0.24	0	0	1.2	0	0	12.0	0.0	0.0	32400.0	0.0	0.0	16.2	0.0					
	Merrimack	7	0.1	0	0	0.7	0	0	7.0	0.0	0.0	18900.0	0.0	0.0	9.5	0.0					
	Nashua	2	0	0.78	0.41	0	1.56	0.82	0.0	2.4	4.1	0.0	6462.9	11070.0	0.0	3.2					
	Nashua	4	0	0.17	0	0	0.68	0	0.0	1.0	0.0	0.0	2817.1	0.0	0.0	1.4					
	Nashua	5	0	0.31	0	0	1.55	0	0.0	2.4	0.0	0.0	6421.4	0.0	0.0	3.2					
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
			Totals			4.04	18.63	3.54	40.4	177.6	17.7	109080.0	479451.4	47790.0	54.5	239.7	23.9				
10	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Hollis	2	0	1.67	0.07	0	3.34	0.14	0.0	81.5	0.7	0.0	219951.2	1890.0	0.0	110.0		0.0	82.9	0.7	83.6
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Nashua	2	0	0.47	0	0	0.94	0	0.0	1.4	0.0	0.0	3894.3	0.0	0.0	1.9		0.0	111.9	0.9	112.9
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0			
			Totals			0	4.28	0.14	0.0	82.9	0.7	0.0	223845.5	1890.0	0.0	111.9	0.9				
11	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Hollis	1	0	0	0.2	0	0	0.2	0.0	0.0	1.0	0.0	0.0	2700.0	0.0	0.0		0.0	173.7	1.7	175.4
	Hollis	2	0	3.56	0.07	0	7.12	0.14	0.0	173.7	0.7	0.0	468878.0	1890.0	0.0	234.4		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	234.4	2.3	236.7
	Nashua	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0			
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0			
			Totals			0	7.12	0.34	0.0	173.7	1.7	0.0	468878.0	4590.0	0.0	234.4	2.3				
12	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Hollis	1	0	0.43	0.58	0	0.43	0.58	0.0	10.5	2.9	0.0	28317.1	7830.0	0.0	14.2		0.0	114.3	7.4	121.7
	Hollis	2	0	2.11	0.45	0	4.22	0.9	0.0	102.9	4.5	0.0	277902.4	12150.0	0.0	139.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	154.3	10.0	164.3
	Nashua	2	0	0.28	0	0	0.56	0	0.0	0.9	0.0	0.0	2320.0	0.0	0.0	1.2		0.0			
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0			
			Totals			0	5.21	1.48	0.0	114.3	7.4	0.0	308539.5	19980.0	0.0	154.3	10.0				
13	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Hollis	2	0	6.23	0.3	0	12.46	0.6	0.0	303.9	3.0	0.0	820536.6	8100.0	0.0	410.3		0.0	304.9	3.0	307.9
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Nashua	2	0	0.33	0	0	0.66	0	0.0	1.0	0.0	0.0	2734.3	0.0	0.0	1.4		0.0	411.6	4.1	415.7
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0			
			Totals			0	13.12	0.6	0.0	304.9	3.0	0.0	823270.9	8100.0	0.0	411.6	4.1				
14	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Hollis	2	1.7	4.49	0.48	3.4	8.98	0.96	34.0	219.0	4.8	91800.0	591365.9	12960.0	45.9	295.7		34.0	219.0	4.8	257.8
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Nashua	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		45.9	295.7	6.5	348.1
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0			
			Totals			3.4	8.98	0.96	34.0	219.0	4.8	91800.0	591365.9	12960.0	45.9	295.7	6.5				
15	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Hollis	2	0	0.04	0.13	0	0.08	0.26	0.0	2.0	1.3	0.0	5268.3	3510.0	0.0	2.6		0.0	4.0	1.3	5.3
	Merrimack	2	0	0.09	0	0	0.18	0	0.0	2.1	0.0	0.0	5625.0	0.0	0.0	2.8		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Nashua	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	5.4	1.8	7.2
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0			
			Totals			0	0.26	0.26	0.0	4.0	1.3	0.0	10893.3	3510.0	0.0	5.4	1.8				

17	Amherst	2	0	5.93	0.51	0	11.86	1.02	0.0	136.8	5.1	0.0	369484.6	13770.0	0.0	184.7	6.9	17	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Amherst	4	0.5	0	0	2	0	0	20.0	0.0	0.0	54000.0	0.0	0.0	27.0	0.0	0.0		44.8	384.4	5.4	434.6
	Hollis	4	0.09	0	0	0.36	0	0	3.6	0.0	0.0	9720.0	0.0	0.0	4.9	0.0	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Merrimack	1	0.14	0.43	0.01	0.14	0.43	0.01	1.4	5.0	0.1	3780.0	13437.5	135.0	1.9	6.7	0.1		60.5	519.0	7.2	586.7
	Merrimack	2	0	10.48	0.02	0	20.96	0.04	0.0	242.6	0.2	0.0	655000.0	540.0	0.0	327.5	0.3					
	Merrimack	4	0.32	0	0	1.28	0	0	12.8	0.0	0.0	34560.0	0.0	0.0	17.3	0.0	0.0					
	Merrimack	5	0.14	0	0	0.7	0	0	7.0	0.0	0.0	18900.0	0.0	0.0	9.5	0.0	0.0					
	Nashua	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
			Totals			4.48	33.25	1.07	44.8	384.4	5.4	120960.0	1037922.1	14445.0	60.5	519.0	7.2					
18	Amherst	2	0.05	3.11	1.14	0.1	6.22	2.28	1.0	71.8	11.4	2700.0	193776.9	30780.0	1.4	96.9	15.4	18	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Amherst	4	1.13	0	0	4.52	0	0	45.2	0.0	0.0	122040.0	0.0	0.0	61.0	0.0	0.0		46.2	185.9	11.4	243.5
	Hollis	2	0	2.34	0	0	4.68	0	0.0	114.1	0.0	0.0	308195.1	0.0	0.0	154.1	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		62.4	251.0	15.4	328.7
	Nashua	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
			Totals			4.62	10.9	2.28	46.2	185.9	11.4	124740.0	501972.0	30780.0	62.4	251.0	15.4					
19	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Hollis	1	0	0	0.26	0	0	0.26	0.0	0.0	1.3	0.0	0.0	3510.0	0.0	0.0	1.8		0.0	82.0	1.3	83.3
	Hollis	2	0	1.68	0	0	3.36	0	0.0	82.0	0.0	0.0	221268.3	0.0	0.0	110.6	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	110.6	1.8	112.4
	Nashua	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
			Totals			0	3.36	0.26	0.0	82.0	1.3	0.0	221268.3	3510.0	0.0	110.6	1.8					
20	Amherst	1	0		0.1	0	0	0.1	0.0	0.0	0.5	0.0	0.0	1350.0	0.0	0.0	0.7	20	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Amherst	2	1.12	1.25	1.17	2.24	2.5	2.34	22.4	28.8	11.7	60480.0	77884.6	31590.0	30.2	38.9	15.8		25.8	51.3	12.5	89.6
	Hollis	2	0.17	0.23	0	0.34	0.46	0	3.4	11.2	0.0	9180.0	30292.7	0.0	4.6	15.1	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		34.8	69.3	16.9	121.0
	Nashua	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
	Milford	1	0	0.06	0	0	0.06	0	0.0	0.5	0.0	0.0	1444.4	0.0	0.0	0.7	0.0					
	Milford	2	0	0.6	0.03	0	1.2	0.06	0.0	10.7	0.3	0.0	28888.9	810.0	0.0	14.4	0.4					
			Totals			2.58	4.22	2.5	25.8	51.3	12.5	69660.0	138510.6	33750.0	34.8	69.3	16.9					
21	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Hollis	2	0.05	0.3	0	0.1	0.6	0	1.0	14.6	0.0	2700.0	39512.2	0.0	1.4	19.8	0.0		1.0	14.6	0.0	15.6
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Nashua	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.4	19.8	0.0	21.1
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
			Totals			0.1	0.6	0	1.0	14.6	0.0	2700.0	39512.2	0.0	1.4	19.8	0.0					
22	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Hollis	2	1.28	2.75	0.1	2.56	5.5	0.2	25.6	134.1	1.0	69120.0	362195.1	2700.0	34.6	181.1	1.4		25.6	170.0	3.2	198.8
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Nashua	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		34.6	229.5	4.3	268.4
	Milford	1	0	0.003	0	0	0.003	0	0.0	0.0	0.0	0.0	72.2	0.0	0.0	0.0	0.0					
	Milford	2	0	2.01	0.22	0	4.02	0.44	0.0	35.8	2.2	0.0	96777.8	5940.0	0.0	48.4	3.0					
			Totals			2.56	9.523	0.64	25.6	170.0	3.2	69120.0	459045.1	8640.0	34.6	229.5	4.3					
23	Amherst	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Hollis	2	0.72	6.53	0.69	1.44	13.06	1.38	14.4	318.5	6.9	38880.0	860048.8	18630.0	19.4	430.0	9.3		14.4	318.5	6.9	339.8
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Nashua	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		19.4	430.0	9.3	458.8
	Milford	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
			Totals			1.44	13.06	1.38	14.4	318.5	6.9	38880.0	860048.8	18630.0	19.4	430.0	9.3					
24	Amherst	1			0.13	0	0	0.13	0.0	0.0	0.7	0.0	0.0	1755.0	0.0	0.0	0.9	24	yd3/yr	yd3/yr	yd3/yr	yd3/yr
	Amherst	2	0.07	0.89	0.25	0.14	1.78	0.5	1.4	20.5	2.5	3780.0	55453.8	6750.0	1.9	27.7	3.4		1.4	60.4	3.2	64.9
	Hollis	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		(tons/yr)	(tons/yr)	(tons/yr)	(tons/yr)
	Merrimack	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.9	81.5	4.3	87.7
	Nashua	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
	Milford	1		0.11		0	0.11	0	0.0	1.0	0.0	0.0	2648.1	0.0	0.0	1.3	0.0					
	Milford	2		2.18		0	4.36	0	0.0	38.9	0.0	0.0	104963.0	0.0	0.0	52.5	0.0					
			Totals			0.14	6.25	0.63	1.4	60.4	3.2	3780.0	163065.0	8505.0	1.9	81.5	4.3					

Total Suspended Solids (TSS) Loadings

		Land Use (%):								Land Use (Acres)							
Sub-Watershed	Area (acres)	Commercial	Forest	HighDenRes	LowDenRes	Industrial	Open Space	Road	Water	Commercial	Forest	HighDenRes	LowDenRes	Industrial	Open Space	Road	Water
3	662	1.89	19.97	26.29	19.23	5.90		15.20	11.52	12.51	132.20	174.04	127.30	39.06	0.00	100.62	76.26
4	233	41.03	16.01	7.75		11.56		7.85	15.81	95.60	37.30	18.06	0.00	26.93	0.00	18.29	36.84
5	19		66.25		10.52			23.23		0.00	12.59	0.00	2.00	0.00	0.00	4.41	0.00
6	1406	3.94	28.87	6.40	20.28	29.15		7.45	3.93	55.40	405.91	89.98	285.14	409.85	0.00	104.75	55.26
7	461	41.15	12.13	19.54	4.87	12.41	1.27	8.63		189.70	55.92	90.08	22.45	57.21	5.85	39.78	0.00
8	1088	13.51	27.76	14.51	13.35	15.35	6.51	5.14	3.88	146.99	302.03	157.87	145.25	167.01	70.83	55.92	42.21
9	960	23.33	18.66	0.57	41.64	4.98	0.12	8.42	2.29	223.97	179.14	5.47	399.74	47.81	1.15	80.83	21.98
10	491	2.53	58.23		21.58	13.24	1.02	2.90	0.51	12.42	285.91	0.00	105.96	65.01	5.01	14.24	2.50
11	665		44.16		44.09			3.60	8.15	0.00	293.66	0.00	293.20	0.00	0.00	23.94	54.20
12	939	2.61	65.01		25.67		3.27	2.29	1.15	24.51	610.44	0.00	241.04	0.00	30.71	21.50	10.80
13	1768	0.00	38.5		42.74		16.46	2.24	0.06	0.00	680.68	0.00	755.64	0.00	291.01	39.60	1.06
14	1338	0.25	51.15		27.87		12.88	2.91	4.95	3.35	684.39	0.00	372.90	0.00	172.33	38.94	66.23
15	26		55.48		38.52		4.32	1.67		0.00	14.42	0.00	10.02	0.00	1.12	0.43	0.00
16	34		0.01		74.90	20.52	0.24	0.58	3.74	0.00	0.00	0.00	25.47	6.98	0.08	0.20	1.27
17	1373	6.83	13.94	0.08	69.51		0.17	8.98	0.49	93.78	191.40	1.10	954.37	0.00	2.33	123.30	6.73
18	951	9.67	28.55	2.90	33.10	18.23	1.21	5.97	0.36	91.96	271.51	27.58	314.78	173.37	11.51	56.77	3.42
19	337	5.78	33.5		56.91	0.21		3.59		19.48	112.90	0.00	191.79	0.71	0.00	12.10	0.00
20	686	1.70	16.56	3.33	47.58	26.45	0.62	3.76		11.66	113.60	22.84	326.40	181.45	4.25	25.79	0.00
21	105	36.94	25.18		25.72	10.02		2.14		38.79	26.44	0.00	27.01	10.52	0.00	2.25	0.00
22	1326		56.06	2.86	36.98		0.61	3.49		0.00	743.36	37.92	490.35	0.00	8.09	46.28	0.00
23	1686	0.31	42.96		45.81		8.41	2.51		5.23	724.31	0.00	772.36	0.00	141.79	42.32	0.00
24	741		38.17	1.18	56.59		0.83	3.22		0.00	282.84	8.74	419.33	0.00	6.15	23.86	0.00

Calibrated Coeff.
Lbs/acre/year

Commercial	334.7
Forested	1.4
Multifamily	176.0
Open Urban Land	1.7
Residential-High Density	176.0
Residential-Low Density	73.8
Residential-Med. Density**	N/A
Industrial	224.1
Roadway/Parking Lot	762.1
Open Non-Urban Land	1.4

Total Suspended Solids (TSS) Loadings

TSS Land Use Loads (lbs/yr)								Total Subwatershed TSS Loads				Total Subwatershed TSS Loads - No Roads			
Commercial	Forest	HighDenRes	LowDenRes	Industrial	Open Space	Road	Water	(lb/yr)	(ft ³ /yr)	(yd ³ /yr)	(ton/yr)	(lb/yr)	(ft ³ /yr)	(yd ³ /yr)	(ton/yr)
4187.70	185.08	30631.00	9394.93	8752.90	0.00	76685.55	0.00	129837.17	1298.37	48.09	64.92	53151.62	531.52	19.69	26.58
31997.29	52.22	3178.12	0.00	6036.09	0.00	13939.19	0.00	55202.91	552.03	20.45	27.60	41263.72	412.64	15.28	20.63
0.00	17.62	0.00	147.51	0.00	0.00	3363.68	0.00	3528.81	35.29	1.31	1.76	165.13	1.65	0.06	0.08
18541.18	568.28	15837.18	21043.10	91847.16	0.00	79827.69	0.00	227664.58	2276.65	84.32	113.83	147836.89	1478.37	54.75	73.92
63493.09	78.29	15853.97	1656.86	12820.78	9.95	30319.62	0.00	124232.57	1242.33	46.01	62.12	93912.95	939.13	34.78	46.96
49197.15	422.84	27784.91	10719.30	37426.49	120.41	42619.07	0.00	168290.18	1682.90	62.33	84.15	125671.10	1256.71	46.54	62.84
74962.09	250.79	963.07	29501.11	10713.77	1.96	61602.07	0.00	177994.86	1779.95	65.92	89.00	116392.79	1163.93	43.11	58.20
4157.74	400.27	0.00	7819.69	14568.38	8.51	10851.54	0.00	37806.14	378.06	14.00	18.90	26954.60	269.55	9.98	13.48
0.00	411.13	0.00	21638.05	0.00	0.00	18244.67	0.00	40293.85	402.94	14.92	20.15	22049.18	220.49	8.17	11.02
8202.79	854.62	0.00	17788.85	0.00	52.20	16387.51	0.00	43285.98	432.86	16.03	21.64	26898.46	268.98	9.96	13.45
0.00	952.95	0.00	55766.47	0.00	494.72	30181.60	0.00	87395.74	873.96	32.37	43.70	57214.14	572.14	21.19	28.61
1119.57	958.14	0.00	27520.06	0.00	292.97	29672.97	0.00	59563.72	595.64	22.06	29.78	29890.75	298.91	11.07	14.95
0.00	20.19	0.00	739.12	0.00	1.91	330.90	0.00	1092.13	10.92	0.40	0.55	761.23	7.61	0.28	0.38
0.00	0.00	0.00	1879.39	1563.50	0.14	150.29	0.00	3593.32	35.93	1.33	1.80	3443.04	34.43	1.28	1.72
31386.79	267.95	193.32	70432.68	0.00	3.97	93963.42	0.00	196248.13	1962.48	72.68	98.12	102284.71	1022.85	37.88	51.14
30779.58	380.11	4853.90	23230.84	38851.61	19.56	43268.00	0.00	141383.61	1413.84	52.36	70.69	98115.61	981.16	36.34	49.06
6519.49	158.05	0.00	14153.86	158.60	0.00	9220.11	0.00	30210.11	302.10	11.19	15.11	20989.99	209.90	7.77	10.49
3903.27	159.04	4020.51	24088.23	40662.27	7.23	19657.30	0.00	92497.86	924.98	34.26	46.25	72840.56	728.41	26.98	36.42
12982.01	37.01	0.00	1993.04	2357.76	0.00	1712.44	0.00	19082.26	190.82	7.07	9.54	17369.82	173.70	6.43	8.68
0.00	1040.70	6674.55	36188.18	0.00	13.75	35268.01	0.00	79185.19	791.85	29.33	39.59	43917.19	439.17	16.27	21.96
1749.34	1014.03	0.00	56999.92	0.00	241.05	32251.01	0.00	92255.34	922.55	34.17	46.13	60004.34	600.04	22.22	30.00
0.00	395.98	1538.91	30946.69	0.00	10.46	18183.86	0.00	51075.89	510.76	18.92	25.54	32892.03	328.92	12.18	16.45

Sediment Accumulation Volume Estimates vs Pond Storage										
Pond	Accumulation Rate (cm/yr)	Accumulation Rate (ft/yr)	Time (Years)	Total Accumulation (cm)	Total Accumulation (ft)	Pond Surface Area (ft ²)	Starting Pond Volume (ft ³)	Sediment Volume (ft ³)	Sediment Volume (yd ³)	Loss of Reservoir Volume (%)
Bowers Pond	0.26	0.00853	1	0.26	0.00853	2,871,694	24,060,954	24,496	907	0.1%
	0.51	0.01673	1	0.51	0.01673			48,050	1,780	0.2%
	0.85	0.02789	1	0.85	0.02789			80,083	2,966	0.3%
Harris Pond	0.26	0.00853	1	0.26	0.00853	2,488,960	45,448,469	21,231	786	0.0%
	0.51	0.01673	1	0.51	0.01673			41,646	1,542	0.1%
	0.85	0.02789	1	0.85	0.02789			69,410	2,571	0.2%
Holts Pond	0.26	0.00853	1	0.26	0.00853	189,938	2,029,528	1,620	60	0.1%
	0.51	0.01673	1	0.51	0.01673			3,178	118	0.2%
	0.85	0.02789	1	0.85	0.02789			5,297	196	0.3%
Bowers Pond	0.26	0.00853	50	13.00	0.42651	2,871,694	24,060,954	1,224,804	45,363	5%
	0.51	0.01673	50	25.50	0.83661			2,402,500	88,981	10%
	0.85	0.02789	50	42.50	1.39436			4,004,167	148,302	17%
Harris Pond	0.26	0.00853	50	13.00	0.42651	2,488,960	45,448,469	1,061,564	39,317	2%
	0.51	0.01673	50	25.50	0.83661			2,082,299	77,122	5%
	0.85	0.02789	50	42.50	1.39436			3,470,499	128,537	8%
Holts Pond	0.26	0.00853	50	13.00	0.42651	189,938	2,029,528	81,010	3,000	4%
	0.51	0.01673	50	25.50	0.83661			158,905	5,885	8%
	0.85	0.02789	50	42.50	1.39436			264,841	9,809	13%
Bowers Pond	0.26	0.00853	100	26.00	0.85302	2,871,694	24,060,954	2,449,608	90,726	10%
	0.51	0.01673	100	51.00	1.67323			4,805,000	177,963	20%
	0.85	0.02789	100	85.00	2.78871			8,008,333	296,605	33%
Harris Pond	0.26	0.00853	100	26.00	0.85302	2,488,960	45,448,469	2,123,129	78,634	5%
	0.51	0.01673	100	51.00	1.67323			4,164,598	154,244	9%
	0.85	0.02789	100	85.00	2.78871			6,940,997	257,074	15%
Holts Pond	0.26	0.00853	100	26.00	0.85302	189,938	2,029,528	162,021	6,001	8%
	0.51	0.01673	100	51.00	1.67323			317,810	11,771	16%
	0.85	0.02789	100	85.00	2.78871			529,683	19,618	26%
Bowers Pond	0.26	0.00853	120	31.20	1.02362	2,871,694	24,060,954	2,939,529	108,871	12%
	0.51	0.01673	120	61.20	2.00787			5,766,000	213,556	24%
	0.85	0.02789	120	102.00	3.34646			9,610,000	355,926	40%
Harris Pond	0.26	0.00853	120	31.20	1.02362	2,488,960	45,448,469	2,547,754	94,361	6%
	0.51	0.01673	120	61.20	2.00787			4,997,518	185,093	11%
	0.85	0.02789	120	102.00	3.34646			8,329,197	308,489	18%

Combined Loadings for Holts, Bowers, & Harris Ponds			
Accumulation Rate (cm/yr)	Time (Years)	Sediment Volume (yd³)	Combined Watershed Loadings (yd³)
0.26	1	1,754	3,422
0.85	1	5,733	
0.26	50	87,681	171,083
0.85	50	286,648	
0.26	100	175,361	342,165
0.85	100	573,297	

Directly Contributing Watershed Loadings							
Location	Directly Contributing Watersheds	Roadway Loading (yd³/yr)	Land Use Loading (yd³/yr)	Combined Roadway and Land Use Loadings (yd³/yr)	Sediment Volume Range as Determined by Radiochemical Testing (yd³/yr)		
Holts Pond	8 through 24	2652	318	2,970	60	to	196
Bowers Pond	4,6	200	70	270	907	to	2,966
Harris Pond	3,4,5,7	148	70	218	786	to	2,571

* These directly

Empirical Sediment Accumulation on Annual Basis						
Watersheds	Ponds	Watershed Loadings (cy / yr)	Watershed Loadings (cf / yr)	Surface Area (sf)	Accumulation (ft/yr)	Accumulation (cm/yr)
4 and 6	Harris Direct	270	7,290	2,871,694	0.002538571	0.0774
3,4,5 and 7	Bowers Direct	218	5,886	2,488,960	0.002364843	0.0721
All	All (Harris Total)	3,422	92,385	5,550,592	0.016644089	0.5073
8 through 24	Holts Total	2,970	80,190	189,938	0.422190399	12.8684
3,4,5,7 and 8 - 24	Bowers Total	3,188	86,076	2,871,694	0.029973946	0.9136

Appendix D

Radiochemical Analysis of a New Hampshire Pond Core

Data Report to:

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Project Engineer
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Marlborough, MA 01752

Report by:

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Methods

Ten sections of a sediment core were provided to me, along with sample depths and time of collection. These samples were dried to determine porosity gravimetrically, and then were ground in a porcelain mortar and pestle to a powder. Samples of known mass were subsequently sealed in polypropylene jars and left for 20 days to allow ingrowth and secular equilibrium of intermediate daughter products of Ra-226 and Rn-222 (Pb-214 and Bi-214) to occur. The uppermost two samples were counted immediately to determine the activity of Be-7, a naturally occurring radionuclide with a 50-d half-life, and then counted again for Pb-210 and Cs-137 after the 20 days had passed. Samples were counted for up to three days each on an ORTEC planar germanium detector, using gamma spectroscopic MCA software, to gather enough counts in each peak. Be-7 and Cs-137 were determined by quantification of their gamma emission peaks at 477 and 661 KeV, respectively. Total Pb-210 was determined by quantification of its 46.5-KeV emission peak, whereas Ra-226 (which equals supported Pb-210) activity was determined by averaging the activities of its three daughter isotopes Pb-214 (at 295 and 352 KeV) and Bi-214 (at 609 KeV). Excess Pb-210, the value needed to determine an accumulation rate, was determined by subtracting supported Pb-210 activities (Ra-226) from the total Pb-210 value in each interval. Results were plotted in Sigmaplot 12.0. Detection limits for Cs-137 are 0.05 dpm/g and for excess Pb-210 are 0.3 dpm/g (shown on plots as vertical line). These detection limits are typical for the gamma spectroscopic technique.

Results

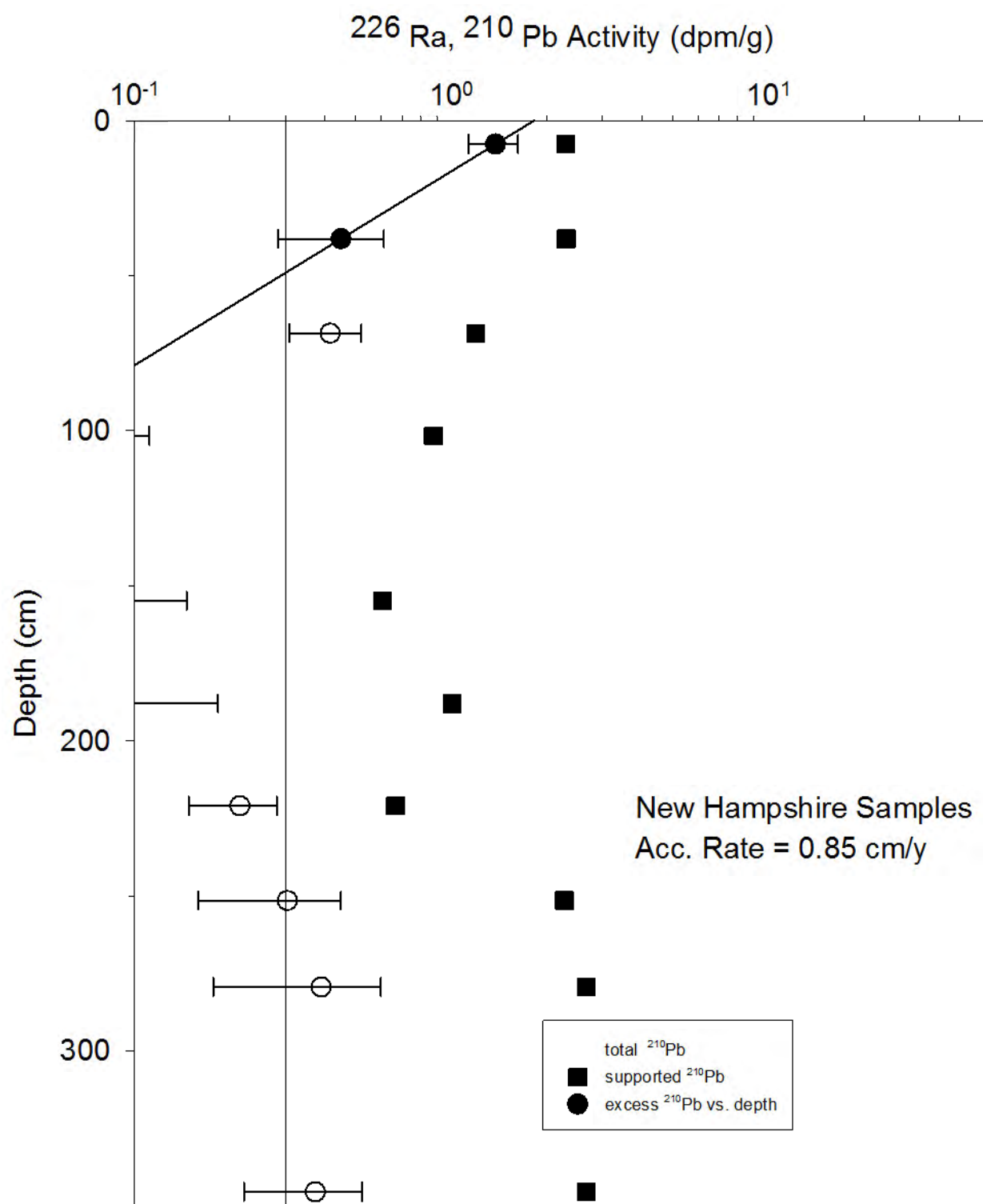
Sediment in the core was very heterogeneous, which complicates the interpretation of Pb-210, Cs-137 and Be-7 radiochemical profiles. Fine-grained materials are preferred for radiochemical studies because clay particles have a high surface area to mass ratio, therefore can carry a strong adsorbed radiochemical signal. The upper two core intervals were suitable, being an organic rich, fine-grained mud, whereas other core intervals were sandy materials of various sizes, except for the last two, which again have some component of mud. Some of these core intervals represent sediment that has accumulated in the pond since construction, and some of the intervals of the core may represent the native sediments below the depth to which the pond was dug.

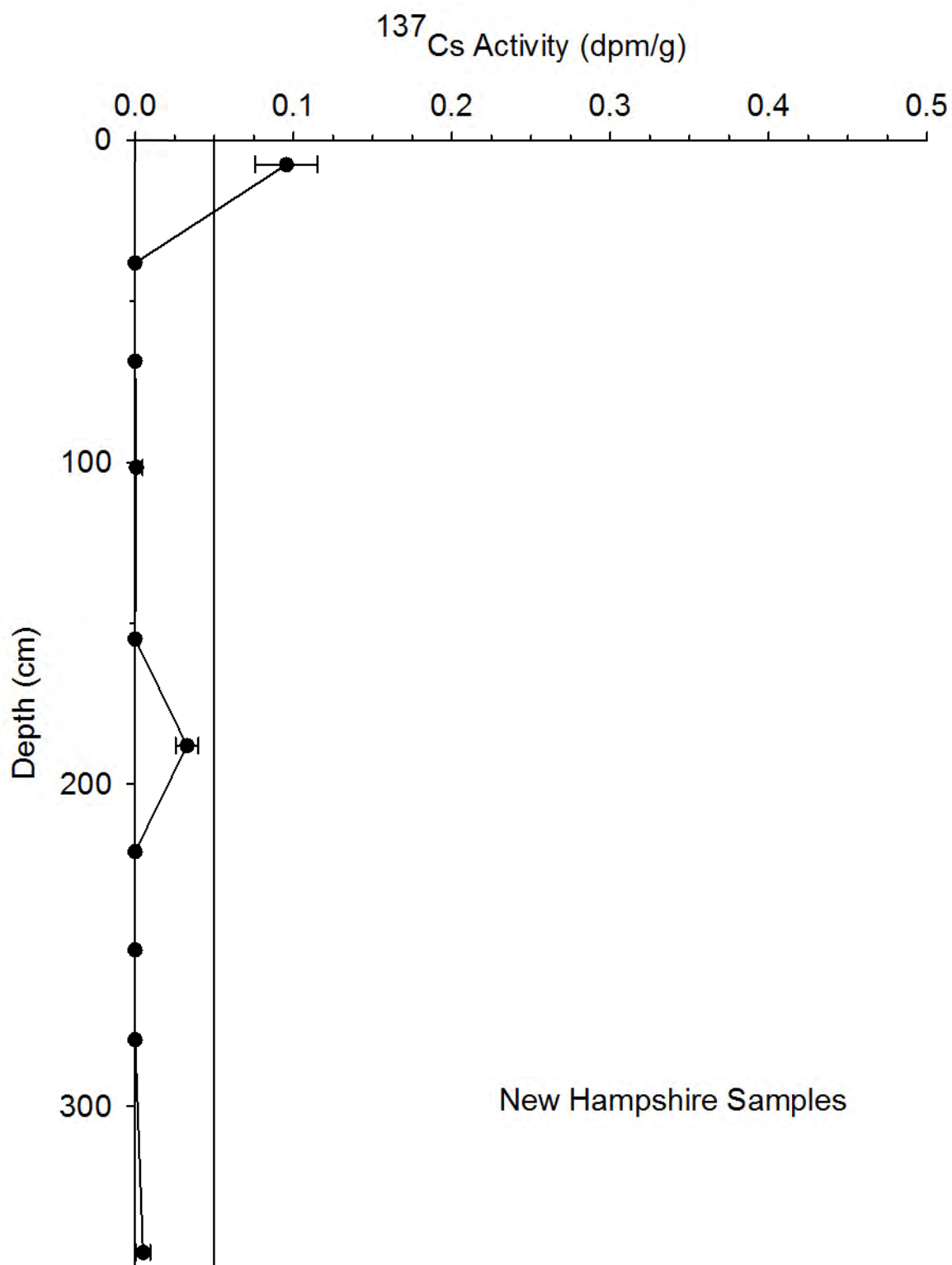
No Be-7 was present in the core. After counting the top two intervals, which were appropriately muddy and representing the upper 50 cm of the core, the absence of any Be-7 activity precluded any need to count the core deeper for Be-7. The absence of Be-7 indicates that there has been little sediment input to the pond within approximately the past 6 months.

Cs-137 is only present above detection limits in the first core interval (0-15.2 cm), providing an upper limit estimate on the accumulation rate of +0.26 cm/y (=15.2 cm/58 y; 2012-1954 = 58 y, with the assumption that 2012 was the year of core collection and 1954 was the first appearance of Cs-137 in the environment).

Significant excess Pb-210 is only observed in the upper two core intervals, and the activity in the second interval is very close to my detection limits. The core sampling interval was too widely spaced to adequately capture the Pb-210 decay profile, to provide a well-constrained accumulation rate, nor to capture the details of the Cs-137 profile. All Pb-210 values below the upper two are very close to or below detection limits. Excess Pb-210 should be observed deeper in the core than should Cs-137 because excess Pb-210 decays away over 112 years, whereas Cs-137 has been in the environment for only 58 years (since 1954). Using the upper two data points as bounding datapoints to determine an accumulation rate, we compute a maximum accumulation rate of 0.85 cm/y over the past 100 years, suggesting that the upper ~85 cm (33 in) represents the sediment input to the pond during that period.

These data and the sediment character data are included in Table 1 (excel file attached to email). These data suggest that the pond is receiving very little sediment currently and has received sediment at rates <0.8 cm/y in the past 100 years. The graded stratigraphy (i.e., coarse sands grading into finer sand and then into muds) also suggests that this pond may have been filled significantly by a large event or events (storms or human land-disturbing activities). Given the variable and coarse nature of the sediments in the core, interpreting the radiochemical data is not straightforward. Without additional knowledge of the context within which this pond resides, interpretations should be considered conjectural. If I had more information on the setting for the pond itself, I would be happy to discuss how my results can be used better to inform your studies. Information that might be pertinent would include when and where the pond was built, how deep it was when constructed, how deep it is now, sources of sediment to the pond and what you are trying to achieve with the radiochemical data.





New Hampshire Pond Core

Dr. Clark Alexander, Skidaway Institute of Oceanography

Results reported Feb. 24, 2013

Section	Interval (cm)	Midpoint (cm)	Porosity (%)	Pb-210 _{tot} (dpm/g)	Pb-210 _{tot} error	Ra-226 (dpm/g)	Ra-226 error	Pb-210 _{xs} (dpm/g)
1	0.0-15.2	7.6	88.25	3.67	0.17	2.30	0.18	1.38
2	30.5-45.7	38.1	71.80	2.75	0.11	2.30	0.12	0.45
3	61.0-76.2	68.6	60.57	1.61	0.07	1.19	0.07	0.41
4	94.0-109.2	101.6	54.42	0.91	0.05	0.88	0.06	0.03
5	147.3-162.6	154.9	34.90	0.70	0.04	0.61	0.04	0.09
6	180.3-195.6	188.0	38.01	1.09	0.07	1.00	0.07	0.08
7	213.4-228.6	221.0	40.75	0.88	0.05	0.67	0.04	0.22
8	243.8-259.1	251.5	34.61	2.57	0.10	2.27	0.10	0.30
9	271.8-287.0	279.4	32.26	3.05	0.15	2.66	0.15	0.39
10	337.8-353.1	345.4	34.77	3.03	0.11	2.66	0.11	0.37

NOTES

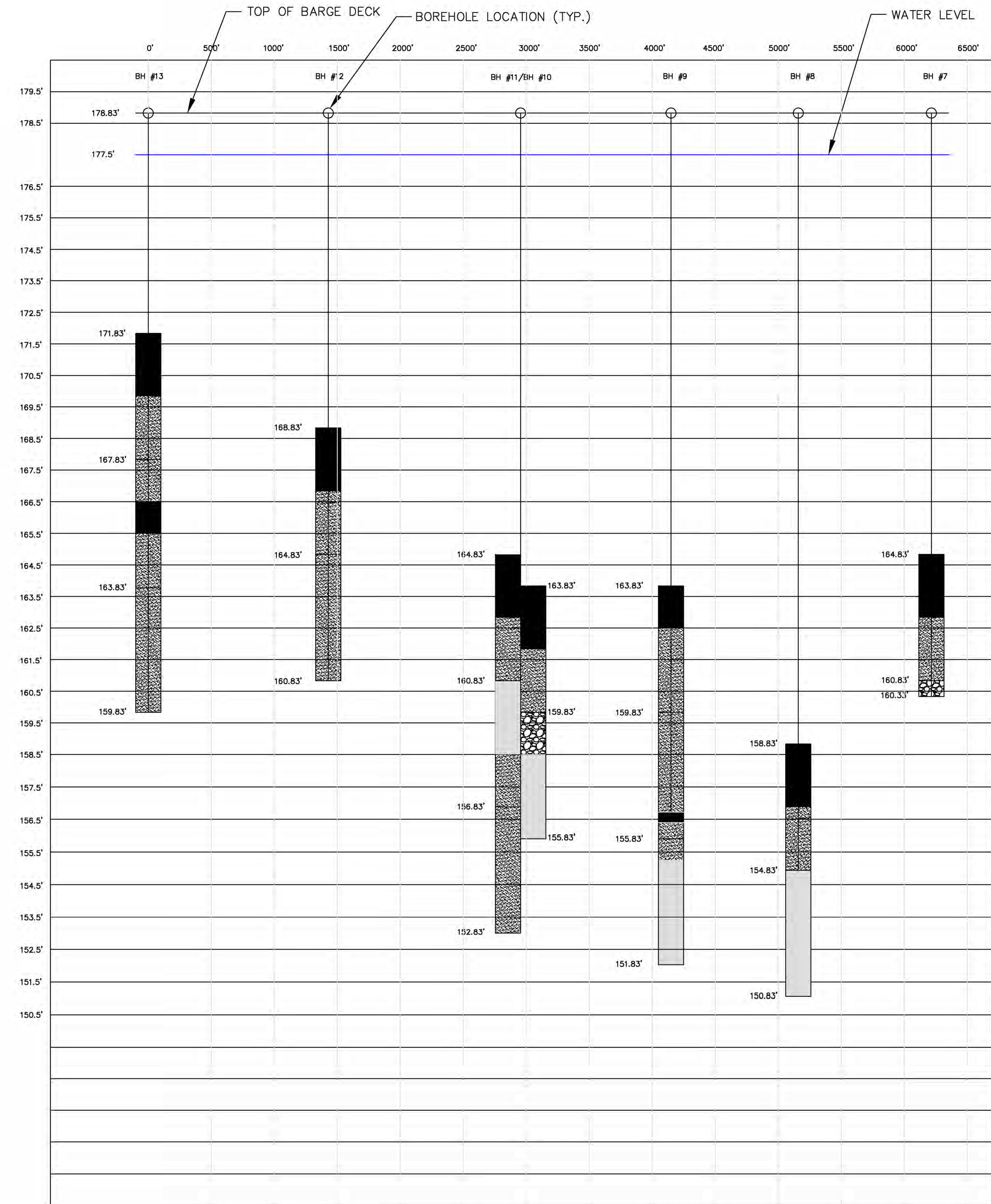
NA: not analyzed

New Hampshire Pond Core

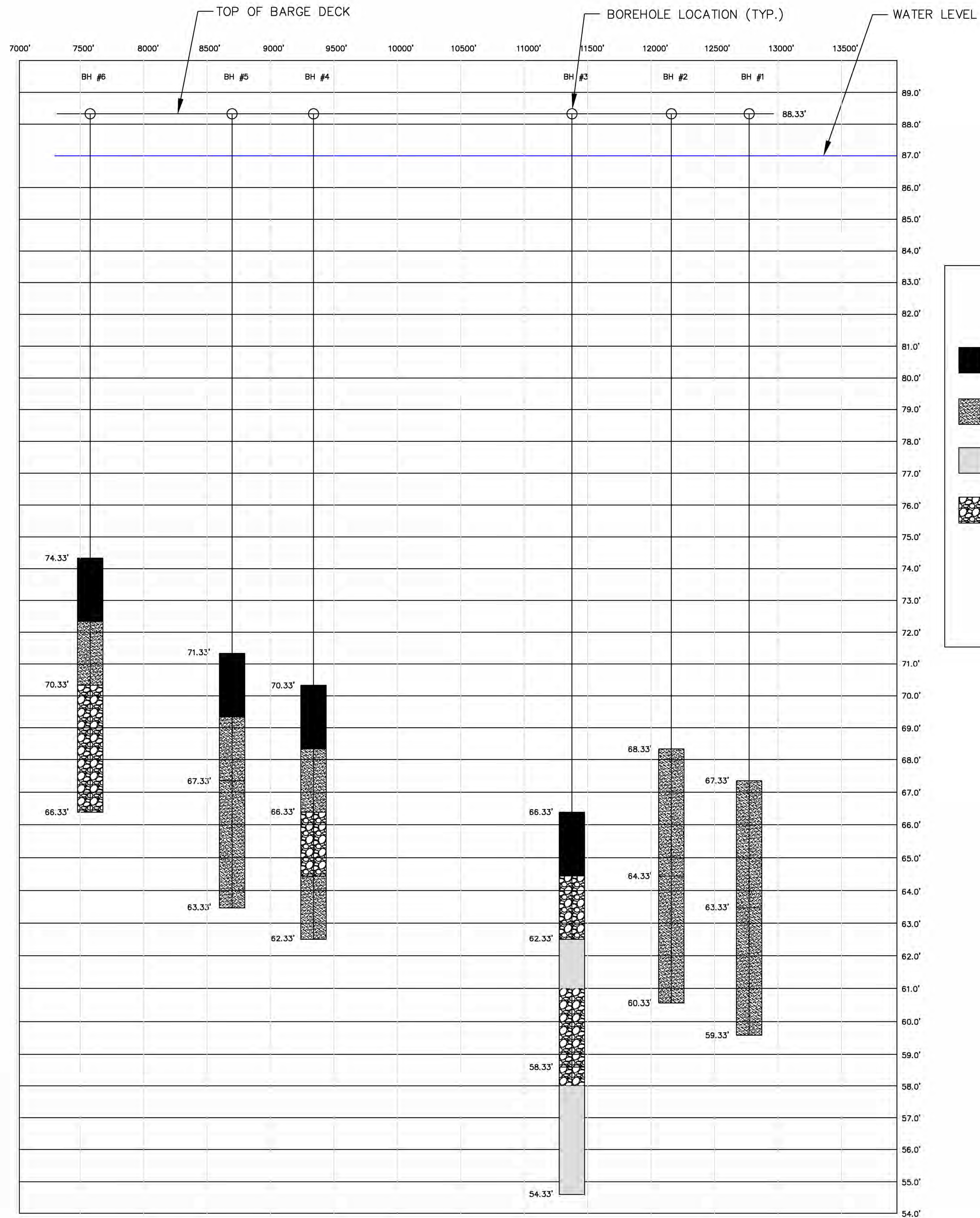
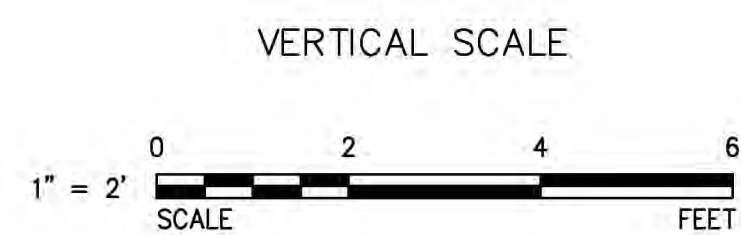
Dr. Clark Alexander, Skidaway Institute of Oceanography

Results reported Feb. 24, 2013

Pb-210_{xs} error	Cs-137 (dpm/g)	Cs-137 error (dpm/g)	Be-7 (dpm/g)	Be-7 error (dpm/g)	Visual Sediment Description
0.24	0.10	0.020	-0.17	-0.06	mud & organic material
0.16	-0.01	-0.004	-0.11	-0.04	mud & organic material
0.11	-0.01	-0.003	NA	NA	medium sand
0.08	0.00	0.004	NA	NA	medium sand
0.06	-0.01	-0.003	NA	NA	very coarse sand
0.10	0.03	0.007	NA	NA	very coarse sand
0.07	-0.01	-0.003	NA	NA	very coarse sand & organic material
0.14	-0.01	-0.003	NA	NA	fine sand
0.21	-0.01	-0.003	NA	NA	fine sand & mud
0.15	0.01	0.005	NA	NA	fine sand & mud



BOWERS POND
ELEVATION=177.5'



HARRIS POND
ELEVATION=90.5'

