

Reservoir Storage Estimates & Tributary and Pond Sediment Accumulation Monitoring

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Executive Summary

The purpose of this project, which was partially funded under a Local Source Water Protection Grant by the New Hampshire Department of Environmental Services (NHDES), was to evaluate sediment accumulation and inputs in the Pennichuck Supply Ponds to enhance their water supply storage capacity. It builds on previous studies conducted by Pennichuck Water Works Inc. (PWW) in 2000, 2010 and 2013 by further analyzing the physical and chemical attributes of sediment deposits within the Pennichuck Brook Watershed, again recording sediment depths at permanent monitoring locations within Bowers and Harris Ponds. As water supply storage ponds, an important aspect of the project was to estimate active and unavailable (aka dead) storage volumes within Holt, Bowers, and Harris Ponds.

The engineering firm of Comprehensive Environmental Inc. (CEI) was hired by PWW to perform the work. CEI completed an assessment of sediment accumulation, sediment sources, inputs and potential contaminant sources on the primary stream tributaries of the Pennichuck Brook and into the Supply Pond systems. CEI evaluated the tributaries by walking and documenting by sUAS video. Summaries and findings of the specific grant funded tasks are provided as grant completion documentation (see Appendices A through I). This work was completed in accordance with a NH DES approved Site-Specific Project Plan (SSPP) that addressed sediment collection, handling, evaluation, and testing protocols used during the tributary and delta investigations (see Appendix E).

Using a combination of drone tributary video surveys, bathymetric mapping of water bodies, and estimating/measuring sediment thicknesses, CEI engineers updated GIS maps of the water bodies and generated estimates comparing data from 2010 and 2017 on active storage volumes. The results indicate that Harris and Bowers Ponds could benefit from dredging to revive active storage, and that several other protection measures could be added to Pennichuck's already expansive watershed protection program as outlined below and in the following report. Many Watershed Restoration Plan recommendations have been identified and could coincide with the following:

1. Estimate supply pond infill rates in more detail by comparing the new 2017 data to data collected by others in 2011 (that has only recently become available).
2. Evaluate the feasibility and cost effectiveness of maintenance dredging of the Tinker Pond detention basin.
3. Evaluate the feasibility of dredging Harris and potentially Bowers Ponds to restore active storage volume including whether targeted sediment removal from active storage would be beneficial and where the material could be staged for dewatering.
4. Evaluate Boire Airfield Brook including a hydraulic analysis of the Tinker Road triple barrel culvert for simulated storm events and identify Best Management Practice (BMP)

*Reservoir Storage Estimates &
Tributary and Pond Sediment Accumulation Monitoring*



options. Also evaluate the condition of the culvert under the Everett Turnpike at each end for potential spill control BMPs. This project should be eligible for Source Water funding.

5. Inventory and assess watershed culverts in watershed towns for condition and potential for washout that could impact the ponds or road crossings. This project should be eligible for Source Water funding.
6. Assess aquatic vegetation and develop a management plan for controlling invasives that are filling in the ponds as they decay.
7. Identify the need for a Public/Private Partnership (PPP) to reestablish tributary buffers in areas of the watershed that were identified by drone as having problematic land uses, for example, a junkyard near the stream boundary. Work with watershed communities to determine if actions have already been taken or are planned, or need to go forward at these locations. Provide a plan for next steps, if any, which might include a PPP involving Pennichuck and the landowner.

These recommendations could be used to update the Watershed Restoration Plan (WRP) and build on previous WRP recommendations. Additional, if implemented, the available NHDES tools can be used to assess the success of NPS pollution reduction efforts. Residents in the watershed can participate in programs such as Soak Up the Rain NH and the Watershed Steward Program

As part of the match funding provided by Pennichuck for this grant, infill comparisons between 2010 and 2017 were completed. The estimated water and sediment volumes in each of the ponds is shown below.

WITHIN THE BOUNDARIES OF THE 2010 BATHYMETRY:

Water Volumes in Active and Dead Storage as of 2017

	Active (cu. ft.)	Active (gal.)	Dead (cu. ft.)	Dead (gal.)
Holt	92,000	690,000	261,000	1,956,000
Bowers	22,373,000	167,361,000	6,664,000	49,849,000
Harris	41,254,000	308,598,000	346,000	2,591,000

Sediment Volumes Occupying Active Storage Space as of 2017

	Active (cu. ft.)	Active (cu. yd.)
Holt	0	0
Bowers	5,090,000	189,000
Harris	21,526,000	797,000

Water Volumes in Active and Dead Storage in 2010

	Active (cu. ft.)	Active (gal.)	Dead (cu. ft.)	Dead (gal.)
Holt	226,000	1,690,000	478,000	3,573,000



Bowers	21,841,000	163,381,000	5,619,000	42,033,000
Harris	40,967,000	306,454,000	382,000	2,855,000

Sediment Volumes Occupying Active Storage Space in 2010

	Active (cu. ft.)	Active (cu. yd.)
Holt	0	0
Bowers	16,331,000	605,000
Harris	40,871,000	1,514,000

Harris Pond, the closest supply pond to the treatment plant, has the greatest volume of sediments occupying the active storage area, so it is the key pond for a dredging feasibility study. Based on previous sediment core efforts in Harris¹, some of these sediment accumulations consist of coarser material possibly associated with NPS pollution or erosion.

Bowers Pond also has varying types of sediment consuming active storage, however, not as substantial as Harris. Based on previous sediment core efforts in Bowers Pond, sediment accumulation appears to be a mixture of fine organic sediment (similar to Holt) with some coarser sediment accumulations. It is also recommended that Bowers Pond be continually monitored for sediment migration and a separate dredging feasibility be conducted based on differing site conditions and access compared to Harris Pond.

The bathymetric and sediment thickness data are somewhat sparse in Holt Pond. The pond is calculated to have zero sediment occupying active storage space within the footprint of the previously mapped 2010 data, but it should be noted that there is very little active storage space available. Additionally, sediment samples taken in Holt Pond reveal a much finer organic sediment possibly associated with excessive plant growth and decayed material noted throughout Holt Pond, the lower reaches of Pennichuck Brook and Witches Brook. For these reasons, a separate aquatic vegetation management strategy is proposed for Holt Pond and portions of Bowers Pond.

Changes in volume between the 2010 and 2017 measurements may be due to shifting sediments, differences in methodology, or major storms that washed sediments downstream. More will be known when the 2011 data (which only recently became available) is assessed. Also, the expense of dredging (including permitting) will be compared by PWW to the cost of producing water from other sources before proceeding.

In the tributaries directly upgradient of Holt Pond, slope and erodible soils issues are not prominent in erosion and sedimentation issues. Portions of Pennichuck Brook and Witches Brook are relatively flat and are often surrounded by large tracts of flat vegetated floodplains. Potential pollution sources in Boire Field and Stump Pond Brooks tend to have more relation to erosion, steep banks and higher velocity runoff. As part of the Local Source Water Protection Grant, CEI compiled an inventory of the tributary conditions, sediment accumulation and potential protection measures. The table below summarizes the sediment input types, potential

¹ Pennichuck Corporation, Merrimack, NH. (August 2013) "Bowers & Harris Pond Sediment Analysis Study." Retrieved from: pennichuck.com/source-water-protection/about-pennichuck-watershed/sediment-analysis/.



sources and protection measures for each tributary section based on observations made under the grant funded tasks. The BMPs, costs, permitting and land ownership are also summarized for each tributary section based on the list of recommendations from this report and the WRP.

Summary Table						
Tributary	Description of Terrain & Buffer/ Floodplain	Sediment Types	Potential Sources	Proposed BMPs Recommendations	Cost Range	Feasibility/ Permitting/ Constraints
Pennichuck Brook – Lower	• Flat terrain • Large floodplain • Good vegetated buffer • Less erosive soils	Finer material; high organics; high TP (Samples S-1,2,3)	Plant decay; excessive plant growth	• Dredging ponds	\$1M-\$3M	Large scale projects; challenging permitting; access issues
				• Aquatic plant assessment	\$20K-\$50K	Minimal permitting issues; accessible areas
				• Culvert assessments & replacements	\$40K-\$180K	Large culverts
Pennichuck Brook – Upper	• Steeper sections upgradient of Pennichuck Pond • High erosion potential • Less developed areas	N/A	Erosion; stream impacts	• Culvert assessments & replacements	\$50K-\$200K	Steeper areas; multiple crossings; smaller culverts
Witches Brook	• Flat terrain • Large floodplain • Good vegetated buffer • Highly developed areas	Finer material; high organics	Erosion; NPS pollution; buffer loss; excessive plant growth/die-off	• Buffer repairs	\$10K-\$30K	Private ownership; challenging permitting
				• BMP assessments	\$100K-\$300K	Private ownership; challenging permitting
Muddy Pond Brook	• Steeper sections in upper watershed • Flat floodplain • Well vegetated leading to Pennichuck Brook • Less developed	N/A	Erosion; excessive plant growth	• Culvert assessments & replacements	\$40K-\$100K	Multiple crossings; some large crossings
				• Buffer repairs	\$10K-\$30K	Private ownership; challenging permitting
Stump Pond Brook	• Steeper sections • Highly developed areas • Some buffer loss	Finer material; lower organics; moderate TP (Sample S-5)	Erosion; NPS pollution; buffer loss	• Culvert assessments & replacements	\$30K-\$90K	Small sized culverts; good access
				• Buffer repairs	\$10K-\$30K	Private ownership
				• BMP assessments	\$10K-\$150K	Private ownership
Boire Field Brook	• Steeper sections • Higher developed areas with less buffers	Course material; low organics; low TP; (Sample S-4)	Erosion; NPS pollution	• BMP evaluation	\$100K-\$300K	DOT coordination required
				• Culvert assessments & replacements	\$50K-\$100K	Large culverts
				• Tinker Pond dredge	\$500K	Challenging permitting; accessible
				• Dredging ponds	\$1M-\$3M	Challenging permitting; access issues



Appendix A

Project Tasks Summary

Introduction

The scope of services for this study included twelve tasks, as described below. Tasks 1 through 9 were completed under and funded through the Local Source Water (LSW) Grant Program provided by the New Hampshire Department of Environmental Services (NHDES) to Pennichuck Water Works (PWW). As part of grant match funding, PWW funded the completion of Task 10, 11 and 12. This section provides a summary of completed tasks, methods, findings and results for each of the NHDES LSW grant tasks and tasks funded by PWW as match.

NHDES Local Source Water (LSW) Grant Funded Tasks

1. Data Collection - Collect the most recent high-resolution aerial imagery and Lidar elevation data available from state, local, or private sources;
2. Selection of Areas for Field Evaluation - Evaluate the aerial imagery to identify potential sediment deltas within the ponds and tributaries, and select the largest for more detailed field evaluation;
3. Soils Data - Collect soils data for the watershed, and review in the context of topographic data to identify locations where soil type and terrain indicate a higher likelihood of erosion or sediment transport;
4. Field Evaluation - Conduct field evaluation of four tributaries with existing or potential erosion issues, including collection of data on streambank conditions, surrounding land use, and any existing sediment deltas;
5. Sediment Sampling - Collect sediment samples from deltas and deposits;
6. Sediment Physical Analysis - Analyze the samples for grain size distribution, moisture content, and organic content (copies of results in Appendix B);
7. Sediment Nutrient Analysis - Analyze the samples for phosphorus levels and iron content (copies of results in Appendix C);
8. Potential Measures - Recommend potential measures to prevent further degradation of the tributaries and sediment transport into the supply pond chain;
9. Site Specific Project Plan - Prepare a Site Specific Project Plan (SSPP) to address procedures and protocols employed in the tributary and sediment delta investigations;

Grant Match Tasks - Funded by PWW

10. Active and Dead Storage Volumes - Compare active and dead storage volumes with current and projected sediment volumes in Bowers and Harris Ponds;
11. Soundings at Permanent Monitoring Stations - Take echo-sounding and sediment depth measurements at each of the thirteen permanent sediment monitoring stations, and establish an electronic database for future data collection (attached in Appendix I); and,
12. Soundings and Samples - Take echo-sounding and sediment depth measurements in traverses across Holt Pond, and collect up to four sediment samples.



Task 1 & 2. Data Collection and Selection of Areas for Field Evaluation (NHDES LSW Grant Funded Tasks)

CEI completed a desktop investigation involving a review of existing high-resolution aerial imagery and LiDAR from various available data sources, such as the University of New Hampshire's GRANIT GIS database, the City of Nashua, NHDES, and the United States Geological Survey (USGS). Spatial information retrieved from these sources was used in identifying relevant features within the watershed, including potential sediment sources, upstream tributaries connected to the supply ponds, slope and elevation data, and geologic soil characteristics. See Figure 1 Watershed Orthophoto in the Appendices.

The aerial data was all free available downloads from GIS and NRPC online sources. The research did not identify any available high resolution imagery for purchase online. It was originally planned to hire aerial imagery collection services (via airplane flyover), however it was decided to use the sUAS to supplement the lack of available high resolution imagery since the drone was going to be used to walk and observe the tributaries. Video documentation is provided in electronic format on a thumb drive in Appendix H.

Lidar-derived elevation at 1-meter resolution (available from GRANIT, New Hampshire's GIS data repository) varies from a low of about 140 feet, near the Supply Pond dam, to a high of over 800 feet in the extreme western corner of the Witches Brook South subwatershed. See Figure 2: LiDAR Elevations, displays elevation differential throughout the Pennichuck Brook Watershed. There are two significant faults that run through the watershed, and the course of Pennichuck Brook from the southern border, north to Pennichuck Pond, appears influenced by one of the faults. Slope information throughout the watershed was obtained through LiDAR, and is displayed in Figure 3: LiDAR-Derived Slope. This figure highlights some steep terrain in the southern and western portions of the watershed, attributed to some stony slopes and rocky outcrops in the area. Table 1: Slope Categories by Subwatershed, displays the slopes within each of the 10 subwatersheds that comprise the Pennichuck Brook Watershed, with respect to their surface area.

According to the New Hampshire Conservation/Public Lands GIS data layer available from GRANIT and updated in May 2016, there are about 2,439 acres of conservation land owned by federal, state, municipal, or private entities in the Pennichuck Brook watershed, comprising about 14% of the total area, which can be seen in Figure 4: Conservation Lands. Most of these lands restrict or prohibit any form of development or large-scale disturbance of the vegetation or soils.

Task 3 & 4. Soils Data & Field Evaluation (NHDES LSW Grant Funded Tasks)

According to soil surveys produced by the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS), the soils of the Pennichuck Brook Watershed primarily consist of loams with varying proportions of sand, silt, and clay. Figure 5: General Soil Types, depicts the varying soil types found in the watershed. The soil parent material is glacial till and outwash gravels in a wide range of particle sizes, left in poorly consolidated deposits by the retreat of the ice



sheet. The soils tend to be favorable to the growth of hardwood or mixed hardwood and softwood tree stands. Some portions of the watershed are under cultivation and are farmlands of local or statewide significance. The class of natural soil drainage throughout the watershed is recognized as moderately-to-excessively well drained.

Large tracts of the soils in the watershed are rated by the NRCS as erodible or potentially highly erodible, as shown in Figure 6: Soil Erodibility. Areas where these erodible soils coincide with topographically steep terrain represent potential sources of sediment input into the Pennichuck Brook system. It is likely that the tributary channels have similar erosion-susceptible substrates in many areas and also represent a possible sediment source.

The distribution of highly erodible and less erodible soils is shown in Table 2: Erodible Soils by Subwatershed. Significant amounts of highly or potentially highly erodible material are found in the northeastern and southern parts of the watershed. Most of the unpaved roads are located in southern portions of the watershed and drain via roadside ditches, increasing the likelihood of localized erosion. Table 3: Paved and Unpaved Road Miles by Subwatershed, contains information pertaining to the road types and lengths found in each subwatershed within the Pennichuck Brook Watershed. Of particular relevance to this study is the amount of highly or potentially highly erodible soils at steep slopes (greater than 30 percent), as broken down in Table 4: Acres of Highly or Potentially Highly Erodible Soils by Slope Category, and as shown in Figure 7: Soil Erodibility with Slope.

Table 4 identifies Witches Brook South subwatershed as containing the largest total area of erodible steep slopes, followed by the hilly regions close to the supply ponds themselves. The steep slopes generally border the streams that incised them and that now flow into the supply ponds.

Tributaries experiencing existing or potential erosion issues were chosen for further evaluation in the field. The initial goal of this task was to assess these tributaries by kayaking the waterways and travelling adjacent to the streambanks by foot to identify potential erosion or sediment transport concerns. However, the scope of work under this task changed per discussion with Pennichuck Water Works Inc. to survey the tributaries of interest and the surrounding land features by means of a sUAS, or drone. The decision to alter the scope of work came about as a result of CEI developing a sUAS survey service during the contract agreement period. This approach allowed for significant improvements to the quantity of tributary data, data quality, and the efficiency of data collection. Although the goal of this task remained the same, the method was changed from photo documentation to drone video documentation to allow for improved evaluation of tributaries with potential erosion or sediment transport problems. CEI received authorized clearance from the Federal Aviation Administration (FAA) to operate a sUAS in areas within the Pennichuck Brook Watershed (attached in Appendix D).

There was no use of Source Water Protection grant funds to purchase the sUAS and camera. No billable hours covered by source water protection grant funds were used to obtain FAA clearance for use of the sUAS. The sUAS was used in conjunction with tributary evaluations. The original scope included walking or kayaking the tributaries. Under the original scope, it was assumed for safety purposes that two people would walk or kayak the tributaries. Due to the scale and level of access to some of the remote tributary portions, the drone was used to cover the remote areas while walking the tributaries. Two people walked the streams, one person sampled sediment as encountered while the



other flew the sUAS (documented conditions with a sUAS camera vs. a hand held camera). The only portion that was kayaked was the lower portion of Pennichuck Brook closest to Holt Pond. It is our understanding the sUAS was an added benefit to grant hours originally set aside for walking and photographing the streams.

The sUAS used for this study was a DJI® Phantom equipped with an on-board GPS and a camera. The camera captured 4K ultra high-resolution real-time videos from altitudes between 150-200 feet, as well as straight-down, overlapping photographs of the ground with a resolution generally in the range of 2 inches to less than an inch. The imagery taken with the drone was used to identify areas of erosion, sediment deposition, or disturbance in places that would otherwise be difficult to access by foot or kayak. A CD containing a compilation of drone aerial footage has been attached under Appendix H. This aerial footage helped to identify places that should be further investigated by performing additional drone flights during fall or winter months when the tree canopy becomes less dense, and/or conducting site walks to visit these sites that have the potential to be sediment and pollution sources.

Areas with potential sediment sources were chosen for further investigation based on several variables as listed below:

- Steep slopes composed of highly erodible or potentially highly erodible material;
- Soil or vegetation disturbance;
- Land use change since 2010;
- Areas of disturbance or development coinciding with erodible soils; and,
- Locations where any of these variables occur proximal to previously observed sediment accumulation areas in the ponds.

Areas within the watershed were then assessed for their potential to transport sediments to the supply ponds based on the variables listed above. The areas were prioritized and final locations were chosen for further investigation by tributary walks and sUAS flyovers to record detailed imagery and GPS data. Twelve sUAS flyovers were performed throughout the Pennichuck Brook Watershed, capturing a vast amount of high-resolution imagery of tributaries and adjacent features. The tributaries that were reviewed included Muddy Brook, Witches Brook, Stump Pond Brook, Boire Field Brook, and Pennichuck Brook. Figure 8: sUAS Surveys, identifies the flightpaths for the sUAS surveys. Portions of the tributaries that were evaluated and walked are also shown in Figure 8.

Tinker Pond and its associated stormwater Best Management Practices (BMPs), located directly to the east of the Everett Turnpike and to the south of Tinker Road, were flown over as part of this investigation. At the time of the sUAS flyover, Tinker Pond appeared to be experiencing a bloom of cyanobacteria (blue-green algae) and had significant areas of shallow depth with dense growth of water lilies and other aquatic vegetation. The potential cyanobacteria bloom was identified by sUAS footage only, no addition sampling was completed to confirm this. Given the conditions observed at Tinker Pond, an engineering evaluation should be conducted to determine (1) recommendations for both remedial and ongoing maintenance of the BMP to ensure optimal performance for pollutant attenuation, and (2) recommendations for any additional BMP features that could be retrofit to improve pollutant attenuation performance. Based on the engineering evaluation, recommendations should also be coordinated with a comprehensive approach to management of Tinkers Pond that may include the



dredging and aquatic vegetation control options such as hydro-raking to control the growth of water lilies (see Section 8 for further discussion of aquatic plant management).

Tasks 5, 6, 7 and 9 - Sediment Sampling & Analysis / SSSP (NHDES LSW Grant Funded Tasks)

CEI completed a Site-Specific Project Plan (SSPP) for this study as part of the Local Source Water Protection Grant requirements. The SSPP addresses site-specific sediment collection, handling, evaluation, and testing protocols that were applied during the tributary and sediment delta investigations described throughout this section. A draft of the SSPP was submitted to the NHDES for review, and a final version of the document was sent to Pennichuck Corporation for approval and signatures. The Final SSPP is contained within Appendix E.

Sediment samples were taken at points where sediment deposits had been observed within the supply ponds and/or adjoining tributaries. Methods of identifying sediment deposits included visual observation (deltas, mid-channel, point, or side deposits) within tributaries from aerial imagery and site walks, and by means of echo-sounding the supply ponds to differentiate current and historic sediment depths in order to find areas of buildup and erosion. Samples were retrieved in accordance with applicable standards and methods contained in the McQuesten Brook Watershed Dam Removal and Restoration Project Quality Assurance Program Plan (QAPP). Furthermore, the SSPP developed as part of the project scope, was used to provide greater technical detail regarding sampling and data collection procedures.

CEI collected a total of 5 sediment samples from within Holt Pond, Stump Pond Brook, and Boire Field Brook, based on observed sediment deposits observed during tributary evaluations, as displayed in Figure 9: Sediment Sample Locations which details the 5 sediment sampling locations. Duplicates of each sample were collected so that identical composite samples could be sent to multiple labs for specified analyses. Prior to collecting a sample, the given area of interest was divided into a grid and one sample was taken from each grid cell. The size of the grid was dependent and proportional to the size of the sediment deposition area. This approach was employed to allow best use of resources to recover composite samples that are equally representative from differently-sized areas.

A stainless-steel Van Veen grab sampler (metal clamshell bucket apparatus) was used to collect samples from a kayak within Holt Pond at three locations. These three samples (S-1, S-2, and S-3) were taken by gradually lowering the device into the water until it reached the sediment floor, and then pulling up gently, allowing the instrument to close and capture sediments within. Each sample in Holt Pond was composited from five (5) grab samples collected within the respective sample grid. Samples were taken along the riverine pond's thalweg, where echo-sounding data identified the greatest sediment buildups to occur.

Another sample (S-4) was taken from a large sediment deposit within Boire Field Brook, located along Tinker Road in Nashua, NH, to the west of the Everett Turnpike. The sediment deposit was positioned immediately upstream of a triple barrel series of culverts that pass under Tinker Road, which may be restricting streamflow and causing sediments to settle upstream. Positioned near the left bank of the stream channel, this sediment deposit had dimensions of approximately 15 feet long by 5 feet wide. A



total of four (4) grab samples were taken at this location using a stainless-steel, hand-driven coring tool, and then equally combined and mixed to create a composite sample.

The final sample (S-5) was collected in Stump Pond Brook near the intersection of Landau Way and Hansom Drive in Nashua, NH. This tributary is located upstream of Stump Pond, which flows into Witches Brook and ultimately discharges into Holt Pond. Sediment and decaying vegetation buildup was observed along the shoreline at this location during field investigations. A culvert was also located immediately downstream of where this sample was collected, and may have contributed to sediment buildup upstream due to flow restriction from being undersized. Four (4) grab samples were taken at this location and composited using the same collection and processing protocols employed at the previous site and that found in the SSPP. A *Field Investigation Photographs* attachment is provided in this report and contains multiple images for each of the areas where samples were collected during field investigations.

CEI sent five (5) sediment samples to S.W. Cole Engineering Inc. for a laboratory analysis of grain size and moisture/organic content. Five (5) duplicate samples were sent to ChemServe Analytical for laboratory analysis of phosphorus levels and iron content. Copies of these results are provided in Appendices B and C.

Sample S-1 was the first of three taken from Holt Pond and had a total phosphorous (TP) concentration of 118 mg/kg of dry weight and an iron content of 2,980 mg/kg of dry weight. This sample consisted of sands with some fines and possessed an organic odor. Laboratory results identified samples S-2 and S-3 to have significantly higher TP concentrations, containing 710 and 842 mg/kg of dry weight, respectively. These samples were comprised of very saturated sediments that appeared to be a combination of decaying plant matter and fine, silty materials. Iron content results for samples S-2 and S-3 were 12,300 and 7,560 mg/kg of dry weight, respectively. These results suggest that Holt Pond is rich in nutrients and may be losing active storage volume due to the presence of excessive vegetation and accumulating plant die-off.

Boire Field Brook and Stump Pond Brook, where samples S-4 and S-5 were collected, eventually discharge into the supply ponds. TP concentrations for each of these samples were significantly lower than samples S-2 and S-3, retrieved from Holt Pond. Laboratory results identified TP levels in samples S-4 and S-5 to be 218 and 211 mg/kg of dry weight, respectively. Iron content levels found within samples S-4 and S-5 were 7,320 and 4,700 mg/kg of dry weight, respectively. Lower TP concentrations found in samples S-4 and S-5 suggests that these tributaries are at a lower risk of aquatic vegetation breakouts, and further indicates the these tributaries are not contributing to high TP levels found in Holt Pond.

Results for samples S-2 and S-3 identified the sediments to contain particularly high moisture contents. Sample S-2 did not contain a sufficient amount of solids to run organic content and grain size testing, while samples S-1 and S-3 only contained enough solids to run organic content testing. Contrarily, samples S-4 and S-5 contained significantly less moisture content and had adequate solids to run all three of the abovementioned tests. Alternate sampling sites were attempted within Holt or nearby Pennichuck Brook to obtain sediment. It was noted through most of this corridor the dominant sediment type was very organic, likely due to plant die-off and excess aquatic vegetation stretching from the Holt Pond Dam to the Amherst Street crossing with Pennichuck Brook. Deeper cores were attempted by hand within those corridors, however, all attempts produced little recovery within the



sample tubes. This has been noted and additional future studies recommend deeper cores be taken by different sample methods to establish the total depth of organic layers and the underlying material types.

Two gradation tests (ASTM C-117 and ASTM C-136) were conducted on samples S-4 and S-5. Sample S-4 contained grainy sand with a trace of fines, and only 3.5% of the sample passed through sieve number 200. The sediment deposit which this sample was taken from may be a result of winter road sanding due to the common gradation similarities shared between the two. On the other hand, sample S-5 contained sediments where a 51% passing was observed at sieve size number 200, identifying the material to be significantly finer. Sample S-5 was collected from a slow moving ponded area, where heavy vegetation was observed immediately upstream. Consequently, finer sediments were likely found in this sample due to a combination of silty materials settling in the ponded area and decomposing plant matter. This ponded area may be an engineered design that was implemented while the surrounding residential development was constructed, yet a further investigation should be performed to determine if the streamflow is being restricted by an undersized culvert located directly downstream.

Organic content results were broken into two (2) percentage categories, including ash content and organic content. Each sample was heated to a furnace temperature of 440°F during this test, and the results are shown as follows:

- Sample S-1: Ash Content – 97.0%, Organic Content – 3.0%
- Sample S-3: Ash Content – 89.9%, Organic Content – 10.1%
- Sample S-4: Ash Content – 97.2%, Organic Content – 2.8%
- Sample S-5: Ash Content – 96.7%, Organic Content – 3.3%

Sample S-3, the most upstream sample collected from Holt Pond, contained the highest organic content among the samples tested, possessing more than twice the organics to the next closest sample. The upstream segment of Holt Pond in which sample S-3 was taken becomes enclosed by excessive aquatic vegetation, including areas of dense water lilies. Further upstream, Holt Pond changes from an open channel to a heavily vegetated wetland-like environment. Plant die-off originating further upstream may be transported downstream and settling in areas where sample S-3 was taken from, accounting for the significant organic content levels. Sample S-1 was taken further downstream near the Holt Pond Dam, where the pond becomes less vegetated, and the organic content in this sample was only 3.0%. This further supports the logic that excessive vegetation may be causing an increase in plant decay accumulation, and consequently higher organic and phosphorous levels within sediment samples upstream. Sample S-5 contained the second highest organic content, which can likely be correlated to the heavily vegetated areas upstream and surrounding the location where the sample was collected.

Task 10 Active and Dead Storage Volumes (Grant Match Funded by PWW)

CEI recorded updated bathymetric data within the supply ponds and collected specific dam elevations in order to calculate the current active and dead storage volumes of each reservoir. The first step in this



process was to compare past and present bathymetric data to gain a better understanding of where sediment thicknesses had increased and decreased over time. The second step involved an assessment of dam elevations obtained during field investigations and elevations included in dam construction drawings. Based on this review, CEI determined the elevation of important dam features such as spillways and intakes with respect to the same reference datum. Using these sets of data, CEI estimated the amount of active and dead storage volumes for Holt, Bowers, and Harris Ponds, as described in the sections below.

Initial steps taken to develop updated bathymetry for the supply ponds included converting all the pond surface elevations to the same reference datum, and adjusting the water depths in each pond such that surface elevations become equivalent for all surveys in each pond. Any differences in the water depth over time can then be attributed to a change in sediment layer thickness. Additionally, updated water and sediment depths in each supply pond needed to be established to compare differences in storage capacities from previous studies. Historical bathymetric maps already existed for Bowers and Harris Ponds from past studies, however there was no data regarding the water or sediment depths in Holt Pond and as a result, CEI collected sonar data and generated new contour maps as part of this water storage investigation project.

CEI sent out a two-person crew on November 4, 2016 to survey Bowers and Harris Ponds. The survey was conducted via an electrically powered boat equipped with a Garmin® GPS and transducer with echo-sounding capabilities. GPS-based sonar readings produced GPS XY coordinates for each point with a depth sounding measurement down to sediment. The XY coordinates and the associated sounding measurements were taken automatically and instantaneously every 30 seconds while the boat traveled across specific transects of Harris, Bowers and Holt Ponds. Specific readings were also taken manually at specific locations within Harris and Bowers Ponds based on previous sediment mapping efforts and where borings had been taken in prior studies¹. In Harris and Bowers, thirteen specific locations were visited via boat and GPS XY coordinates were collected while taking a sounding measurement to the sediment. Additionally, Secchi-disk measurements were also recorded at those thirteen pre-determined monitoring locations. The 13 monitoring locations and their GPS positions are shown in Figure 10: Permanent Monitoring Locations. No physical sediment depths or samples were taken with these points. No permanent monitoring locations were developed in the Holt Pond mapping. The Holt Pond mapping was completed by taking 30 second interval GPS XY readings and soundings along boat travelled transects only. See Section 7 for more detail on monitoring locations.

On July 19, 2017, CEI sent out a second two-person crew to collect water and sediment depth measurements from Holt Pond and an upstream portion of Bowers Pond that was not visited on the previous survey date. The same echo-sounding methods were used to collect water and sediment depths throughout these ponded sections. Sonar data was collected within Holt Pond beginning at the Holt Pond Dam and ending approximately 1,000 feet upstream, where dense vegetation prevented further travel by boat. Immediately below the dam and south of Thornton Road, additional sonar data was recorded in Bowers Pond, stretching to areas further downstream until reaching a culvert that runs under Tinker Road.

¹ Pennichuck Corporation, Merrimack, NH. (August 2013) “Bowers & Harris Pond Sediment Analysis Study.” Retrieved from: pennichuck.com/source-water-protection/about-pennichuck-watershed/sediment-analysis/.



Additional dam and water surface elevation data was collected with a GPS during the field investigation on July 19, 2017. CEI rented a survey-grade GS14 Leica® GPS unit to collect precise horizontal and vertical data of specific dam features for the Holt, Bowers, and Harris Pond Dams, including concrete walkways, training walls, and staff gauges. This elevation data was compared to elevations found in dam construction drawings, allowing for calculations to be made to determine spillway and intake elevations for each of the three dams with respect to the same reference datum. For example, construction drawings provided by Pennichuck Water Works Inc. for the Holt Pond Dam indicated that the top of spillway wall and ogee crest spillway elevations were to be constructed at 188.00 feet and 182.60, respectively, resulting in a 5.40-foot differential between the two features.

Using this dam elevation data, CEI was able to shoot a GPS point on top of the spillway wall, and then calculate the elevation of the ogee crest spillway, both referencing the same datum. This method was used at all three of the supply pond dams and was required due to safety concerns associated with collecting spillway elevations by foot or by boat. Below is an example calculation used to derive the dam spillway elevation at Holt Pond Dam with respect to the NGVD29 datum used for collection of GPS points.

Holt Pond Dam Construction Drawings:

$$188.00 \text{ (Top of Spillway Wall Elev.)} - 182.60 \text{ (Ogee Crest Spillway Elev.)} = 5.40$$

GPS Elevation Data Used to Calculate New Spillway Elevation Referencing NGVD29 Datum:

$$187.32 \text{ (Top of Spillway Wall Elev. Shot with GPS)} \\ - 5.40 \text{ (Elevation Differential from Construction Drawings)} = 181.92$$

These calculations were important in determining active and dead storage volumes within Holt and Bowers Pond, as their spillway elevations represent the highest point that active storage can exist. Holt and Bowers Pond are not equipped with intake valves or low-flow outlets, therefore dead storage exists throughout the pond volume located below the spillway invert, extending through the water column to the top layer of sediment. Contrarily, the Harris Pond Dam has a low-flow intake and 5-foot diameter penstock that can be manually opened to draw water from the upstream reservoir during drought conditions. Thus, obtaining the intake invert elevation was required to understand the lowest elevation where active storage may exist, and where dead storage volume begins. It is important to note that the Bowers Pond Dam was originally constructed with a concrete intake structure and 5-foot diameter penstock. These structures were removed as part of the 2004 dam improvement as shown on construction drawings provided by the Pennichuck Water Works Inc. Specific elevations obtained from dam construction drawings have been highlighted and attached under Appendix F.

CEI collected field measurements at each dam on July 19, 2017, to establish water surface elevations of each supply pond with respect to the same reference datum. This was accomplished at each supply pond by measuring the distance between their water surfaces and shot points taken along each dam with the survey-grade GPS. For quality control, additional measurements were taken at Holt and Bowers Pond between the GPS shot points and specific elevations shown on staff gauges at each dam. The staff gauge at the Harris Pond dam is not visible (digital measurements are captured throughout the day from a machine housed in an adjacent building) and therefore the distance from a GPS shot



point on the dam to the water surface was taken, as well as an additional GPS point on the pond's water surface. Calculated elevations for pond water surfaces and dam features are listed in Table 5: *Adjusted Pond and Dam Elevations (2017)*.

CEI calculated estimates of active and dead storage using the NGVD29 datum, and working in the ArcGIS Spatial Analyst extension. First, the 2010 bathymetric and sedimentary contours were converted to grids in GIS to facilitate incorporating the 2016/2017 data and calculating water and sediment volumes. Since the 2010 data are somewhat patchy, the grids were clipped to cover only the areas where sufficient bathymetric data was available to make meaningful comparison between 2010 and 2017 data. Next, the total volume of each pond was calculated by adding the 2010 bathymetric and sediment map grids in GIS. The sum represents depth to refusal rather than depth to bedrock, owing to the subjective nature of the sediment measuring methods. These methods are detailed in the 2010 project report. The purpose of this "basement" surface is just to provide a consistent depth from which to calculate changes in sediment volumes.

Like the 2010 data, the bathymetric data collected in 2016 and 2017 does not cover all parts of the three ponds. As such, this data was used to supplement the 2010 bathymetry to produce a 2017 bathymetry grid, as shown in Figure 11: Supply Pond Bathymetry 2017. Next, the thickness of sediments in 2017 was calculated by subtracting the bathymetry of 2017 from the basement depth. Figure 12: Sediment Thickness 2010 and 2017, displays the sediment thickness measurements for both 2017 and 2010.

The change in sediment distribution from 2010 to 2017 was calculated by subtracting the 2017 bathymetry from the 2010 bathymetry, which can be found in Figure 13: Sediment Change between 2010 and 2017. Because the water surface elevations have been equalized, an increase in bathymetric depth over time would indicate a decrease in sediment volume, and vice versa. It is important to remember that many parts of the ponds have sparse or underestimated water depths and sediment thicknesses. As a result, observed differences may be due to the presence of new data where little or none existed before, rather than actual changes in sediment distribution.

CEI proceeded to develop estimates of water volumes in active and dead storage, and of sediment volumes occupying space in active and dead storage. Treating each pond separately, CEI created a horizontal plane at the elevation of the top of the spillway in Holt Pond, at the top of spillway below the stoplogs in Bowers, and at the penstock pipe invert in Harris Pond. This plane represents the threshold between active and dead storage.

Using the normal pond elevations as an upper surface and the threshold as a lower surface, the volume of water in active storage and the volume of sediments currently occupying space in active storage were calculated. Using the threshold as an upper and the basement as a lower surface, CEI calculated the volume of water in dead storage and the volume of sediments occupying space in active storage. The results are shown in Table 7: *Estimated Active and Dead Storage Volumes in 2010 and 2017 Within Boundaries of 2010 Bathymetry*. The active and dead storage bathymetry for 2017 are provided in Figure 14: Bathymetry Above Active/Dead Storage Threshold and Figure 15: Bathymetry Below Active/Dead Storage Threshold, respectively. A summary of the results are provided in Table 6: *Summary of Water and Sediment Volumes in Active/Dead Storage*.



Harris Pond, the closest supply pond to the treatment plant, has the greatest volume of sediments occupying the active storage area ranging between 20 and 40 million cubic feet. Based on on-going sediment mapping and the comparisons completed under this study, it is the key pond for any recommended dredging feasibility studies. Bowers Pond also has sediment consuming active storage ranging between 5 and 16 million cubic feet, however, the apparent volume accumulation is not as substantial as Harris. It is recommended that Bowers Pond be continually monitored for sediment migration and a separate dredging feasibility be conducted based on differing site conditions and access compared to Harris Pond. It is apparent from the tributary evaluations that the Boire Field Brook Watershed and other minor tributaries to Harris Pond appear to produce higher quantities of coarser sediment possibly associated with NPS pollution and erosion within those corridors. Sediment accumulation in Holt Pond tends to be a finer organic consistency possibly associated with plant decay. Bowers Pond appears to have a combination of coarse and fine sediment depending on the location within the pond and the associated upgradient land use. Areas in Bowers closest to Holt pond appear to have more aquatic vegetation as well as finer sediment accumulations.

Bathymetric and sediment thickness data are somewhat sparse in Holt Pond. The pond is calculated to have zero sediment occupying active storage space within the footprint of the 2010 data, but it should be noted that there is very little active storage space. The “normal” pond elevation, which was used for these calculations, is only 0.68’ above the spillway elevation which represents the threshold between active and dead storage.

Sediments that are close to the elevation of the spillway may be redistributed into the dead storage space or carried over the spillway into Bowers Pond. There are water depths up to four feet in the area between Holt Landing and Portside Drive. Closer to the dam the sediment rises to within 2’ of the normal pond elevation, or about 1.3’ below the spillway. Moreover, a quantity of aquatic vegetation has established itself in the relatively shallow waters and reaches up to the surface in places. The living plants and accumulated dead material occupy both active and dead storage.

Under this task, the two datasets (2010 and 2017) were combined to form a single model representing 2017 conditions. This was necessary because insufficient bathymetric data were collected in 2016/2017 to construct a model solely from them. Each dataset was converted to a grid and the two grids were combined such that the 2016/2017 data, where they existed, replaced the 2010 data. Elsewhere the 2010 data remained. The new grid was then cropped to the boundary of the 2010 bathymetric contours to allow a statistical comparison between the two surveys.

Apparent changes in volume between the 2010 and 2017 measurements may be due to shifting sediments, differences in methodology, or major storms that washed sediments downstream. More will be known when the 2011 data (which only recently became available) is assessed which is part of the proposed recommendations. Also, the expense of dredging (including permitting) will be compared by PWW to the cost of producing water from other sources before proceeding.

Because of the methods employed under this task, apparent increases in active water storage capacity are likely due at least in part to improved data coverage. Increases in active storage volume occur in some cases due to a decrease in sediments within the active storage volume. This may be a result of eroded sediments being carried downstream, or due to the contour grids being cropped to focus on specific areas where adequate data from 2010 was available.



CEI recommends that future bathymetric surveys should include parts of the pond where current data coverage is sparse or estimated. Bathymetry should be measured by an acoustic method, and ideally by dual-frequency sonar equipment which would return both bottom and sub-bottom reflectors. This would result in more accurate sediment thickness measurements as well as water depths.

Tasks 11 & 12 Soundings (Grant Match Funded by PWW)

CEI completed GPS echo-sounding within all three supply ponds in addition to collecting Secchi-disk readings at 13 permanent monitoring locations where borings had occurred in a prior study. When these borings were originally taken in 2012, the metal casings were extracted and an orange marking pole was placed in the borehole to permanently mark its locations. However, upon visiting each marked location in November of 2017, no poles were visible and it was assumed that they likely broke and became submerged below the water surface. As a result, CEI used historical GPS coordinates to relocate the areas where markers had been installed for each boring. Figure 10 shows the position and GPS coordinates of each monitoring location along Bowers and Harris Ponds, where Secchi-disk measurements were recorded.

CEI used the Secchi-disk and water depth readings at each monitoring location to generate an electronic database for recording measurements on a long-term basis. This database was created to store data from the 13 permanent monitoring locations in an organized manner, supporting data analysis with regards to the water clarity and estimated sediment in-fill rates for Bowers and Harris Ponds. The database was created as a Microsoft Excel spreadsheet, and has been included as a deliverable for this project on a compact disc. Expanding this monitoring program into Holt Pond should be considered by implementing permanent monitoring locations similar to Bowers and Harris Ponds. This recommendation is explained in further detail in Section 8.

Task 8. Identification of Protection Measures (NHDES LSW Grant Funded Task)

Recommendation 1: Data Comparisons for Infill Estimates & On-going Monitoring

Build upon previously completed efforts to calculate the rate of infill for the supply ponds by using 2017 sonar data points collected during this study and integrating them into the 2011 multi-beam sonar data previously collected by Pennichuck. This would create a GIS sediment surface, which could then be compared with the original 2011 data to develop infill estimates over a six year period. This would be completed by clipping areas of computation to match the footprints of the 2017 and 2011 surfaces to allow direct comparisons and then calculating volume differences between active/dead threshold and bathymetry, representing dead water and active sediment volumes. This would compute the difference between original 2011 and merged 2011/2017 bathymetry to identify changes in sediment configuration over time.

Additionally, CEI recommends continuation of monitoring at the 13 permanent locations established within Bowers and Harris Ponds every 3-5 years to monitor sediment accumulation. A database was developed as part of the current project, which provides an organized means of collecting and storing data from these locations.

Recommended future monitoring at these locations includes the following on an annual basis:



*Reservoir Storage Estimates &
Tributary and Pond Sediment Accumulation Monitoring*



- water depth
- sediment depth
- Secchi disk (water clarity) measurements

The above monitoring should be conducted during mid-summer (late July-early August), to ensure that water clarity readings reflect conditions when algal productivity is seasonally high. Regular monitoring of water and sediment depth will allow for a more refined understanding of sediment infill rates and associated changes to active storage capacity in the supply ponds.

In addition to the 13 permanent monitoring locations, establishment of new permanent monitoring locations to fill in data gaps within the supply ponds and in particular Holt Pond is also recommended during future monitoring efforts. This will allow for assessment of changes in active and dead storage volumes for each of the three primary water supply ponds. The Holt Pond monitoring locations can be established by performing sediment coring and using a GPS to map the locations for future reference.

Recommendation 2: Tinker Pond Maintenance Dredge Feasibility

Drone imagery of the Tinker Road Wet Pond BMP identified the need for ongoing maintenance to ensure optimal performance for control of sediment and nutrients. A large volume of stormwater runoff from the Everett Turnpike and Tinker Road flows into this treatment system, transporting both sediment and nutrients into the pond. At the time of the drone flyover, Tinker Pond appeared to be experiencing a bloom of cyanobacteria (blue-green algae) and had significant areas of shallow depth with dense growth of water lilies and other aquatic vegetation. The presence of cyanobacteria has not been confirmed with additional sampling.



*Tinker Pond aerial drone imagery
algal bloom & infill*

Tinker Pond functions essentially as a settling basin, allowing for pollutant attenuation prior to discharge to Harris Pond, located to the north across Tinker Road. The importance of Tinker Pond and its Wet Pond BMP are heightened by its location in relatively close proximity to the downstream supply pond and water supply intake. Given the conditions observed at Tinker Pond, an engineering evaluation is necessary to determine recommendations for ongoing maintenance of the BMP to ensure optimal performance for pollutant attenuation. In order to determine feasibility of a maintenance dredge process, several tasks should be completed, including (1) collection of a screening-level sediment sample to determine the most likely options and costs for dredged material disposal and re-use, and (2) bathymetry and sediment mapping of Tinker Pond to establish storage volume estimates and rate of infill. It is recommended that a meeting with stakeholders be held to identify local concerns, obstacles and permit constraints associated with future maintenance dredging. Based on these results, a dredging feasibility study can be completed to evaluate the options, logistics, and costs of dredging to restore depth and water storage volume in Tinker Pond. If maintenance dredging is deemed feasible and an appropriate time frame is established, the design and required permitting according to the recommended options could be completed.



Recommendation 3: Dredging Feasibility Studies: Harris Pond and Bowers Pond

Two dredging feasibility studies are recommended to evaluate the options, logistics, and costs of dredging to restore depth and water storage volume in Harris and potentially Bowers Ponds by removing accumulated sediment. Building off of sediment tracking completed in 2000, 2010, 2014 and 2017 within Bowers and Harris Ponds, specific areas of sediment buildup within the active storage volumes have been identified. This data has shown that over approximately 20 years, sediment is moving around within Bowers Pond between areas of accumulation and scour and some of that scoured sediment is migrating into Harris and accumulating in very specific locations. Based on previous sediment cores that were taken in 2014 and recent sonar data, the material that is moving around in these ponds is heavier and coarser compared to that around the Holt Pond Dam. In many of the locations within Harris Pond, this heavier sediment is taking up active storage. A dredging feasibility study for these ponds would focus on those historic areas of accumulation, in particular those that are taking up active storage volumes.

Although dredging is one of the costliest pond management options, it can often result in the greatest longevity of effectiveness and compare favorably to other options in terms of efficacy per dollar spent over the project life cycle (duration between dredging and sediment refill). A suggested scope of work for these dredging feasibility studies includes the following:

- Building on past sediment mapping and sampling, identify high priority areas for dredging within the supply ponds and classify the type of material that would be anticipated;
- Screening-level sediment sampling for a suite of physical parameters and chemical constituents in each of the supply ponds, to inform the most likely options and costs for dredged material disposal and re-use. This would involve two sample from locations in each pond, collected as a core of the entire depth profile of the sediment to be dredged. Additional sampling may be required for permitting if dredging is implemented in the future, but two samples per pond is recommended as sufficient for a preliminary determination of sediment quality for a feasibility and costing assessment.
- Additional sampling may be required for permitting if dredging is implemented in the future, but for costing purposes two samples per pond is recommended as sufficient for a preliminary determination of sediment quality for a feasibility and costing assessment;
- Recommended dredging zones, depths, and volume of sediment removal for each of the supply ponds and then estimate the potential benefit for associated increases in active storage;
- Identify recommended dredging methods (e.g., hydraulic, clamshell, conventional excavation with long-reach excavator, etc.);
- Based on the specific dredge location and material type, develop site specific options for sediment dewatering, and other site-specific logistic considerations (e.g., equipment access, transport route, etc.);
- Anticipated project costs, including evaluation of design, permitting, and construction phases and associated costs;
- Provide a cost-benefit analysis for each of the identified locations based on a cost per volume of active storage gained; and,
- Preparation of findings and recommendations in a letter report.



Recommendation 4: Boire Field Brook Evaluation

During field investigations, a large sediment deposit was discovered immediately upstream of a culvert located on Tinker Road in Nashua, NH. Boire Field Brook is the tributary that flows through the culvert under Tinker Road, and discharges into Harris Pond approximately 1/3-mile downstream. Upstream of this culvert are several major roadways including Somerset Parkway and the southbound off ramp from the Everett Turnpike. This area has been built-out over the years with several large commercial developments all of which drain to Boire Field Brook.



*Sediment deposit at Boire Field Brook
adjacent to Tinker Road*

As evidenced by the sediment accumulation, there have been significant impacts to this area from stormwater runoff. It was also noted that downstream of the Tinker Road culvert near the end of Boire Field Brook, stormwater from the Everett Turnpike drains directly into the brook with minimal treatment or protection against accidental spills prior to reaching Harris Pond. It was noted that Pennichuck owns most of the land adjacent to the Boire Field Brook corridor and portions of this area may have been historically designed as a stormwater control for the future upstream development along Somerset Parkway and Route 101A.

Additionally, the Tinker Road culvert consists of 3 concrete barrels in series that are partially perched and appear to be experiencing minor spalling. Based on more extreme storm events and current build-out of commercial developments upstream of this culvert and along Route 101A (Somerset Parkway), the culverts original hydraulic design capacity may be now undersized. Furthermore, sediments may be transporting into Boire Field Brook at a higher rate, resulting in a heavier load and more deposits.

A subwatershed evaluation of the Boire Field Brook corridor is recommended to identify impacts to the stream and Harris Pond from stormwater runoff. Part of this study would include identifying potential BMPs throughout the subwatershed which could include stormwater treatment, accidental spill containment, sediment removal and stream restoration. This subwatershed evaluation would include the following:

- Detailed field visits and/or drone flights along the corridor during leaf out to identify any stream distress, sediment deposits and to map the immediate floodplain area;
- Conduct windshield survey of the immediate contributing stormwater drainage systems to identify pollutant concerns and potential treatment options;
- Develop a matrix of potential BMPs with best engineer judgment of costs including, design, permitting and construction estimates; and,
- Preparation of findings and recommendations in a letter report.

As part of the subwatershed evaluation, the Tinker Road culvert and the surrounding area should be evaluated to determine the hydrologic and hydraulic characteristics of the contributing subwatershed. Completing this culvert assessment involves the following:



- Examining upstream and downstream bankfull widths to determine the necessary culvert width;
- Estimate storage capacity of impounded areas and floodplain around the brook;
- Complete routing calculations to determine whether the storage capacity and hydraulic capacity of the culvert is adequate for current conditions and extreme precipitation events;
- Using GeoHECRAS to run a hydraulic analysis of the surrounding area during different simulated storm events;
- Conducting a thorough assessment on the condition of the culvert and the crossing as a whole; and,
- Providing recommendations on removing built up sediment and potentially replacing the culvert.

CEI can also investigate the condition of a nearby culvert running under the Everett Turnpike and discharging into Harris Pond for potential BMP locations that would intercept sediments and nutrients in runoff originating from the highway. Further suggestions could be recommended to improve the structural condition and stability of the culvert following field assessments. The recommendations generated from this study could be used to update the Watershed Restoration Plan (WRP) as well as build on previous WRP recommendations. Additionally, if BMPs are proposed, funding could be available through many NHDES grant programs. If any BMPs are implemented through the WRP, available NHDES tools can be used to assess the success of any NPS pollution reduction efforts.

Recommendation 5: Culvert Inventory & Assessments

Culverts are located all throughout the Pennichuck Brook Watershed, including a large number that are proximal to the water supply reservoirs. Based on the sediment deposits discovered immediately upstream of some of the culverts seen during this study, a culvert investigation and assessment is recommended for some certain portions of the Pennichuck Brook Watershed that if clogged might result in a roadway washout that would end up with extensive sediments in the supply ponds. The work could be done in phases, including an initial watershed community outreach and to identify the location of unknown culverts, a fieldwork effort to thoroughly inspect a number stream crossings (15-20), and a prioritization of high-risk culverts to provide precautionary solution recommendations.



*Culvert Crossing of Boire Field Brook at
Tinker Road*

Developing an inventory that contains culvert data (quantity, location, age, etc.) in key areas of the watershed is an important project both for PWW and the towns involved. Once culverts are mapped and an inventory has been established, field inspections can then be completed to prioritize culverts that are undersized, in critical structural condition, or at risk of washout of the roadway bedding.

Using hydraulic analysis modeling software, the subwatershed areas contributing stormwater flows should be mapped and the amount of stress that the culvert is under estimated for simulated storm events and their resulting likelihood of failure. Field inspection and modeling data can be used to generate a

prioritization table based on field findings. Recommendations for potential culvert repairs or replacements can then be made to enhance the fluvial and geomorphic stream characteristics, while



reducing sediment buildups and potential wash-outs. This type of assessment is important to water quality and storage capacity because heavy and more frequent precipitation events can potentially dislodge trapped sediments or wash out entire roadways and displace these materials downstream into the drinking water supply ponds.

Additionally, the infrastructure to house stream crossing data that already exists can be used as a starting point to identify any previously completed assessments within the watershed communities. The statewide database already contains fields to house the data to collect the necessary data to rank culverts for their compatibility with stream geomorphology, aquatic organism (fish) passage, and hydraulic capacity. Through the NHDES partnership with NHDOT, data fields exist to capture crossing condition and this database can be used to identify completed assessments or can be updated by PWW with any new inventories or assessments completed through this program. All of this can be accomplished using the existing statewide assessment protocol that fulfills statewide needs. Additionally, with the data collected, it would be possible to analyze culverts in a coarse screen form for hydraulic capacity and whether culverts can pass the 10-, 25-, 50- and 100-year predicted flows. PWW can work with NHDES using the Streamworks-TU hydraulic model. Even though this program does not incorporate the greater level of detail (such as from GeoHEC-RAS), it can be a valuable tool and can be used as an effective preliminary analysis of any assessed culverts within the watershed.

Recommendation 6: Aquatic Vegetation Assessment and Management Plan

CEI's field investigations have documented abundant aquatic vegetation within the supply ponds and their tributaries, including significant areas dominated by dense growth of floating-leaf species such as white water lily (*Nymphaea odorata*) and a variety of submerged species such as coontail (*Ceratophyllum demersum*) and ribbon-leaf pondweed (*Potamogeton epihydrus*).



Drone imagery showing dense growth of white water lily within Tinker Pond.

Rooted aquatic vegetation plays an important role within pond ecosystems and is often critical to maintaining water clarity and providing natural control of algal abundance.

However, over time, the accumulated biomass of decomposing aquatic plants will reduce pond volume and this process can be greatly accelerated by elevated in-pond and sediment nutrient concentrations. Species such as white water lily can produce significant plant biomass each year, and non-native species such as Eurasian milfoil can outcompete native species and accelerate the process of eutrophication and volume loss.

To provide the basis for management recommendations related to management of aquatic vegetation, a mapping and inventory of aquatic species with the supply ponds is recommended. If any exotic aquatic plants are identified during this assessment, PWW could apply as a municipality for funding to control those species through the NHDES Exotic Aquatic Plants Control Grant. Management strategies and any potential grant projects would be highlighted in an Aquatic Vegetation Management Plan. A suggested scope of work for this assessment includes the following:



- Field survey to document the aquatic plant community in each of the supply ponds, including (1) mapping of dominant species and common assemblages, (2) inventory of all species observed, and (3) mapping of all locations where non-native, invasive species are observed;
- Develop aquatic plant management recommendations based on the findings of the plant survey. These strategies could include recommended areas for specific control (e.g., zones where hydro-raking of white water lily is recommended), and protocols for rapid response if new areas of invasive species occur in the future; and,
- An additional step in later projects could be to identify potential invasive species, and develop a “*Field Guide to the Aquatic Plants of the Pennichuck Brook Watershed*”. This field guide could include line drawings, color photos, and a description of each species identified in the supply ponds, as well as reference section for non-native species.



Example layout for *Field Guide to the Aquatic Plants of the Pennichuck Brook Watershed*

Recommendation 7: Identify Need for Public/Private Partnership to Re-establish Tributary Buffers

Based on recent aerial drone surveys of the tributaries, a few locations of buffer loss or encroachment onto the tributary buffers by private landowners were identified. Vegetated buffers are important to protection of the water supplies. In some cases, the town where the land use is located may be able to work with the homeowner if there is a direct violation of their rules, but in some cases a public private partnership (PPP) where PWW would assist the homeowner to establish a buffer might be necessary. Steps include:

- Summarize specific locations and problem areas from drone footage and provide PWW with a list of addresses and property information to initiate communication;
- Reach out to the associated community or NHDES to discuss the specific buffer loss or land use activity and identify any historic background or potential actions;
- Work with Pennichuck to develop letters that could be sent to the individual private owners to propose a partnership for reestablishing the buffer;
- Develop education materials to be sent with the letters that describe the importance of buffers and the protection of water supply tributaries from “land uses with higher potential pollutant loads” and potential negative impacts from NPS pollution on drinking water; and,
- Using aerial drone footage, develop conceptual plans to present to landowners the appropriate buffer area on their property and details for buffer establishment.

These recommendations provide options for enhancing existing and future conditions of the Pennichuck Brook Watershed, the Pennichuck supply ponds, and the surrounding tributaries, by locating sediment sources, reducing sediment transportation and increasing sediment and nutrient



treatment, and expanding active storage capacity and water quality. If any BMPs or buffer enhancements are implemented, many available NHDES tools can be used to assess the success of NPS pollution reduction efforts. Residents in the watershed can participate in programs such as Soak Up the Rain NH which is a voluntary program managed by NHDES to inform residents about rain runoff management through the installation of small-scale BMPs. Information on this program can be found at the following link: <https://www4.des.state.nh.us/SoakNH/>

Another program includes the Watershed Stewards Program which is managed by the New Hampshire Rivers Council and takes a more full-property management approach which includes controls for stormwater runoff, septic systems, lawn care, overall property management practices, and home owner interviews that are conducted both before and after their participation in the program to gauge their success in reducing NPS pollution.



Table 1: Slope Categories by Subwatershed

Table 1. Slope Categories by Subwatershed							
Subwatershed	Acres	Slope by Acre			Slope as Percent of Total		
		0 - 15%	15 - 30%	30%+	0 - 15%	15 - 30%	30%+
Pennichuck Brook to Pennichuck Pond	2002	1819	177	6	90.9	8.8	0.3
Muddy Brook	2706	2526	175	5	93.3	6.5	0.2
Pennichuck Brook to Bowers Pond	2487	2390	89	8	96.1	3.6	0.3
Pennichuck Brook to Holt Pond	1452	1401	49	2	96.5	3.4	0.1
Stump Pond Brook	1400	1340	57	2	95.8	4.1	0.2
Witches Brook East	1322	1255	62	4	95.0	4.7	0.3
Witches Brook North	1428	1321	101	5	92.6	7.1	0.3
Witches Brook South	3118	2837	268	13	91.0	8.6	0.4
Boire Field Brook	496	465	29	2	93.7	5.9	0.4
Pennichuck Brook to Supply Pond	914	846	61	7	92.6	6.7	0.7

Table 2: Erodible Soils by Subwatershed

Table 2. Erodible Soils by Subwatershed									
Subwatershed	Acres	Erodibility by Acre				Erodibility as Percent of Total			
		Highly Erodible	Potentially High	Not Highly Erodible	Not Rated	Highly Erodible	Potentially High	Not Highly Erodible	Not Rated
Pennichuck Brook to Pennichuck Pond	2002	564	787	461	190	28.2	39.3	23.0	9.5
Muddy Brook	2706	396	1374	676	260	14.6	50.8	25.0	9.6
Pennichuck Brook to Bowers Pond	2487	366	963	948	211	14.7	38.7	38.1	8.5
Pennichuck Brook to Holt Pond	1452	148	386	705	213	10.2	26.6	48.6	14.7
Stump Pond Brook	1400	264	552	541	41	18.9	39.5	38.7	3.0
Witches Brook East	1322	101	536	632	53	7.6	40.6	47.8	4.0
Witches Brook North	1428	329	839	252	7	23.1	58.8	17.6	0.5
Witches Brook South	3118	868	1815	399	36	27.8	58.2	12.8	1.1
Boire Field Brook	496	113	80	179	124	22.8	16.1	36.2	24.9
Pennichuck Brook to Supply Pond	914	86	560	129	138	9.5	61.3	14.1	15.1



Table 3: Paved and Unpaved Road Miles by Subwatershed

Table 3. Paved and Unpaved Road Miles by Subwatershed		
Subwatershed	Road Miles	
	Paved	Unpaved
Pennichuck Brook to Pennichuck Pond	10	2
Muddy Brook	9	2
Pennichuck Brook to Bowers Pond	29	1
Pennichuck Brook to Holt Pond	14	0
Stump Pond Brook	18	1
Witches Brook East	9	0
Witches Brook North	8	1
Witches Brook South	12	5
Boire Field Brook	8	0
Pennichuck Brook to Supply Pond	13	1

Table 4: Acres of Highly or Potentially Highly Erodible Soils by Slope

Table 4. Acres of Highly or Potentially Highly Erodible Soils by Slope Category			
Subwatershed	Slope		
	0 - 15%	15 - 30%	30%+
Pennichuck Brook to Pennichuck Pond	1175	146	5
Muddy Brook	1602	159	4
Pennichuck Brook to Bowers Pond	1247	69	7
Pennichuck Brook to Holt Pond	502	32	1
Stump Pond Brook	771	44	2
Witches Brook East	588	45	3
Witches Brook North	1067	94	5
Witches Brook South	2409	251	12
Boire Field Brook	170	22	1
Pennichuck Brook to Supply Pond	582	50	6

Table 5: Adjusted Pond and Dam Elevations (2017)

Table 5. Adjusted Pond and Dam Elevations (2017)			
Pond/Dam	Water Surface Elev.	Spillway Elev.	Intake Invert Elev.
Holt	182.12	181.92	
Bowers	175.98	167.88	
Harris	167.89	165.37	142.17



Table 6: Summary of Water and Sediment Volumes in Active/Dead Storage

Table 6. Summary of Water and Sediment Volumes in Active/Dead Storage				
Water Volumes in Active and Dead Storage as of 2017				
Pond/Dam	Active (cu. ft.)	Active (gal.)	Dead (cu. ft.)	Dead (gal.)
Holt	92,000	690,000	261,000	1,956,000
Bowers	22,373,000	167,361,000	6,664,000	49,849,000
Harris	41,254,000	308,598,000	346,000	2,591,000
Sediment Volumes Occupying Active Storage Space as of 2017				
Pond/Dam	Active (cu. ft.)	Active (cu.yd.)		
Holt	0	0		
Bowers	5,090,000	189,000		
Harris	21,526,000	797,000		
Water Volumes in Active and Dead Storage as of 2010				
Pond/Dam	Active (cu. ft.)	Active (gal.)	Dead (cu. ft.)	Dead (gal.)
Holt	226,000	1,690,000	478,000	3,573,000
Bowers	21,841,000	163,381,000	5,619,000	42,033,000
Harris	40,967,000	306,454,000	382,000	2,855,000
Sediment Volumes Occupying Active Storage Space as of 2010				
Pond/Dam	Active (cu. ft.)	Active (cu.yd.)		
Holt	0	0		
Bowers	16,331,000	605,000		
Harris	40,871,000	1,514,000		

Table 7: Estimated Active and Dead Storage Volumes in 2010 and 2017

Table 7. Estimated Water Volumes in Active and Dead Storage Within Boundaries of 2010 Bathymetry						
	Active Storage Volumes			Dead Storage Volumes		
Pond	2010 (cu. ft.)	2017 (cu. ft.)	Volume Δ (%)	2010 (cu. ft.)	2017 (cu. ft.)	Volume Δ (%)
Holt	226,000	92,000	-144.7	478,000	261,000	-82.7
Bowers	21,841,000	22,373,000	2.4	5,619,000	6,664,000	15.7
Harris	40,967,000	41,254,000	0.7	382,000	346,000	-10.2



Appendix B

Sediment Sample Laboratory Results for Grain Size Distribution, Moisture Content, and Organic Content



**Report of Moisture Content
of Soil and Rock**
ASTM D2216-10

Project Name:	Sediment Sample Testing	Project Number:	17-1086
Project Location:	Londonderry, NH	Lab ID:	
Client:	Comprehensive Environmental, Inc.	Date Received:	09/15/17
Material Description:	sediment	Date Completed:	09/18/17
Material Source:		Tested By:	A. Michaud

Lab ID	Nominal Maximum Aggregate Size	Material Description	Moisture Content	
S-1	3/8"	Sediment	85.0%	165 g (organic content)
S-2	3/8"	Sediment	1201.1%	19 g (no enough sample)
S-3	3/8"	Sediment	310.8%	99 g (organic content)
S-4	3/8"	Sediment	37.5%	630 g (organic and grain size)
S-5	3/8"	Sediment	48.2%	505 g (organic and grain size)

Comments:

Reviewed By: _____



Report of Loss on Ignition Ash and Organic Content

ASTM D2974-07a

Project Name: Sediment Sample Testing
Project Location: Londonderry, NH
Client: Comprehensive Environmental
Material Description: Sediment Material
Material Source: S-1

Project Number: 17-1086
Lab ID: 2183M
Date Received: 09/15/17
Date Completed: 09/26/17
Tested By: BLG

Organic Content

3.0%

(Maximum)

Ash Content

97.0%

Furnace Temperature

440°

Comments: Moisture Content = 85.0%

Reviewed By:

Chad Michaud

13 Delta Drive, Unit 8, Londonderry, NH 03053 • P: (603) 716.2111 • F: (603) 716.2112 • E: infomanchester@swcole.com

Geotechnical Engineering

Construction Materials Testing

GeoEnvironmental Services

Ecological Services



Report of Loss on Ignition Ash and Organic Content

ASTM D2974-07a

Project Name: Sediment Sample Testing
Project Location: Londonderry, NH
Client: Comprehensive Environmental
Material Description: Sediment Material
Material Source: S-3

Project Number: 17-1086
Lab ID: 2185M
Date Received: 09/15/17
Date Completed: 09/26/17
Tested By: BLG

Organic Content

10.1%

(Maximum)

Ash Content

89.9%

Furnace Temperature

440°

Comments: Moisture Content = 310.8%

Reviewed By:

Chad Michaud

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Geotechnical Engineering

Construction Materials Testing

GeoEnvironmental Services

Ecological Services



Report of Loss on Ignition Ash and Organic Content

ASTM D2974-07a

Project Name: Sediment Sample Testing
Project Location: Londonderry, NH
Client: Comprehensive Environmental
Material Description: Sediment Material
Material Source: S-4

Project Number: 17-1086
Lab ID: 2186M
Date Received: 09/15/17
Date Completed: 09/26/17
Tested By: BLG

Organic Content

2.8%

(Maximum)

Ash Content

97.2%

Furnace Temperature

440°

Comments: Moisture Content = 37.5%

Reviewed By:

Chad Michaud

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Geotechnical Engineering

Construction Materials Testing

GeoEnvironmental Services

Ecological Services



Report of Loss on Ignition Ash and Organic Content

ASTM D2974-07a

Project Name: Sediment Sample Testing
Project Location: Londonderry, NH
Client: Comprehensive Environmental
Material Description: Sediment Material
Material Source: S-5

Project Number: 17-1086
Lab ID: 2187M
Date Received: 09/15/17
Date Completed: 09/26/17
Tested By: BLG

Organic Content

3.3%

(Maximum)

Ash Content

96.7%

Furnace Temperature

440°

Comments: Moisture Content = 48.2%

Reviewed By:

Chad Michaud

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Geotechnical Engineering

Construction Materials Testing

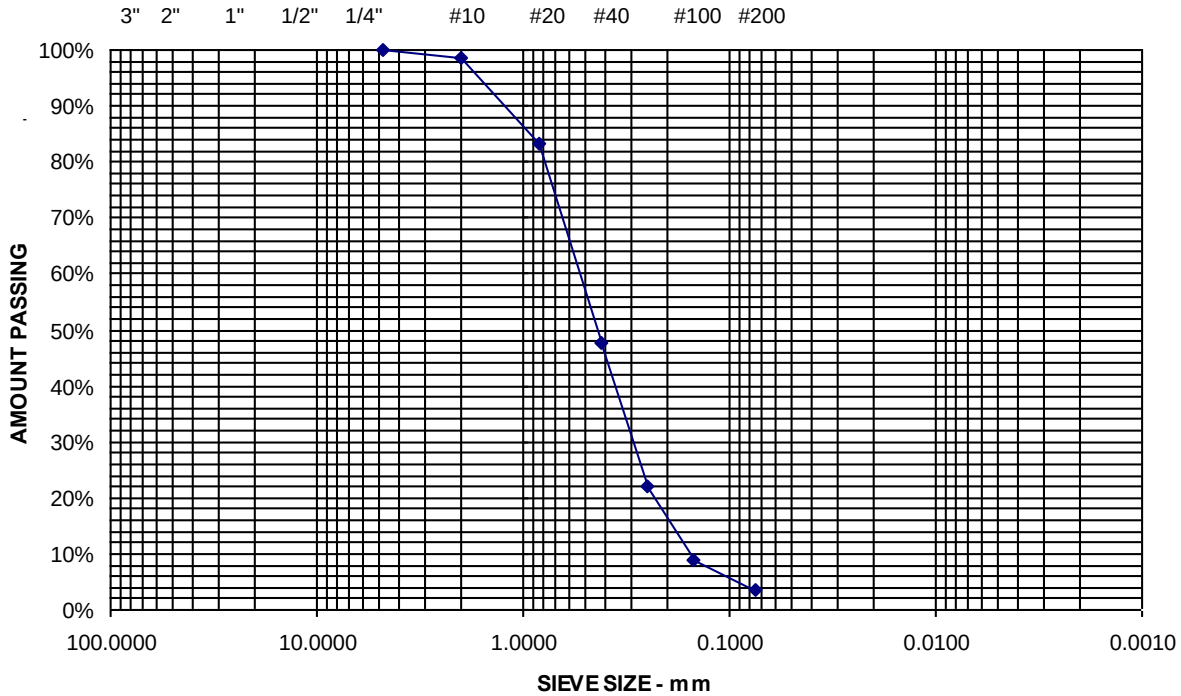
GeoEnvironmental Services

Ecological Services

Project Name LONDONDERRY NH - LABORATORY TESTING OF SEDIMENT
 SAMPLES
 Client COMPREHENSIVE ENVIRONMENTAL, INC.,
 Material Type SEDIMENT
 Material Source S-4

Project Number 17-1086
 Lab ID 2186M
 Date Received 9/18/2017
 Date Completed 9/19/2017
 Tested By MARK BENNETT

<u>STANDARD</u> <u>DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	<u>SPECIFICATIONS (%)</u>
4.75 mm	No. 4	100	
2.00 mm	No. 10	99	
850 μm	No. 20	83	
425 μm	No. 40	48	
250 μm	No. 60	22	
150 μm	No. 100	9	
75 μm	No. 200	3.5	



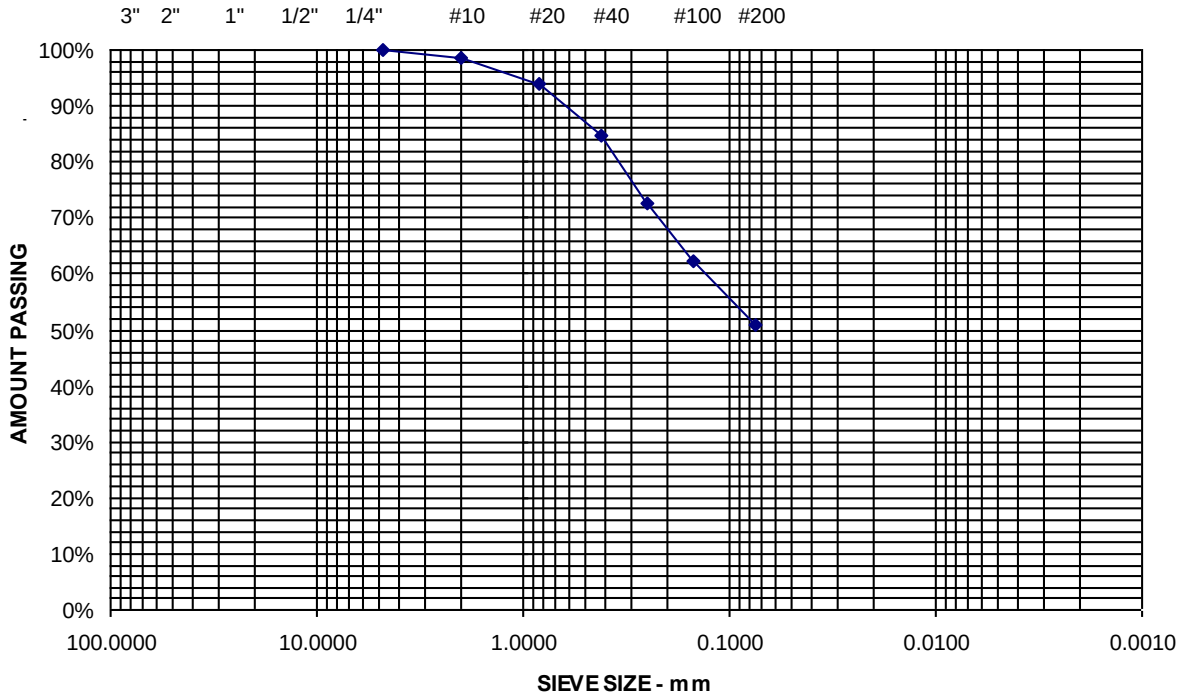
Comments



Project Name LONDONDERRY NH - LABORATORY TESTING OF SEDIMENT
 SAMPLES
 Client COMPREHENSIVE ENVIRONMENTAL, INC.,
 Material Type SEDIMENT
 Material Source S-5

Project Number 17-1086
 Lab ID 2187M
 Date Received 9/18/2017
 Date Completed 9/19/2017
 Tested By MARK BENNETT

<u>STANDARD</u> <u>DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	<u>SPECIFICATIONS (%)</u>
4.75 mm	No. 4	100	
2.00 mm	No. 10	98	
850 μm	No. 20	94	
425 μm	No. 40	85	
250 μm	No. 60	73	
150 μm	No. 100	62	
75 μm	No. 200	51.0	



Comments



Appendix C

Sediment Sample Laboratory Results for Phosphorus Level and Iron Content

Friday, September 22, 2017

Ben Lundsted
Comprehensive Environmental Inc.
21 Depot St
Merrimack NH 03054

Project Name: Pennichuck 131-55

Lab ID: 17090128

Project #: N/A

Date Received: 9/13/2017

Project Location: NH

Control #: 17090128

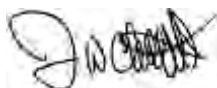
Dear Ben Lundsted

Enclosed please find the laboratory results for the above referenced samples that were received by the ChemServe sample custodian on the above referenced date. Any abnormalities to the samples upon receipt would be noted on the enclosed chain of custody document. This report is not valid without a completed chain of custody with the corresponding control number, attached.

All samples analyzed by ChemServe are subject to quality standards. These standards are as stringent or more stringent than those established under NELAC, 40 CFR Part 136, state certification programs, and corresponding methodologies. ChemServe has a written QA/QC Procedures Manual that outlines these standards, and is available for your reference, upon request. Unless otherwise stated on the Chain of Custody or within the report, all holding times, preservation techniques, container types, and analytical methods are analogous with those outlined by NELAC. All units are based on "as received" weight unless denoted "dry".

Residual chlorine, sulfite and pH are intended to be performed as an immediate field analysis. Should any of these analyses be performed in the lab instead of in the field it will result in those analyses being performed out of holding time.

I certify that I have reviewed the above referenced analytical data and state forms, and I have found this report within compliance with the procedures outlined within NELAC. ChemServe's certified parameter list can be found at <http://www.chemservelab.com/Laboratory-Information-and-Documentation.aspx>



Jay Chrystal - President/Laboratory Director



Comprehensive Environmental Inc.

Ben Lundsted

21 Depot St

Merrimack NH 03054

Control #: 17090128

Project Number: N/A

Project Name: Pennichuck 131-55

Project Location: NH

Lab ID: 17090128

Date: 9/22/2017

Lab ID: 17090128

Sample Receiving and Comment Summary

Were samples submitted with a chain of custody?	Yes
Do all samples received match the chain of custody?	Yes
Were all samples received within applicable holding times?	Yes
Were all containers intact when received?	Yes
Were samples for volatile organic analysis free of headspace (per method)?	N/A
Was there evidence of cooling or were samples received on the same day as collection?	Yes
If the sample pH was not correct was it adjusted where applicable?	Yes
Were samples for dissolved metals already filtered by the client or field sampling?	N/A
Were Samples for O-phos filtered in the field?	N/A
Were samples received in the appropriate containers?	Yes
Were samples submitted with a chain of custody?	Yes

Sample	Method	Client Identity	Matrix	Analyst
17090128-001	SW 3050B	S-1 TP	Solid	CharleneF

Comment: no comment

* Blank comment sections denote "No Comment"



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Milford, NH 03055
(603) 673-5440
Sales@chemservelab.com

Comprehensive Environmental Inc.

Ben Lundsted

21 Depot St

Merrimack NH 03054

Control #: 17090128

Project Number: N/A

Project Name: Pennichuck 131-55

Project Location: NH

Analytical Results

Lab ID: 17090128

Date: 9/22/2017

Sample	Client Sample Identity	Start Date/Time Sampled:	Matrix
17090128-001	S-1 TP	9/13/2017 11:30:00 AM	Solid
Composite Start Date and Time		9/13/2017 11:30:00 AM	Composite End Date and Time

Parameter	Method	Result	Qualifier	Date/Time Analyzed	Dilution Factor	RDL
Total Solids	In House	59 %		9/14/2017	1	0.1
Hot Plate Digestion	SW 3050B			9/14/2017	1	0
Iron	SW 6010C	2980 mg/kg dry Wt.		9/20/2017	1	4.21
Phosphorous-P Total	SW 6010C	118 mg/kg dry Wt.		9/20/2017	1	0.842



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Comprehensive Environmental Inc.

Ben Lundsted

21 Depot St

Merrimack NH 03054

Control #: 17090128

Project Number: N/A

Project Name: Pennichuck 131-55

Project Location: NH

Analytical Results

Lab ID: 17090128

Date: 9/22/2017

Sample	Client Sample Identity	Start Date/Time Sampled:	Matrix
17090128-002	S-2 TP	9/13/2017 12:00:00 PM	Solid
Composite Start Date and Time		Composite End Date and Time	
9/13/2017 12:00:00 PM			

Parameter	Method	Result	Qualifier	Date/Time Analyzed	Dilution Factor	RDL
Total Solids	In House	8.8 %		9/14/2017	1	0.1
Hot Plate Digestion	SW 3050B			9/14/2017	1	0
Iron	SW 6010C	12300 mg/kg dry Wt.		9/20/2017	1	28.4
Phosphorous-P Total	SW 6010C	710 mg/kg dry Wt.		9/20/2017	1	5.68



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Ben Lundsted

21 Depot St

Merrimack NH 03054

Control #: 17090128

Project Number: N/A

Project Name: Pennichuck 131-55

Project Location: NH

Analytical Results

Lab ID: 17090128

Date: 9/22/2017

Sample	Client Sample Identity	Start Date/Time Sampled:	Matrix
17090128-003	S-3 TP	9/13/2017 12:30:00 PM	Solid
Composite Start Date and Time		Composite End Date and Time	
9/13/2017 12:30:00 PM			

Parameter	Method	Result	Qualifier	Date/Time Analyzed	Dilution Factor	RDL
Total Solids	In House	7.7 %		9/14/2017	1	0.1
Hot Plate Digestion	SW 3050B			9/14/2017	1	0
Iron	SW 6010C	7560 mg/kg dry Wt.		9/20/2017	1	32.5
Phosphorous-P Total	SW 6010C	842 mg/kg dry Wt.		9/20/2017	1	6.49



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Ben Lundsted

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Merrimack NH 03054

Control #: 17090128

Project Number: N/A

Project Name: Pennichuck 131-55

Project Location: NH

Analytical Results

Lab ID: 17090128

Date: 9/22/2017

Sample	Client Sample Identity	Start Date/Time Sampled:	Matrix
17090128-004	S-4 TP	9/13/2017 1:00:00 PM	Solid
Composite Start Date and Time		9/13/2017 1:00:00 PM	Composite End Date and Time

Parameter	Method	Result	Qualifier	Date/Time Analyzed	Dilution Factor	RDL
Total Solids	In House	61 %		9/14/2017	1	0.1
Hot Plate Digestion	SW 3050B			9/14/2017	1	0
Iron	SW 6010C	7320 mg/kg dry Wt.		9/20/2017	1	4.09
Phosphorous-P Total	SW 6010C	218 mg/kg dry Wt.		9/20/2017	1	0.818



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Ben Lundstedt
 21 Depot St
 Merrimack NH 03054

Control #: 17090128
 Project Number: N/A
 Project Name: Pennichuck 131-55
 Project Location: NH

Analytical Results

Lab ID: 17090128
 Date: 9/22/2017

Sample	Client Sample Identity	Start Date/Time Sampled:	Matrix
17090128-005	S-5 TP	9/13/2017 1:30:00 PM	Solid
Composite Start Date and Time		9/13/2017 1:30:00 PM	Composite End Date and Time

Parameter	Method	Result	Qualifier	Date/Time Analyzed	Dilution Factor	RDL
Total Solids	In House	65 %		9/14/2017	1	0.1
Hot Plate Digestion	SW 3050B			9/14/2017	1	0
Iron	SW 6010C	4700 mg/kg dry Wt.		9/20/2017	1	3.87
Phosphorous-P Total	SW 6010C	211 mg/kg dry Wt.		9/20/2017	1	0.774

Qualifier: Description:

B-	Method blank contaminated with target analyte.
B1-	BOD had total oxygen loss. Result reported as ">"the highest dilution.
B2-	BOD had no oxygen loss. Result reported as "<" the lowest dilution.
G-	Reporting limit elevated due to matrix interference.
H-	Method prescribed holding time exceeded.
J-	Indicates an estimated value. Value is less than the quantitation limit.
IL-	Internal Standard(s) recovery was low due to matrix. Result may be biased high.
IH-	Internal Standard(s) recovery was high due to matrix. Result may be biased low.
LH-	Laboratory control spike(s) was high. Results may be biased high.
LL-	Laboratory control spike(s) was low. Results may be biased low.
MH-	Matrix spike recovery high due to matrix. Results may be biased high.
ML-	Matrix spike recovery low due to matrix. Results may be biased low.
N-	Non-target compound. Reported as a TIC.
NC-	Spike recovery was not calculated due to the concentration of the analyte being >4 times the concentration of the spike added.
R-	RPD outside acceptable recovery limits.
RO-	Sample received out of holding time.
SH-	Surrogate recovery high due to matrix
SL-	Surrogate recovery low due to matrix
U-	BOD/CBOD blank had an oxygen depletion greater than the suggested amount of 0.200.
V-	Sample pH for volatile analysis was not <2 when checked at time of analysis.
Z	Too numerous to count (TNTC)

An "A" in the result column on the report indicates absent for presence/absent bacteria and a "P" indicates present for presence/absent bacteria.

Multiple COC's	Yes	No
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317 Elm Street Milford, NH 03055
(603) 673-5440/ Fax (603) 673-0366

CHAIN OF CUSTODY

A CUSTOMER INFORMATION			B PROJECT INFORMATION			C SAMPLE INFORMATION												
CUSTOMER: COMPREHENSIVE ENVIRONMENTAL INC.			JOB NAME: PENNICHUCK			TURNAROUND TIME: (CIRCLE ONE):												
ADDRESS: 21 DEPOT STREET			JOB NUMBER: 131-55			10 DAY STANDARD RUSH (MUST BE PRE-APPROVED)												
CITY/STATE/ZIP MERRIMACK, NH 03054			LOCATION: NH			7 day 5 day 4 day 3 day 2 day 1 day Same day												
TELEPHONE: (603) 424-8444			INVOICE EMAIL: mkneeland@ceiengineers.com			MCP YES NO GW1 GW2 GW3												
REPORT TO: BEN LUNDSTED			INVOICE TO: MARY KNEELAND			CONTAINER PRESERVATIVE PHOSPHORUS IRON												
EMAIL TO: blundsted@ceiengineers.com			P.O. NUMBER: 131-55															
STATION #	SAMPLE IDENTIFICATION & LOCATION	COLLECTED		SAMPLE TYPE	MATRIX	# OF CONTAINERS	ANALYSIS											
	S-1 TP	DATE	TIME	GRAB	COMP													
	S-2 TP	DATE	TIME															
	S-3 TP	DATE	TIME															
	S-4 TP	DATE	TIME															
	S-5 TP	DATE	TIME															
		DATE	TIME															
		DATE	TIME															
		DATE	TIME															
		DATE	TIME															
CUSTODY			SAMPLER: JUSTIN MACEK		DATE	MILITARY TIME	SAMPLE CHECK LIST:					FIELD READING(S) & COMMENTS:						
SIGNATURE: Justin Macek			9/13/17		15:45	RECEIVED WITHIN HOLD TIME YES OR NO												
RELINQUISHED: Justin Macek			9/13/17		15:45	RECEIVED IN GOOD CONDITION YES OR NO												
RECEIVED:						TEMP BLANK n/a °C												
RELINQUISHED:						SHIPPED OR (AND) DELIVERED												
RECEIVED FOR LAB: Justin Macek			9/13/17		15:45	SAMPLES WERE PROPERLY PRESERVED YES NO N/A												
							SAMPLES WERE FILTERED IN FIELD LAB											
							IF NO EXPLAIN:											
							GROUP # 17090128											

Appendix D

FFA Authorization Documentation

DEPARTMENT OF TRANSPORTATION FEDERAL AVIATION ADMINISTRATION CERTIFICATE OF WAIVER OR AUTHORIZATION	
ISSUED TO Pennichuck Water 21 Depot street Merrimack, NH 03054	POC PHONE NUMBER (603) 494-0558
This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.	
OPERATIONS AUTHORIZED Operations under this certificate of authorization are limited to the maximum altitude listed below. This altitude is an absolute value and it shall not be added to the height of any structures. Class of Airspace: D At or Below: 200 feet Above Ground Level (AGL) With a radius of: 1 NM Under the Jurisdiction of: Boire Field (ASH)	
LIST OF WAIVED REGULATIONS BY SECTION AND TITLE N/A	
STANDARD PROVISIONS	
1. A copy of the application made for this certificate shall be attached and become a part hereof. 2. This certificate shall be presented for inspection upon the request of any authorized representative of the Federal Aviation Administration, or of any State or municipal official charged with the duty of enforcing local laws or regulations. 3. The holder of this certificate shall be responsible for the strict observance of the terms and provisions contained herein. 4. This certificate is nontransferable.	
Note-This certificate constitutes a waiver of those Federal rules or regulations specifically referred to above. It does not constitute a waiver of any State law or local ordinance.	
SPECIAL PROVISIONS	
Special Provisions 1 thru 3, inclusive, are set forth in this authorization.	
This certificate, 2017-P107-ESA-8481, is effective from August 10, 2017 through June 30, 2018, and is subject to cancellation at any time upon notice by the Administrator or his/her authorized representative.	
BY DIRECTION OF THE ADMINISTRATOR	
<u>FAA Headquarters, AJV-115</u> (Region)	SCOTT JAMES GARDNER Digitally signed by SCOTT JAMES GARDNER Date: 2017.08.07 14:25:04 -04'00' <u>Scott J. Gardner</u> (Signature)
<u>August 7, 2017</u> (Date)	<u>Acting Manager, UAS Tactical Operations Section</u> (Title)

SPECIAL PROVISIONS

1. CONTACT INFORMATION:

David Cote is the person designated as responsible for the overall safety of UAS operations under this Certificate of Waiver or Authorization. During UAS operations for on-site communication/recall, the Responsible Person shall be continuously available for direct contact at (603) 494-0558 by ASH or designated representative.

2. SCHEDULE OF FLIGHT OPERATIONS:

- a. This Certificate of Waiver or Authorization and the Special Provisions shall be in effect between civil sunrise and civil sunset local time.
- b. This airspace authorization does not relieve the remote pilots from the responsibility to check the airspace they are operating in and comply with all restrictions that may be present in accordance with see 14 CFR 107.45 and 107.49 (a)(2), such as restricted and Prohibited Airspace, Temporary Flight Restrictions, etc.
- c. The facility may disapprove, terminate, restrict, or delay UAS flight operations covered by this authorization at any time.

3. EMERGENCY/CONTINGENCY PROCEDURES - Lost Link/Lost Communications Procedures:

- a. If the UAS loses communications or loses its GPS signal, the UA must return to a pre-determined location within the operating area and land.
- b. The PIC must abort the flight in the event of unpredicted obstacles or emergencies.

Attachment 1

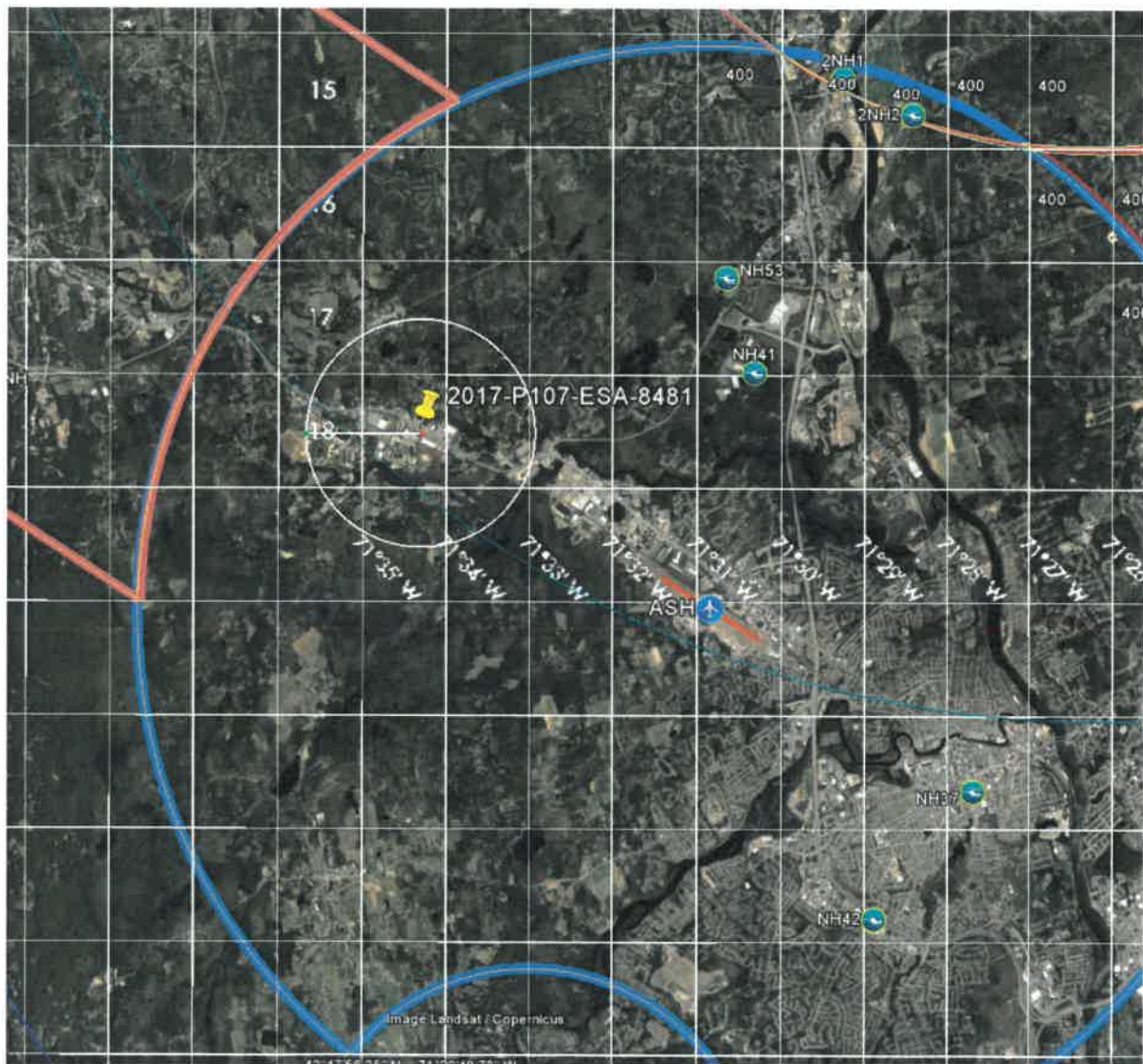
OPERATIONS AREA

Class D Airspace

At or below 200 feet AGL

42° 48' 32.00" N, 71° 34' 19.00" W

1 NM Radius



DEPARTMENT OF TRANSPORTATION FEDERAL AVIATION ADMINISTRATION	
CERTIFICATE OF WAIVER OR AUTHORIZATION	
ISSUED TO CEI on behalf of Pennichuck Water	POC PHONE NUMBER 603-494-0925
21 Depot Street Merrimack, NH 03054	
This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.	
OPERATIONS AUTHORIZED Operations under this certificate of authorization are limited to the maximum altitude listed below. This altitude is an absolute value and it shall not be added to the height of any structures. Class of Airspace: D At or Below: 200 feet Above Ground Level (AGL) With a radius of: 1 NM Under the Jurisdiction of: Nashua FAA Contract Tower (ASH FCT)	
LIST OF WAIVED REGULATIONS BY SECTION AND TITLE N/A	
STANDARD PROVISIONS	
1. A copy of the application made for this certificate shall be attached and become a part hereof. 2. This certificate shall be presented for inspection upon the request of any authorized representative of the Federal Aviation Administration, or of any State or municipal official charged with the duty of enforcing local laws or regulations. 3. The holder of this certificate shall be responsible for the strict observance of the terms and provisions contained herein. 4. This certificate is nontransferable.	
Note-This certificate constitutes a waiver of those Federal rules or regulations specifically referred to above. It does not constitute a waiver of any State law or local ordinance.	
SPECIAL PROVISIONS	
Special Provisions 1 thru 3, inclusive, are set forth in this authorization.	
This certificate 2017-P107-ESA-8294 is effective from August 16, 2017 to June 30, 2018, and is subject to cancellation at any time upon notice by the Administrator or his/her authorized representative.	
BY DIRECTION OF THE ADMINISTRATOR	
<u>FAA Headquarters, AJV-115</u> (Region)	SCOTT JAMES Digitally signed by SCOTT JAMES GARDNER GARDNER Date: 2017.08.15 16:28:09 -04'00' <u>Scott J. Gardner</u> (Signature)
<u>August 15, 2017</u> (Date)	<u>Acting Manager, UAS Tactical Operations Section</u> (Title)

SPECIAL PROVISIONS

1. CONTACT INFORMATION:

Eileen Pannetier is the person designated as responsible for the overall safety of UAS operations under this Certificate of Waiver or Authorization. During UAS operations for on-site communication/recall, the Responsible Person shall be continuously available for direct contact at 603-494-0925 by ASH FCT or designated representative.

2. SCHEDULE OF FLIGHT OPERATIONS:

- a. This Certificate of Waiver or Authorization and the Special Provisions shall be in effect between civil sunrise and civil sunset local time.
- b. This airspace authorization does not relieve the remote pilots from the responsibility to check the airspace they are operating in and comply with all restrictions that may be present in accordance with see 14 CFR 107.45 and 107.49 (a)(2), such as restricted and Prohibited Airspace, Temporary Flight Restrictions, etc.
- c. The facility may disapprove, terminate, restrict, or delay UAS flight operations covered by this authorization at any time.
- d. To prevent sUAS contact with Special VFR (SVFR) operations, sUAS operations are not authorized when there is a ceiling of less than 1,000 feet AGL.

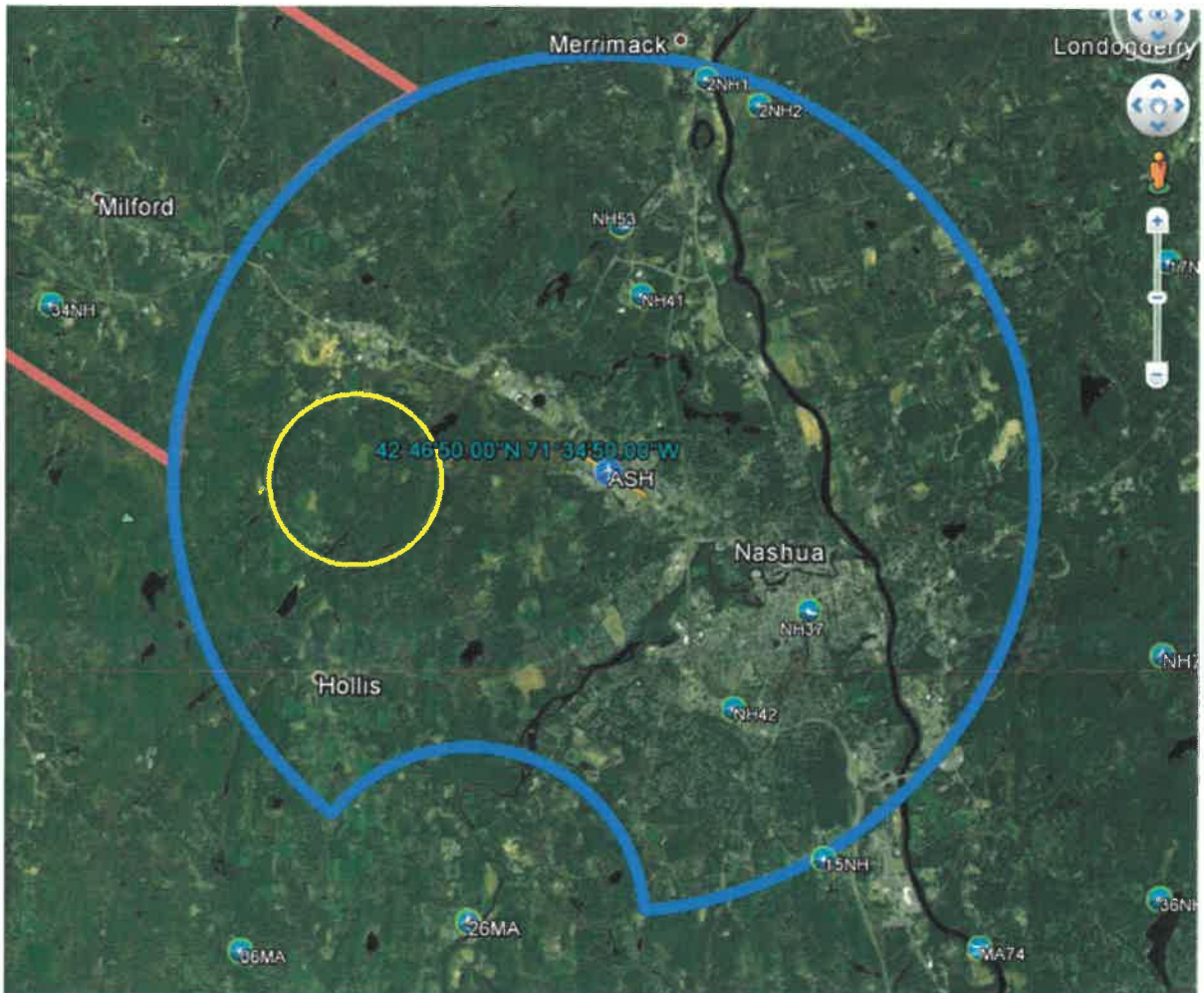
3. EMERGENCY/CONTINGENCY PROCEDURES - Lost Link/Lost Communications Procedures:

- a. If the UAS loses communications or loses its GPS signal, the UA must return to a pre-determined location within the operating area and land.
- b. The PIC must abort the flight in the event of unpredicted obstacles or emergencies.

Attachment 1

Operations Area

Class D Airspace
At or below 200 feet AGL
1 NM Radius



DEPARTMENT OF TRANSPORTATION FEDERAL AVIATION ADMINISTRATION	
CERTIFICATE OF WAIVER OR AUTHORIZATION	
ISSUED TO Eileen Pannetier	POC PHONE NUMBER 603-494-0925
21 Depot Street Merrimack, NH 03054	
This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.	
OPERATIONS AUTHORIZED Operations under this certificate of authorization are limited to the maximum altitude listed below. This altitude is an absolute value and it shall not be added to the height of any structures. Class of Airspace: D At or Below: 200 feet Above Ground Level (AGL) With a radius of: .80 NM Under the Jurisdiction of: Nashua Tower (ASH)	
LIST OF WAIVED REGULATIONS BY SECTION AND TITLE NONE	
STANDARD PROVISIONS	
1. A copy of the application made for this certificate shall be attached and become a part hereof. 2. This certificate shall be presented for inspection upon the request of any authorized representative of the Federal Aviation Administration, or of any State or municipal official charged with the duty of enforcing local laws or regulations. 3. The holder of this certificate shall be responsible for the strict observance of the terms and provisions contained herein. 4. This certificate is nontransferable.	
Note-This certificate constitutes a waiver of those Federal rules or regulations specifically referred to above. It does not constitute a waiver of any State law or local ordinance.	
SPECIAL PROVISIONS	
Special Provisions 1 thru 3, inclusive, are set forth in this authorization.	
This certificate 2017-P107-ESA-7240 is effective from July 14, 2017 to June 30, 2018, and is subject to cancellation at any time upon notice by the Administrator or his/her authorized representative.	
BY DIRECTION OF THE ADMINISTRATOR	
FAA Headquarters, AJV-115 (Region)	SCOTT JAMES GARDNER Digitally signed by SCOTT JAMES GARDNER Date: 2017.07.13 12:24:41 -04'00' <u>Scott J. Gardner</u> (Signature)
<u>July 13, 2017</u> (Date)	<u>Acting Manager, UAS Tactical Operations Section</u> (Title)

FAA Form 7711-1 (7-74)

CIVIL PART 107 AUTHORIZATION, JULY 3, 2017

SPECIAL PROVISIONS

1. CONTACT INFORMATION:

David Cote is the person designated as responsible for the overall safety of UAS operations under this Certificate of Waiver or Authorization. During UAS operations for on-site communication/recall, the Responsible Person shall be continuously available for direct contact at **603-494-0558** by **Nashua Tower** or designated representative.

2. SCHEDULE OF FLIGHT OPERATIONS:

- a. This Certificate of Waiver or Authorization and the Special Provisions shall be in effect between civil sunrise and civil sunset local time.
- b. This airspace authorization does not relieve the remote pilots from the responsibility to check the airspace they are operating in and comply with all restrictions that may be present in accordance with see 14 CFR 107.45 and 107.49 (a)(2), such as restricted and Prohibited Airspace, Temporary Flight Restrictions, etc.
- c. The facility may disapprove, terminate, restrict, or delay UAS flight operations covered by this authorization at any time.
- d. To prevent sUAS contact with Special VFR (SVFR) operations, sUAS operations are not authorized when there is a ceiling of less than 1,000 feet AGL.

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- a. If the UAS loses communications or loses its GPS signal, the UA must return to a pre-determined location within the operating area and land.
- b. The PIC must abort the flight in the event of unpredicted obstacles or emergencies.

Attachment 1

Operations Area

Class D Airspace

At or below 200 feet AGL

42 47 28 N, 71 29 53 W

.80 NM Radius



CIVIL PART 107 AUTHORIZATION, JULY 3, 2017

Appendix E

Site-Specific Project Plan (SSPP) for: Pennichuck Reservoir Pond and Tributary Sedimentation Study

SITE SPECIFIC PROJECT PLAN (SSPP) FOR:

Pennichuck Reservoir Pond and Tributary Sedimentation Study

Operated Under:

**McQuesten Brook Watershed Dam Removal and Restoration Project
Impoundment Sediment Collection and Analysis and Hydraulic Analysis QAPP**

RFA #14075

(March 2014)

December 2016

Prepared by:

Comprehensive Environmental Inc. (CEI)

21 Depot Street

Merrimack, NH 03054

800-725-2550

For Review:

Project Manager CEI:



Signature/Date
Benjamin Lundsted, P.E.

Technical Project Manager/QA Officer CEI:



Signature/Date
Rebecca Balke, P.E.

Project Mgr. /Grantee Pennichuck:



Signature/Date
Donald Ware, P.E., Pennichuck

NHDES Project Manager & QA Coordinator:

Signature/Date
Amy Hudnor, NHDES

NHDES Quality Assurance Manager:

Signature/Date
Vincent Perelli, NHDES

For Receipt:

US EPA Project Manager:

Signature/Date
Erik Beck, US EPA Region I

2 – Table of Contents

Title Page	1
Table of Contents	2
List of Tables	2
List of Figures	2
Distribution List	3
Project Task Organization	3
Site Information	5
Project Rationale	5
Problem Definition	5
Historical Data	6
Project Description and Schedule	7
Project Purpose and Schedule	7
Project Methodolgy	7
Sediment Sample Collection and Processing Protocols	9
Final Products and Reporting	11

List of Tables

Table 1. SSPP Distribution List	3
Table 2. Personnel Responsibilities and Qualifications	5

List of Figures

Figure 1. Project Organizational Chart	4
Figure 2. Locus Map	End of Document
Figure 3. Sediment Depth 2000 & 2010	End of Document
Figure 4. Possible Sediment Sources Soil Types and Slopes	End of Document
Figure 5. Possible Sediment Sources Orthophorographs and Contours ...	End of Document

List of Appendices

Appendix A – Sediment Impact Studies July 2000 and November 2012
Appendix B - Sediment Analysis Study November 2013
Appendix C - McQuesten Brook Watershed Dam Removal and Restoration Project Impoundment Sediment Collection and Analysis and Hydraulic Analysis QAPP
Appendix D – ChemServe Accreditation Details

3- Distribution List

Table 1 lists people who will receive copies of the approved Site Specific Project Plan (SSPP) under the *McQuesten Brook Watershed Dam Removal and Restoration Project Impoundment Sediment Collection and Analysis and Hydraulic Analysis QAPP – RFA #14075 (March 2014)*.

Table 1. SSPP Distribution List

SSPP Recipient Name	Project Role	Organization	Telephone number and e-mail address
Benjamin Lundsted, P.E.	Project Manager	Comprehensive Environmental Inc.	603-429-3584 blundsted@ceiengineers.com
Rebecca Balke, P.E.	Technical Project Manager and QA Officer	Comprehensive Environmental Inc.	603-424-8443 rbalke@ceiengineers.com
Donald Ware, P.E.	Project Manager	Pennichuck Corp.	603-913-2330 donald.ware@pennichuck.com
Amy Hudnor	NHDES Project Manager and Project QA Coordinator	NHDES, Drinking Water and Groundwater Bureau	603-271-2950 amy.hudnor@des.nh.gov
Vincent Perelli	NHDES QA Manager	NHDES, Planning, Prevention, & Assistance Unit	603-271-8989 vincent.perelli@des.nh.gov
Erik Beck	USEPA Project Manager	USEPA New England	617-918-1606 beck.erik@epa.gov

4- Project Task Organization

This project is funded under the 2016, New Hampshire Department of Environmental Services (NHDES) Local Source Water Protection Grant Program. Comprehensive Environmental Inc. (CEI) was selected by the Pennichuck Corporation of Merrimack, NH to complete the field work, prepare deliverables and manage the grant project.

Benjamin Lundsted, P.E., serves as CEI's Project Manager. He is responsible for overseeing the completion of field work and grant deliverables. He is also responsible for ensuring that grant tasks are completed in accordance with project scope and grant agreement.

CEI's Technical Project Manager and QA Officer, Rebecca Balke, P.E. is responsible for providing technical assistance during data collection and field work. Rebecca will be responsible for providing CEI's internal technical quality control and assurance for the mapping and sampling program.

Donald Ware, P.E. is the Project Manager and Grantee (Pennichuck Corporation) for this project. He is responsible for managing the grant project and is the chief liaison between the New Hampshire Department of Environmental Services, Comprehensive Environmental, Inc. and Pennichuck Corporation. He will be responsible for managing subcontracts and appropriating procurement funds for the grant project. He will also be responsible for the review of final grant deliverables and provide project oversight as Grantee for the Pennichuck Corporation.

The NHDES Project Manager and QA Coordinator, Amy Hudnor, will oversee all aspects of the grant project and will manage the review process and submittal by CEI of grant deliverables and reporting to NHDES and the U.S. Environmental Protection Agency (USEPA). Amy will also review Grant Reporting/Status, process and track Payment Requests/Match Documentation and provide quality assurance and technical review of the grant deliverables.

Vincent Perelli, NHDES QA manager, will review and approve this Site Specific Project Plan.

Figure 1 outlines the organization structure of the project personnel.

Figure 1. Project Organizational Chart

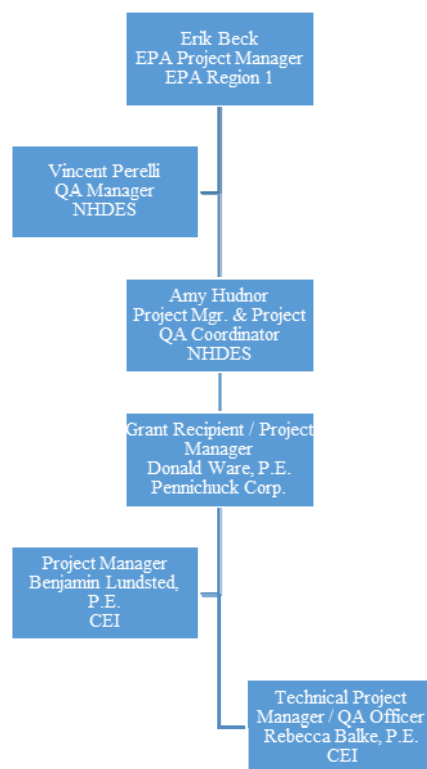


Table 2 identifies the roles and responsibilities of those individuals involved in the project.

Table 2. Personnel Responsibilities and Qualifications

Name and Affiliation	Responsibilities	Qualifications
Benjamin Lundsted, P.E., CEI	Project Manager	Registered NH Professional Engineer
Rebecca Balke, P.E., CEI	Technical Project Manager Project QA/QC Officer	Registered NH Professional Engineer
Donald Ware, P.E., Pennichuck Corp.	Project Manager	Registered NH Professional Engineer
Amy Hudnor, NHDES, Drinking Water and Groundwater Bureau	Reviews and oversees projects funded by Local Water Supply Protection Grants in NH.	On file at NHDES
Vincent Perelli, NHDES Planning, Prevention & Assistance Unit	Reviews and approves QAPPs	On file at NHDES
Erik Beck, US EPA Region I	EPA Project Manager	On file at US EPA

5-Site Information

Pennichuck Brook has long been the primary source of water for a significant portion of southern New Hampshire. The water supply is operated by the Pennichuck Corporation located in Merrimack, NH. It consists of about 351 acres of water in a series of chain ponds that include Supply Pond, Harris Pond, Bowers Pond, and Holts Pond. Stump Pond, Pennichuck Pond, and many smaller ponds also contribute water to Pennichuck's supply (see Figure 2 for a locus map). Peak summer demands are sometimes supplemented by the Merrimack River.

Over the last 100 years, extensive development throughout the approximately 18,000 acre watershed has resulted in declining yields and water quality, a common phenomenon in urbanizing areas. Increased sedimentation rates associated with this development have caused infilling of the supply ponds as well as increased algal blooms in Holts, Bowers and Harris Ponds. Changes in land use, construction of major highways, urban traffic and dense commercial/industrial development all represent land-based sources of sediment and phosphorus influx that compromise water quantity and quality in the water supply ponds.

6-Project Rationale

A. Problem Definition

Concurrent with the steady development of the Pennichuck watershed is an increase in sediment deposition in the water supply ponds. This increased sediment load contributes to infilling of the ponds and loss of water storage capacity, as well as increasing the phosphorus loading and compromising of the water quality.

The purposes of this project are 1) to identify possible sources of observed sediment influx into the supply pond chain; 2) to measure sediment depth and collect and analyze samples to estimate the amount of sediment input; and 3) to formulate protection and mitigation measures to reduce sediment and pollutant input into the supply ponds.

B. Historical Data

Pennichuck Water Works has been monitoring groundwater and tributary water in the Pennichuck watershed since 1991, and has used a standardized method and fixed sampling locations since 2005. Water samples were tested for TSS, nitrogen, phosphorus, *E. coli* and fecal coliform bacteria, among other parameters. Broadly, the samples demonstrate significant variability in phosphorus levels in surface water and especially groundwater samples. Pennichuck provides an interactive website detailing results of the tributary phosphorus monitoring trends on an annual basis¹. Other parameters are within expected bounds except where they appear to reflect runoff from salt-treated roads and the municipal airport in the spring.

Surveys of the Pennichuck water supply ponds were made by CEI in 2000 and 2010 to measure sediment thickness and geochemistry at several points throughout the pond series (Appendix A). Figure 3 provides in-pond sediment depth mapping results from 2000 and 2010. Permanent sediment monitoring locations were established to measure sedimentation rates at fixed locations using a secchi disk and a probe that was pushed to refusal. During an additional sediment analysis study completed in 2013 (Appendix B), sediment samples were taken using a barge mounted boring machine to take deep sediment cores at specific locations and measure chemical profiles and distribution of grain sizes of that sediment at different depths, to focus on likely sources, in-pond transport and approximate age of sediment deposits.

The 2000 and 2010 studies demonstrated a net increase of sediments over the intervening years. Sediments appeared to be accumulating the most in three key areas: 1) Holts Pond at the tributary inlets, 2) Bowers Pond upstream of the Everett Turnpike, and 3) Harris Pond downstream of Bowers Pond. The 2013 study revealed that sediment could be accumulating within the pond systems at a varying rate of 0.26 to 0.85 centimeters per year with a likely increase in accumulation rates over the past 50 years.

The current project is intended to build on these previous studies by further characterizing the sediment input; continuing to monitor sediment depths; mapping the sediments in a currently unmapped pond (Holts Pond); and reviewing potential tributary/watershed sediment sources so that mitigation measures may be taken. These may include implementation of stormwater BMPs, erosion reduction, culvert modifications or repair, and stabilization of damaged streambank sections.

¹ “Watershed Interactive Map”, *Pennichuck.com*, last modified 2016, http://www.pennichuck.com/watershed_interactive_map.php

7-Project Description and Schedule

A. Project Purpose and Schedule

A sedimentation analysis will be conducted for this project which is expected to improve understanding of the amount and source of sediments that enter the Pennichuck water supply ponds and adversely impact the water quality and quantity. The project is organized as follows, concluding with a final report synthesizing the outcomes of each step. It is expected that fieldwork will begin in late fall or early winter of 2016 and finish in early spring of 2017, with deliverables finalized by the end of May 2017.

B. Project Methodology

Recent high-resolution aerial imagery obtained from NHDES, NHDOT, GRANIT, or other appropriate source will be reviewed to gain a first overview of (1) possible sources of sediment on the shores of the ponds and their tributaries, and (2) sediment deltas in the supply ponds and their tributaries. Using data on soil types and topography from a LiDAR-derived digital elevation model, CEI will then focus on areas in the watershed where topographic slope and soil characteristics together indicate that erosion and sediment transport are more likely.

Based on the desktop review of aerial photos, soils, and topography, specific tributary sections with probable erosion will be evaluated in the field. Areas of visible erosion, construction, or changes in land use, as shown in aerial photos between 2010 and 2015, and locations where steep slopes (greater than 30 degrees) are composed of highly erodible soils, will represent the type of potential erosion worthy of investigation. Tributary sections will be examined from 100 to 500 feet downgradient of the identified potential sources. Potential sediment deposition sources are shown in Figures 4 and 5. During the visual investigation, any culvert crossings and/or drainage outfalls will also be examined within these tributary sections for potential impacts to bank erosion and bed sediment deposition.

The initial screening of sediment sources is to represent a potential erosion source using visual observation of local conditions and gradation of the sediment to compare to material found in the supply ponds in addition to known winter sanding material used on roadways in the area. It is not our intent to evaluate geomorphic conditions or how material is moving through the stream system. The intent of the investigation will be to identify erosion sources that have been caused by man-made land use changes or other unnatural stream disturbances which may be potentially remedied through corrective actions (e.g. undersized culverts, erosion drainage outfalls, etc.).

Visible observations will be made on local terrain, streambank slope, visible erosion or undercutting, loss of buffer or sediment in-fill, and nearby land use or infrastructure that could influence sediment transport characteristics. Visual observations will be made by tributary walks or fly-overs of the identified tributary sections based on accessibility of that section.

Within the tributary sections, sediment samples will be taken from the stream, bank, or sediment deltas in accordance with the standards and methods indicated in the *McQuesten Brook Watershed Dam Removal and Restoration Project Quality Assurance Program Plan (QAPP)* (Appendix C). Depending on the extent, type and source of erosion, sediment samples will be gathered and logged based on visual inspection observations. If bed sediment deposition is observed within a tributary section downgradient of an obvious source of erosion, samples will be gathered and analyzed from both the deposition area and the assumed source area to correlate the deposition sources (e.g. steep eroded slope and downgradient sediment deposit or clogged drainage outfall and downgradient sediment deposit)

The samples will be sent to ChemServe in Milford, NH, for analysis of moisture/organic content and grain size distribution to enable comparison with previous and ongoing sediment sampling. Sample collection and processing protocols are described in further detail at the end of this section. ChemServe accreditation details are provided in Appendix D.

The samples from the tributary sections will also be analyzed for phosphorus levels and iron content. These data will allow CEI to quantify phosphorus loads associated with sediment influx, and to estimate background phosphorus levels in the soils of the watershed for comparison with ongoing watershed and groundwater monitoring as referenced in Section 6B. This analysis will provide correlation between the nutrient content in bed sediment deposition samples and the potential upgradient erosion source areas. This information will be used for comparison to the on-going yearly nutrient monitoring study to identify potential excess nutrient loadings and remedies for nearby permanent monitoring station throughout that respective subwatershed area.

Building on the results from the sediment analyses, the soils, topography effort and field site review, CEI will formulate measures to address the problem of excess sediment influx into the supply ponds. CEI will then prepare a report summarizing the work to this point. The report will include the results from the desktop analysis of watershed conditions, with relevant maps, and the lab results from the sediment sample analyses. Maps will include the location of identified bed sediment deposition and correlated erosion source with information classifying the type and class of sediment throughout the watershed so that the spatial distribution of sediment character is clearly displayed. These maps will also identify noted sediment sources with no obvious resulting deposition area or bed deposition areas with no obvious source so that future studies can focus on those areas and continued monitoring of sediment transport can occur.

The final report will also include an estimation of sediment input derived from each tributary section, and recommended protection and mitigation measures. These recommendations will identify the potential sediment source(s), best management practices, cost, engineering and permitting requirements, along with available land ownership data for future use in supply pond protection plans.

C. Sediment Sample Collection and Processing Protocols

The desktop survey of the study area will provide some guidance as to where and how many samples should be taken. When an area is chosen for sampling, it will be divided into a grid and one sample taken from each grid cell. If a large sediment source or deposition area is to be sampled, it will be subdivided into a proportionately larger grid than a smaller area would be. This approach is intended to allow best use of resources to recover composite samples that are equally representative from differently-sized areas.

The collection and analysis of composite samples will allow CEI to screen the material for project specific purposes and to meet the proposed budget. Duplicates in each grid will also be grabbed, stored and not composited so that future analysis for different aspects of the sediment deposition area can be completed in the future.

Supplies required during field sampling, sample handling and laboratory preparation will include sample bottles provided by the accredited testing laboratory (ChemServe), sterile plastic containers used for field transport, stainless steel sample collection devices (hand-driven “Beeker” sampling unit or spring-operated sampling devices), stainless steel collection/mixing containers, stainless steel mixing utensils (spoons or spatulas) and deionized water. All sample bottles will be inspected prior to use to ensure seals have not been broken and no signs of contamination or breakage have occurred.

Photographs and aerial video will be taken of the bed sediment deposition and potential erosion source. Additionally, coordinates of each identified area or sample location will be taken using GPS equipment.

Sediment samples will be collected in either of two ways, depending upon sediment depth and quality of sample recovery.

The core sampling procedure and all other field sampling QA/QC protocols described in *McQuesten Brook Watershed Dam Removal and Restoration Project QAPP* will be followed.

The preferred method of sediment sampling will be shallow (6”-24”) hand-driven coring, using a shallow-sediment coring device (“Beeker” sampling unit) with a plastic liner and a plastic trap at the lower end to hold the sample in the tube. The “Beeker” sampling unit, plastic sleeve and plastic trap will be cleaned and rinsed with ambient water and assembled, and the device pushed straight down into the sediment to refusal. The “Beeker” sampling unit is then withdrawn from the sediment, the liner containing the sediment core is extracted from the device, and the core is capped with plastic caps to preserve the integrity of the layers during transport. The “Beeker” sampling unit will be rinsed again with ambient water before the next core sample is taken.

If the preferred *McQuesten Brook Watershed Dam Removal and Restoration Project QAPP* hand-driven core sampling method is not possible or does not produce competent samples, an alternative method will be employed. This method will use similar sampling

QA/QC protocols, however a spring-operated, stainless steel sampling device (similar to a clam-shell bucket) will be used to grab sediment samples from the surface of the sediment. The sampling device will be cleaned and rinsed with deionized water before being placed on the surface. The spring is released to close the sampling device, and the sediments thus captured are transferred to a clean, sealed, plastic container in lieu of the removal tube employed under the “Becker” sampling device method. The spring operated sampling device will be rinsed again with ambient water before the next sample is taken.

Each gridded sampling area will be described in a field data sheet detailing the local field conditions; size of the sampled area; number of samples recovered; sample IDs; method of sampling (“Becker” core or spring-operated surface sample); and success of sample recovery. Each sample will be clearly labeled with indelible pen and stored in the sterile plastic container or securely capped core tube for transport.

Sample handling methods and field QA/QC procedures will also follow *McQuesten Brook Watershed Dam Removal and Restoration Project QAPP* (Appendix C). One person will be responsible for tracking samples and sample records from the field to the office and then to the laboratory.

Before delivery to the laboratory for analysis, the samples will be logged and photographed, and their grain size, color and debris content will be examined and recorded. If sediment layering is noted during field reconnaissance or during visual examination of the core samples, this will be documented through photo documentation and in field notes/logs. Field log information on layering will include layer thickness in addition to the color and material classification data.

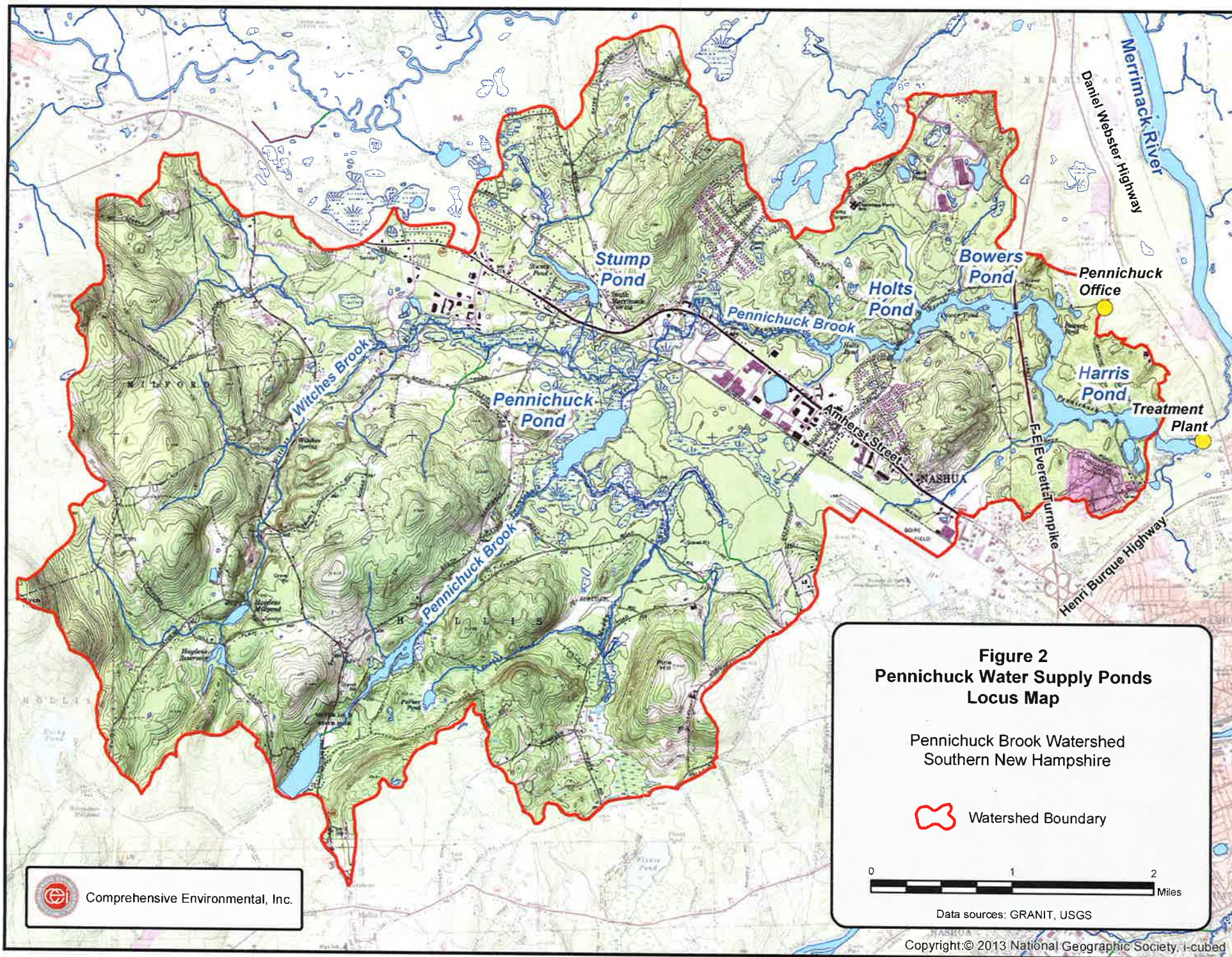
The samples derived from each sampling area will then be composited in a clean stainless steel container using a stainless steel spoon or spatula that are cleaned prior to use with ambient water. Standard sampling and compositing methods for QA/QC of aggregates used in construction (similar to ASTM D75 / D75M) will be used for compositing. The use of stainless steel equipment will not influence the phosphorus levels or physical characteristics for which the samples are to be analyzed. The bowls and spatulas will also be cleaned and rinsed before and after each sample to prevent cross-contamination among samples.

Once compositing of the gridded subarea samples is completed, samples will be placed into subsample containers provided by ChemServe. These sample containers will be filled using QA/QC methods for aggregate sample size reductions similar to those used in construction under ASTM C702 and C702M. The composited sample bottles will then be delivered to ChemServe, in Milford, NH, for analysis of grain size and moisture/organic content. Additional subsamples will be sent to ChemServe for data on phosphorus levels and iron content. See Appendix D for ChemServe accreditation details. QA/QC procedures for Data Management and Sample Analysis (including sample transfer to the accredited laboratory, chain of custody tracking and review of laboratory reports) will also be completed in accordance with *McQuesten Brook Watershed Dam Removal and Restoration Project QAPP* (Appendix C).

8-Final Products and Reporting

CEI will prepare a final report which will itemize each of the above steps and its result. It will include a summary of the aerial imagery used to identify sediment sources along tributaries, with relevant maps, along with watershed soil maps and a summary of soil characteristics and surficial geology. CEI will estimate total sediment and phosphorus loads derived from the identified sources. Laboratory results showing grain size distribution, moisture/organic content, phosphorus levels, and iron content will be included. Based on the laboratory results, the sediment contribution and distribution in the supply ponds will be evaluated. CEI will recommend protection measures to mitigate the sediment infilling derived from upstream sources, and will itemize their associated costs, calculated sediment and phosphorus reductions resulting from the measures, responsible parties, and ongoing maintenance.

All products will be submitted by **Comprehensive Environmental, Inc.**, in both electronic and paper copies, to the NHDES Local Source Water Protection Grant Program for review and approval.



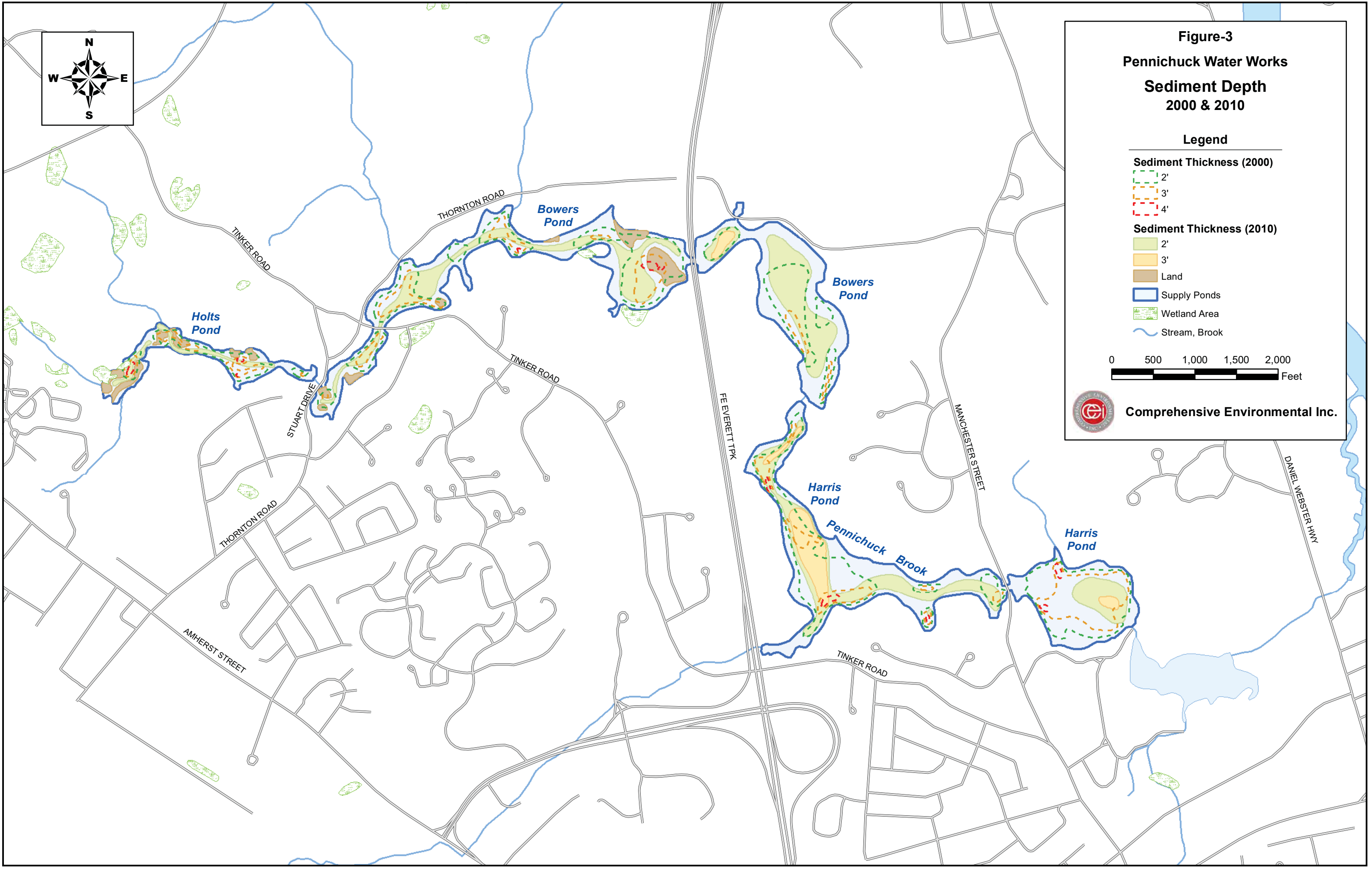


Figure-3
Pennichuck Water Works
Sediment Depth
2000 & 2010

Legend

Sediment Thickness (2000)

- 2'
- 3'
- 4'

Sediment Thickness (2010)

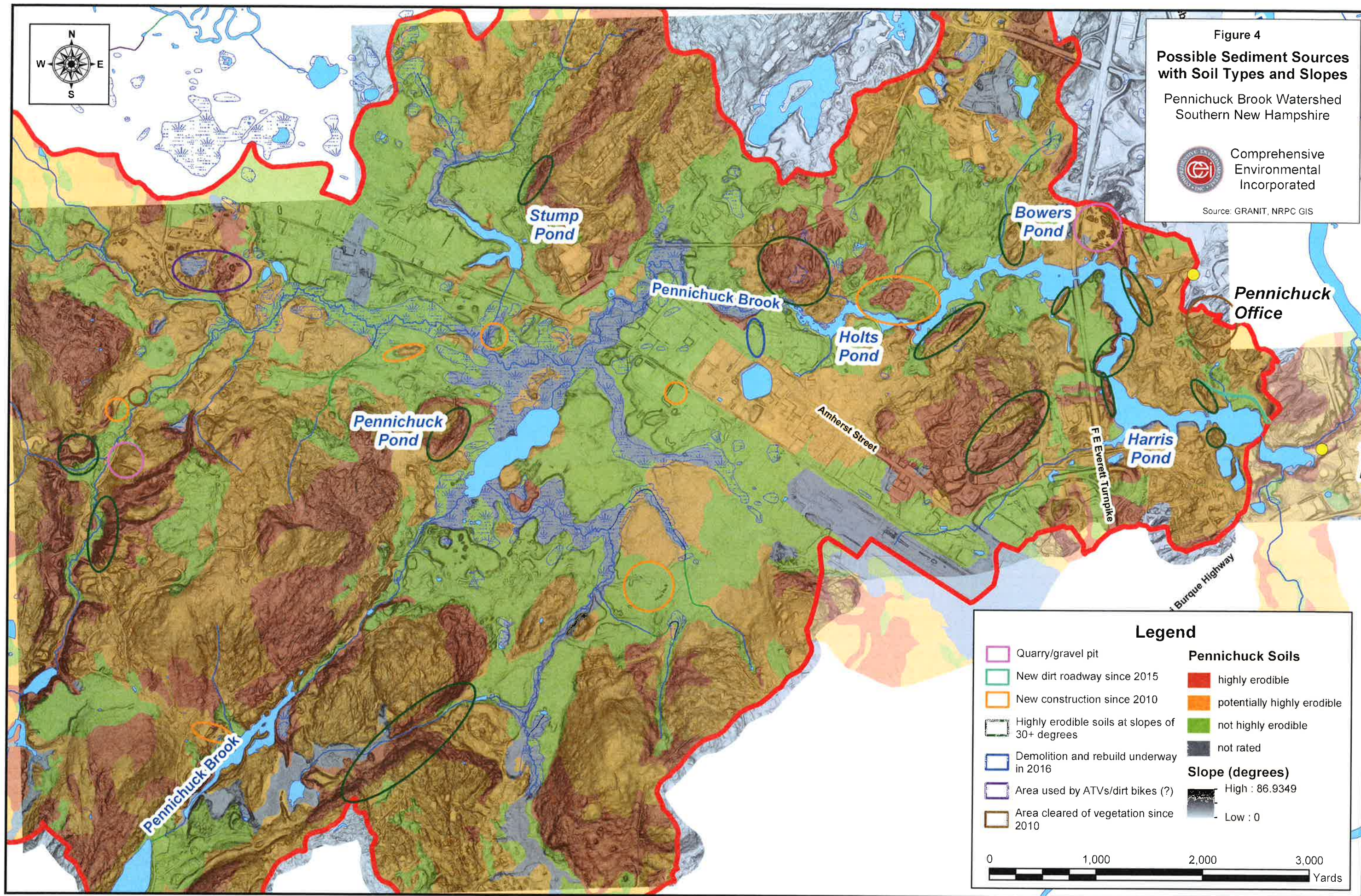
- 2'
- 3'
- Land

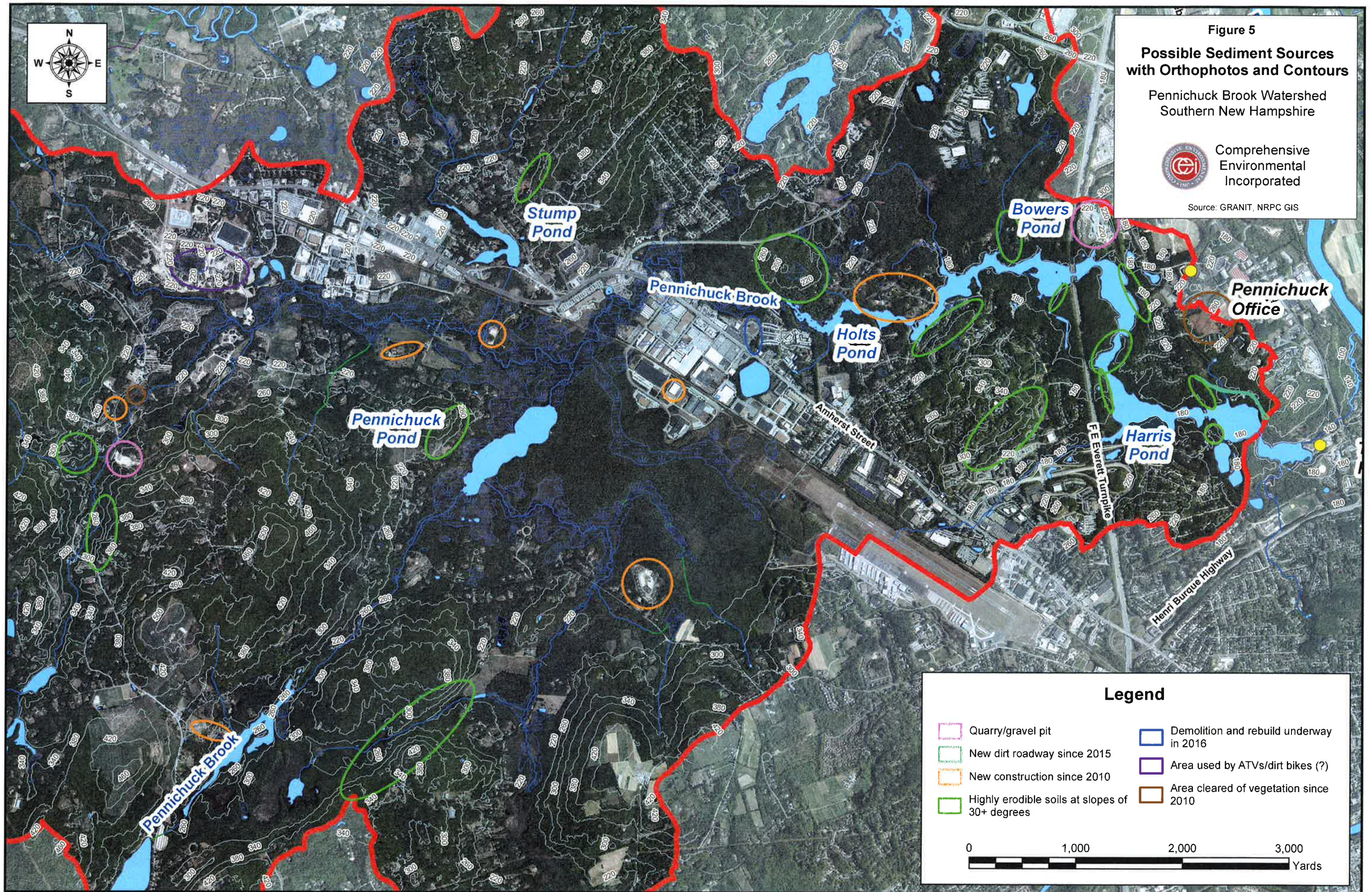
- Supply Ponds
- Wetland Area
- Stream, Brook

0 500 1,000 1,500 2,000
 Feet



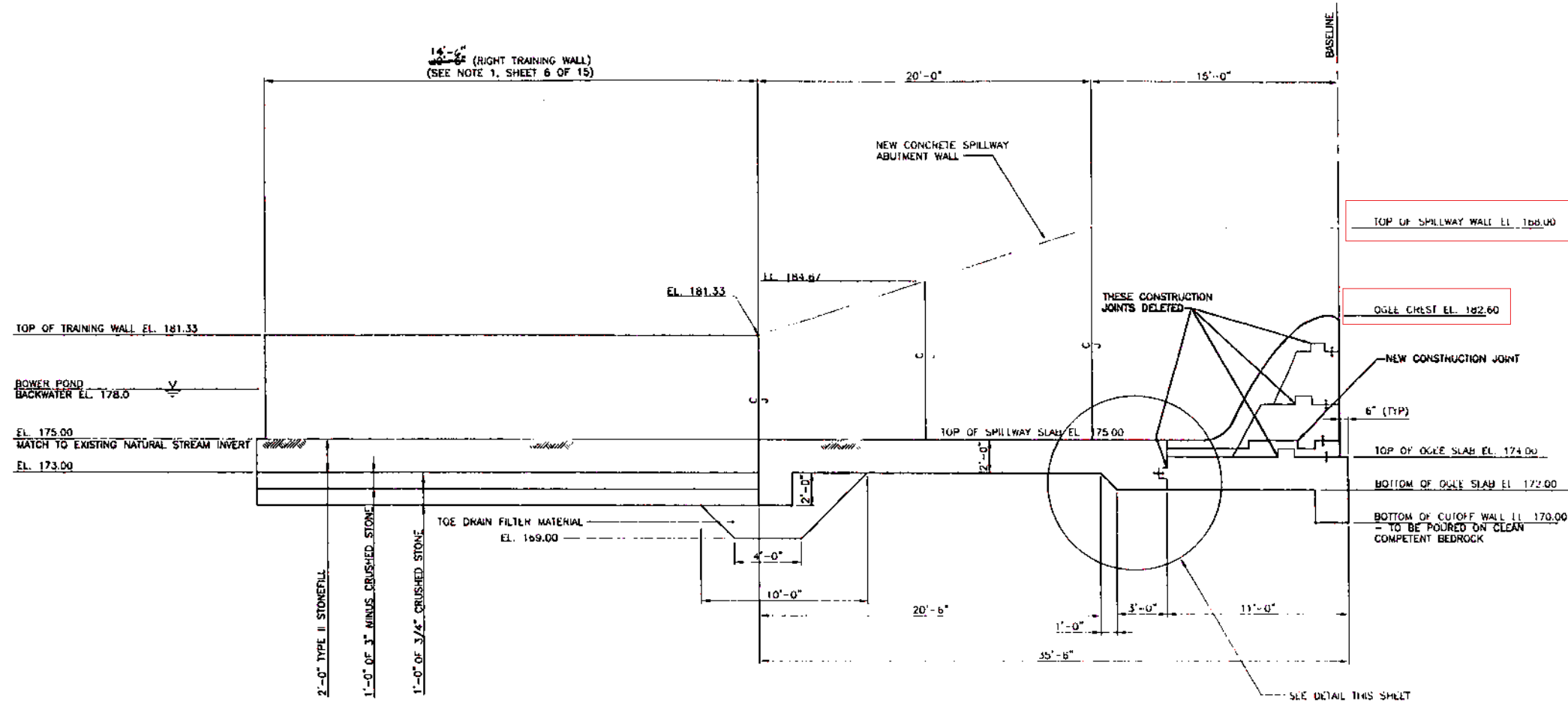
Comprehensive Environmental Inc.





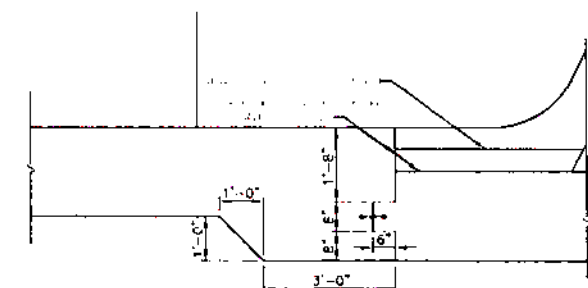
Appendix F

Pennichuck Supply Ponds Dam Construction Drawings



- NOTES:
1. THE 14'-6" TRAINING WALL ON RIGHT SIDE AND 7'-9" TRAINING WALL ON LEFT SIDE IS REINFORCED CONCRETE ON A VIBRA-CON RETAINING WALL SYSTEM TO BE APPROVED BY THE ENGINEER.
 2. CONSTRUCT NEW SPILLWAY SLAB AND WALL FOOTINGS ON SUITABLE FOUNDATION MATERIAL. EXCAVATE UNSUITABLE MATERIAL AND PREPARE FOUNDATION IN ACCORDANCE WITH SPECIFICATION SECTION 02260. ENGINEER SHALL APPROVE FOUNDATION PRIOR TO PLACEMENT OF SLAB AND FOOTINGS.
 3. BACKFILL UPSTREAM FACE OF NEW UPSTREAM CUTOFF WALL WITH NEW EMBANKMENT MATERIAL.
 4. THE TOE DRAIN FILTER UNDER THE SPILLWAY SLAB ~~WAS~~ ^{WAS} ~~BE~~ ^{BE} ~~INSTALLED. IF THE SLAB IS CONSTRUCTED ON GRANULAR~~ ^{BE} ~~SOILS IF THE SLAB IS CONSTRUCTED ON BEDROCK, AS~~ ^{INDICATED, THEN THE FILTER WILL NOT BE INSTALLED. THE} ~~ENGINEER SHALL MAKE THE FINAL DETERMINATION WHEN THE~~ ^{ENGINEER SHALL MAKE THE FINAL DETERMINATION WHEN THE} ~~SPILLWAY SLAB FOUNDATION IS PREPARED.~~ ^{SPILLWAY SLAB FOUNDATION IS PREPARED.}

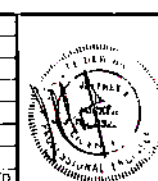
NEW SPILLWAY PROFILE
SCALE: 1/4" = 1'-0"



WATERSTOP DETAIL
SCALE: 1/2" = 1'-0"

RECORD DRAWINGS

NO.	DATE	REVISIONS	BY	CHK'D



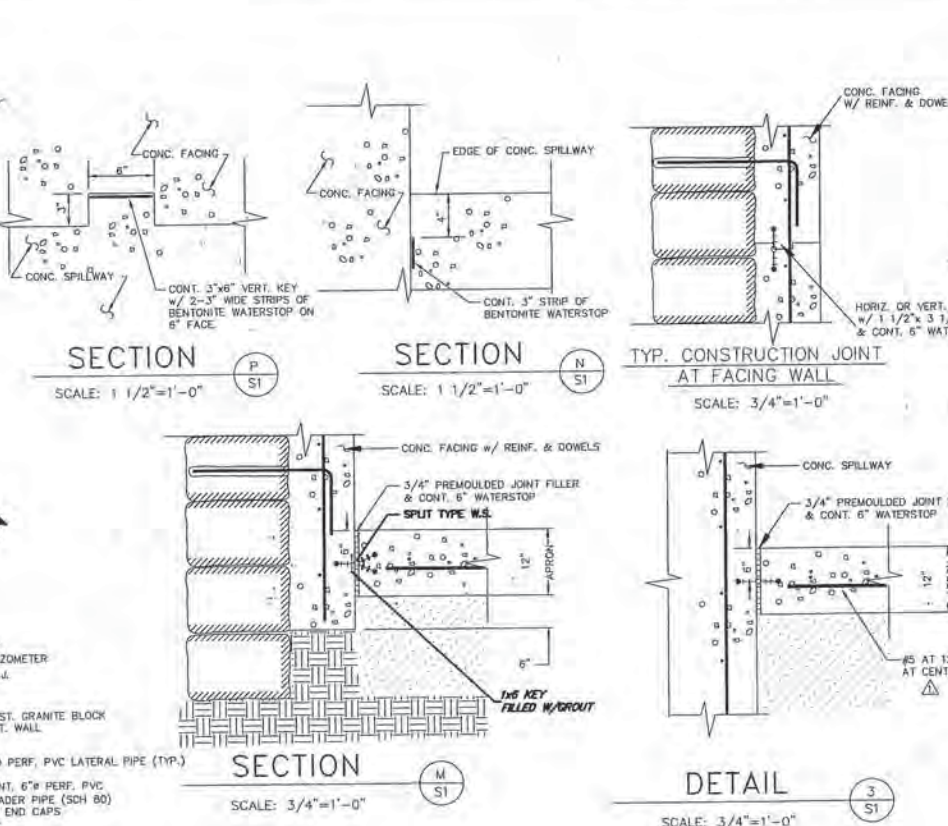
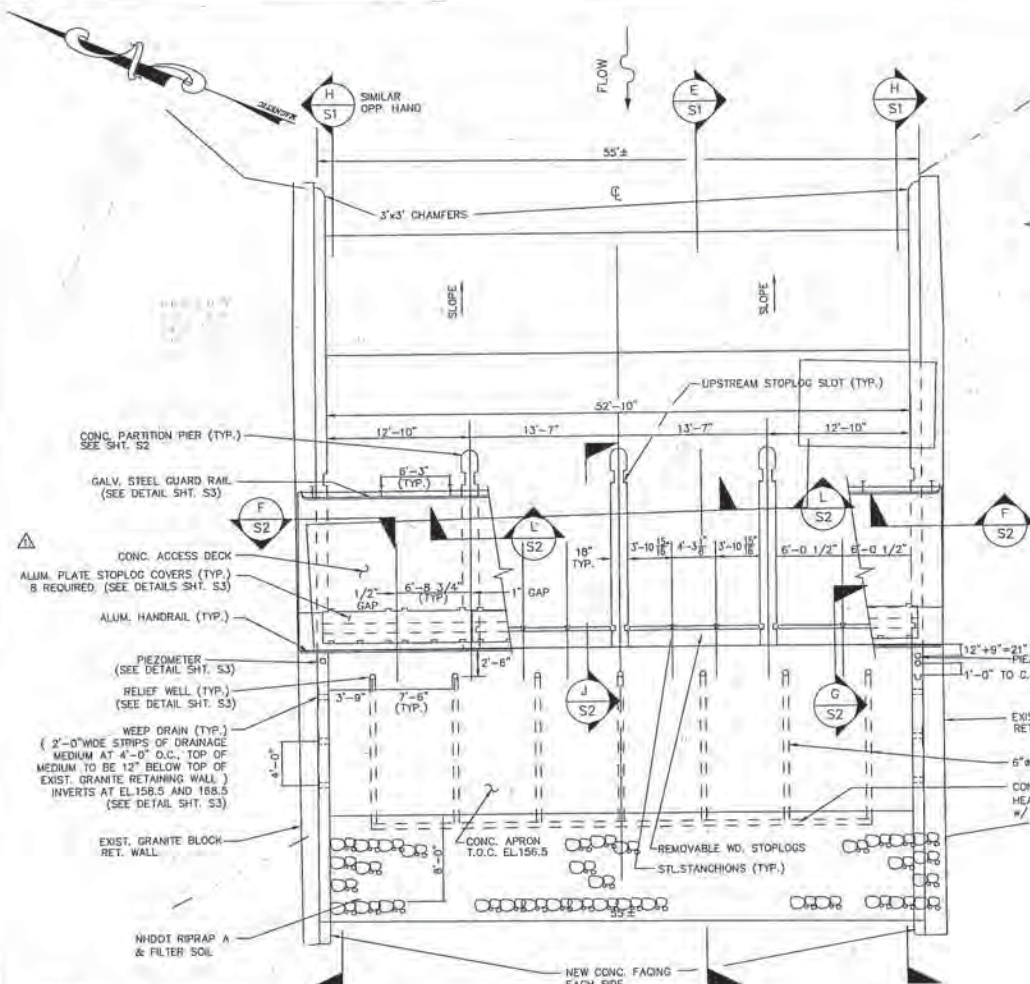
PENNICHUCK WATER WORKS INC.
NASHUA, NEW HAMPSHIRE

HOLT POND DAM IMPROVEMENT PROJECT

SPILLWAY PROFILE

DESIGNED BY EBS	DATE JUNE 1993
CHECKED BY JW	PROJ. NO. N14094
PROJ. ENG. WSC	DRAW. NO. 9780
SHEET 6 OF 15	

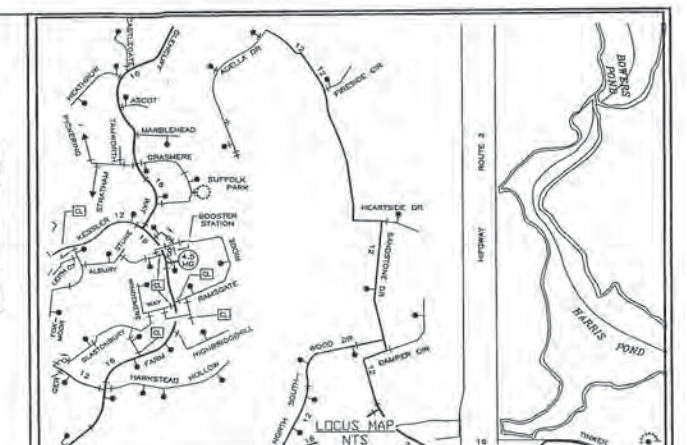
4337/16



* HORIZONTAL REINFORCEMENT SO PLACED THAT MORE THAN 12" OF CONCRETE IS CAST IN THE MEMBER BELOW THE BAR.

REIN. BAR SIZE	#4	#5	#6	#7	#8	#9	#10
LAP DIM.	18"	24"	28"	32"	36"	42"	50"
*TOP REIN	18"	24"	28"	34"	43"	56"	70"

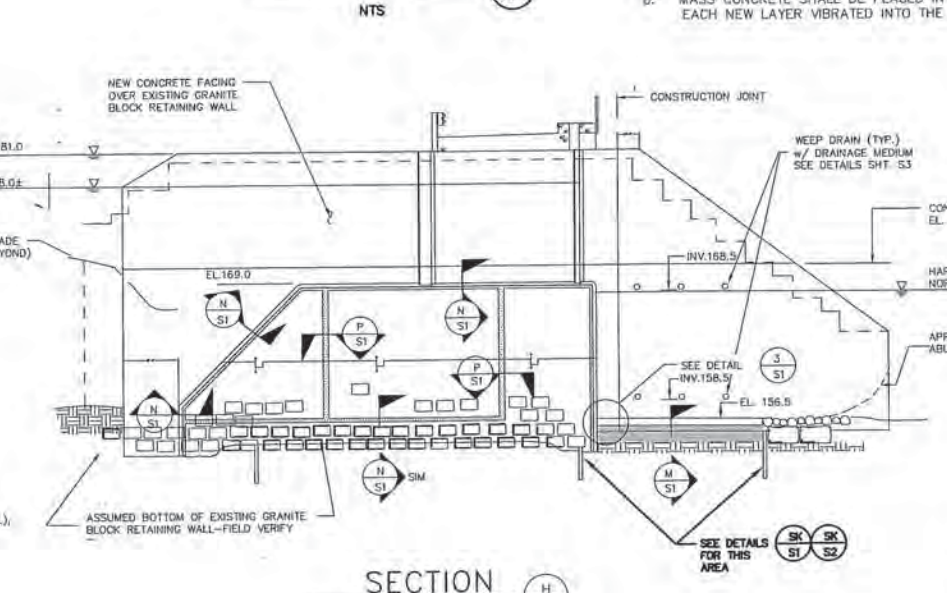
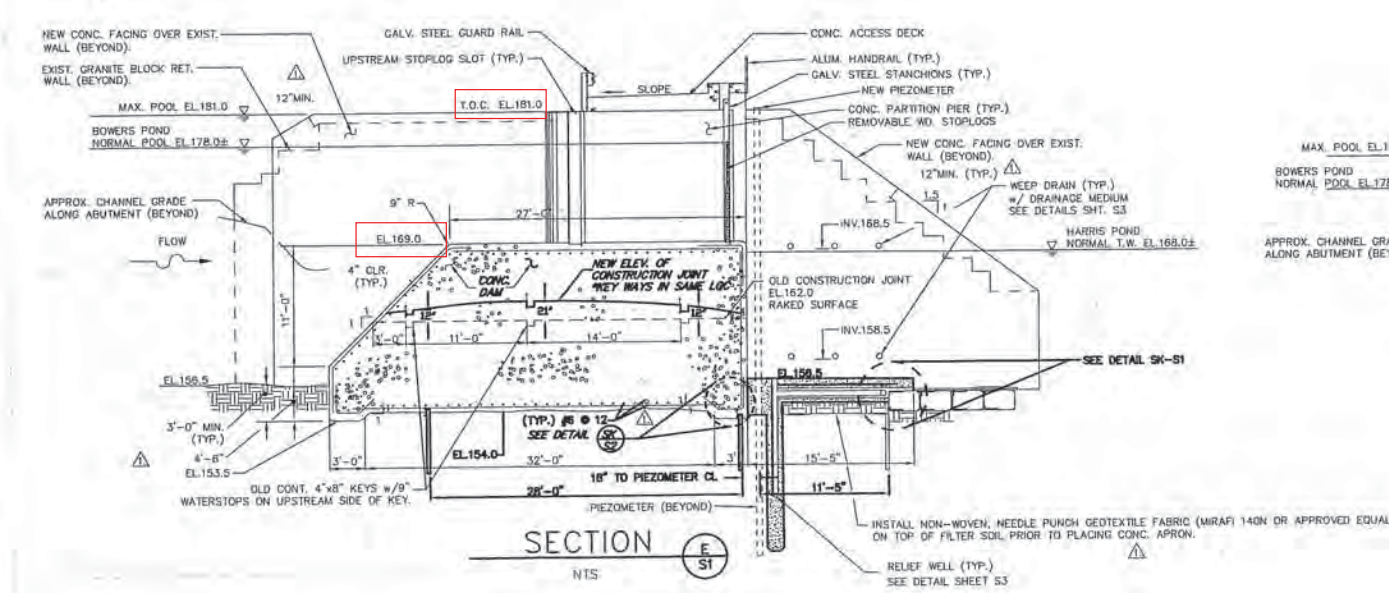
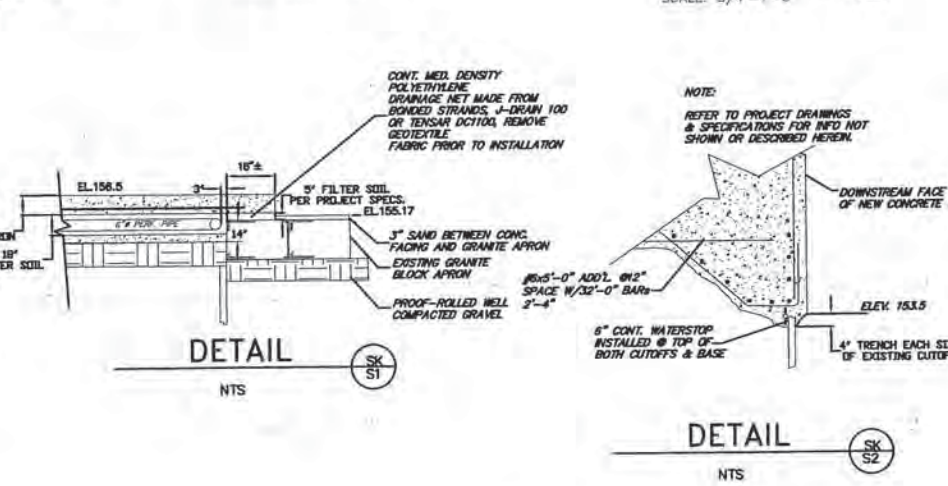
ADD'L INCREASE FOR BUNDLED BARS:
3 BARS - 20% 4 BARS - 33%



LAYER NAME	DESCRIPTION
EGPNTS.ELEV	EXISTING CONDITIONS NOT NEEDED IN VIEW
FBESC.FELEV.FPNTS	FUTURE CONDITIONS INFO NOT NEEDED IN VIEW
PNTS	POINTS
PVWIDE	INFO NOT NEEDED IN VIEW
T...	TIN, TOP

GENERAL STRUCTURAL NOTES

- COMPLY WITH THE PROVISIONS OF THE FOLLOWING CODES, SPECIFICATIONS AND STANDARDS, EXCEPT AS OTHERWISE SHOWN OR SPECIFIED.
 - ACI 301 "SPECIFICATIONS FOR STRUCTURAL CONCRETE FOR BUILDINGS".
 - ACI 318 "BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE".
 - ACI 304 "RECOMMENDED PRACTICE FOR MEASURING, MIXING, TRANSPORTING AND PLACING CONCRETE".
- CAST-IN-PLACE CONCRETE SHALL DEVELOP AN ULTIMATE COMPRESSIVE STRENGTH OF 4,000 PSI AT 28 DAYS.
- REINFORCEMENT SHALL CONFORM TO ASTM A615, GRADE 60, WITH EPOXY COATING PER SPECIFICATIONS. BARS SHALL BE IN CONTACT AND TIED AS REQUIRED TO MAINTAIN PROPER PLACEMENT.
- UNLESS OTHERWISE NOTED, CONCRETE COVER OF REINFORCEMENT SHALL BE:
 - FACE OF WALLS, SLABS AND BEAMS - 2"
 - CONCRETE WALL FACING - 4"
 - GRAVITY DAM - 4"
- UNLESS OTHERWISE NOTED, REINFORCEMENT SHALL BE SPICED ACCORDING TO THE SCHEDULE PROVIDED ON THE DRAWINGS.
- SHOP DETAILS OF REINFORCEMENT SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL PRIOR TO INSTALLATION.
- CONCRETE SHALL BE KEPT MOIST DURING THE CURING PERIOD BY AN ACCEPTABLE METHOD FOR:
 - 7 DAYS - ALL CONCRETE EXCEPT GRAVITY DAM
 - 14 DAYS - GRAVITY DAM
- MASS CONCRETE SHALL BE PLACED IN 7-1/2' LIFTS, WITH EACH NEW LAYER VIBRATED INTO THE PREVIOUS ONE.
- MASS CONCRETE SHALL BE PLACED IN MAXIMUM 7-1/2' LIFTS, CONSISTING OF PROPERLY VIBRATED LAYERS. A MINIMUM OF 72 HOURS SHALL PASS BEFORE PLACEMENT OF SUCCESSIVE LIFTS.
- UNLESS OTHERWISE NOTED, 6" OR 9" PVC WATERSTOPS SHALL BE USED IN ALL CONSTRUCTION JOINTS WHERE INDICATED ON THE DRAWINGS. WATERSTOPS SHALL CONFORM TO CORPS OF ENGINEERS' CRO-572, WEB THICKNESS NOT LESS THAN 3/8", WITH A 1" O.D. CENTER BULB AS MANUFACTURED BY VINYLEX, GREENSTREAK OR APPROVED EQUAL.
- BENTONITE WATERSTOP TO BE CONTINUOUS 3" WIDE STRIPS OF HIGH DENSITY POLYETHYLENE WITH BENTONITE BONDED TO EACH SIDE. PARASTOP II AS MANUFACTURED BY PARAMOUNT TECHNICAL PRODUCTS, INC., SPEARFISH, SD (1-800-325-8715).
- PREMOLDED JOINT FILLER SHALL BE SPONGE RUBBER EXPANSION JOINT FILLER CONFORMING TO ASTM D1752, TYPE I AS MANUFACTURED BY W.R. MEADOWS OR APPROVED EQUAL.
- ELASTOMERIC JOINT SEALANT SHALL BE A ONE COMPONENT, PREMIUM GRADE, POLYURETHANE BASED, MOISTURE CURED NON-SAG ELASTOMERIC SEALANT - SIKAFLEX - 1A BY SIKA CORPORATION OR APPROVED EQUAL.
- CHEMICAL FLOOR HARDENER TO BE USED ON BRIDGE DECK SHALL BE HORNOLITH AS MANUFACTURED BY ANTI-HYDRO WATERPROOFING CO., OR EQUAL.



REVISION	DATE	DESCRIPTION
C		
B		
A	12/22/04	CHANGED DET E-S1, ADDED DET SK-S1 & SK-S2, REVISED PLAN

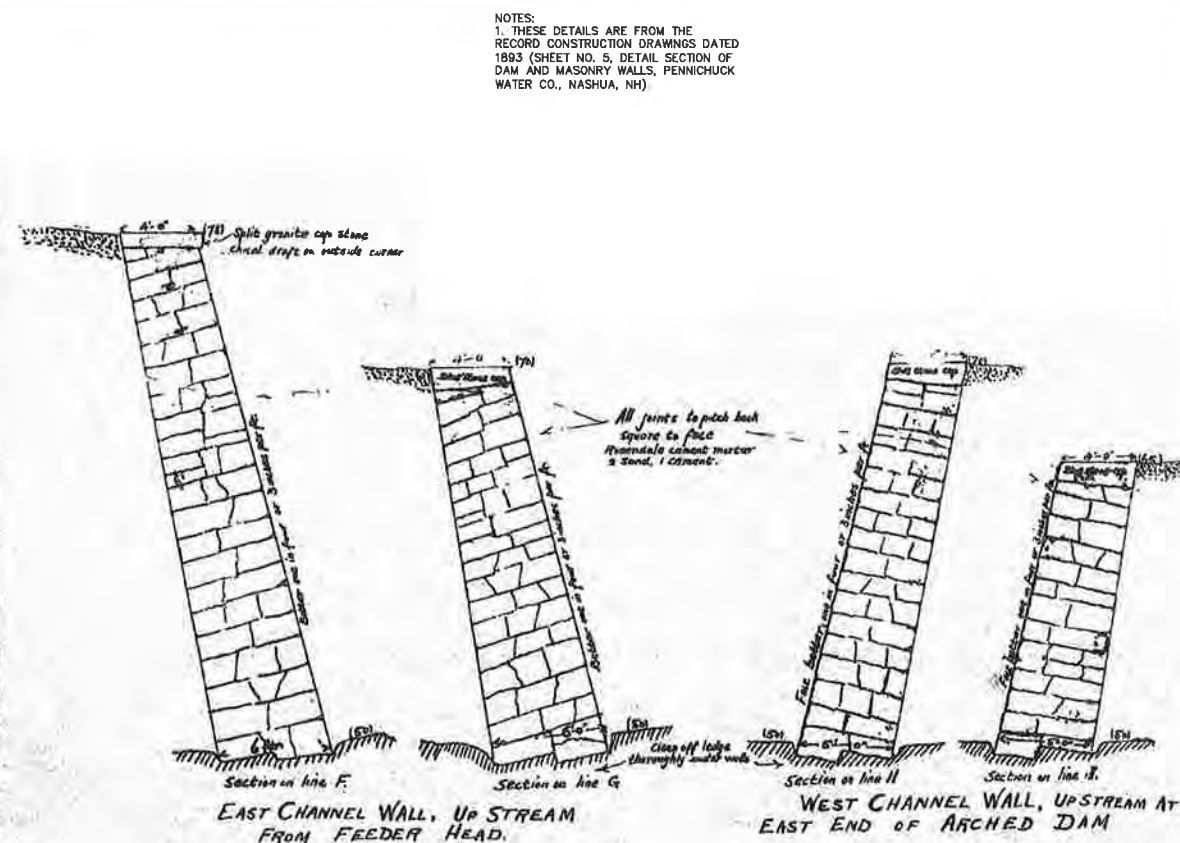
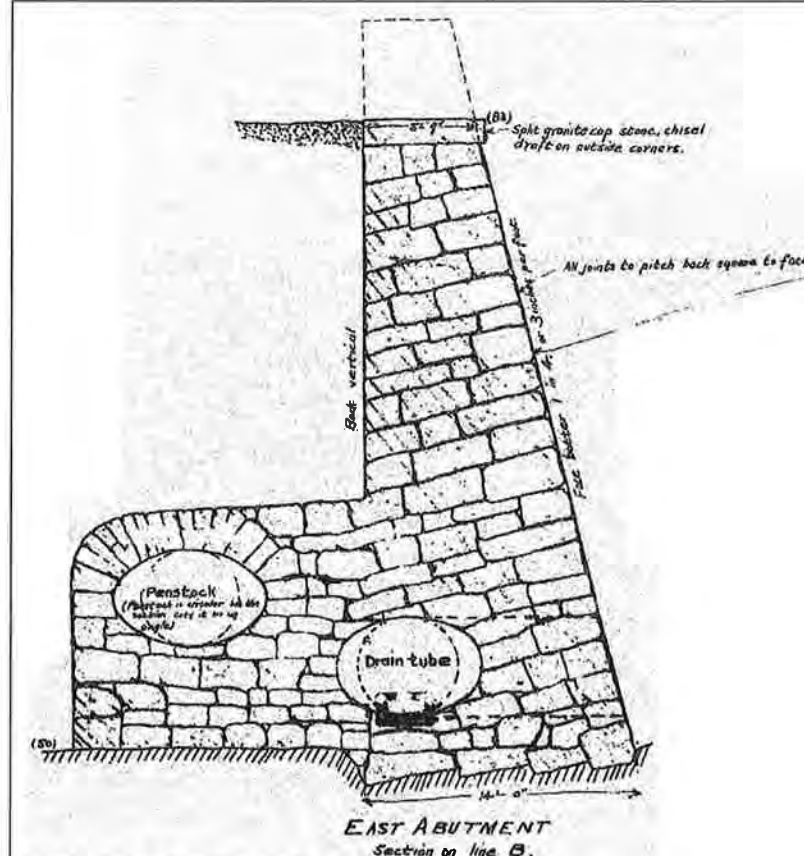
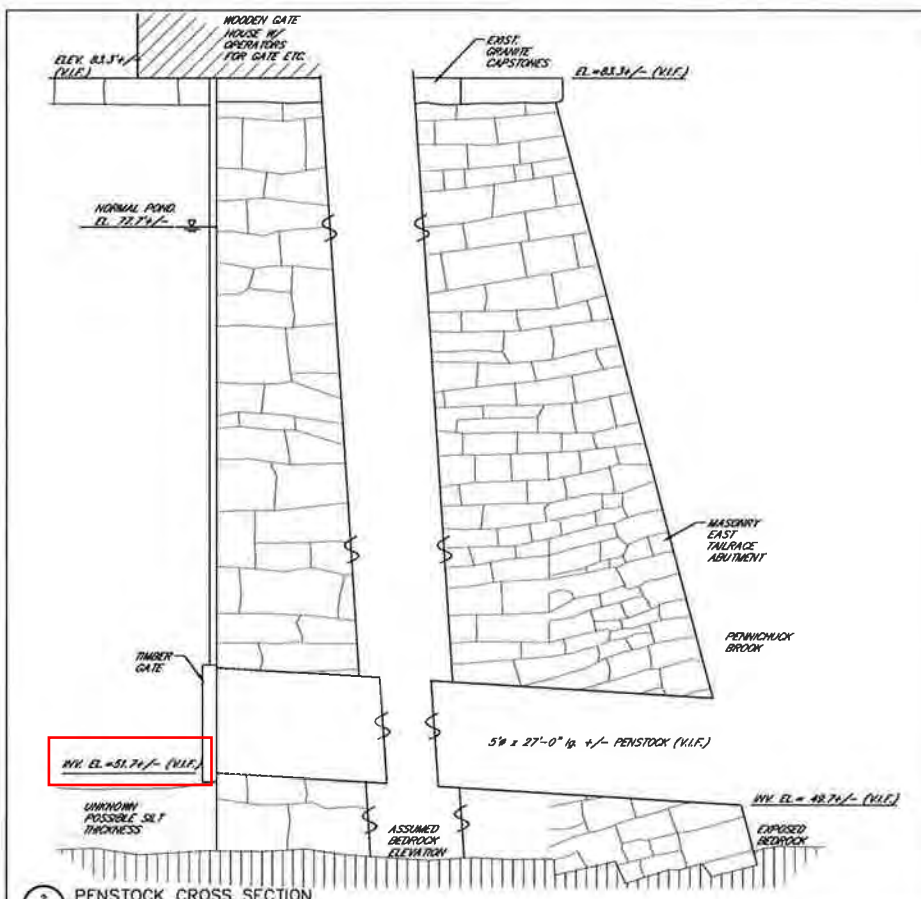
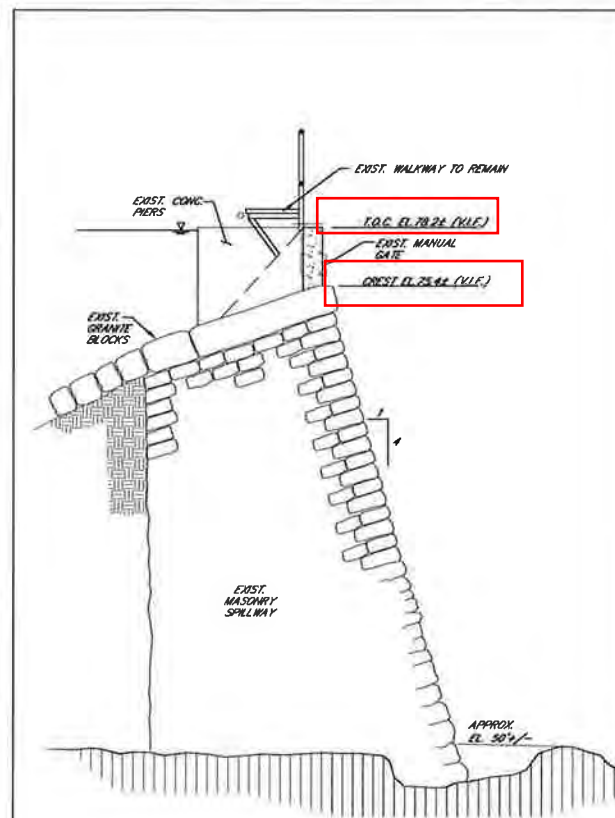
PENNICHUCK WATER

25 Manchester Street
Marion, MA 01944
Tel 603-913-2300
Fax 603-913-2362
www.pennichuck.com

SHEET 3 OF 5
SPILLWAY STRUCTURE
PLAN & PROFILE
BOWERS POND DAM
NASHUA, NEW HAMPSHIRE

DESIGNED BY	DRAWING DATE	CONSTRUCTION DATE	INSTALLER BY
G. FELICIANO	DEC 22, 2004	SUMMER, 1990 WINTER 90-91	RHWHITE

SCALE	APPROX SCALE	SHEET NO.
AS SHOWN		3



NOTE:
THE REFERENCE ELEVATION FOR ALL
WORK SHALL BE TOP OF EXISTING
SPILLWAY AT 78.2'

TURNER
GROUP

THE H.L. TURNER GROUP Inc.

ARCHITECTS ENGINEERS BUILDING SCIENTISTS
27 LOCKE ROAD
CONCORD, NEW HAMPSHIRE 03301
T:603 228 1122 / F:603 228 1126
W:www.hllurner.com

CONCORD NH HARRISON ME LYNDONVILLE VT
LITTLETON MA HARTFORD CT



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ISSUED FOR

BID
CONSTRUCTION

KEY PLAN	NT
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[illegible]

PENNICHUCK WATERWORKS HARRIS POND DAM RENOVATION PROJECT

NASHUA, NEW HAMPSHIRE

PROJ. NO.: 4207

SCALE 1/4"=1'-0"

DATE: 1/4/1984

DATA, BY: **WPM**

DRAWN BY: MMH

CHIEF BY: GMB

ISSUE DATE: 09.29

**EXISTING
CONSTRUCTION
DETAILS**

SHEET OF

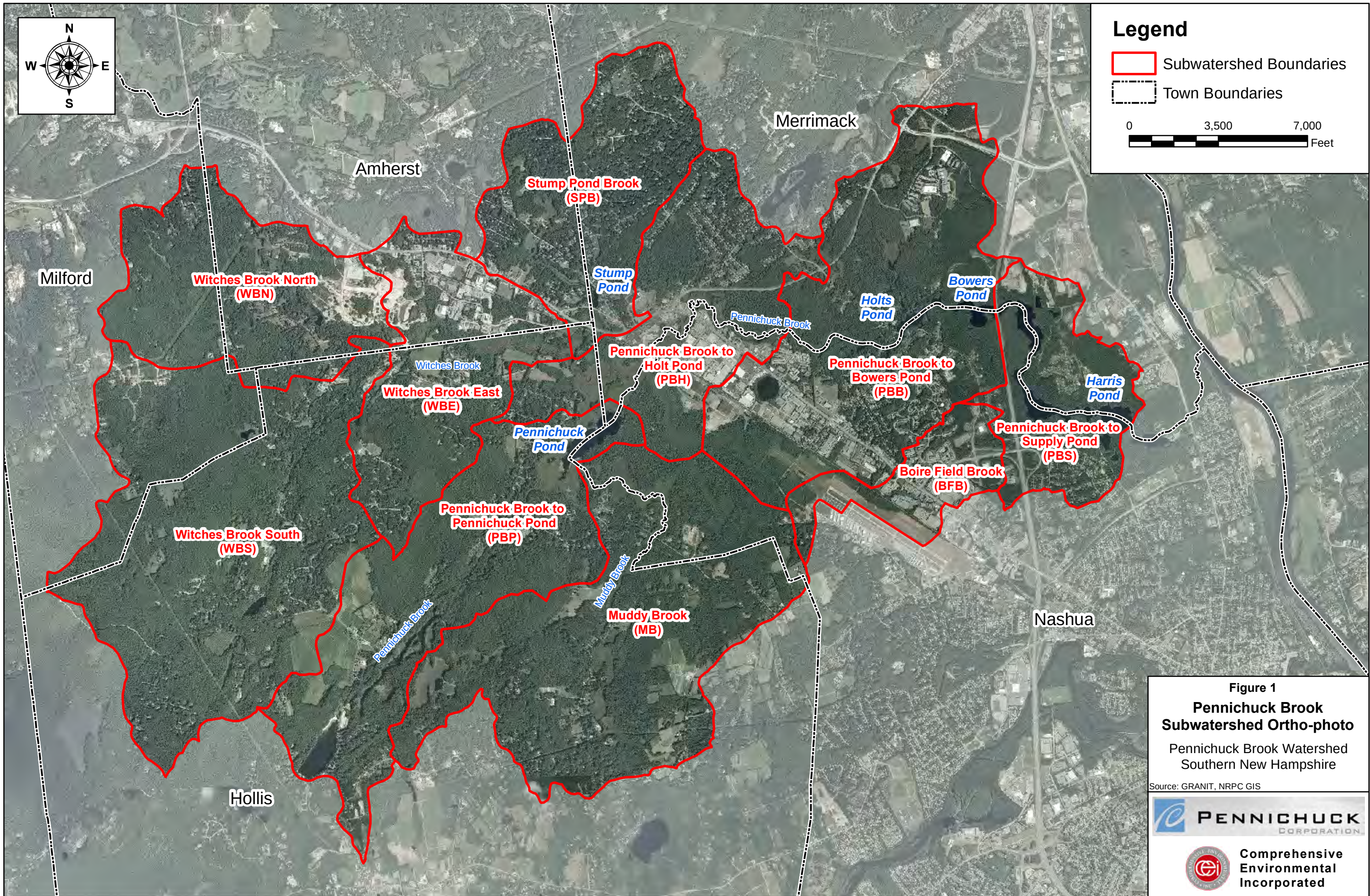
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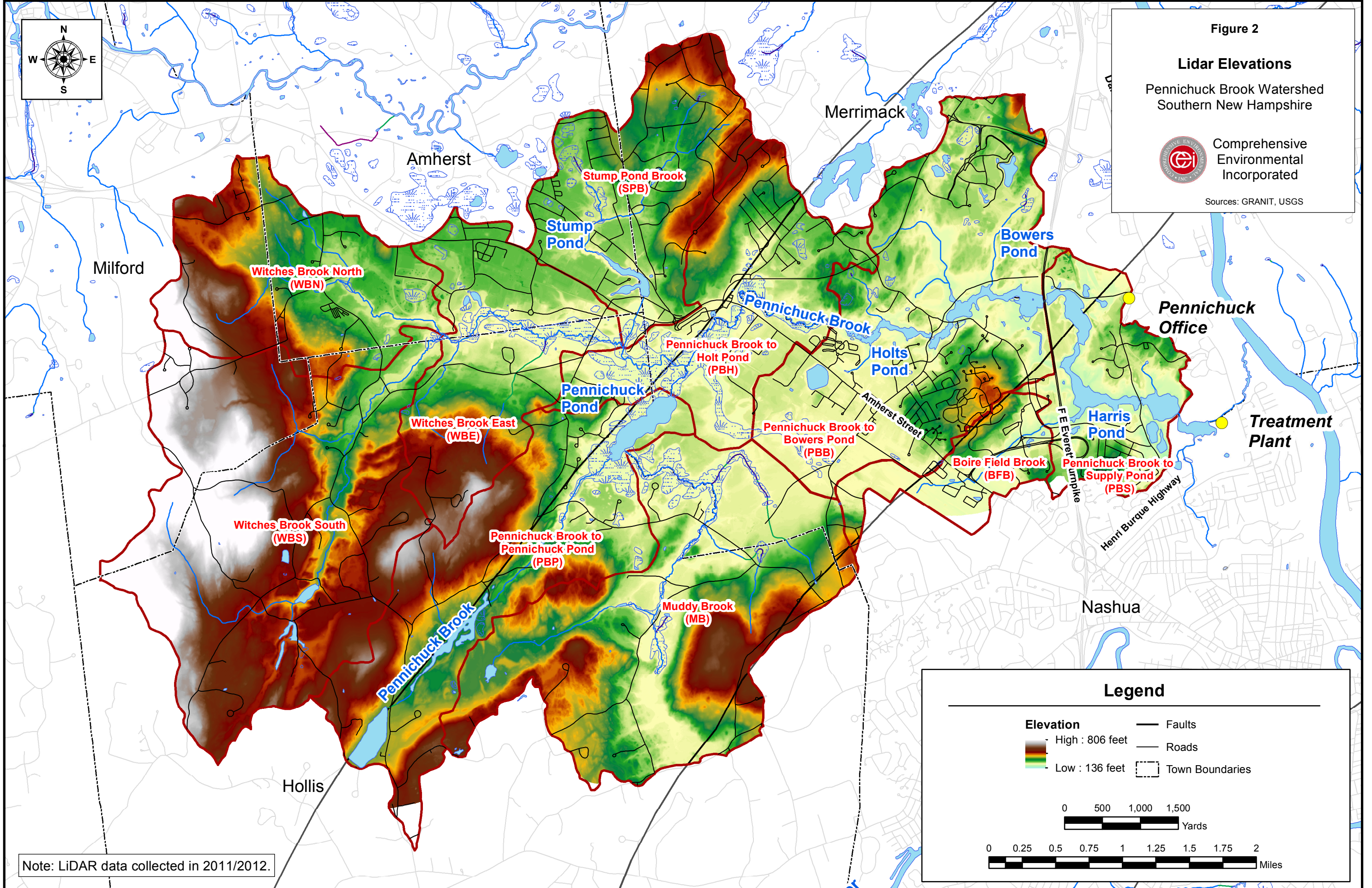
BIOGRAPHY: CIVIL-

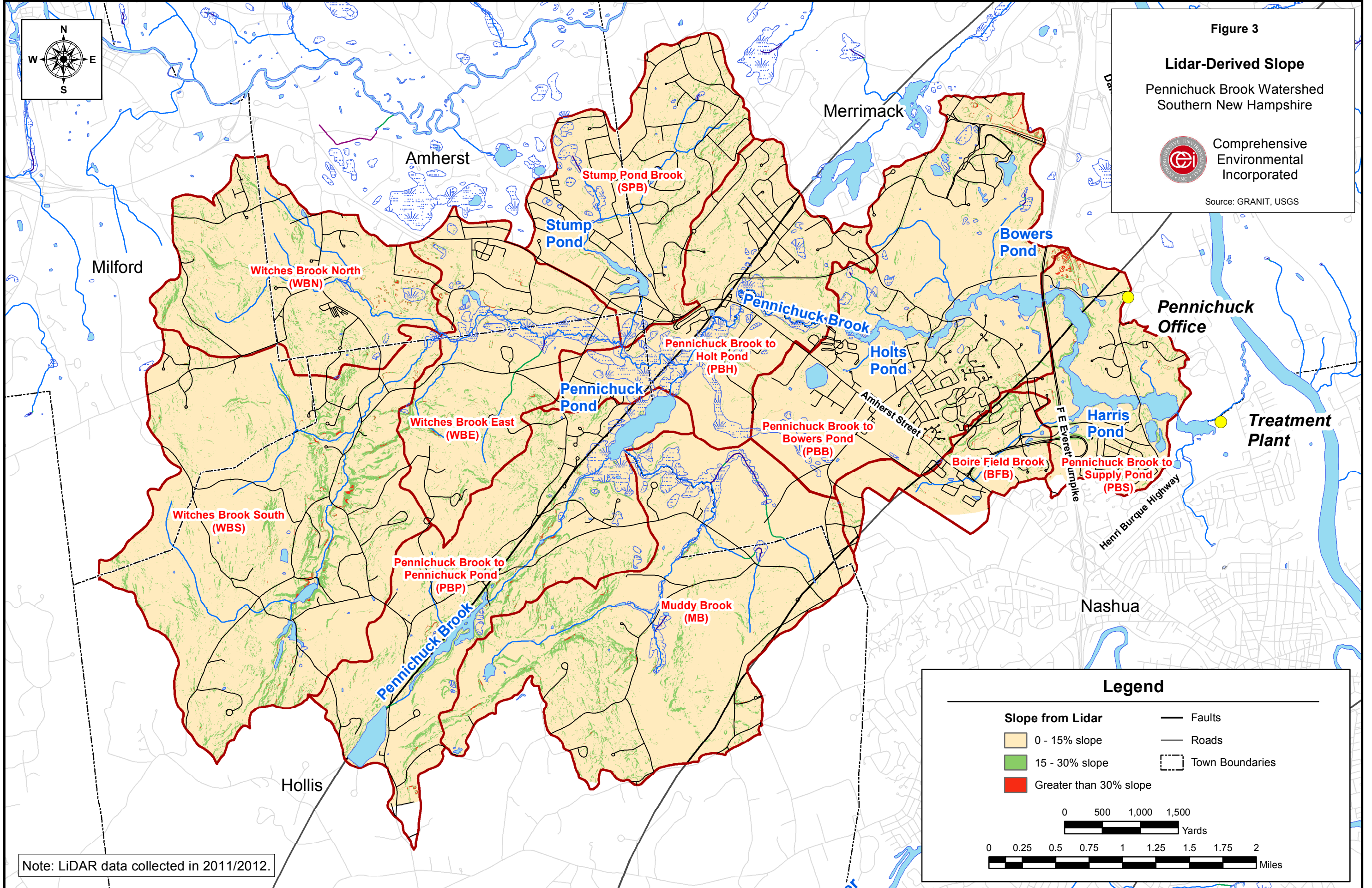
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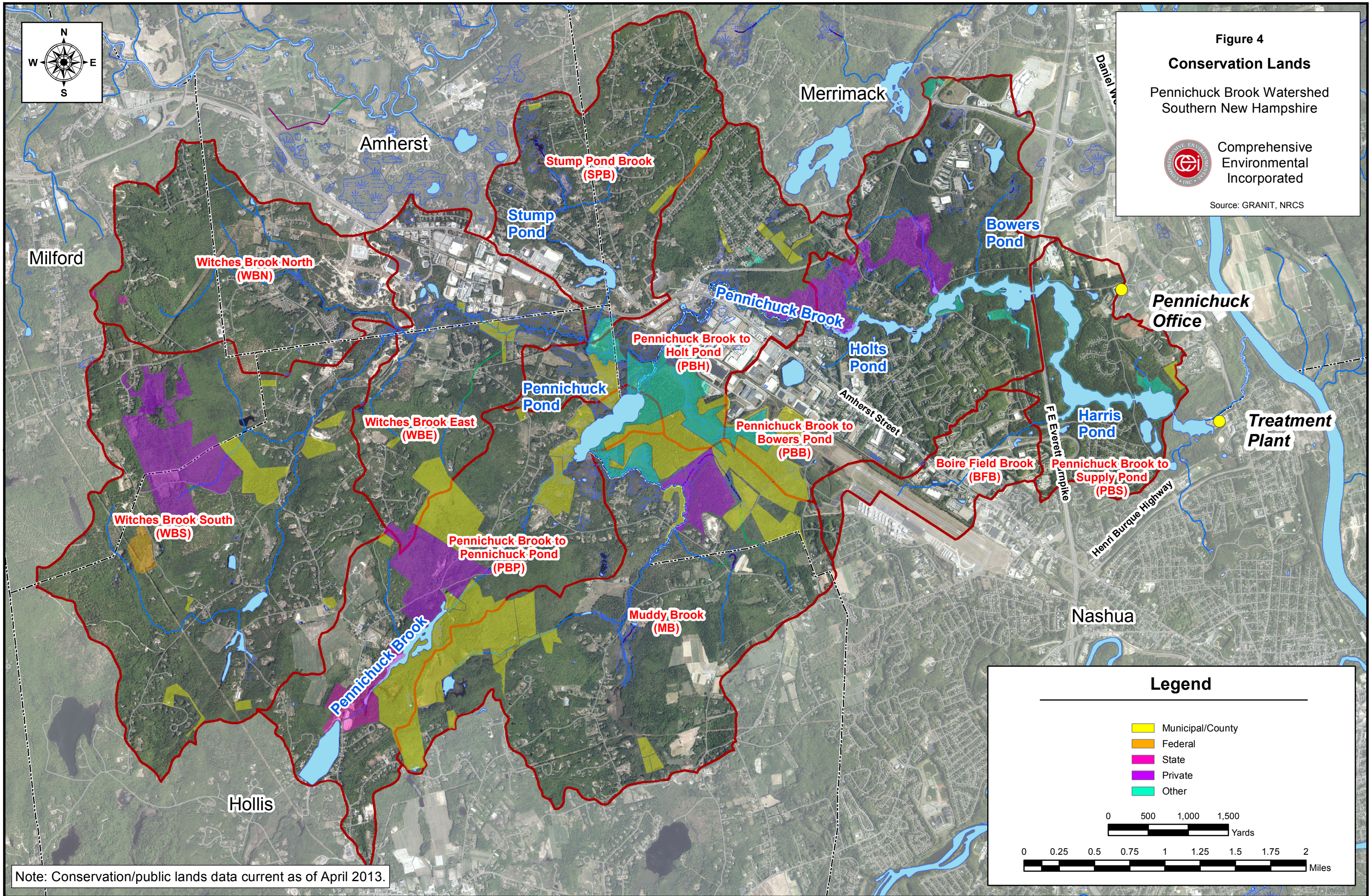
Appendix G

GIS Report Figures









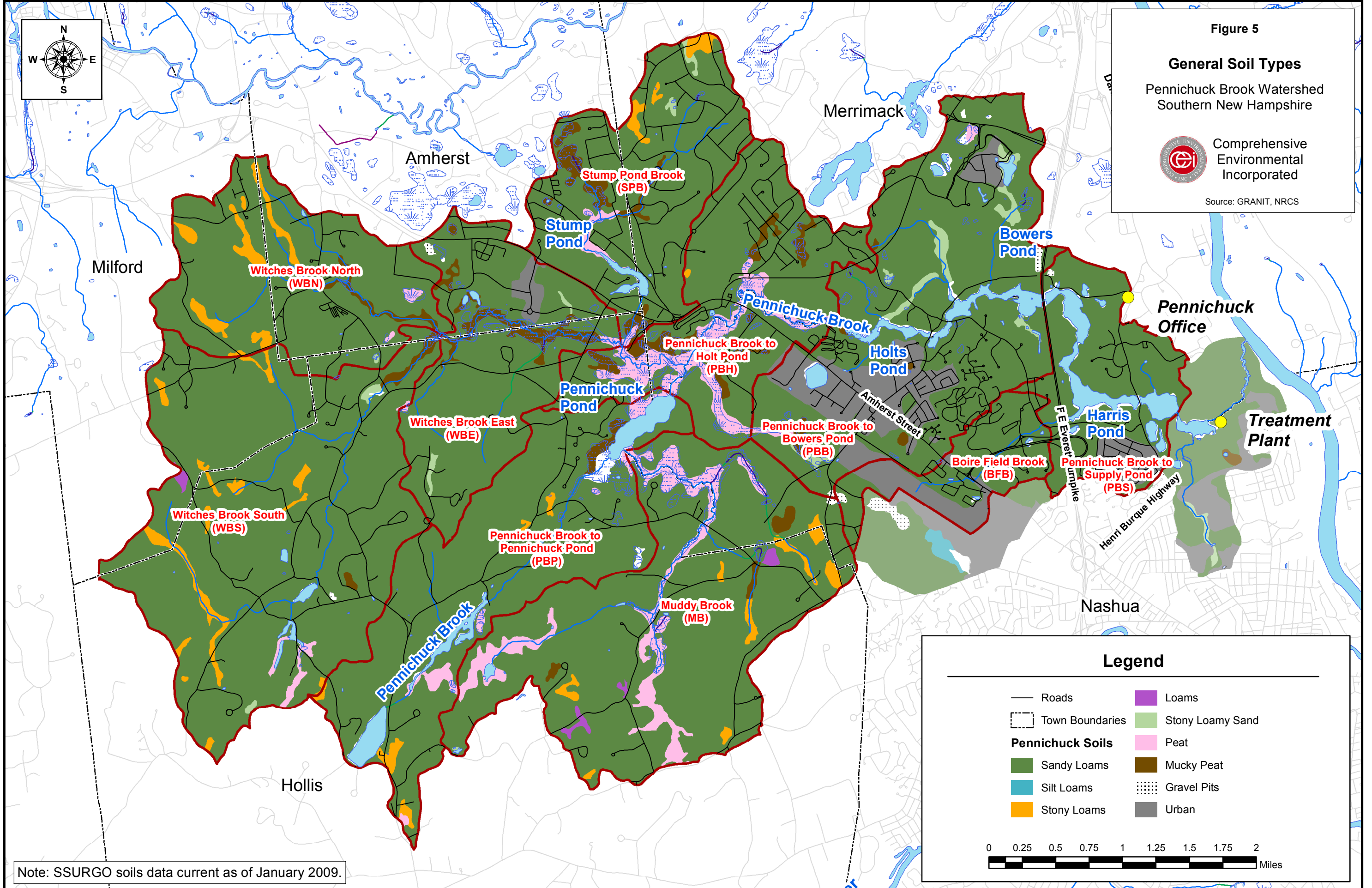


Figure 5

General Soil Types

Pennichuck Brook Watershed
Southern New Hampshire

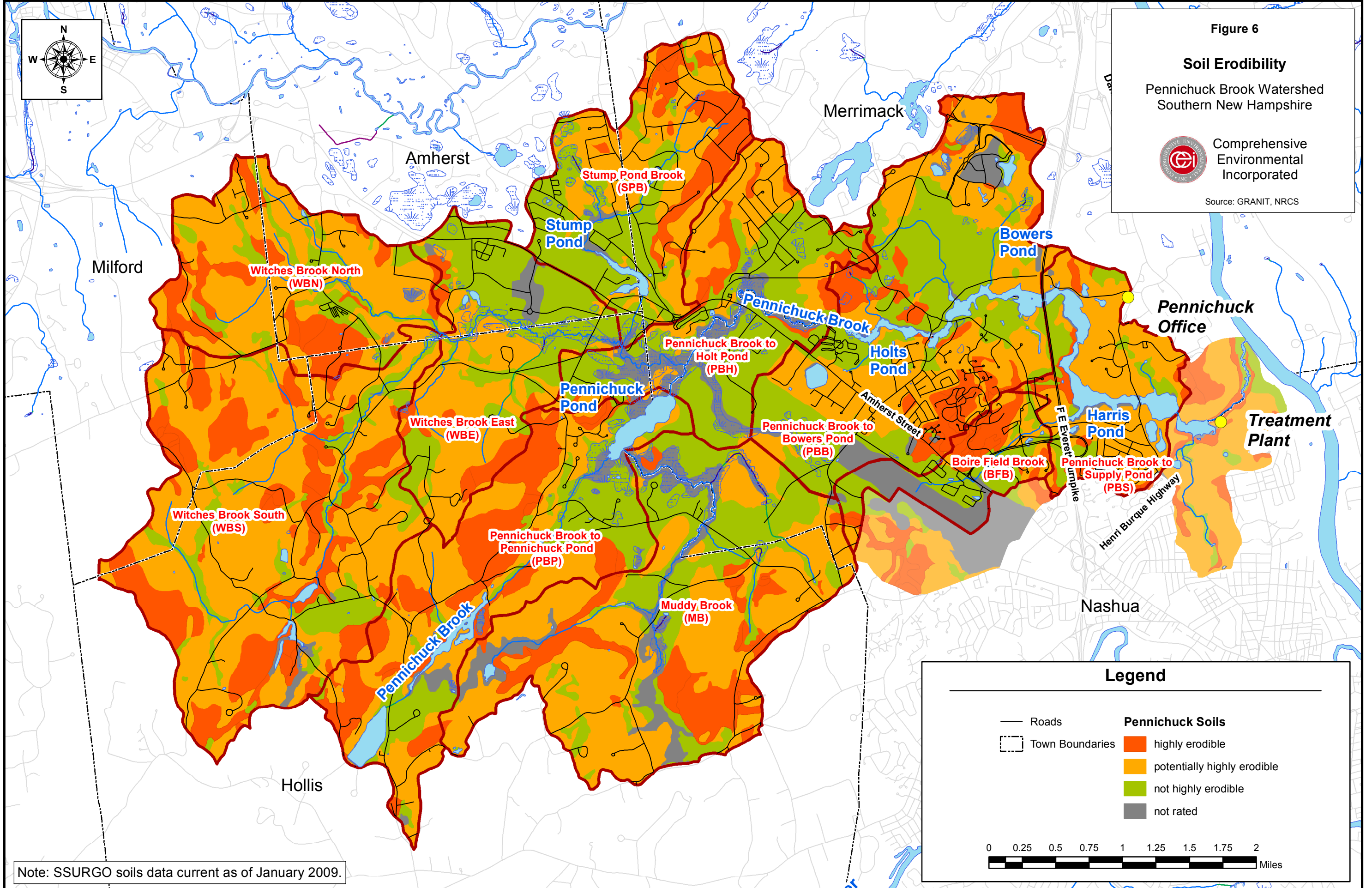
 Comprehensive
Environmental
Incorporated

Source: GRANIT, NRCS

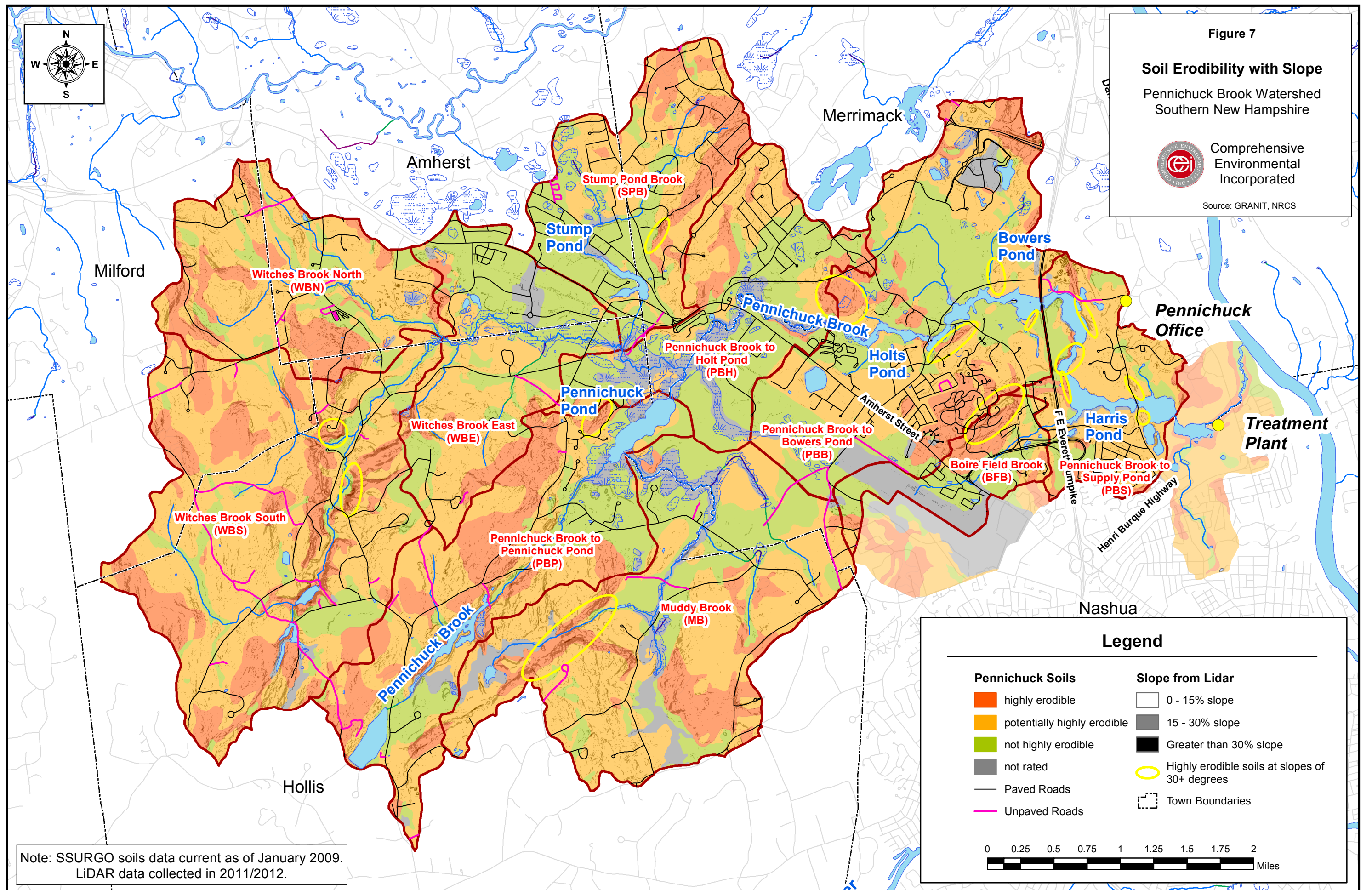
Legend

— Roads	 Loams
 Town Boundaries	 Stony Loamy Sand
Pennichuck Soils	 Peat
 Sandy Loams	 Mucky Peat
 Silt Loams	 Gravel Pits
 Stony Loams	 Urban

0 0.25 0.5 0.75 1 1.25 1.5 1.75 2 Miles



Note: SSURGO soils data current as of January 2009.



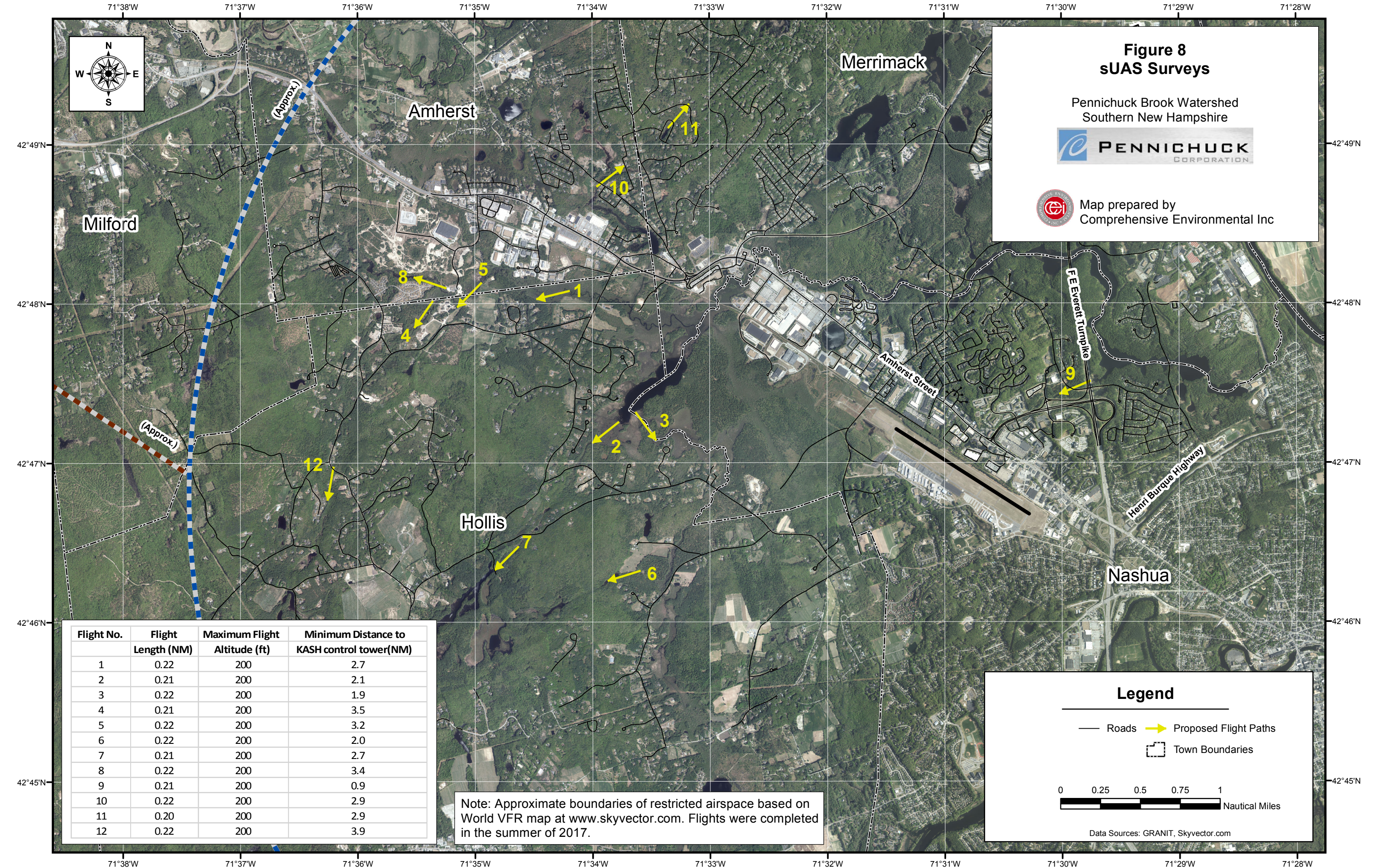


Figure 8
sUAS Surveys

Pennichuck Brook Watershed
Southern New Hampshire



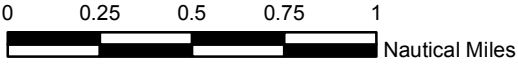
Map prepared by
Comprehensive Environmental Inc

Flight No.	Flight Length (NM)	Maximum Flight Altitude (ft)	Minimum Distance to KASH control tower(NM)
1	0.22	200	2.7
2	0.21	200	2.1
3	0.22	200	1.9
4	0.21	200	3.5
5	0.22	200	3.2
6	0.22	200	2.0
7	0.21	200	2.7
8	0.22	200	3.4
9	0.21	200	0.9
10	0.22	200	2.9
11	0.20	200	2.9
12	0.22	200	3.9

Note: Approximate boundaries of restricted airspace based on World VFR map at www.skyvector.com. Flights were completed in the summer of 2017.

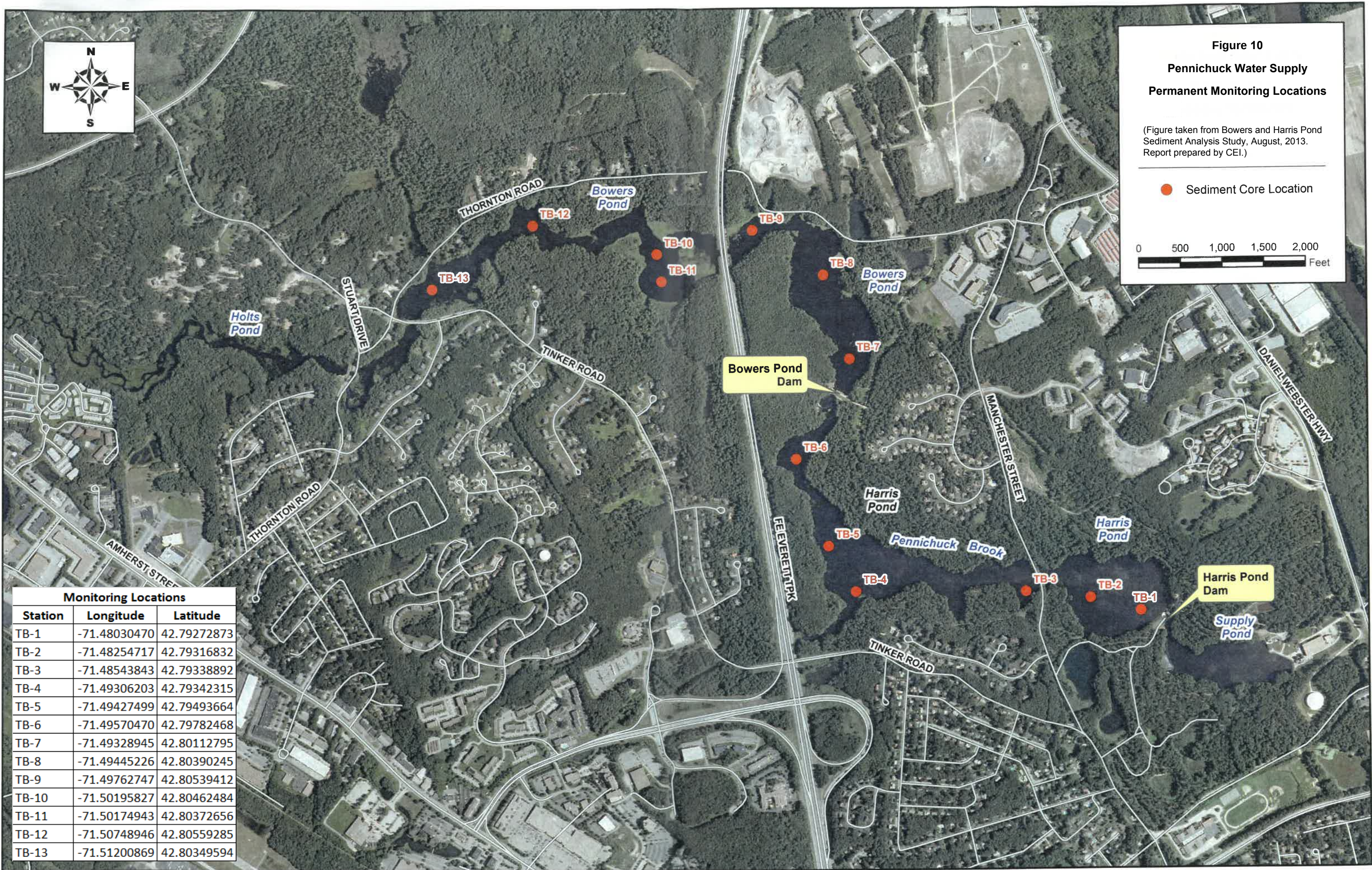
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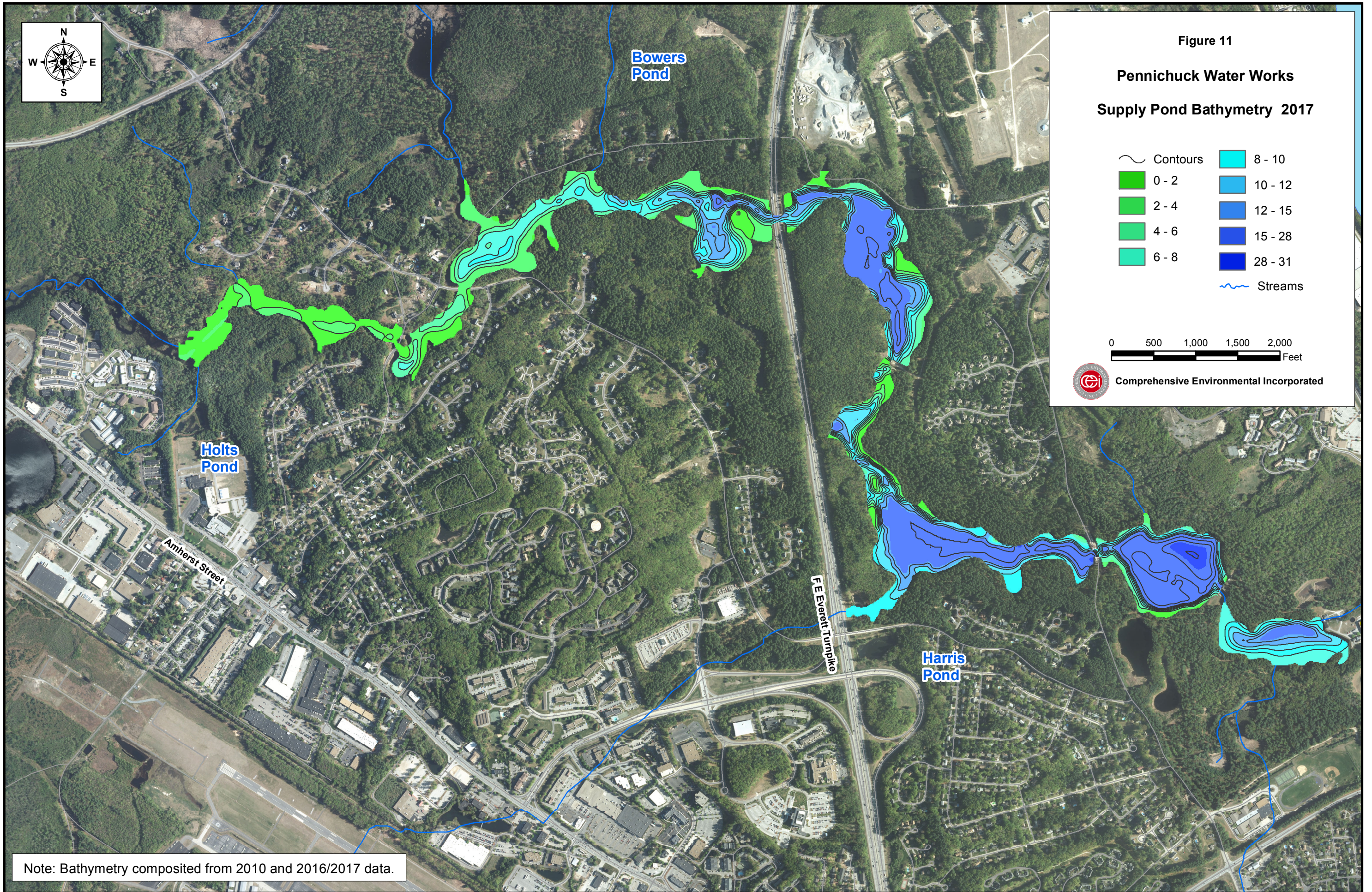
- Roads
- Proposed Flight Paths
- Town Boundaries

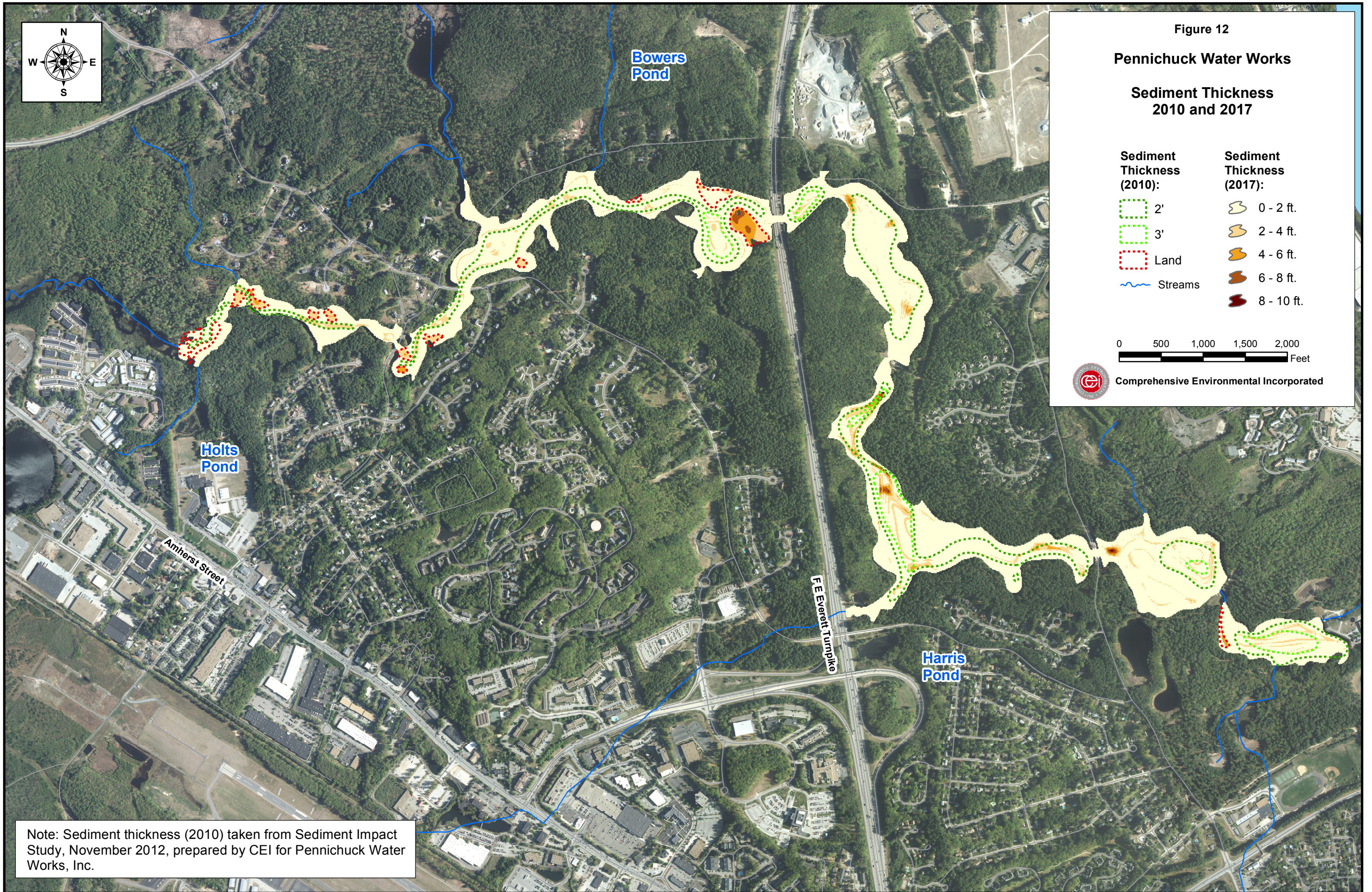


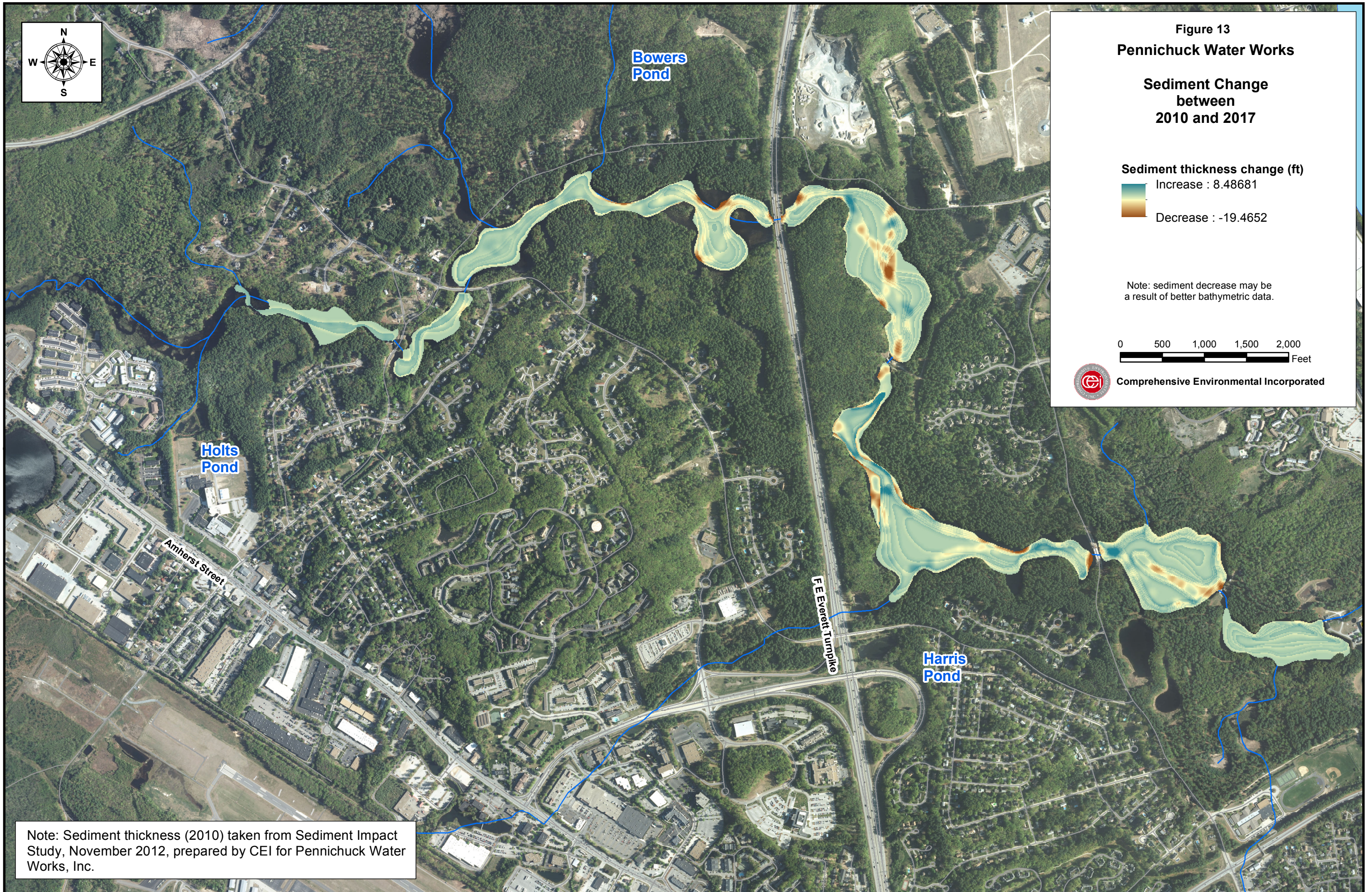
Data Sources: GRANIT, Skyvector.com

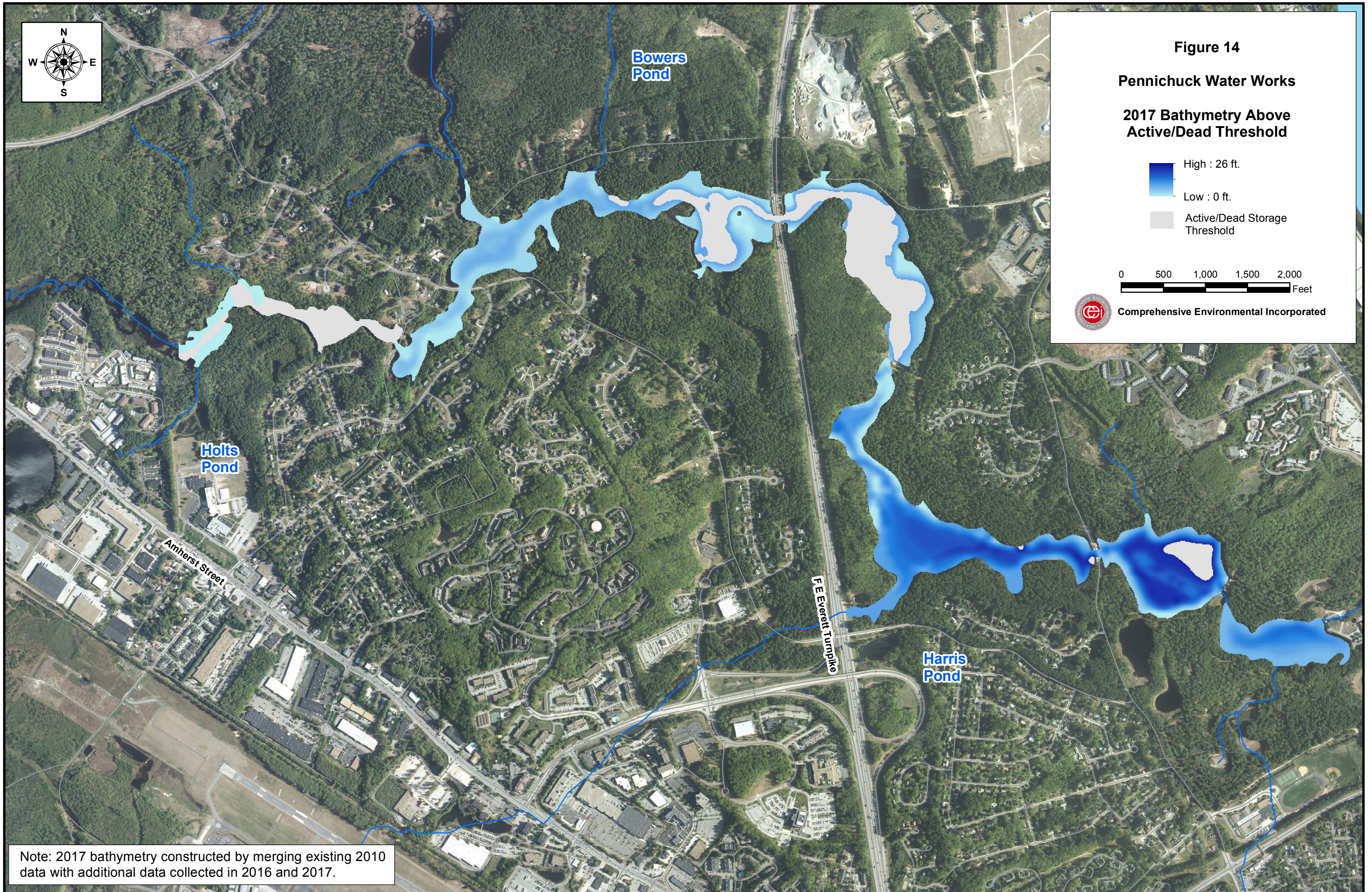


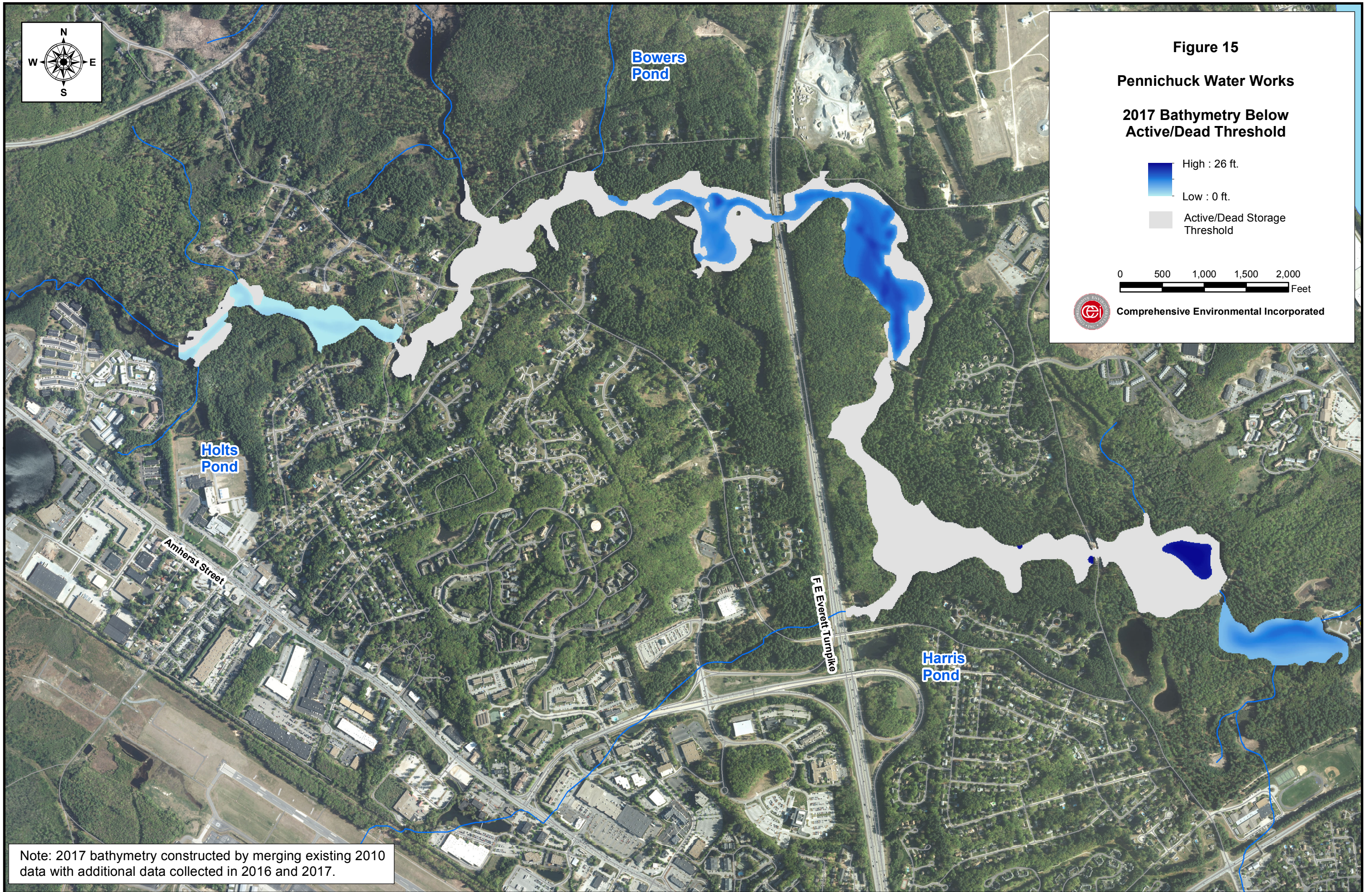












Appendix H

sUAS Aerial Video Footage

Appendix I

Monitoring Locations Electronic Database