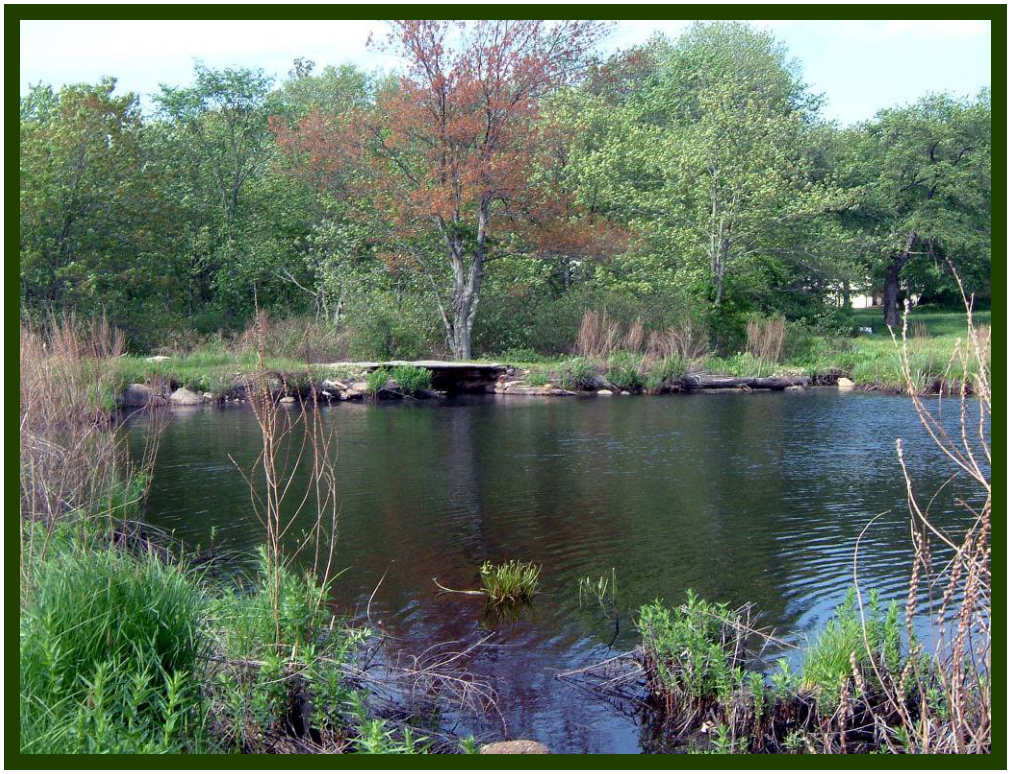
Town of Andover, Massachusetts

Fish Brook Watershed Advisory Committee
Final Report

April 2010



Report

April 15, 2010

Reginald S. Stapczynski, Town Manager
Town Hall
36 Bartlett Street
Andover, Massachusetts 01810

Subject: Fish Brook Watershed Advisory Committee Final Report

Dear Mr. Stapczynski,

The Fish Brook Watershed Advisory Committee (FBWAC) was established in 2006 to advise the Town of Andover on measures to help ensure long-term maintenance of a safe and reliable water supply. Particular focus was given to protecting and preserving Fish Brook as an integral component of the Town's drinking water system.

The Fish Brook Watershed Advisory Committee is pleased to submit this final report to you. It summarizes work performed by the FBWAC, and presents the committee's conclusions and recommendations with the intent to preserve Fish Brook as a valuable economic and environmental resource.

Respectfully,

Fish Brook Watershed Advisory Committee

Committee Members
Stephen Boynton, Chairman
David Adilman
Tom Brady
Richard Bizzozero
Ron Clausen
Pat Donahue
John Zipeto

Staff Liaisons
Thomas Carbone, Health Department
Cynthia Vaughn, Water Department

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1

Section One

Section 1 - Executive Summary

The Fish Brook Watershed Advisory Committee (FBWAC) was established in 2006 to advise the Town of Andover on measures to help ensure long-term maintenance of a safe and reliable water supply. This "Final Committee Report" summarizes work performed by the FBWAC, and presents the committee's conclusions and recommendations.

The committee consists of several citizen volunteers, and is assisted by the Town's Health Director and the Department of Public Works-Water Division's Source Protection Manager. The committee has held monthly progress meetings since 2006.

Upon inception of committee meetings, several critical water supply protection initiatives were identified, as follows:

- Mass Department of Transportation (MDOT) low salt zone and salt shed relocation
- Fish Brook water quality monitoring
- Town of Andover deicing practices
- Groundwater Monitoring in Fish Brook Watershed
- Haggetts Pond water quality and bathymetry
- Watershed protection overlay district review
- Ledge Road Landfill impacts to Fish Brook

A work plan was developed for each initiative, and funding requirements were identified. At the annual Town Meeting in 2007, the committee requested funding of $50,000 to implement the initiative work plans. This funding request was approved during the 2007 Town meeting.

To-date, the committee has expended a total of $29,382 toward meeting the goals of the critical initiatives. Significant expenditures by the committee include the following:

- **Fish Brook Water Quality Monitoring Station** – A water quality monitoring station was installed at the confluence of Fish Brook and the Merrimac River to continuously monitor and record numerous water quality parameters. Two multi-parameter water quality probes were installed in 2008, and have been recording continuously. These probes provide critical information on stream flow in Fish Brook, and water quality in both Fish Brook and the Merrimac River.
- **Haggetts Pond Comprehensive Water Quality Assessment** – In 2007 the FBWAC retained CR Environmental, Inc. (CRE) of East Falmouth, Massachusetts to provide a multi-parameter assessment of physical and chemical conditions in Haggetts Pond. CRE developed a detailed bathymetric profile of Haggetts Pond, including sediment thickness,

and recorded salinity, temperature, and dissolved oxygen throughout the pond. These data will be available to the Town as a baseline to monitor future changes in the pond.

- **Groundwater Monitoring Network –** The committee retained the services of Pine and Swallow Associates, Inc. (PSA) to install a groundwater monitoring network near Haggetts Pond. The network consists of five (5) groundwater monitoring well clusters installed at critical locations identified by the FBWAC. Groundwater samples collected from the network allow evaluation of potential sodium chloride contributions to Haggetts Pond.

The FBWAC has laid the groundwork for a long-term and sustainable water supply protection program in Andover. The committee's significant accomplishments including the following:

- **Low Salt Zone Designation** – In 2007 MDOT established a Low-Salt Application Zone along Interstate Highways 93 and 495 within the Fish Brook Watershed.

- **Fish Brook Water Quality Monitoring Station –** The Fish Brook Water Quality Monitoring station will allow long-term monitoring of sodium application within the Fish Brook watershed, and can aid the Andover Water Department in water quality management decisions.

- **Haggetts Pond Groundwater Quality Monitoring Network –** The Haggetts Pond Groundwater Quality Monitoring Network will allow the Water Department to evaluate groundwater quality near Haggetts Pond, and to identify long-term trends in groundwater quality.

- **Revised Watershed Protection Overlay District –** At the 2009 Town Meeting, a revise Watershed Protection Bylaw was adopted. This by-law, amended by the FBWAC, provides additional protection from detrimental use and development of land and waters within the district.

- **Alternative De-Icing Chemicals –** The FBWAC evaluated contributions of sodium chloride within the Fish Brook watershed by both MDOT and the Town of Andover. Alternative de-icing chemical were evaluated, and results have been reviewed with the Department of Public Works.

The FBWAC presents detailed conclusions and recommendations for each committee initiative within this report, and presents the following recommendations for follow-up actions that will help ensure a viable water supply in Andover:

- **Town of Andover Low Salt Application Program –** FBWAC recommends that Andover establish a Low Salt Application Program for Town maintained roads within the

Fish Brook Watershed. The Town should work to minimize application of sodium chloride within the impacted zone, and should consider use of alternative de-icing agents.

- **Salt Shed Relocation –** The Town should continue to meet with MDOT to work toward relocation of the MDOT Salt Storage Shed currently located at the interchange of Interstate Highways 93 & 496.

- **Long-term Monitoring –** The FBWAC recommends that the Town maintain a working group to assist in evaluating the data collected by the Fish Brook Monitoring Station.

2

Section Two

Section 2 - Introduction

2.1 Purpose of Report

The Fish Brook Watershed Advisory Committee (FBWAC) was formed in 2006 to advise the Town Manager about potential environmental threats to Fish Brook. Fish Brook is a Class A surface water body that provides a portion of Andover's potable water supply. This report is the final committee report for the FBWAC. The report summarizes work performed by the committee, and presents the committee's conclusions and recommendations to the Town of Andover.

2.2 Committee Members

The FBWAC is made up of citizen volunteers from Andover, and is advised by two Town Employees. Volunteer committee members are as follows:

Stephen Boynton, Committee Chair
David Adilman
Richard Bizzozero
Thomas Brady
Ronald Clausen
Patricia Donahue
John Zipeto

Staff Liaisons advising the committee include:

Thomas Carbone, Director of Public Health
Cynthia Vaughn, Water Resources Manager

2.3 Committee History

In 2003, former Andover health director Everett Penney raised concerns about elevated sodium chloride levels in finished water supplied to Andover residents. Water is supplied to Andover residents from the water treatment plant located on the shore of Haggetts Pond. Penney initiated an ad hoc committee, the Fish Brook Initiative (FBI), to assist the Town in identifying and evaluating potential threats to the Town's water supply. In particular, threats to Fish Brook, a "Class A" drinking water source, were the focus of the FBI work.

The FBI identified potential contaminant sources along Fish Brook, and developed data to understand the magnitude of sodium chloride impacts to Fish Brook.

In 2005, the FBI submitted its final report to the Town Manager. The FBI's final report recommended that a Watershed Advisory Committee be established to expand on the work of the FBI, and to provide periodic progress reports to the Town Manager.

The FBWAC held its first meeting in January 2006. Several "initiatives" were identified during the first meeting, with a committee lead representative for each initiative. Committee initiatives and the committee representative for each initiative are as follows:

- Mass Department of Transportation Reduced Salt Area Designation, Stephen Boynton
- Mass Department of Transportation Salt Shed Relocation, Thomas Carbone
- Town of Andover Deicing Practices, Richard Bizzozero
- Groundwater Monitoring Program, Patricia Donahue
- Haggetts Pond Geophysical and Water Quality Investigation, David Adilman
- Fish Brook Gauging Stations, Cynthia Vaughn
- Watershed Protection Bylaw, John Zipeto
- Ledge Road Landfill, David Adilman

This report provides a summary of the purpose of each initiative, work undertaken by the committee on the initiatives, and conclusions and recommendations relative to each initiative.

3

Section Three

Section 3 - MDOT Reduced Salt Area Designation

3.1 Purpose

In 2006, the Massachusetts Department of Transportation (MDOT) designated portions of Interstates 93 and 495 as Low Salt Zones. The initiative sought to ensure compliance with those designations and to note whether they had any short term affect on sodium levels within the watershed.

3.2 Background

In 2004, the Town of Andover requested from MDOT the process for seeking a low salt use designation on the interstate highways where they passed through the town's Watershed Protection Overlay District. After many years of increasing levels of sodium in the town's drinking water, the Fish Brook Initiative sought to decrease the amount of sodium chloride being released to the water supply; the low salt area designation was one of several initiatives undertaken.

MDOT Low Salt Designation, I-93 Andover

In 2006, MDOT officially designated portions of Interstate 93 and Interstate 495 as low salt areas, with the first winter season of this designation being the winter of 2006 and 2007. MDOT erected signs showing the impacted areas to remind salt applicators of the designated areas, and to provide warning to drivers that less salt would be used in those areas. On I-93, the designation is between the Route 133 and River Road interchanges, and on I-495 it runs from just north of the I-93 interchange to the Route 133 interchange.

The application rate for salt in these zones is a 50/50 mixture of sand and sodium chloride (as opposed to straight sodium chloride elsewhere). Yearly "tailgate trainings" are held by MDOT in November where MDOT contractors are trained in the salt application rates in their assigned

areas, and where drivers are reminded that these low salt zones are important to respect since the sodium chloride application can affect the water supply.

3.3 Work Performed

MDOT holds its "tailgate trainings" annually, and the town is invited to attend to hear what is being said, and to provide first hand information to the drivers on the importance of respecting the low salt zone designations. The town has sent a representative at least twice in the past three years. As part of the designation, MDOT has installed two pavement monitoring devices within the watershed to monitor sodium chloride concentrations and pavement temperature. One device is used in the MDOT yard at the I-93/ I-495 interchange, the other is located on I-495 south of the interchange. These devices allow MDOT to monitor road conditions and to more scientifically determine when salting is required.

MDOT monitoring station located on I-495

The Town and MDOT have routinely shared data concerning sodium chloride. MDOT provides the town with the amount of sodium chloride purchased each year, and the town provides monthly water quality data to MDOT.

3.4 Discussion of Results

From 1999 to 2006, the amount of sodium chloride applied within the watershed by MDOT climbed virtually continuously as the MDOT administration had adopted a "bare and black" policy for the highways. This policy required that the roadways be free of snow and ice as soon as possible, resulting in the large scale application of sodium chloride. Following the adoption of the low salt zone, we saw a dramatic drop-off in salt application. A review of water quality in Haggetts Pond indicates that this new low salt zone has had a positive effect on sodium levels in the pond. While still very high, the sodium concentration in the pond has dropped by close to 20 mg/l, the lowest concentration since roughly the year 2000. This is encouraging, but there is still a need for oversight as well as additional methods to decrease the sodium concentration.

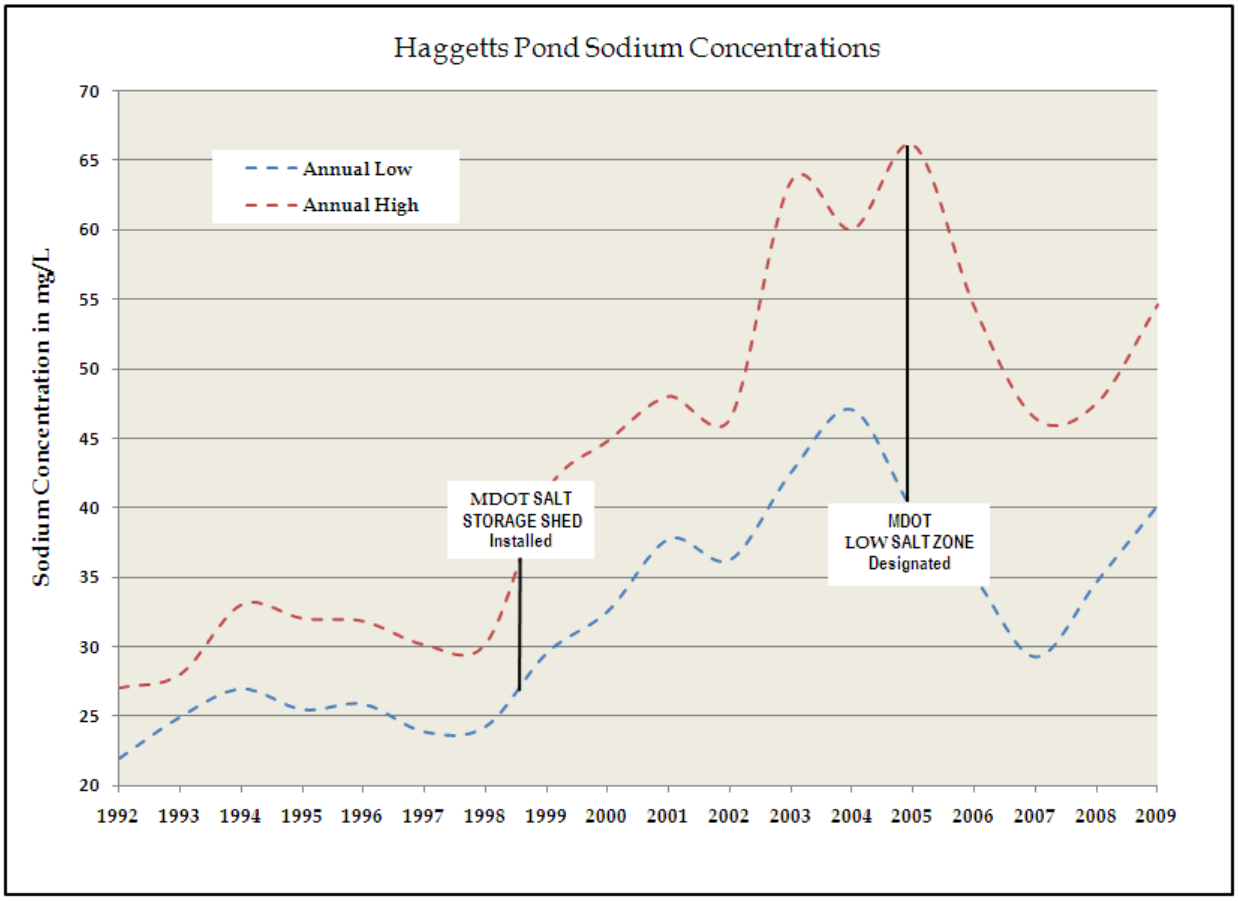
3.5 Conclusions and Recommendations

The Committee recommends that the town continue the following activities:

1. Attend the annual "tailgate training" held in November of each year for MDOT Contractors to ensure that observation of the low salt designation is reinforced.
2. The sharing of sodium data between the town and MDOT is needed to ensure that all is being done to reduce the sodium load within the Watershed Protection Overlay District.

3. Regular monitoring of sodium chloride concentrations at the Fish Brook Water Quality Monitoring Stations and Haggetts Pond should occur annually to follow trends on concentration within that water body.

Haggetts Pond Sodium Levels, Annual Highs & Lows



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Section Four

Section 4 - MDOT Salt Shed Relocation

4.1 Purpose

The purpose of this initiative was to educate the Massachusetts Department of Transportation (MDOT) of the importance of the Fish Brook Watershed to Andover's water supply, and to protect it from further salt intrusion by having MDOT relocate the salt shed to a location outside of the watershed.

4.2 Background

Salt shed located at I-93 & I-495 interchange

In 1998, MDOT located a major salt storage shed in the area abutting the northbound Connector between Interstates 93 and 495, located along the northeastern edge of the Fish Brook watershed. Initially, MDOT's activities resulted in apparent major discharges of sodium chloride to the Fish Brook aquifer. During the years between 1998 and 2003, the sodium level in Andover's finished drinking water more than doubled, increasing from 32 ppm to 70 ppm, more than three times the Environmental Protection Agency (EPA) recommended level for drinking water. The Fish Brook Initiative identified the salt storage shed as a potential major contributor to the increased sodium levels and thus began communications with highway officials to rectify the problem. MDOT recognized the threat and began implementation of better site control methods. The ultimate objective of the Fish Brook Initiative regarding this issue was the relocation of the salt storage shed. MDOT officials had verbally committed to moving the storage shed to the River Rd. interchange on I-93.

4.3 Work Performed

The Town has initiated several face-to-face meetings with MDOT in an effort to continue momentum in the relocation of the salt shed. In the fall of 2007, the Acting Chief Engineer of MDOT and his staff met with town officials, members of the Fish Brook Watershed Advisory Committee, and the town's legislative delegation to discuss the next steps in the relocation plan. At that time, they provided a conceptual site design for review and comment, and the plan was presented to the Board of Selectmen and the community on behalf of MDOT by municipal staff, with the promise of a follow-up meeting by MDOT officials.

As a result of that meeting, the legislative delegation, including Senator Susan Tucker, Barry Finegold, and Barbara L'Italien were able to have state funds allocated in Fiscal Year 2009 for the design work involved in the relocation. MDOT reports that it continues with site design work, including the drilling of test borings, and hopes to release a progress design soon.

4.4 Conclusions and Recommendations

The Committee recommends that the town continue efforts to relocate the salt shed to an area outside of the watershed. While MDOT has instituted the low salt designation of both I-93 and I-495, and has instituted better management practices, the existence of the salt shed anywhere within the watershed is a direct threat to the water quality of Haggetts Pond.

5

Section Five

Section 5 - Town of Andover Deicing Practices

5.1 Purpose

To identify the current snow removal and deicing practices used for maintaining clear and safe roadways by the town of Andover and Mass Department of Transportation (MDOT) and to identify and evaluate those practices contributing the most significant quantity of sodium to the town's drinking water supply. For the most significant sources, identify and recommend practical strategies to reduce and minimize future sodium loadings to a major source of the town's drinking water supply, the Fish Brook Watershed (FBWS).

5.2 Background

The FBWAC requested meetings with the town of Andover Highway Superintendent and the MDOT engineering personnel to develop an understanding of the current deicing practices used by both entities. Prior to each meeting, written questions were prepared and sent to the parties in advance to ensure the meetings would be productive. During these meetings several strategies for reducing salt use were identified for further investigation and research.

5.3 Work Performed

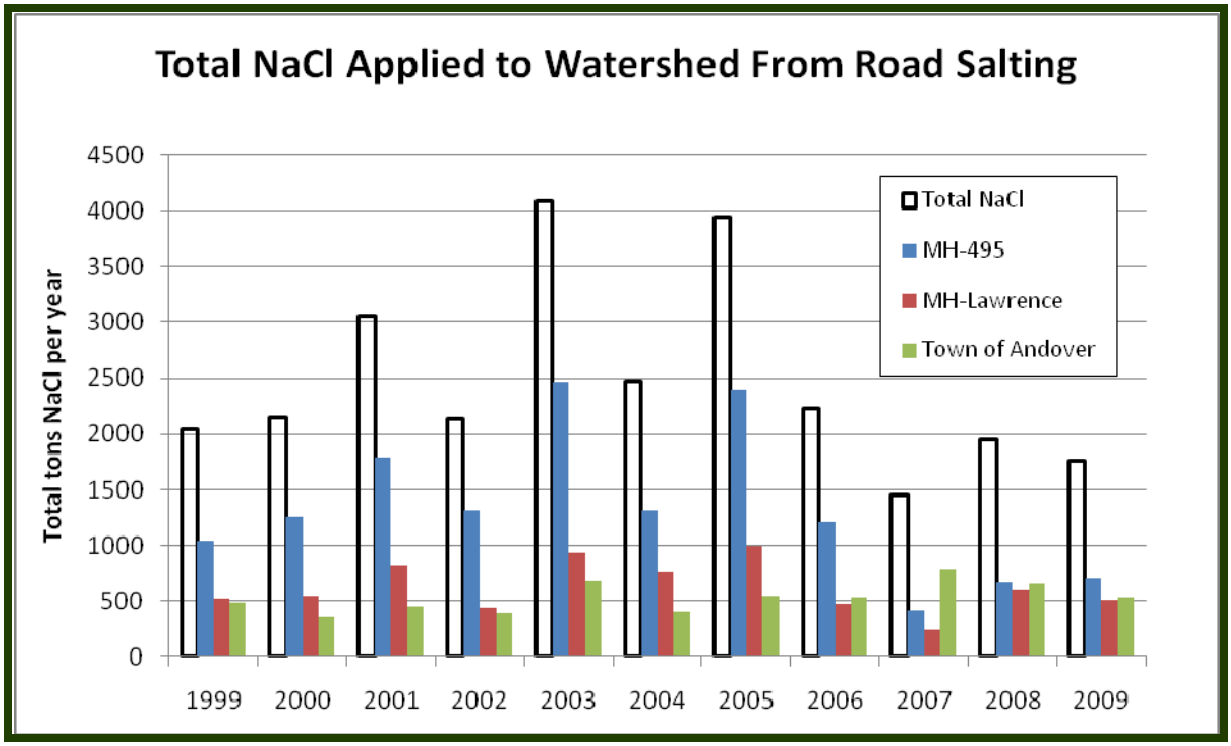
Salt application data (sodium chloride and calcium chloride) were analyzed for the town of Andover and the two MDOT depots (Lawrence and Andover 495/93) that service the FBWS. A geographic information system (GIS) analysis was performed to determine the number lane miles serviced by the town of Andover and by the two Mass Highway depots. Road lane miles were calculated for the FBWS and were attributed to either the town of Andover or one of the two MDOT depots, depending on which entity serviced the individual lane mile. An estimate of the annual salt loading was calculated using the relationship of the lane miles within the FBWS compared to the total number of lane miles serviced by particular highway department.

In addition to performing an analysis to determine the amount of salt applied to the roadways within the FBWS, research was performed to identify cost effective practices, technologies, and pollution prevention strategies that could be implemented by the town and MDOT to reduce sodium loading to the town's drinking water supply.

5.4 Results

The GIS analysis of roadways within the watershed boundary's identified a total of 95-lane miles of state and town highways. The town of Andover is responsible for snow removal and the application of deicing chemicals on 38 lane miles, or 40% of the total lane miles within FBWS. The MDOT performs similar services on the remaining 60% of the lane miles within the FBWS and all lane miles are located on either interstate highways 495 or 93.

During the winter, the Andover Highway Department removes snow and applies deicing chemicals on 412-lane miles of roadway. Approximately 38-lane miles (9.2%) of the total are contained within the boundary of the FBWS. The town applies deicing chemicals at the same rate (240 pounds of sodium chloride per lane mile) within and outside of the FBWS, resulting is 9.2% of the town's annual salt use being applied to roads within the FBWS. Since 1997 the town has applied an average of 564-tons per year of sodium chloride to the roads within the FBWS. Interstate highway routes 495 and 93 are serviced by three adjoining MDOT facilities; Andover 495/93, Lawrence, and Tewksbury highway depots. The Andover 495/93 depot, performs snow removal and applies deicing chemicals exclusively on route 93. Approximately 38.8-lane miles of the 180-lane mile service area are contained within the FBWS, representing approximately 22% of that depot's salt use and application.



The Tewksbury and the Lawrence depots service interstate highway route 495. The Tewksbury depot provides snow removal service for route 495 and the Lawrence depot applies the deicing chemicals. There are 19-lane miles in the FBWS, representing 13% of the total lane miles serviced by Lawrence depot and 13% of its salt use.
Between the years 1999 and 2008, MDOT averaged 1017-tons of sodium chloride applied to roadway within the FBWS. In calendar year 2007, they adopted a low-salt zone for the 58 lane miles of roadway contained within the FBWS. This policy cut the application rate of sodium chloride in-half by mixing one part of sodium chloride rock salt with an equal volume of sand. The mixture is pre-wetted with 32% liquid calcium chloride solution and applied at a rate of 240 pounds per lane mile, eliminating the application of 120 pounds of sodium chloride per lane mile of roadway within the FBWS.

The graph on the previous page shows a significant proportional reduction in sodium chloride application by MDOT in year 2007, and a corresponding proportional increase in the town of Andover's contribution to the total salt loading to the FBWS.

During the years 1999 to 2006 the town of Andover contributed approximately 18% of the total sodium chloride use in the FBWS. Beginning in 2007, the percentage of Andover's contribution increased to 28% and in year 2008 43% of the total application in the FBWS. These percentages are in line with Andover's 40% of the lane miles within the FBWS, however the town is playing an increasingly larger role in the application of sodium chloride within the watershed, as a result of the MDOT low salt application program.

5.5 Conclusions and Recommendations

There are a number of opportunities for the town to decrease the use of sodium chloride rock salt while increasing the efficacy of salt use within the FBWS. The establishment of a written snow and ice control policy and procedures document, which communicates the practices and procedures for maintaining roadways, is an appropriate place to start to ensure uniform communication and implementation of the Highway Superintendent's approved snow removal practices. The document should specify operating procedures for: salt storage, handling and yard management; managing snow events including when snow plowing and deicing operations will begin and end; the level of service for each roadway type; snow removal procedures and practices; equipment use and chemical application rates; equipment maintenance and calibration; and operator training. A section of the procedures document should address operational

practices for activities within sensitive receptor areas such the town's drinking water supply and the FBWS. Ultimately, the manual clarifies and documents procedures and practices currently in place and helps to ensure that the same snow removal and deicing practices are used by all operators serving the town.

There are a number of technologies and deicing practices that could be adopted by the town that would result in less sodium chloride use within the FBWS. Strategies the town adopts can be incorporated into the policy and procedures manual, and training on the practices incorporated into the annual refresher training provided to truck and snow removal operators. The following options are recommended for further investigation and evaluation by the town highway department to determine their applicability to integration into the town's snow removal and deicing practices:

- investing in integrated electronic ground speed controllers on trucks
- increasing the use of pre-wetted (with calcium chloride) sodium chloride rock salt
- pre-wetting roads with a sodium chloride brine solution
- designating the FBWS as an environmentally sensitive receptor and adopting low-salt zone practices within the watershed

Invest in Integrated Ground Speed Controllers on Trucks

Outfitting trucks with electronic ground speed controllers will optimize the application of deicing chemicals by matching the chemical application rates with the actual speed of the truck over the roadway, eliminating the need for operator decision-making and manual control. For example, when a truck slows down as it approaches an intersection, the rate of deicing chemicals dispensed slows down by a corresponding amount ensuring uniform application of deicing chemicals no matter what the truck speed. Ground speed controllers can improve application efficiency by up to 20% and typically cost $8,000 to $10,000 per truck.

Pre-wetting Sodium Chloride (rock salt) with Liquid Calcium Chloride

State and local highway departments commonly employ the technique of pre-wetting solid sodium chloride with liquid calcium chloride. The town of Andover currently uses this practice and many highway departments use this combination of chemicals to maintain clear roadways when temperatures drop below 25°F.
The addition of calcium chloride to rock salt lowers the freezing point of water more than sodium chloride alone, leading to the use of smaller quantities of sodium chloride needed to maintain safe highways. The town should evaluate the beneficial environmental impacts and costs associated with expanding this practice to reduce sodium chloride use within the FBWS.

Besides extending the efficacy of sodium chloride at lower temperatures, pre-wetting with a 32% solution of liquid calcium chloride reduces rock salt scatter during application by increasing

surface tack of the solid deicing materials. Results of studies performed by MHD and other highway departments have shown up to a 30% increase in rock salt remaining on roadways when compared to the straight application of solid sodium chloride. When applied down the center of the road, 96% of pre-wet rock salt remains on the roadway compared with 70% without the liquid pre-wet application. Because more of the salt remains on the road during application, up to 30% less sodium chloride is needed to achieve the same result. Additional benefits may be in the form of increased truck application speeds when applying to dry roads, due to the increased surface tack of the pre-wet materials.

Most Andover trucks currently have pre-wetting capability, and those that don't can be retrofitted for a few thousand dollars to add the necessary dispensing tanks. A potential reduction in sodium chloride use and cost savings of up to 30% will be partially offset by the increased cost of using liquid calcium chloride ($1.05 per gallon). Calcium chloride is very corrosive and will accelerate the degradation of application equipment, so accelerated equipment depreciation should be factored into the cost-benefit analysis.

Pre-wetting Roadways with Sodium Chloride Brine Solution

In recent years the use of a liquid sodium chloride brine solution to pre-treat roads has gained popularity with highway departments. The solution is applied to roads via spray nozzles from a boom mounted on the back of a tank truck and is dispensed several hours prior to the snow event. It is effective when applied at pavement temperatures above 22 degrees and when the precipitation is expected to start as snow or freezing rain, since rain will wash the brine off the road. The application of brine prevents ice and snow from bonding to the pavement and will delay the need for the first salt application by up to an hour. The use of brine doesn't replace rock salt application, but when it prevents a bond of snow to the road, the amount of salt needed to maintain the road is reduced.

The sodium chloride brine solution cost approximately $0.12 per gallon to make compared with $1.05 per gallon for calcium chloride. The solution is applied at a rate of 60 gallons per lane mile. Besides the benefit of uniform application of deicing chemicals and the overall reduced use of salt, under some weather conditions it can be substituted for calcium chloride traditionally used as a pre-wetting solution at the spinner, which helps to reduce scatter of the dry rock salt materials during application.

Under some storm conditions brine solution can increase the level of service on the roadways. At the outset of a storm, untreated roads can ice over in a matter of a few minutes, resulting in

numerous accidents and travel safety concerns. Roads treated with brine remain open and wet maintaining road safety and preventing accidents.

The New Hampshire Department of Transportation has demonstrated this technology on the route 93 corridor south of Hookset and along other secondary roads in the area. Pam Mitchell, NHDOT District 5 Manager, is the supervisor overseeing the implementation of this technology and is a good source of information on the pros and cons of the technique. The department does intend to expand the use of pre-treating and pre-wetting to other highways in the southern part of the state.

There can be significant capital investment required for the purchase of equipment to make, store and apply the brine solution, so identifying creative ways to address these capital outlays will be an important consideration when evaluating the technology and its applicability to the town of Andover's situation.

Designate FBWS as a Low-salt Zone and Adopt New Practices

If the goal is to reduce sodium loading to the town's drinking water supply, a systems approach is recommended for arriving at the solution. This would include evaluating sodium use at the water treatment plant, water pumping practices from the Fish Brook pump station on the Merrimack River, and practices used by the highway department to maintain clear and safe town roadways.

Mass Highways is minimizing sodium loading to the town of Andover's drinking water supply by designating the lane miles on interstate routes 495 and 93 within the FBWS as a low-salt zone. In low-salt designated areas, MHD applies a 50-50 mix of solid sodium chloride and sand that is pre-wet with liquid calcium chloride. The resulting mixture is applied at a rate of 250 pounds per lane mile, effectively reducing MHD use and application of sodium chloride within the FBWS by 50%.

Designating the town roadways within the FBWS as a low-salt zone is a significant and sensible first step to reducing sodium loading to the town's drinking water supply. To that end, there are a number of technically feasible and cost effective options for the town to reduce the use of sodium within the FBWS.

6

Section Six

Section 6 - Groundwater Monitoring Program

6.1 Introduction

To evaluate groundwater quality around Haggetts Pond and determine if groundwater is a significant source of sodium, groundwater monitoring wells were installed at selected locations. Funding for this initiative was approved at the April 2007 Town Meeting. Additional details regarding the monitoring well installation can be found in a report entitled "Limited Subsurface Investigation, Haggetts Pond Reservoir, Andover, Massachusetts" dated April 22, 2008 and prepared by Pine & Swallow Environmental.

6.2 Well Installation Summary

A total of fourteen (14) small diameter monitoring wells were installed at five locations. Each location included cluster wells with two to three wells screened at progress-ively greater depths below the water table. Locations include: FBMW-1 south of Haggetts Pond closest to the Water Treatment Plant, FBMW-2 west of the pond, FBMW-3 northwest of the pond and downgradient of drainage from Rte 495, FBMW-4 and 5 near the intersection of High Plain Road and Fish Brook (downgradient of the Salt Storage Shed), and at the MDOT Salt Storage facility. The well locations are shown on page 23. The committee determined small diameter direct push wells and groundwater profiling would be the most cost effective approach and provide the information needed. In January and March of 2008, wells at the MDOT facility and around the pond were installed and groundwater sampled by Pine & Swallow Environmental. Groundwater profiling entailed collection of groundwater samples at ten (10) foot intervals with field screening for specific conductivity (SpC) and other water quality parameters, and submittal of samples to the water treatment laboratory for sodium and chloride analysis. Specific conductivity data were used to

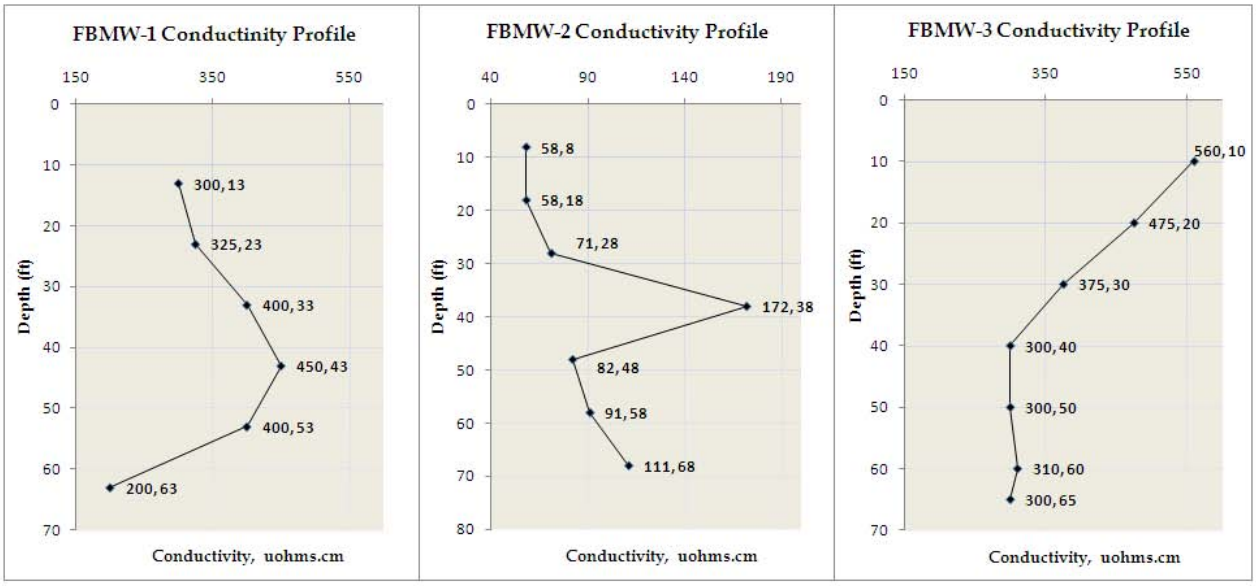
Geographical locations of GW Wells

identify possible zones of elevated sodium chloride to select well screen depths. Wells at the location north of Haggetts Pond near High Plain Road were installed in May 2009. The terrain at the MDOT facility appeared to be a dense till not conducive to this drilling technique. Several attempts were made but the driller's repeatedly encountered refusal. Two shallow wells were installed but were dry on subsequent visits. Likewise, deep wells could not be installed at FBMW-4 & 5 because of refusal and shallow wells were installed.

6.3 Results

In addition to the conductivity data collected during drilling, researchers from Boston College collected conductivity and water level measurements during the summer of 2008. All data is tabulated in Appendix A. In addition, the sodium and chloride data from water samples collected during profiling and analyzed by the Town show a strong correlation to SpC data allowing SpC to be used as a surrogate for sodium chloride concentration.

Groundwater elevation data from July 2008 indicate a slight gradient toward the pond at all three locations. Graphs of the specific conductance vs. depth show different profiles depending upon the location. FBMW-1 shows the highest conductivity at the middle interval (33-34 feet) indicating the source is some distance from this location.



Elevated conductivity is seen throughout the profile, but the SpC drops off significantly below 53 feet. The average sodium concentration in this location is 33 mg/l. The profile at FBMW-2 is somewhat similar however the peak at the middle interval (28-38 feet) is more extreme and the

overall conductivity readings are significantly higher at FBMW-2 and continue to be elevated at depth. The measured average sodium concentration at this location is 92 mg/l which is twice the average concentration in the pond (41 mg/l). The elevated readings at this location on the west side of the pond were not expected and warrant further monitoring. The profile at FBMW-3 shows an opposite trend; conductivity at this location is highest in the shallowest samples and decreases steadily, leveling off at 30 feet. The average sodium concentration in groundwater is 43 mg/l, similar to the average concentration in the pond. This well is located near a large wetland area between 495 and the pond. Based on results at this well surface water runoff from 495 is likely to impact the wetland which flows into Haggetts Pond.

The monitoring wells north of Haggetts Pond near the intersection of High Plain Road and Fish Brook were intended to evaluate direct impacts to groundwater from the MassHighway salt storage facility. The depth to refusal (till or bedrock) was shallow at this location, so two sets of wells (FBMW-4 and FBMW-5) were installed along High Plain Road approximately 200 feet apart. Because these wells are all less than 17 feet in depth, groundwater at these locations could be influenced by direct road runoff from High Plain Road as well as more distant sources. Sodium concentrations in groundwater at the salt storage shed was 380 mg/l. Very high conductivity and sodium levels were measured in groundwater at this location indicating a significant impact to Fish Brook. Sodium levels at FBMW-4 averaged 622 mg/l, compared to 380 mg/L at the salt storage shed and an average of 90 mg/L further downstream at the Fish Brook pumping station.

The data collected indicates that groundwater with elevated sodium concentrations is likely migrating into the pond. The average sodium concentrations at FBMW-1 and FBMW-3 are at the same concentration as the pond but higher than the water quality goal of 20 mg/l. Significant sodium levels are discharging into the pond at FBMW-2 and the source at this location is unknown. High levels of sodium were also found in groundwater at the salt storage facility and near Fish Brook.

6.4 Recommendations

The committee recommends continued groundwater monitoring for specific conductance, sodium and chloride and water levels to continue to monitor the sodium load into the pond and to track any increasing or decreasing trends. Consideration should be given to installing a deeper well north of the pond using conventional drilling methods to better evaluate potential sodium contribution from the salt storage shed.

7

Section Seven

Section 7 - Haggetts Pond Geophysical and Water Quality Investigation

7.1 Purpose

Understanding the cause of elevated sodium in Haggetts Pond requires water quality information for the water inputs. One input that had not been evaluated was the potential for groundwater influx to the pond. Various methods are available to determine if groundwater is discharging to the pond and if so, the water quality of that groundwater. In addition to new groundwater monitoring wells installed around the pond, specific conductivity and temperature measurements were taken within the pond. It was theorized that identification of zones of elevated specific conductance could be considered surrogate measurements for zones of high salinity groundwater discharge to the pond.

7.2 Scope of Work

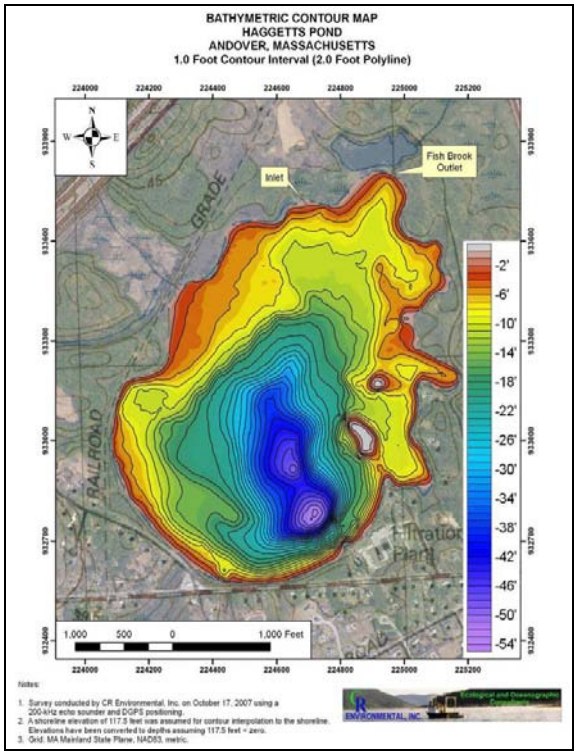
CR Environmental, Inc. (CR) of Falmouth, Massachusetts was hired to perform hydrographic, geophysical and water quality surveys of Haggetts Pond. This work was completed from October 17-18, 2007. Components of the survey included single-beam bathymetry, mapping of water column and lakebed temperature and specific conductivity and sub-bottom sonar profiling.

The bathymetric survey was conducted to more accurately assess the volume of Haggetts Pond and the sub-bottom sonar work was aimed at determining the sediment thickness at the bottom of the pond. These last two items were requested by the town of Andover to aid in water management. Sediment thickness mapping was used to assess the buildup of alum discharge to the pond bottom from the water treatment plant.

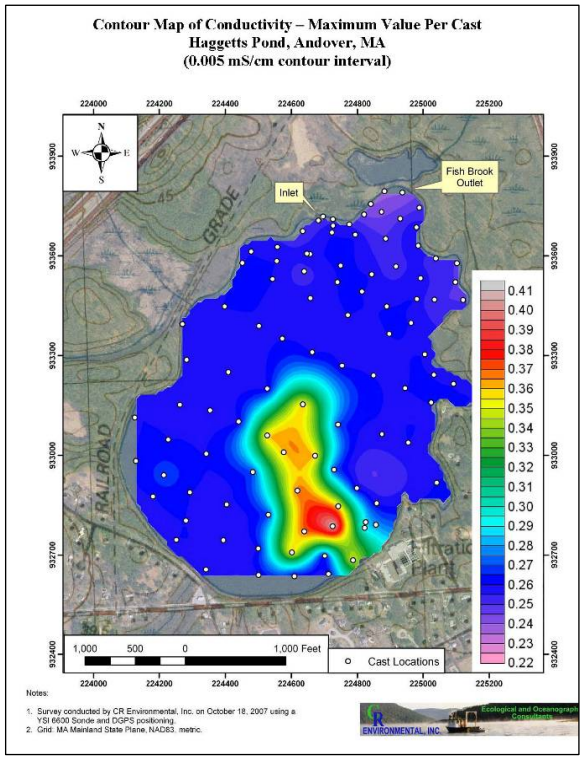
7.3 Results

CR issued a report which summarized the methods used for data acquisition and the results obtained. All of the survey data was provided in digital format to the Town of Andover on a project DVD. As shown on the following figures, the maximum depth of the lakebed was recorded at 52.45 feet. The average depth of the pond was 14.3 feet. The full-pool volume of the pond was calculated as 1,027.7 million gallons, with approximately 50 percent of the Pond's volume in the upper 8.5 feet.

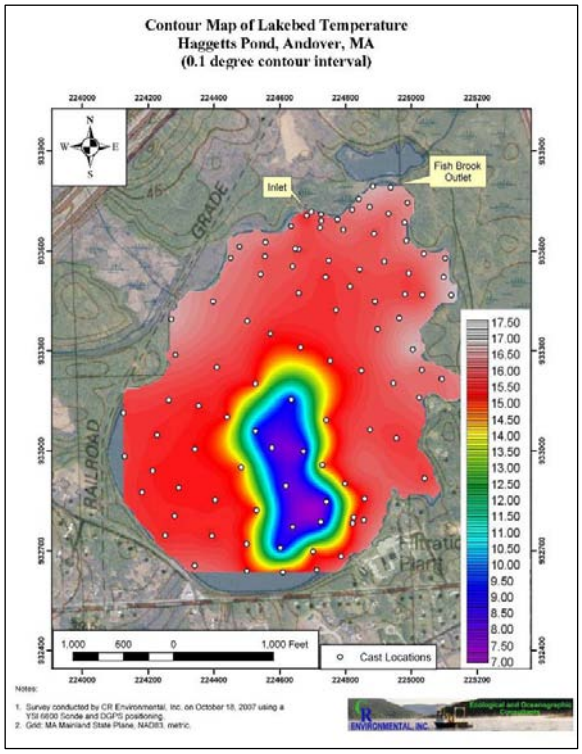
Haggetts Pond Bathymetric Contour Map



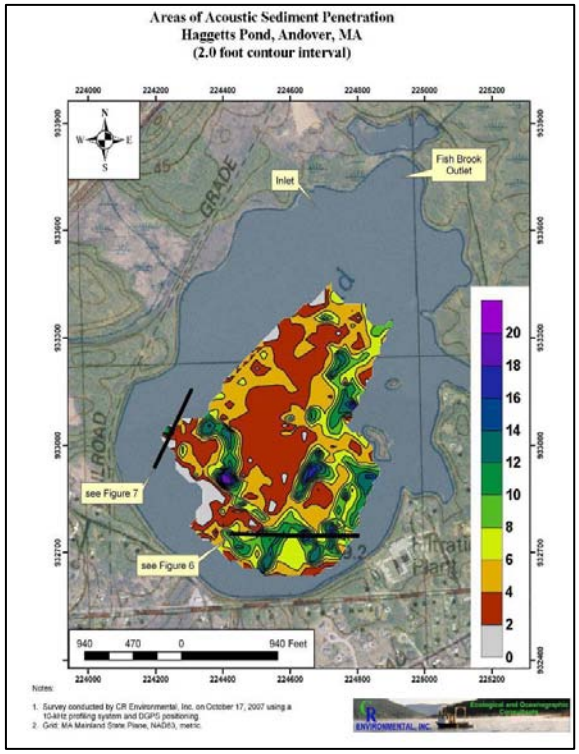
Contour Map of Conductivity



Contour Map of Lakebed Temperature



Contour Map of Sediment Penetration



Approximately 9,250 temperature and specific conductivity (SpC) data points were collected by towing a sensor behind the boat. Near-bottom SpC in this database ranged from 0.21 mS/cm to 0.37 mS/cm (average = 0.252 mS/cm). Temperature ranged from 7.92^{o} C to 16.36^{o} C (average = 15.67^{o} C). Contour maps of near-bottom temperature and specific conductivity indicate a distinct higher conductivity and lower temperature signature for the deeper areas of the pond as illustrated on the figures below. The area where Fish Brook water enters the pond exhibited a lower conductivity signature (~ 0.21 mS/cm). The inlet water temperature appears colder than ambient basin water, but is rapidly lost due to thermal mixing. Patterns in near-bottom temperature appear to mimic bottom elevations. It was CR's opinion that these data were not necessarily indicative of high salinity groundwater discharge into the pond.

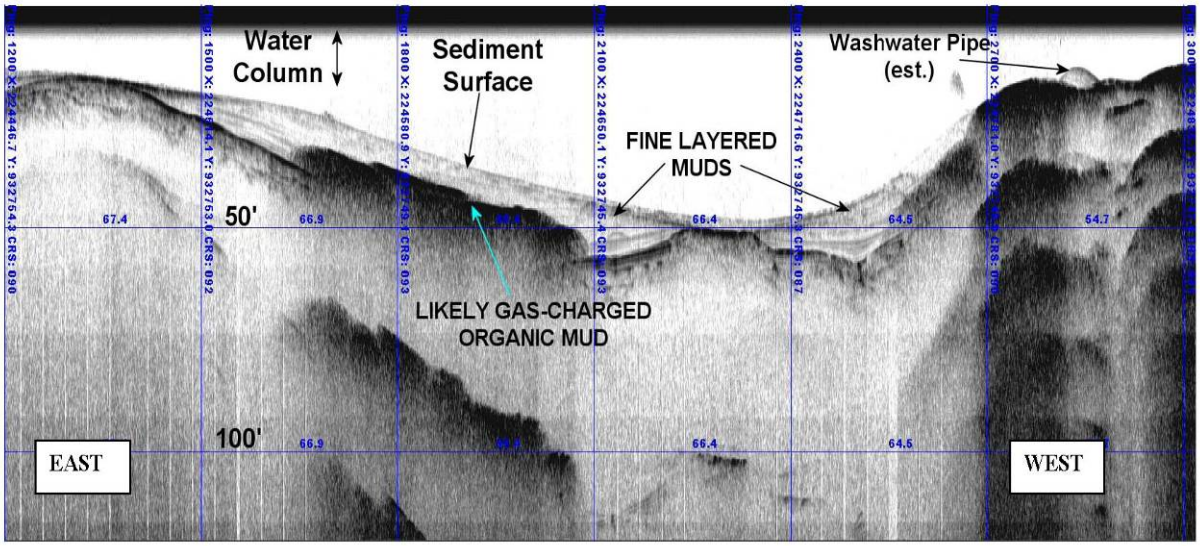
Additional vertical profiling data was collected (5,330 measurements from 102 profiles). Results indicate the pond was strongly stratified during the surveys. Temperatures ranged from approximately 16.3^{o} C at the surface to 7.7^{o} C at the deepest point of the lake. Temperature measurements at the lakebed reflect its bathymetry. Specific conductance was relatively homogeneous in the shallower depths. The profile generated specific conductivity data show the same flow pattern near the inlet suggested by towed data, with apparent migration of the influent water towards the outlet and subsequent dilution and dispersal into the main basin. Profile data show SpC measurements as high as 0.41 mS/cm in the deeper portions of the pond adjacent to the treatment plant.

Sub-Bottom Sonography and Sediment Distribution

The sub-bottom sonar system successfully penetrated as much as 20 feet of sediment. Penetration was greatest in the deeper portions of the basin as shown in the figure below. The data suggest the presence of fine acoustically transparent sediment over 80 acres of the lake bed. The average depth to acoustic basement (i.e., minimum sediment thickness) was estimated as 5.7 feet. However, it appears likely that natural gases entrained in the sediments may have limited penetration in substantial portions of the basin. Sub-bottom sonar data seems to confirm visual observations that the surficial substrate of the majority of the littoral and immediately sub-littoral zones is composed of sand, gravel and coarser substrates.

The bathymetric and sub-bottom sonar data from Haggetts Pond provide the spatial and morphological context required for interpretation of water quality data. A conductivity sensor interfaced to a precision DGPS system successfully detected a conductivity signal associated with the pond's inlet. While neither, temperature or conductivity data, indicated the presence of groundwater discharge zones, this absence may be associated with the artificially maintained high water surface elevation and/or with the season of the survey. Shallow zone conductivity is elevated adjacent to the Town's treatment plant on the southeastern shore of the pond.

Sample of Sub-bottom Sonograph Showing Up To 16 Feet of Fine Sediment Adjacent to the Water Treatment Plant



Haggetts Pond Sub-bottom Sonograph

7.4 Recommendations

Additional conductivity profiling under different seasonal regimes would likely increase knowledge of possible saline water transport mechanisms in the pond. Specifically, data collected through the ice (if safe) and *immediately* following spring ice-out would best describe conditions during a high salt use season. Profiling and sampling during a summer period of low water (i.e., no discharge from the outlet) might better allow characterization of base flow to the pond.

8

Section Eight

Section 8 - Fish Brook & Merrimack River Gauging Stations

8.1 Purpose

Significant improvements in flow and water quality monitoring were necessary to evaluate the sodium content in Fish Brook and its effect on the Town's drinking water supply. Expanded flow and water quality data could be used to a) increase the accuracy of flow and salt balance modeling, (b) evaluate baseflow conditions and seasonal effects on sodium content, c) begin the compilation of data for long-term trend analysis, d) evaluate the effects of reduced salt zone implementation and other BMPs on sodium chloride (NaCl) in Fish Brook, and e) upgrade management of the Town's water supply sources to minimize sodium concentrations to the pond.

8.2 Scope of Work

To help address this need, the committee installed two monitoring stations near the Fish Brook Pumping Station – one located on Fish Brook immediately upstream of the footbridge – and the other located in the Merrimack River adjacent to the fish ladder. These monitoring stations were designed to provide automated recording of flow and water quality from both water sources to the Fish Brook Pumping Station and subsequently to Haggetts Pond.

Fish Brook Gauging Station

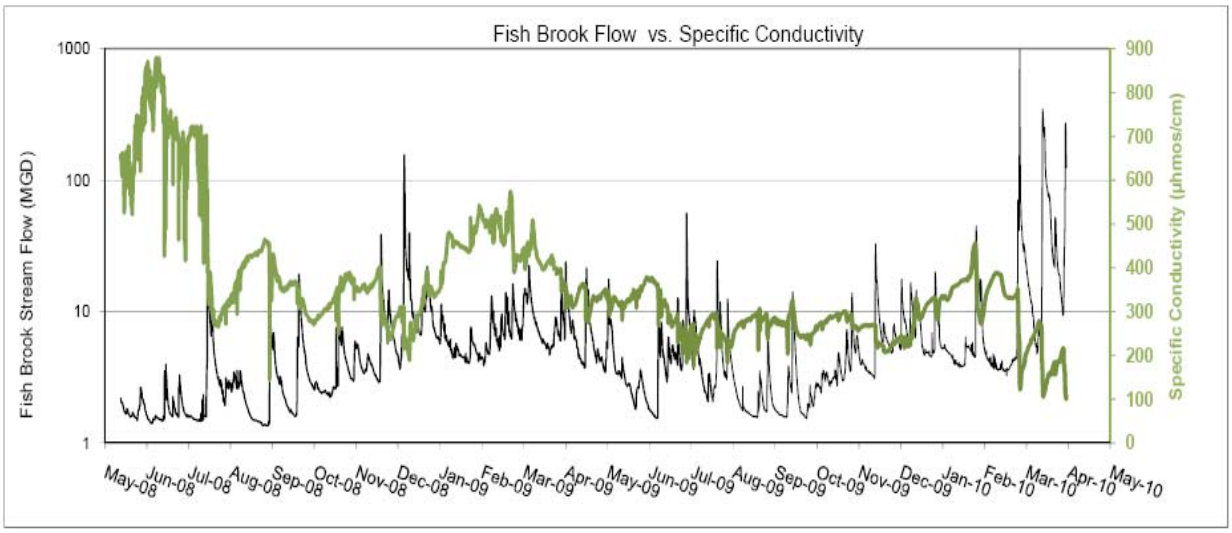
The monitoring station in the brook consists of an anchored stainless steel pipe on the brook bottom which houses an In-Situ water quality monitoring device. The device is accessed through a wire in a permanent stainless steel box at the brook's edge. There is a similar structure at the Merrimack River location. The stations are battery operated, equipped with data-logging hardware and software, and are capable of storing up to 5 years of downloadable data. Pressure (water level), specific conductivity (SpC) and temperature are measured and recorded every 15 minutes. Previously collected stream gauging data was used to create stream-discharge curves whereby Fish Brook flow could be estimated by knowing the level in the brook. Sodium and

chloride concentration data can be estimated directly from the SpC data. Occasional confirmatory water sampling and lab-testing for sodium and chloride were used to validate the sodium and chloride estimates from SpC data.

With continuous water level and SpC data, flow rates and NaCl concentration data can be used to estimate the total loading of NaCl leaving the watershed at the Fish Brook terminus.

8.3 Results

Results from the Fish Brook monitoring station over a 2 year period are illustrated on the plot below. The plot shows all the data collected, and the lower flow data provides information on base flow in Fish Brook during low water periods.



These data indicate:

- There is a quick response to rainfall events with steep spikes in flow following rainstorms.
- Base flow approaches 1.0 million gallons per day (MGD) during the drier summer months.
- Specific conductance (NaCl concentrations) are highest during baseflow periods.
- Rainfall events appear to dilute NaCl concentrations.
- There is variability in NaCl concentrations over the monitoring period. Data during summer 2008 appears to show higher concentrations than data in summer 2009. This may be due to factors such as reduced salt loading from a milder winter or other factors.

- Annualized salt loading estimated from these data indicate discharge of approximately 1,500 tons of NaCl in calendar year 2009 through the Fish Brook terminus. Specifically, this was determined based on:

  Converting brook level to flow (based on stream discharge curve equation for station)[1]

  $$\text{Flow in CFM} = 0.15 \times 2.72^{(1.7386 \times \text{brook level [ft]})}$$

  Estimating NaCl concentration (based on relationship to SpC)

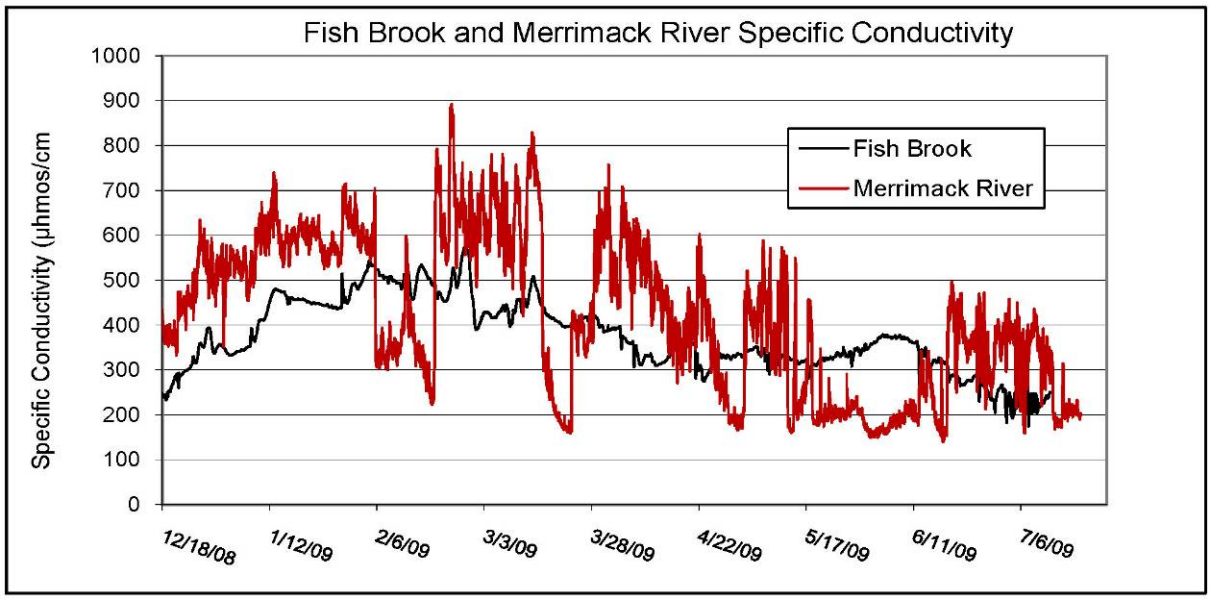
  NaCl (mg/L) = SpC (µS) x 0.48 (determined empirically)

  Estimating tons of NaCl per year leaving watershed

  Flow (l/yr) x average NaCl (mg/L) = mg/yr NaCl

  Convert mg/yr NaCl to tons NaCl per year

The plot below illustrates SpC in the Merrimack River vs. Fish Brook over the recording period.



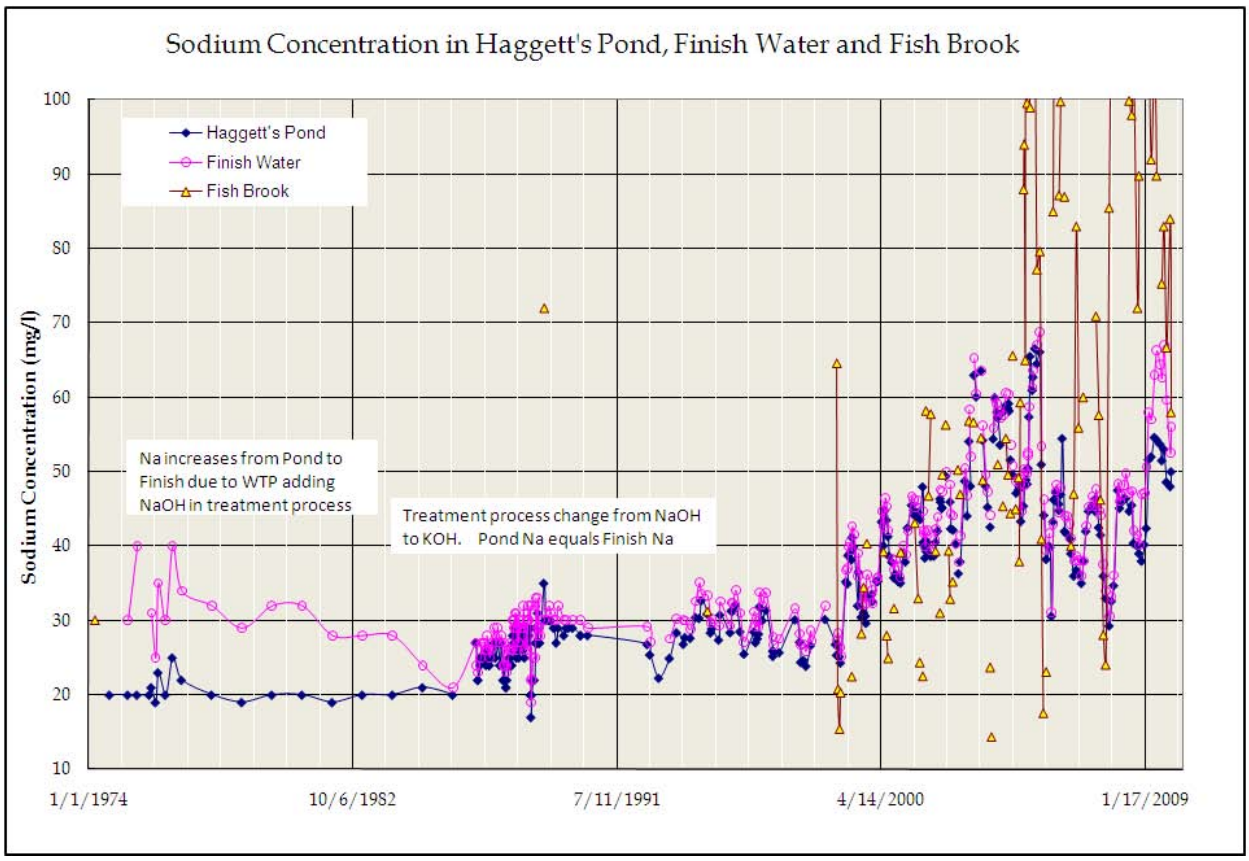
These data indicate SpC and thus NaCl concentrations in the Merrimack River are more variable than in Fish Brook and attain both higher and lower concentrations than Fish Brook. This may be due to more direct high volumes of NaCl impacted stormwater runoff to the Merrimack River compared to Fish Brook.

[1] The stream discharge equation is based on the committee's initial gauging of streamflows at various water levels. Additional stream gauging should be conducted over the next year to improve/corroborate the level to flow relationship.

8.4 Results Relative to Future Water Management

Monitoring data and salt loading calculations indicate that both Fish Brook and the Merrimack River contribute NaCl to Haggetts Pond and in turn, cause sodium and chloride concentrations to increase over background levels in the Town's drinking water.

The following plot shows sodium concentrations over time in Fish Brook, Haggetts Pond and the town's Finish water.

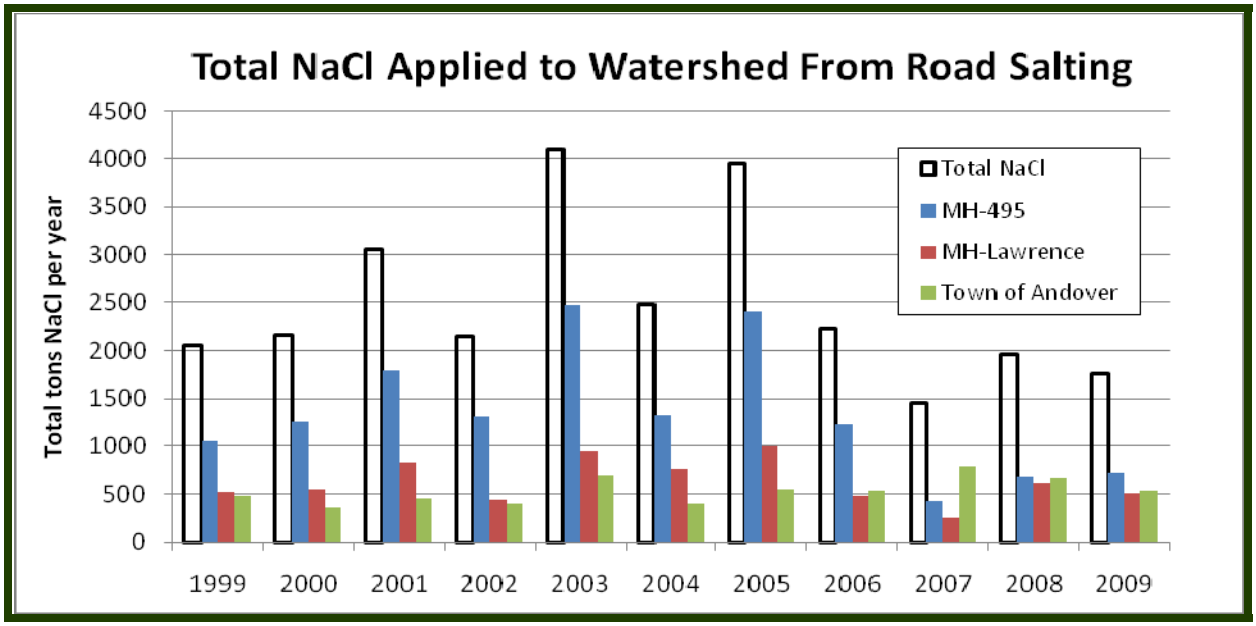


Increases in sodium concentration in approximately 1999 are theorized to be attributable to the placement of the Mass Highway Department (MHD) salt storage facility located within the I-495/I-93 cloverleaf. Concentrations of sodium peaked in the town's finish water in approximately 2005 to 2006. As reported in previous years, excess salt loading to the cloverleaf and historically poor BMPs may have led to spikes in sodium concentrations to Fish Brook. Although concentrations of sodium have declined since then, the concentration in Fish Brook has continued to increase. The cause of the reduction in total sodium in the finish water is not completely known.

Potential causes include:

- A change in the percentage of supply extracted from Fish Brook vs. the Merrimack River;
- The implementation of a reduced Salt designation for state highways within the WPOD; and
- Improvement in management of the salt storage facility (i.e, improved Best Management Practices (BMPs) such as covering the salt piles, paving the area, and reducing direct runoff).

However, evaluation of NaCl concentrations in groundwater within the basin, general knowledge of road salting effects on groundwater, and the continued elevated NaCl in Fish Brook indicates a probable long-term source of NaCl within the watershed. This is evident based on high SpC readings during recent baseflow conditions at Fish Brook.
The initial evaluation of the annualized NaCl loading to Fish Brook of 1600 tons can be evaluated against the total salt loading to the roadways (see Figure below).



The above figure illustrates the average total NaCl loading to roads within the watershed over the last three years has been approximately 1500 tons. Considering that a significant portion of the brine produced by salting infiltrates to groundwater, as evidenced by high SpC measurements in groundwater, the approximately equal application (1500 tons on roads versus 1600 tons discharging at Fish Brook), indicates the aquifer likely contains a significant long-term mass of NaCl. These data should be considered approximate at best, and additional data will need to be collected.

8.5 Recommendations

Although Haggetts Pond short-term sodium trend has apparently decreased, further data gathering is needed to confirm whether this recent trend will continue. Results appear, but not conclusively, that MDOT best management practices (BMPs) and interstate reduced salting practices may have contributed to short-term improvements. In addition to the MDOT salting of State roads, the presence of the storage facility as well as Town deicing practices likely lead to significant additional sources of NaCl to the watershed. The Town should continue to focus salt management efforts on efficient application that results in the minimum amount of NaCl application to have safe roads. For example, it is relatively easy to apply too much road salt during warmer temperatures when only low concentrations of NaCl (2%) are sufficient to melt ice.

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The town should continue to work with the State to achieve complete relocation of the salt storage facility out of the watershed. Solving the problem of NaCl impacts related to the MDOT salt storage facility may not fully achieve the Town's goal of reducing sodium in the drinking water due to long-term effects of NaCl loading to groundwater within the watershed. This is an important finding of the committee and thus continued monitoring and maintenance of the automated level and SpC sensors should be continued to collect additional salt loading data. Lastly, the stream-discharge relationship at FB-6 should be corroborated with additional flow measurements.

9

Section Nine

Section 9 - Watershed Protection Bylaw

9.1 Purpose

Part of the mission of the FBWAC has been to provide advice and recommendations to the Town Manager regarding the long term protection of the Andover Water Supply. This mission has included reviewing steps and actions intended to reduce existing and potential threats to the safety and purity of the water supply. Based on its review, the FBWAC concluded that amendments to the existing regulatory authority that are intended to strengthen the Town's ability to protect Haggetts Pond and Fish Brook were warranted. Therefore, the FBWAC has provided recommendations to revise Section 8.1 of the Zoning By-Law, also known as the Fish Brook/Haggetts Pond Watershed Overlay District.

9.2 Existing Regulatory Provisions

Local regulatory authority intended to protect the Town's drinking water supply at Haggetts Pond, Fish Brook, and the associated ground water regime is provided by Section 8.1 of the Zoning By-Law, known as the Watershed Protection Overlay District (WPOD). Its stated purpose is "to preserve and protect surface and ground water resources in the Fish Brook/Haggetts Pond Watershed Protection Overlay District (WPOD) for the health, safety and welfare of its people and "to protect the community from the detrimental use and development of land and waters within the Watershed Protection Overlay District". According to information available on the official Andover web site, the Town of Andover adopted the WPOD at Town Meeting in April, 1986, with amendments approved during Town Meetings in 1987, 1988 and 2006.

The WPOD By-Law has delineated land development activities which are either permitted, prohibited, or subject to the issuance of a Special Permit by the Planning Board. In addition, the WPOD imposed supplemental design standards that have been relevant to land development restrictions previously established in other sections of the Zoning By-Law.

9.3 Regulatory Deficiencies

The regulatory focus of the WPOD as provided in the current Zoning By-Law has been to control land development activities as they pertain to impacts to Andover's public water supply. The FBWAC believes that a more comprehensive approach to minimizing or eliminating threats

to water quality, regardless of source, is needed to ensure long term protection of the public water supply. A review of state and federal laws and regulations regarding the management of hazardous materials and hazardous waste identified a significant body of regulatory material that is relevant to a broader protection mandate. In addition, the Commonwealth of Massachusetts has promulgated regulations regarding the protection of surface water supplies, ground water resources and the management of subsurface treatment and disposal of wastes that are especially applicable to providing the local authority the enforcement tools needed to help protect the unique and irreplaceable resources that exist within the WPOD.

9.4 Major Changes to the Current By-Law

Proposed changes that are deemed significant are provided below. Please see Appendix B to review all edits and changes to Section 8.1 of the Zoning By-Law recommended by the FWAC.

Section 8.1.2 – Establishment: Zone 1 and 2 designations have been incorporated into the by-law revisions. These designations are consistent with state regulations and guidelines for protecting surface water supplies.

Section 8.1.6 – Prohibited Uses: Update of regulatory references to solid waste, hazardous waste, etc.; controls on direct stormwater discharges to Haggetts Pond, Fish Brook, and tributaries within Priority Zone 1; as of June 1, 2009, no new construction within Priority Zone 1; the bulk storage of salt and other road de-icing chemicals; the storage, management, or disposal (including septic systems and floor drains) of hazardous materials as defined in Massachusetts regulations cited at 310 CMR 40.1600 (Oil and Hazardous Materials List) and Federal regulations cited at 40CFR Part 355 (Extremely Hazardous Materials List); Storage, stockpiling, or spreading of animal manure within Priority Zone 1; any new on-site sewage treatment and disposal systems within 400 feet of a surface water supply as provided for in 310 CMR 15.211 and within 200 feet of one or more rivers, streams, or swales which are tributary to the surface water supplies.

Section 8.1.7—Design Standards: Prepare a Sedimentation and Control Plan for construction activities allowed within Priority Zone 1. The renovation, expansion, and/or upgrade of existing on-site sewage treatment and disposal systems shall be conducted in accordance with requirements set forth in 310CMR 15.000 et seq., unless otherwise specified.

9.5 Recommendations

The FWAC presented recommendations at the 2009 annual Town Meeting, which were accepted and adopted. The FBWAC further recommends that the Andover Board of Health conduct an outreach program to property owners who reside within Priority Zone 1 regarding the

management of existing subsurface disposal systems in accordance with local and state requirements.

In addition, the FWAC recommends that a review of Section 8.6 of the Zoning By-Law, the Groundwater Protection Overlay District, be conducted in the near future to assess the need for revision and updating as may be needed.

10

Section Ten

Section 10 - Ledge Road Landfill

10.1 Purpose

The Ledge Road Landfill is located on the eastern edge of the Fish Brook Watershed, northwest of the intersection of I-495 and I-93. It was originally used as a gravel pit, then for burning solid waste (1950–1961), then as a sanitary landfill (1961-1972). A Comprehensive Site Assessment (CSA) conducted under the Massachusetts Department of Environmental Protection (MADEP) Solid Waste Rules was completed in 2001. The MADEP called for supplemental CSA work to further define the distribution and extent of arsenic in sediment and groundwater. Various environmental investigations have revealed elevated levels of arsenic in sediment, surface water and groundwater immediately downgradient of the landfill. The FBWAC has been reviewing the ongoing arsenic investigation to evaluate the potential for arsenic impacts to the watershed and water supply.

10.2 Scope of Work

Over the last year, members of the committee have attended Public Involvement Process (PIP) meetings (conducted by Camp Dresser and Mckee (CDM)) at which investigation plans and results have been presented, and the committee has reviewed periodic reports of findings. The summary of results presented below was largely taken from the September 2008 Report by CDM entitled: "Ledge Road Landfill, Supplemental Comprehensive Site Assessment (CSA) – Arsenic Investigation".

10.3 Results

A Supplemental Comprehensive Site Assessment completed in 2008 included additional sampling of sediment, surface water and groundwater for arsenic impacts. Results included:

- The extent of arsenic impacted sediment is approximately 13 acres, primarily in the top 6-inches, and limited to stream channels and wetlands. Background concentrations range up to 20 ppm. The furthest downgradient extent of arsenic in sediment above background levels was approximately 500 ft west of I-93. This location is in a tributary to Fish Brook approximately 200 to 300 feet west of Fish Brook.

- Elevated arsenic was detected in surface water downgradient of the landfill, however, concentrations in surface water west of I-93 were below 5 parts per billion (ppb). The current drinking water standard is 10ppb.

- Arsenic concentrations exceeding the drinking water standard (10 ppb) have consistently been detected in shallow and deep groundwater wells immediately downgradient of the landfill. Elevated arsenic has been detected in shallow groundwater in wells installed during the Supplemental CSA. Elevated arsenic in groundwater appears to be limited to the area between the landfill and I-93 with a maximum concentration of 243 ppb. Groundwater and sediment data indicates that arsenic impacted groundwater is originating from the landfill and moving in a southwesterly direction.

- Arsenic has never been detected above the drinking water standard at the Andover Water Treatment Plant intake.

- No private or public drinking water wells have been affected.

- Arsenic bearing soils exist in areas upgradient of existing wells and may be a source of arsenic to groundwater due to reduced groundwater conditions caused by the breakdown of organic landfill waste. Reduced groundwater (low in oxygen) can lead to mobilization of naturally occurring arsenic and iron resulting in aqueous phase elevated arsenic and iron. When impacted groundwater discharges to wetlands, arsenic and iron precipitate resulting in sediment contamination. These sediments can then migrate within the surface water.

- An Imminent Hazard (IH) Evaluation was conducted under the MCP and showed a potential IH condition for sediment. This IH condition was based on areas in which sediment arsenic values exceed 300 mg/kg and exposure to these sediments could persist for a 5-year duration. In response, signage and gates were placed at the Site as part of an Immediate Response Action (IRA).

- A preliminary evaluation of the health of the wetland was conducted. Results indicated the wetlands are of high quality supporting a variety of wetland and water associated plants and animals, however, additional assessment is required.

The supplemental CSA recommended conducting a Human Health and Ecological Risk Assessment as required by regulations. The purpose of this assessment was to help derive a risk based clean-up standard for the Site and develop strategies remediation of arsenic in sediment and groundwater. These studies will be documented in a Corrective Action Alternatives Analysis (CAAA) Report under the Solid Waste Management Regulations (310 CMR 19.000). The site will continue to be monitored in 2009.

10.4 Recommendations

Elevated arsenic is present in stream sediments west of I-93 within the Fish Brook Watershed. Although elevated arsenic in groundwater has not been detected west of I-93, it should be noted that there is only one well (PZ-2) located west of I-93 and it is a shallow well only intercepting the upper few feet of the saturated zone. The next closest well (PZ-1) is located approximately 700 feet east of I-93 and had 62 ppb of arsenic in April 2008. Therefore, the committee recommends continued monitoring of ongoing investigations, risk assessment results and remedial action alternatives for the Site.

11

Section Eleven

Section 11 - Conclusions and Recommendations

This report presents a summary of eight initiatives undertaken by the FBWAC, including a review of each initiative's purpose, and the scope of work performed by the committee. Detailed conclusions and recommendations for each initiative are presented in the individual sections of the report. The most significant recommendations developed by the FBWAC are as follows:

1. FBWAC recommends that ongoing Fish Brook water quality monitoring continue indefinitely. The ongoing monitoring is an automated process using the Fish Brook gauging station installed under supervision of the FBWAC. It is further recommended that the data be downloaded from the gauging station data-logger quarterly, and analyzed to evaluate long-term trends in Fish Brook water quality and flow. A working group should be established to complete the recommended data analysis.

2. FBWAC recommends that the Town continue to seek relocation of the MDOT Salt Shed to the River Road interchange on Interstate Highway 93. Responsibility for continued negotiation with MDOT should be assigned to the Andover Health Director.

3. FBWAC recommends that the Town of Andover develop a low-salt application program for Town-maintained roads within the Fish Brook watershed. The policy should include use of alternative de-icing chemicals where applicable, low-salt applications in environmentally sensitive areas, and personnel training in best management practices.

A Appendix

LIMITED SUBSURFACE INVESTIGATIONS

Haggatts Pond Reservoir

Andover, Massachusetts

I. INTRODUCTION AND PROGRAM SUMMARY

On May 11, 2009, Pine & Swallow Environmental (P&S) conducted limited subsurface investigations of the Haggatts Pond Reservoir site. The purpose of P&S's effort was to assist Town of Andover in assessing groundwater conditions at the site. Details of equipment and procedures for MicroWell® installation are enclosed.

Program Summary

P&S installed three MicroWells. Two of the wells were sequentially sampled to permit vertical profiling of groundwater quality. Four groundwater samples were relinquished to Town of Andover field personnel.

All installation and sampling locations were chosen by Town of Andover field personnel.

® MicroWell and VibraDrill are registered trademarks of Pine & Swallow Environmental

II. FIELD INVESTIGATION METHODS AND PROCEDURES

GROUNDWATER INVESTIGATION

MicroWell Installation Equipment and Methods

P&S's study included installation of MicroWells for groundwater sampling and water level measurements. MicroWells consist of 0.84-inch, 1.3-inch or 1.9-inch O.D. steam-cleaned steel pipe whose leading end is fitted with a drive point. Screens, manufactured from the same material, consist of a double row of longitudinal slots 0.015-inch wide on the half-inch pipe. Screens in 1.3-inch or 1.9-inch pipe may consist of double rows of longitudinal slots 0.015-inch wide. In all cases, each slot is two inches long and is separated from the next slot by 1/4-inch of unslotted pipe.

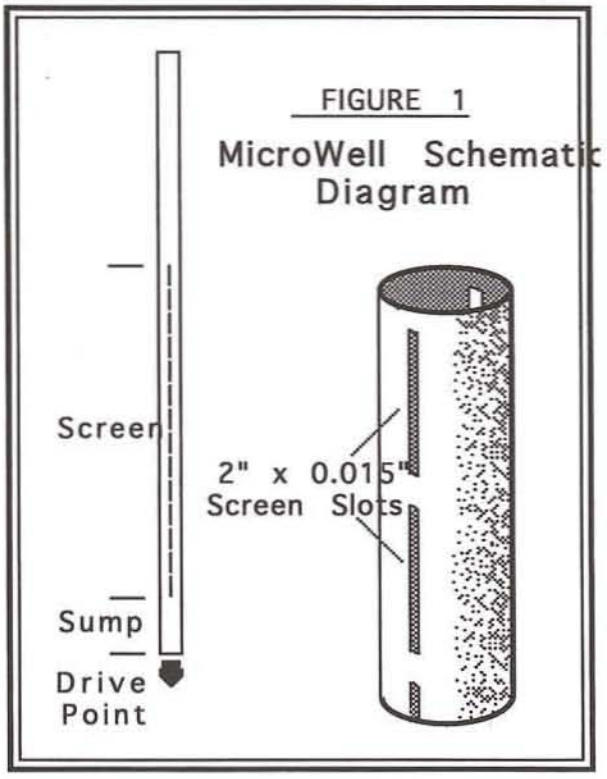


FIGURE 1
MicroWell Schematic Diagram

MicroWells are installed by a high frequency vibratory hammer mounted on a VibraDrill® all terrain drilling machine. VibraDrills are capable of driving 12-foot sections or 21-foot sections of pipe depending upon the model; to drive deeper, additional sections of riser pipe are welded or crimped on by means of an external steel collar.

Immediately after driving is completed a water level measurement is taken with a Slope Indicator water level meter. Wells are then developed with an inertial pump to remove silt and fine sand that has entered through screen slots. Pumping continues until discharge water is free of sediment wherever possible. Samples from MicroWells for VOC analysis are obtained in lab-clean 40mL vials with septum screw caps using new polyethylene tubing dedicated to each well and sampling interval and following P&S

sampling protocols. All re-usable sampling equipment is decontaminated between locations by rinsing with methanol and distilled water.

Sequential sampling is performed by driving the well screen to a predetermined depth and collecting a sample following P&S's standard sampling procedures. A section of riser pipe is then connected, the well driven to the next sampling interval and a subsequent sample taken. At each sampling level, at least three well volumes are removed from the well prior to sampling. Samples are collected in lab-clean 40mL vials using new polyethylene tubing dedicated to each sampling level. Pump valves are decontaminated with methanol and rinsed with distilled water between samples.

MicroWell Program

A total of three MicroWells constructed of 1.32-inch steel pipe, with ten-foot screens, were installed at this site by P&S's VibraDrill H641 at locations chosen by Town of Andover field personnel. Two MicroWells were installed to depths of 17.5, and 13.5, feet BGS and were sequentially sampled. One well was installed as a couplet to the sequentially sampled well FBMW-4. Installations were completed with a stickup and locking cap. MicroWell logs are included in the Appendix.

Wells were sampled with an inertial pump according to P&S's Standard Operating Procedures. Sequential sampling was performed at two of the MicroWells at ten-foot intervals. Three groundwater samples and one wetland sample were field screeened with a calibrated Horrriba U-10 water quality meter for dissolved oxygen, pH, temperature, and conductivity. The field screening data is provided in the Appendix.

Three groundwater samples were relinquished to Town of Andover field personnel.

This report is submitted subject to the limitations stated in the Appendix.

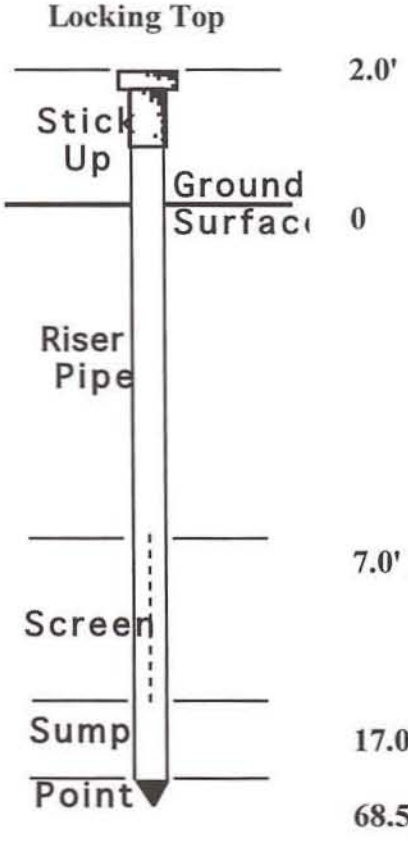
MicroWell® Installation Log

FBMW-4A

Project Name: Town of Andover	**Date:** 5/11/09
PSA Project Number: 07253	**Equipment:** VD H641
Location:	**PSA Personnel:** MC
Pipe ID: 1.05", **Pipe OD:** 1.32" **Screen Slot Width:** 0.015"	**W.L.:** 4.3' BGS, (may not be stabilized)

Well Schematic

(not to scale)



Refusal: Yes

Sampling Information

Sample ID	Screened Interval
FBMW-4AA	0-10.0 feet BGS
FBMW-2AB	7.0-17.0 feet BGS

GPS N 42° 39' 34.7"
W 071° 11' 42.7"

Materials

Unscreened Pipe:	**9.5 feet**	**Additional Tubing:**	**25 feet**
Screen Length:	**10 feet**	**Additional Vials:**	**0**
Points:	**1**	**Bailers:**	**0**
Finish:	**Locking Top**		

Pine & Swallow Environmental

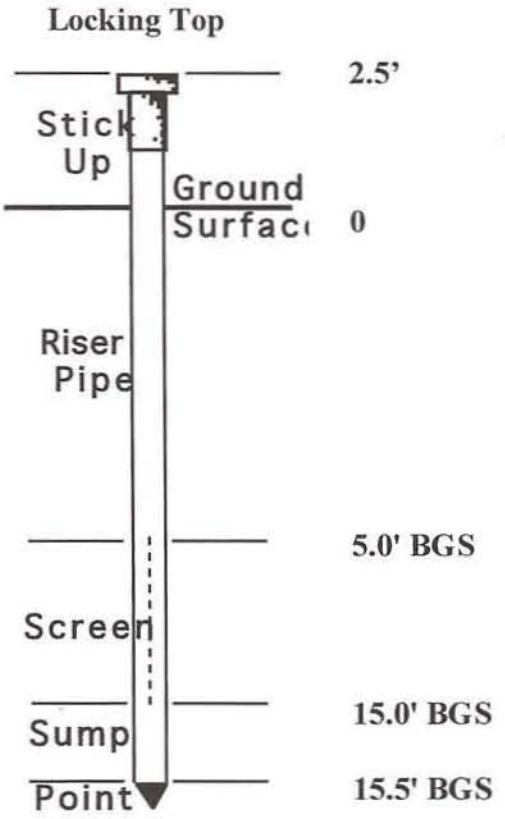
MicroWell® Installation Log

FBMW-4B

Project Name: Town of Andover	**Date:** 5/11/09
PSA Project Number: 07253	**Equipment:** VD H641
Location:	**PSA Personnel:** MC
Pipe ID: 1.05", **Pipe OD:** 1.32" **Screen Slot Width:** 0.015"	**W.L.:** 4.3' BGS, (may not be stabilized)

Well Schematic

(not to scale)



Refusal: No

Comments Couplet to FBMW-4A.

Materials

Unscreened Pipe:	**8 feet**	**Additional Tubing:**	**0 feet**
Screen Length:	**10 feet**	**Additional Vials:**	**0**
Points:	**1**	**Bailers:**	**0**
Finish:	**Locking Top**		

Pine & Swallow Environmental

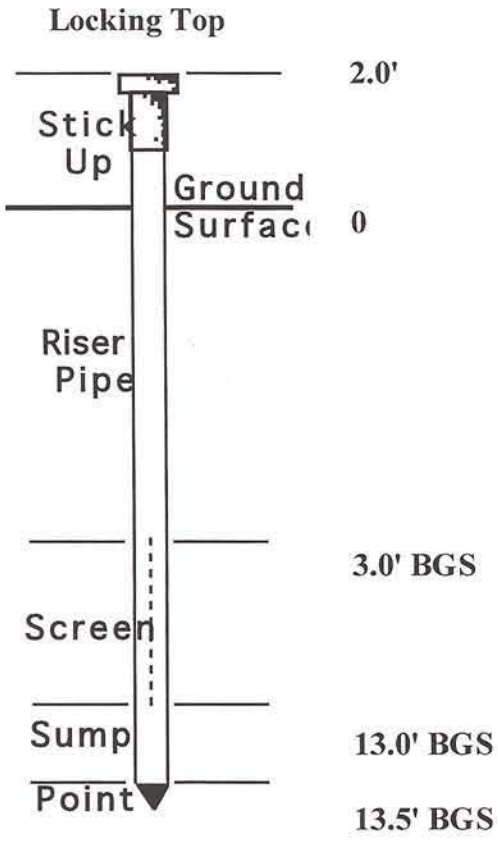
MicroWell® Installation Log

FBMW-5

Project Name: Town of Andover	**Date:** 3/25/08
PSA Project Number: 07253	**Equipment:** VD H641
Location:	**PSA Personnel:** MC
Pipe ID: 1.05", **Pipe OD:** 1.32" **Screen Slot Width:** 0.015"	**W.L.:** 8.2' BGS, (may not be stabilized)

Well Schematic

(not to scale)



Refusal: Yes

Sampling Information

Sample ID	Screened Interval
FBMW-5A	0-10.0 feet BGS
FBMW-5B	3.0-13.0 feet BGS

GPS N 42° 39' 34.9"
W 071° 11' 45.6"

Materials

Unscreened Pipe:	**5.5 feet**	**Additional Tubing:**	**0 feet**
Screen Length:	**10 feet**	**Additional Vials:**	**0**
Points:	**1**	**Bailers:**	**0**
Finish:	**Locking Top**		

Pine & Swallow Environmental

Pine&Swallow
ENVIRONMENTAL

Vertical Profiling • Direct Push Drilling • Mobile Laboratory • Soil Vapor Surveys • High Pressure Injection

Project: 07253/Town of Andover
Date: March 25, 2008, May 11, 2009

Groundwater Field Screening Results

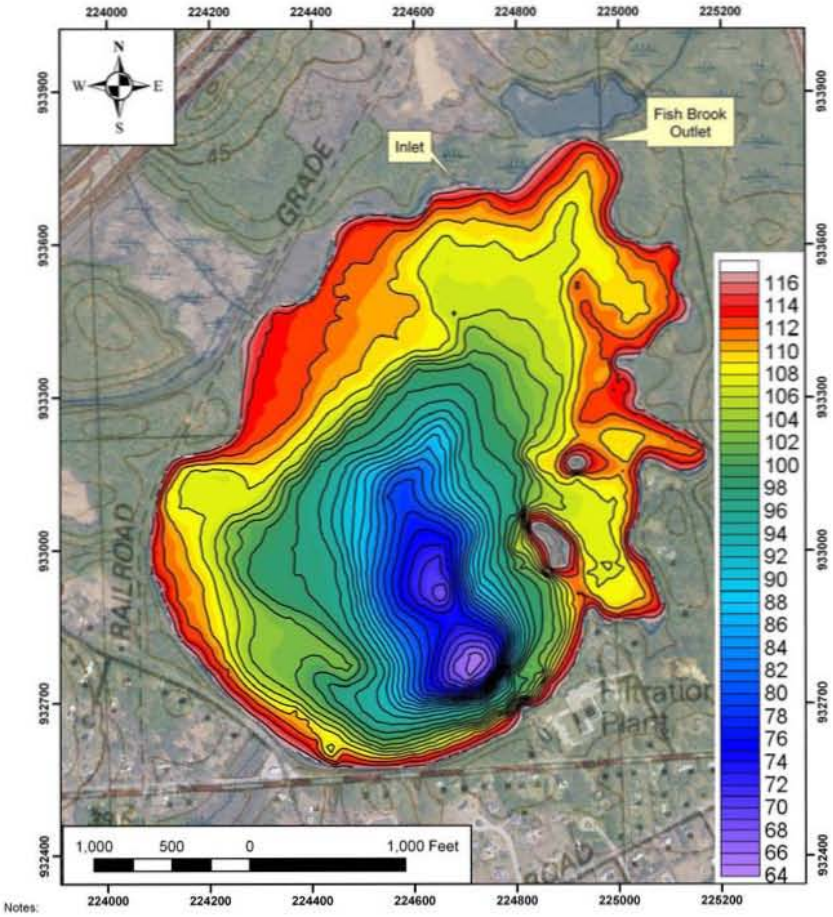
Well ID	Sample Interval	WL before Sampling	WL after purge/ Sample	WL after 2 mins of Sampling	Turbidity	DO %	pH	Temp C	Conductivity (units) ms/cm[c]
FBMW-7	0-9.0'	3.0'	dewatered	8.0'	High	112.8	6.92	6.24	2.714
FBMW-2	0-8.0'	2.8'	2.8'	2.8'	High	40.0	4.42	6.7	0.421
	8.0'-18.0'	4.0'	5.6'	5.3'	High	6.0	5.08	8.52	0.381
	18.0'-28.0'	6.9'	6.2'	6.2'	High	24.0	5.06	8.75	0.450
	28.0'-38.0'	8.7'	8.4'	8.1'	High	68.0	5.43	9.76	1.136
	38.0'-48.0'	9.2'	9.8'	9.2'	High	63.3	5.90	9.68	0.812
	48.0'-58.0'	13.2'	13.9'	13.0'	High	64.2	6.08	9.49	0.544
	58.0'-68.0'	13.6'	13.8'	10.2'	High	60.0	5.86	9.7	0.910
May 11, 2009									
FBMW-4	0-10.0'	8.7	dewatered	8.7	High	88.2	5.41	11.45	3.879
	7.0-17.0'	2.8	2.4	2.4	High	21.9	5.16	9.52	1.985
FBMW-5	0-10.0'	8.2	9.1	8.8	High	8.4	6.69	14.69	0.856
	3.0-13.0'	7.8	10.2	7.8	High	56.2	6.47	12.72	0.617
Wetland						47.1	6.01	18.7	1.415

867 Boston Road, Groton, MA 01450 Tel: 978-448-9511 Fax: 978-448-6645 www.pineandswallow.com

B

Appendix

GEOPHYSICAL AND WATER QUALITY SURVEYS
HAGGETTS POND
ANDOVER, MASSACUSETTS



Bathymetric Contour Map of Haggetts Pond

Prepared by:

CR Environmental, Inc.
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Prepared for:

The Fish Brook Watershed Advisory Committee
and
Town of Andover
Water Treatment Plant
397 Lowell Street
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January 2008

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1.0 INTRODUCTION

CR Environmental, Inc. (CR) performed hydrographic, geophysical and water quality surveys of Haggetts Pond in Andover, Massachusetts on October 17 and 18, 2007 for the Fish Brook Watershed Advisory Committee (FBWAC). The surveys were designed to identify zones of elevated salinity in the pond, with the primary goal of identifying regions of high-conductivity groundwater discharge; and to better define the basin morphology, volume and hypsography for the Town of Andover Department of Public Works (DPW).

Components of the survey included single-beam bathymetry, sub-bottom sonar profiling and mapping of water column and lakebed temperature and specific conductivity. The initial survey design also called for acquisition of flow velocity and vector data using an acoustic Doppler profiling (ADP) instrument. However, based on field observations of low velocity even at the aqueduct inlet made during the first day of the survey, and shorter than anticipated daylight hours, the decision was made with Ms. Vaughn (DPW) and Mr. Adilman (FBWAC) to eliminate the ADP survey in favor of an increased density of water column profiles.

This report summarizes the methods used for data acquisition and the results obtained. All of the survey data has been provided digitally to the Town of Andover on a project DVD. Where applicable, data have been projected to the Massachusetts Mainland State Plane, NAD83 (metric).

2.0 HAGGETTS POND HYDROLOGY

Figure 1 depicts a Digital Elevation Model of Haggetts Pond created from USGS topographic data and CR's bathymetric data. The model utilizes artificial illumination and slight vertical exaggeration to show the pond's position in the drainage basin relative to important hydrologic features. The Pond lies within the headwaters of Fish Brook, with a full pool shoreline elevation of 117.5 feet reported by the DPW. The sole outlet of the Pond is located at its northernmost extent (see Figures 1 and 2A). The Pond is frequently perched several tenths of feet above the surrounding northern wetlands, apparently as a result of levee building activities by both humans and beavers.

The wetlands surrounding the outlet consist predominantly of red maple swamp. The outlet flow passes over a short beaver dam into an approximately 4.5 acre deep flooded marsh (beaver pond, see Figure 2A). Water exits the northeastern corner of the marsh and flows approximately 1,100 feet until it merges with the main channel of Fish Brook. At

this point the elevation of Fish Brook is approximately 115 feet (based on interpretation of USGS topographic data). The brook flows for approximately 1,280 feet to the northwest through shallow marsh and deciduous wooded swamp until it intersects High Plain Road. After passing under the road, the brook flows to the northwest for approximately 260 feet where it intersects Interstate Route 495. The approximate bank elevation of the brook after passing under Route 495 is not discernibly lower than it is immediately below the Pond's outlet (based on USGS data), highlighting the very low gradient of this reach. At this point, the brook is closest to the salt storage facility i.e. approximately 1,800 feet to the Northeast.

Fish Brook continues to meander through swamp and marsh habitats in a generally northerly direction parallel to Interstate Route 93 for approximately 2,900 feet, then it's gradient sharply increases and the course becomes strongly channelized. The bank elevation drops from approximately 113 feet to 85 feet over the next 3,200 foot reach (see Figure 1). The brook then resumes it's northwesterly course and low gradient for the next 4,900 feet until it intersects a small impoundment approximately 250 feet upstream (south) of River Road (see Figure 2B). The brook becomes channelized below this structure and flows to the north-northwest until it reaches the Fish Brook Pumping Station Dam approximately 3,200 feet downstream of River Road. The bank elevation above this impoundment is approximately 50 feet.

The DPW pumps water from this impoundment through a 24-inch aqueduct back into Haggetts Pond. During periods of high water demand or low flow in Fish Brook, water from the Merrimack River is used to augment the water supply (Town of Andover FBI, 2006). Monitoring data collected by FBWAC and others shows that the specific conductance and salinity of Fish Brook sharply increase after the Brook passes under Route 93 (TOA FBI, 2006) (see Figure 1).

3.0 METHODS

The geophysical surveys were designed to allow the simultaneous acquisition of data from each sensor, while meeting the hydrographic survey standards promulgated by the U.S. Army Corps of Engineers (USACE, EM-1110-2-1003). Survey transects were designed using HYPACK hydrographic survey software. Background imagery including a georeferenced orthophoto and USGS Quadrangles were obtained from MA GIS. These data were imported to HYPACK to guide the survey design. Survey transects were established using a 100 ft (on-center) line spacing augmented by several perpendicular lines used for Quality Control.

The two man CR survey crew consisted of a senior hydrographer/field scientist and a U.S. Coast Guard licensed captain. The survey operation was performed from a 14 ft aluminum survey vessel with a 10 Hp 4 cycle outboard motor, instrument enclosure, over the side transducer mount, and 12 volt power supplies

Navigation for each aspect of the survey was accomplished using a Trimble AgGPS 132 12-channel Differential Global Positioning System (DGPS) system capable of receiving the U.S. Coast Guard (USCG) Beacon corrections as well as OmniStar subscription-based satellite differential corrections. The system is capable of sub-meter horizontal position accuracy. The DGPS system was interfaced to a laptop computer running HYPACK MAX hydrographic survey software. HYPACK recorded vessel position, water depth, all parameters collected by the YSI water quality sonde, and provided a steering display for the vessel captain.

3.1 Bathymetric Data Acquisition & Processing

Acquisition

The bathymetric data acquisition system consisted of laptop computer running HYPACK hydrographic survey software, a precision single-beam echosounder and a Trimble DGPS. The echosounder and DGPS were interfaced to the survey computer via RS-232 serial ports.

Depth measurements were collected using a SyQwest, Inc. HydroBox precision echosounder equipped with an 8-degree 200-kHz transducer. The echosounder accurately digitized and recorded the lakebed in proprietary *.odc format (a variant of SEGY) and exported depth values to HYPACK data acquisition software. Dynamic adjustments to signal gain and range were made as necessary to ensure high quality data. The echosounder transducer was mounted to the rail of the survey vessel amidships using one of CR's high-strength adjustable booms. The DGPS antenna was attached to the top of the transducer boom. The transducer depth below water surface was checked and recorded at the start and end of the survey.

The accuracy of the HydroBox is approximately 0.1% of the water depth with a resolution of 0.1 ft. System accuracy was checked at the start and end of the survey day by comparing echosounder water depth measurements to known water depths. Known water depths were obtained using the "bar check" method, in which a metal plate was lowered beneath the echosounder's transducer to several known distances (e.g., 5.0, 10.0, 15.0 and 20.0 ft) below the water surface. Based on these comparisons, the echosounder

was calibrated for shallow water conditions. “Bar-check” calibrations were consistently accurate to within 0.1 ft throughout the survey.

Additional calibrations were conducted in situ by collecting water column profiles of sound velocity. Sound velocity in water can be determined based on measurements of temperature and salinity. Measurements of water column temperature and salinity were performed using a YSI 6600 water quality profiler. Profile data were entered into HYPACK and were used to adjust raw soundings.

Processing

Bathymetric data were processed using the HYPACK Processor Module. Individual transect data were visually inspected in profile format, and components of processing included removal of outlying soundings associated with water column interference (e.g., fish, vegetation, or mid-water column debris), adjustments of soundings for variations in sound velocity, and conversion of soundings to elevations based on water level data provided by DPW. The water level during the survey was reported as 117.05 feet.

After performing data adjustments, the processed bathymetric data were combined into a single comma-delimited ASCII text file including fields for Northing, Easting, and Elevation. High-resolution digital orthophotos of the basin were obtained from MA GIS and imported to ArcMap GIS software. The shoreline of the pond, including two small islands, was digitized yielding 266 points. These points were assigned a full-pool elevation of 117.5 feet and merged with the sounding database to allow interpolation between the shoreline and the nearest depth measurement. The data were then imported to Golden Software, Inc. Surfer V.8.1 Surface Modeling Software and a grid of lakebed elevations was created using Kriging interpolation methods and a 10 meter node interval. A contour map depicting bottom elevations using a 1 foot contour interval was created from this grid and the map was exported in SHP and DXF formats. A second layer was created using conventional hydrographic spectrum shading and was exported as a georeferenced TIF image file.

Hypsographic calculations of volume planar area and benthic surface area were conducted using the 10-meter grid. Calculated values included: full-pool (117.5 feet); 117 to 108 feet (1-foot increments); 108 to 100 feet (2-foot increments); and 100 to 65 feet (5-foot increments).

3.2 Sub-Bottom Profiler Data Acquisition and Processing

Acquisition

Sub-bottom sonar data were collected simultaneously along the same set of survey transects used for the bathymetric survey. Data were collected using a SyQwest 10-kHz Stratabox sub-bottom profiling system. This system consists of a cone-shaped transducer mounted to a vertical boom on the amidships rail, an on-board signal processor and amplifier, and a data acquisition computer. Data were recorded in .odc format using proprietary StrataBox software running on a dedicated laptop computer. The computer was interfaced to the DGPS through a serial port. Offsets between the transducer and the DGPS antenna were recorded to allow position correction during data processing.

Processing

Stratabox 10 kHz profile data were processed using Chesapeake Technology's SonarWeb software. Appropriate adjustments to TVG were made during processing. Sub-bottom profiles were exported in JPG format with accompanying HTML-navigable indices and GIS shapefiles (polygons) of transect navigation data, with the width of the polygons corresponding to sonar range settings. The sediment surface and deepest reflector visible (referred to as the "acoustic basement") were digitized and exported in an ASCII database consisting of Northing, Easting and thickness values. This database was used to create a map representing *minimum* sediment thickness. Sample profiles were selected and annotated to illustrate data quality, penetration and near-surface geology.

3.3 Conductivity & Temperature Surveys

Parameters of specific interest included specific conductivity (SpC) and temperature (T). Near bottom T anomalies were judged to be robust potential indicators of groundwater discharge zones. SpC was considered to be a strong indicator of salt contamination. Lab tests conducted by DPW and others quantify the strong linear relationship between specific conductivity and salt (NaCl) in a deionized water solution. We note that similar relationships likely exist for alum (aluminum sulfate), a byproduct of water treatment which is disposed of in the pond near the treatment plant on the southeastern shore of the pond through a 14-inch "washwater" pipe (Figure 1).

Acquisition

A YSI, Inc. Model 6600 EDS V2 Multiparameter sonde was utilized for measurement of T and SpC due to its compact size, relatively rugged housing (especially when mounted in CR's custom stainless steel oceanographic cage), and ability to export 2-Hz measurements to HYPACK software. Each instrument scan was thus stamped with an accurate DGPS position. The conductivity sensor mounted on the sonde was calibrated before the survey.

Two methods of sonde deployment were conducted. On the morning of October 18, the sonde was deployed in a towed fashion with sensors oriented parallel to the lake bottom, and kept as close to the sediment surface as possible while avoiding unnecessary damage or equipment loss. Debris tangled the sonde several times during the survey, but no lasting damage was done to the instrument. Survey speeds were kept as slow as possible in order to retain spatial precision in the measurements, and complete the towed portion of survey in a reasonable time. Per discussion with FBWAC members, the towed survey focused on the northern ~1/3 of the basin. We also deployed the sonde for a near-shore circumnavigation of the entire basin.

Following the towed deployment, a second survey was conducted using the instrument to perform vertical profiles of the water column. A rough grid of the basin was constructed and data were recorded while the instrument was slowly lowered to the bottom. One hundred and two (102) profiles ("casts") were conducted before the loss of daylight.

Processing

HYPACK editing software was used to process the raw data files. For towed data, the program allowed review and editing of the two YSI parameters (T, SpC) simultaneously. Temperature and conductivity data were examined to identify and remove outlying points caused by impacting the sediment surface or the water surface. All processed data for the towed deployment were converted into delimited ASCII text files with Easting, Northing, Z1 and Z2 fields (i.e., X, Y, T, SpC).

SpC and T data from the profiling effort were processed separately due to HYPACK's two-parameter limit and the need to match each value with a water depth measurement. Two MS Excel worksheets of SpC and T data were prepared.

Both towed and profile data were imported into Golden Software's Surfer v8.1, which was used to produce Kriged grids of each parameter. Contour lines and colored

georeferenced TIF files were produced from the grids with contour intervals appropriate to each parameter. The contours and TIF's were exported to ArcMAP 9.2 GIS software for overlaying of orthographic photos and figure production. Digital copies of the processed data and the figures have been included on the Project DVD

4.0 RESULTS

DPW reported the Haggetts Pond's influent aqueduct pump rate was 10 million gallons per day (MGD) during the survey, and simultaneous withdrawal for distribution was 7 MGD. The majority of water was believed to originate from the Merrimack River. Water was observed flowing out of the Pond's outlet and the water elevation in the pond was observed to be several tenths of a foot higher than in the marsh or wetlands surrounding the outlet. These pump rates and observations suggest that the true static full-pool elevation is somewhat lower than the elevation of 117.05 feet recorded during the survey and the 117.5 foot elevation used to calculate basin hypsography (volume and area relationships). The data also suggest that the basin might have had a substantial head relative to the surrounding watershed and groundwater sources.

4.1 Bathymetry – Hypsography

The minimum recorded elevation of the lakebed was 65.05 feet (i.e., maximum depth = 52.45 feet) (see Figure 3). The mean elevation was 103.2 feet (i.e., average depth = 14.3 feet). The full-pool volume of the pond was calculated as 1,027.7 million gallons (see Table 1). Approximately 50 percent of the Pond's volume is located between El. 117.5 and 109 (see Figure 4).

The basin possesses interesting features judged to be relicts of pre-PWS flow patterns. The morphometry of the lakebed near the outlet, above El. 108, clearly suggests a native southerly flow towards the deeper southern portion of the basin. The remnants of a broader and less pronounced former stream channel, flowing towards the deep section of the pond is visible in the southwestern portion of the Pond. This feature is more clearly depicted in sub-bottom sonar data (see below – Figures 6 and 7).

4.2 Sub-Bottom Sonography and Sediment Distribution

The sub-bottom sonar system successfully penetrated as much as 20 feet of sediment (see Figures 5 through 7). Penetration was greatest in the deeper portions of the basin (see Figure 5). The data suggest the presence of fine acoustically transparent sediment over 80 acres of the lake bed. The average depth to acoustic basement (i.e., minimum sediment

thickness) was estimated as 5.7 feet. However, it appears likely that natural gases entrained in the sediments may have limited penetration in substantial portions of the basin. Sub-bottom sonar data seems to confirm visual observations that the surficial substrate of the majority of the littoral and immediately sub-littoral zones is composed of sand, gravel and coarser substrates.

As previously noted, the sub-bottom sonar and bathymetric data suggest the presence of buried stream channels (see Figure 7). The apparent bank elevation of the channel depicted in Figure 7 and the morphological features described in the bathymetric dataset suggest a pre-PWS water surface elevation at least 10 feet lower than the currently maintained +/- 117.5 feet.

4.3 Conductivity and Temperature Surveys

4.31 Towed Data

The towed sonde database includes 9,248 point measurements (see Figures 8 and 9). The database is included on the Project DVD in an MS Excel workbook. Near-bottom SpC in this database ranged from 0.21 mS/cm to 0.37 mS/cm (average = 0.252 mS/cm). Temperature ranged from 7.92^{o} C to 16.36^{o} C (average = 15.67^{o} C).

Contour maps of near-bottom temperature and specific conductivity were created for the northern portion of the basin. The map of SpC (Figure 8) clearly indicates a distinct flow pattern for inlet water. The low conductivity signature (~ 0.21 mS/cm) originates at the inlet, then follows the northern shoreline towards the outlet, eventually dissipating as the water mass becomes diluted with “native” basin water. The map of inlet temperature does not reflect this flow pattern. Although inlet water appears colder than ambient basin water, this temperature signal is rapidly lost due to thermal mixing. Patterns in near-bottom temperature (Figure 9) appear to mimic bottom elevations. It is CR’s opinion that neither of the towed parameters suggested localized anomalous patterns indicative of groundwater discharge into the basin.

4.32 Vertical Profile Data

The vertical profile database includes 5,330 measurements from 102 profiles. The database consists of separate MS Excel worksheets for SpC and T. Data were evaluated by examining scatter plots and contour maps for outlying points or patterns. We evaluated and mapped the deepest SpC and T for each profile (i.e., lakebed conditions)

and the maximum SpC for each cast in order to minimize the likelihood of overlooking mid-water column anomalies.

The pond was strongly stratified during the surveys (Figure 10). Epilimnetic temperatures ranged from approximately 16.3^{o} C at the surface to 15° C at the metalimnetic interface approximately 28 feet deep. Temperatures dropped to about 8.6^{o} C at the upper hypolimnion and 7.7^{o} C at the deepest point of the lake. Temperature measurements at the lakebed reflect bathymetry (Figure 11). Specific conductance was relatively homogeneous in the epilimnion, generally 0.24 to 0.26 mS/cm (Figures 12 through 15). A single anomalous SpC profile was identified by examination of scatter plot data (Figure 13). This profile was located along the southern shoreline approximately adjacent to the washwater pipe. Water entering the pond at the inlet had much lower conductivity than ambient water, approximately 0.19 mS/cm. Profile SpC data show the same flow pattern near the inlet suggested by towed data, with apparent migration of the influent water towards the outlet and subsequent dilution and dispersal into the main basin (see Figures 14 and 15). Profile data show SpC measurements as high as 0.41 mS/cm in the deep hypolimnetic water adjacent to the treatment plant (see Figures 12, 14 and 15).

5.0 CONCLUSIONS & RECOMMENDATIONS

The bathymetric and sub-bottom sonar data from Haggetts Pond provide the spatial and morphological context required for interpretation of water quality data. A conductivity sensor interfaced to a precision DGPS system successfully detected a conductivity signal associated with the pond's inlet. While neither, temperature or conductivity data, indicated the presence of groundwater discharge zones, this absence may be associated with the artificially maintained high water surface elevation and/or with the season of the survey. Hypolimnetic conductivity is elevated adjacent to the Town's treatment plant on the southeastern shore of the pond. Additional chemical characterization of sediments and water would be necessary to determine the cause(s) of this condition. Analyses should include major cations/anions as well as aluminum to address the possibility that washwater alum discharge is associated with the elevated bottom water conductivity.

We suggest that additional conductivity profiling under different water regimes would likely increase knowledge of salt transport mechanisms in the pond. Specifically, data collected through the ice (if safe) and *immediately* following spring ice-out would best describe conditions during a high salt use season. Profiling and sampling during a summer period of low water (i.e., no discharge from the outlet) might better allow

identification of groundwater discharge zones due to a more pronounced difference between surface water and groundwater temperatures.

6.0 REFERENCES

Town of Andover, *Fish Brook Initiative Final Report*, 2006.

TABLES

TABLE 1

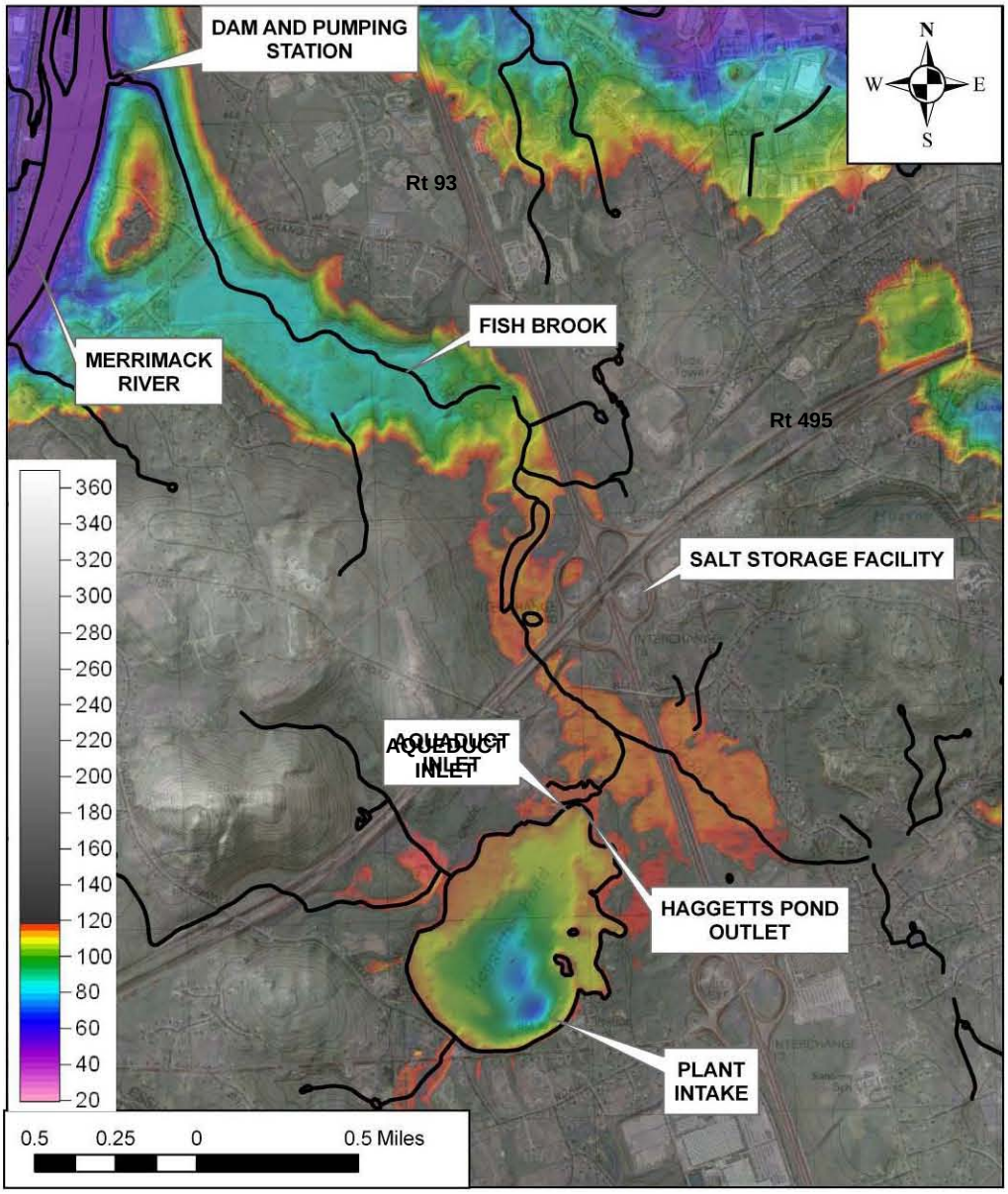
HAGGETTS POND HYPSOGRAPHY
Assumes Full Pool = 117.5 feet

Elevation	Volume (%)	Volume (MFeet^3)	MGallons	Planar Area (acres)	Surface Area (acres)
117.5	100.00%	137.4	1027.7	213.7	216.1
117	96.53%	132.6	992.1	213.2	215.6
116	89.72%	123.3	922.0	210.2	212.5
115	83.08%	114.1	853.8	205.7	208.0
114	76.63%	105.3	787.5	200.2	202.3
113	70.41%	96.7	723.6	191.7	193.7
112	64.53%	88.7	663.2	177.8	179.7
111	59.13%	81.2	607.7	163.4	165.2
110	54.17%	74.4	556.7	149.1	150.8
109	49.66%	68.2	510.4	135.4	137.0
108	45.56%	62.6	468.2	123.1	124.7
106	38.67%	53.1	397.4	98.3	99.6
104	32.77%	45.0	336.8	88.5	89.8
102	27.48%	37.8	282.4	77.5	78.7
100	22.89%	31.4	235.2	67.5	68.5
95	14.50%	19.9	149.0	40.4	41.3
90	9.08%	12.5	93.3	29.1	29.8
85	5.11%	7.0	52.5	21.2	21.7
80	2.31%	3.2	23.8	13.9	14.1
75	0.71%	1.0	7.3	6.7	6.8
70	0.11%	0.1	1.1	1.6	1.6
65	0.00%	0.0	0.0	0.0	0.0

FIGURES

FIGURE 1

Digital Elevation Model Showing Area of Interest Surrounding Haggetts Pond Andover, MA



Notes:

1. Bathymetric survey conducted by CR Environmental, Inc. on October 17, 2007 using a 200-kHz echo sounder and DGPS positioning.
2. Topographic elevations extracted from USGS data.
3. Grid: MA Mainland State Plane, NAD83, metric.
4. 5X vertical exaggeration.

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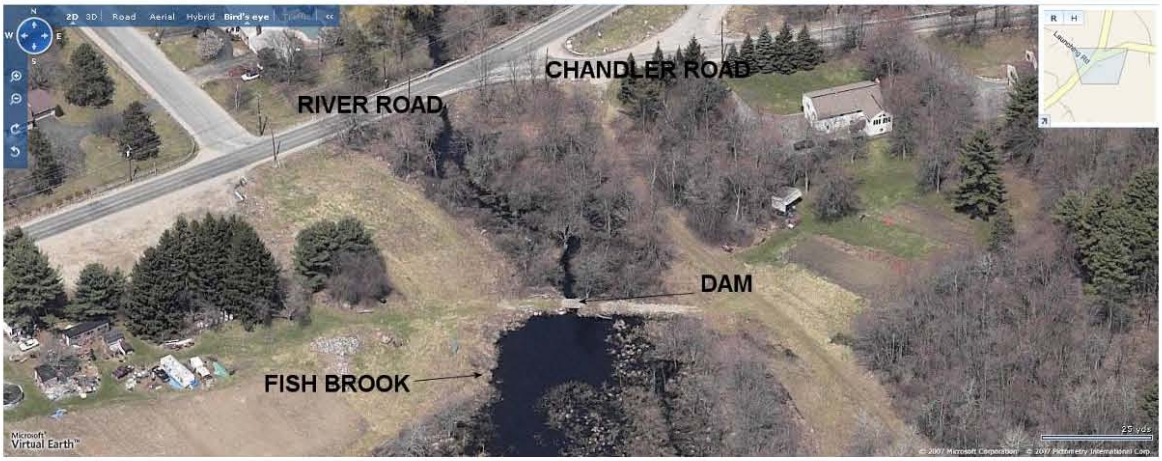
FIGURE 2

Fish Brook Impoundments

2A – Haggetts Pond Outlet

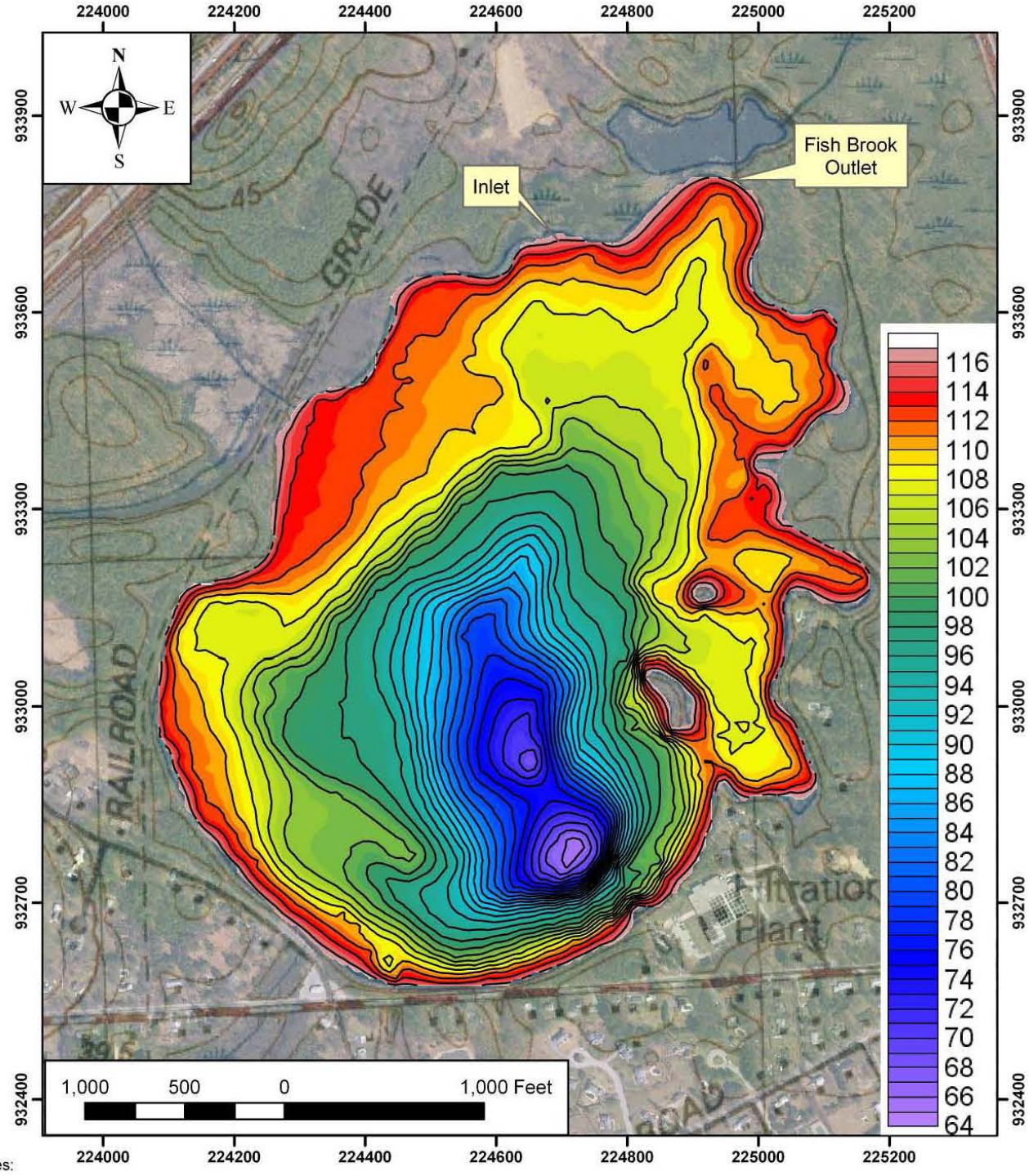


2B – River Road Impoundment

2C – Fish Brook Pumping Station

FIGURE 3

Bathymetric Contour Map Haggetts Pond
Andover, MA
(1.0 foot contour interval; 2 foot polyline)



Notes:

1. Survey conducted by CR Environmental, Inc. on October 17, 2007 using a 200-kHz echo sounder and DGPS positioning.
2. A shoreline elevation of 117.5 feet was assumed for contour interpolation to the shoreline.
3. Grid: MA Mainland State Plane, NAD83, metric.

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FIGURE 4

Haggetts Pond, Andover, MA
Elevation vs. Percent Volume

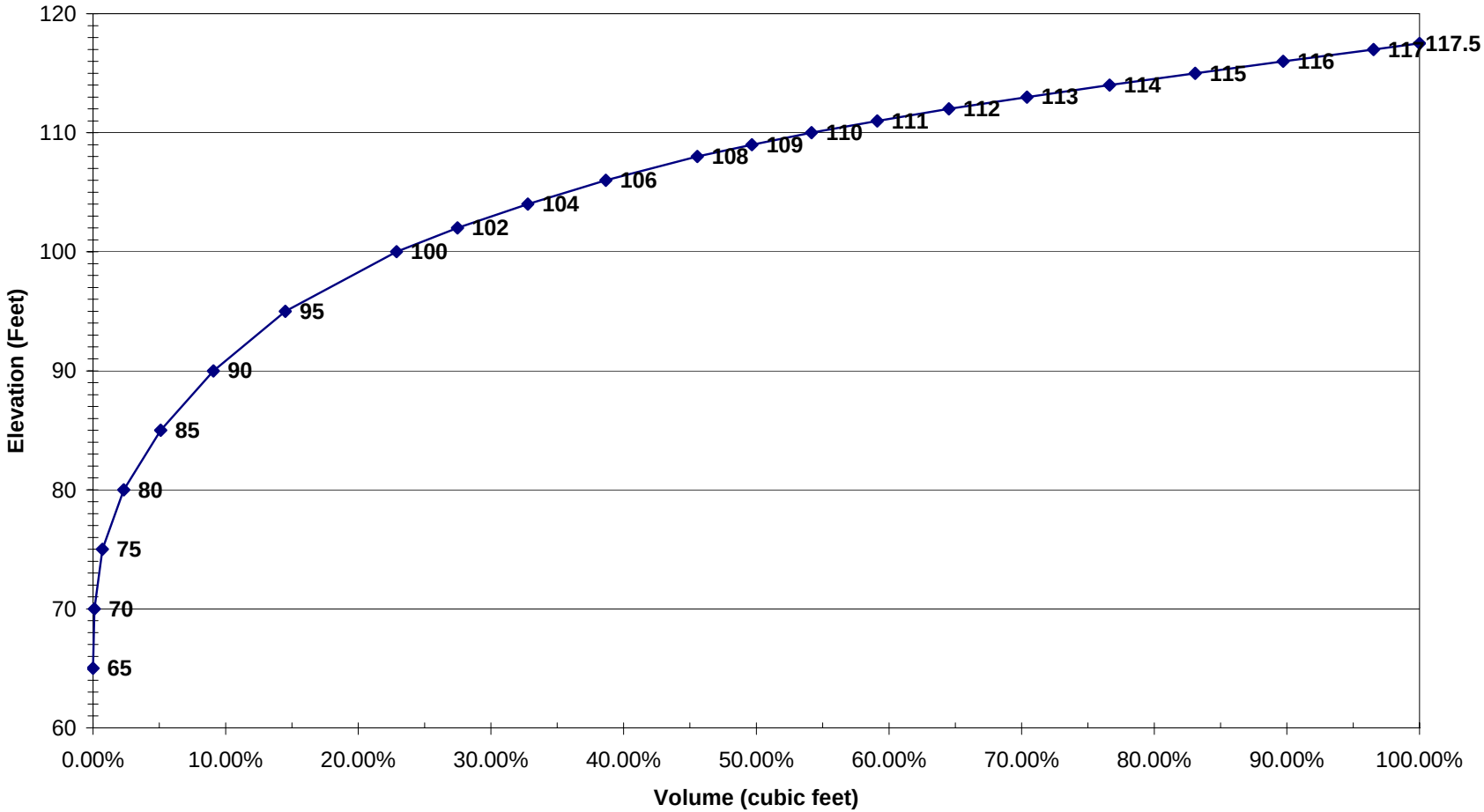
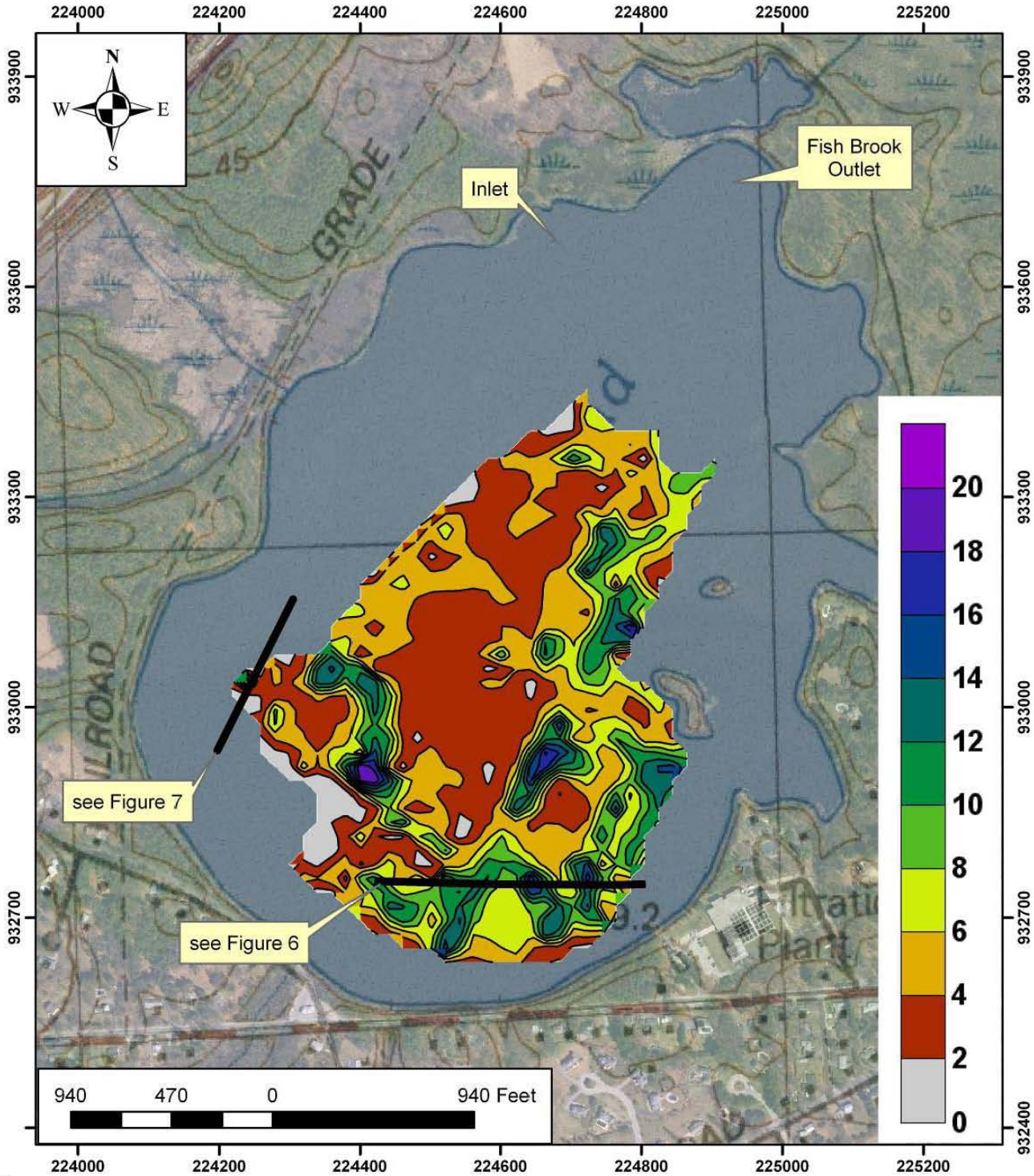


FIGURE 5

Areas of Acoustic Sediment Penetration
Haggetts Pond, Andover, MA
(2.0 foot contour interval)



Notes:

1. Survey conducted by CR Environmental, Inc. on October 17, 2007 using a 10-kHz profiling system and DGPS positioning.
2. Grid: MA Mainland State Plane, NAD83, metric.

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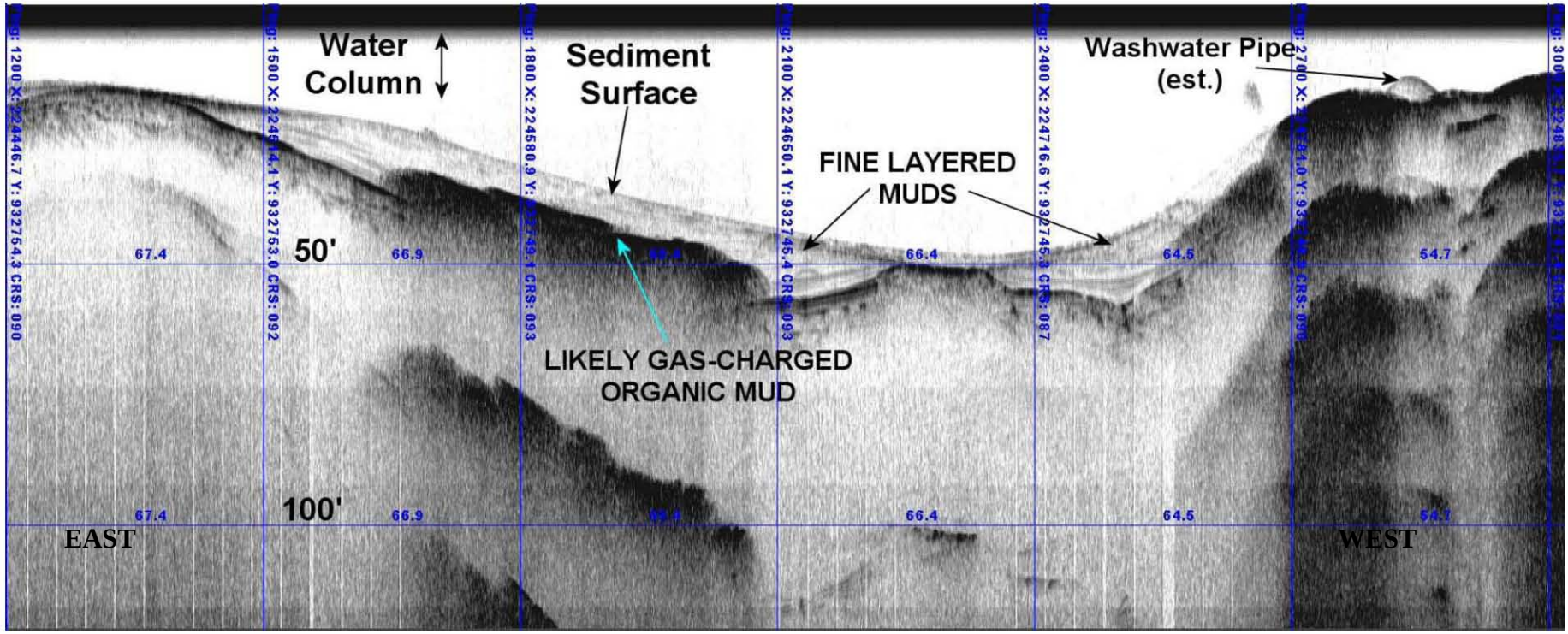
FIGURE 6

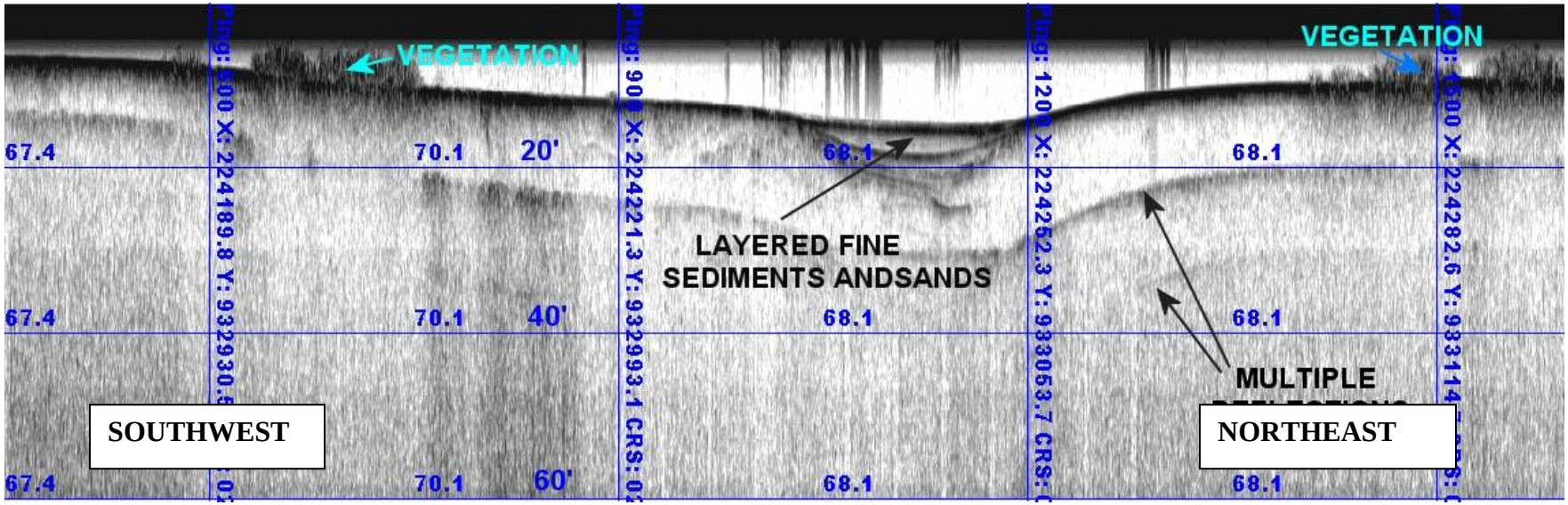
Sample of Sub-bottom Sonograph Showing Up To 16 Feet of Fine Sediment Adjacent to the Water Treatment Plant



(see Figure 5 for Profile location)

FIGURE 7

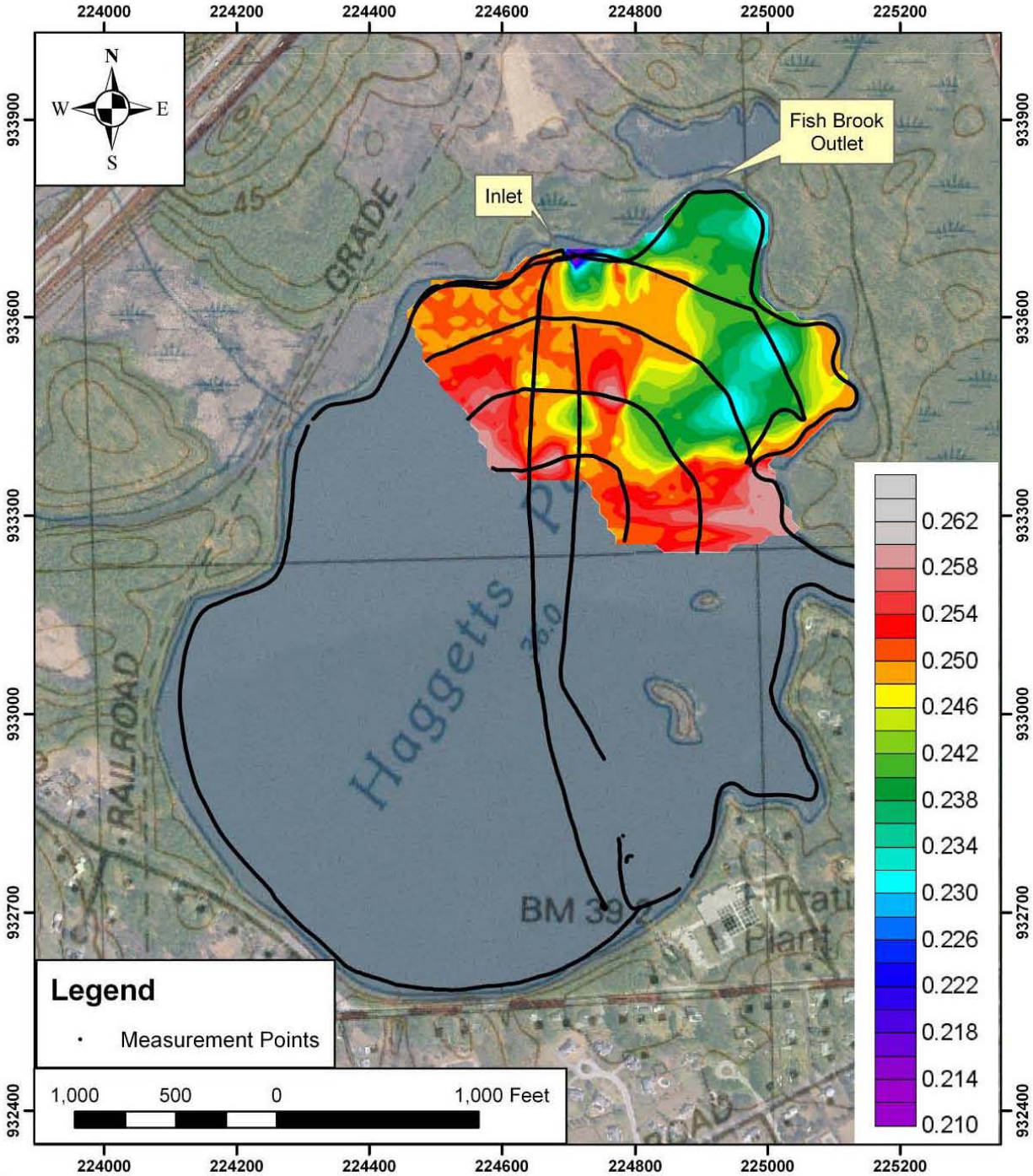
Sample of Sub-bottom Sonograph Shows Up To 10 Feet of Sediment in Former Streambed Haggetts Pond, Andover, MA



(see Figure 5 for Profile location)

FIGURE 8

Near Bottom Specific Conductivity Towed CTD Data
Haggetts Pond, Andover, MA
(2.0 mS/cm contour interval)



Notes:

1. Survey conducted by CR Environmental, Inc. on October 18, 2007 using a YSI 6600 Sonde and DGPS positioning.
2. Grid: MA Mainland State Plane, NAD83, metric.

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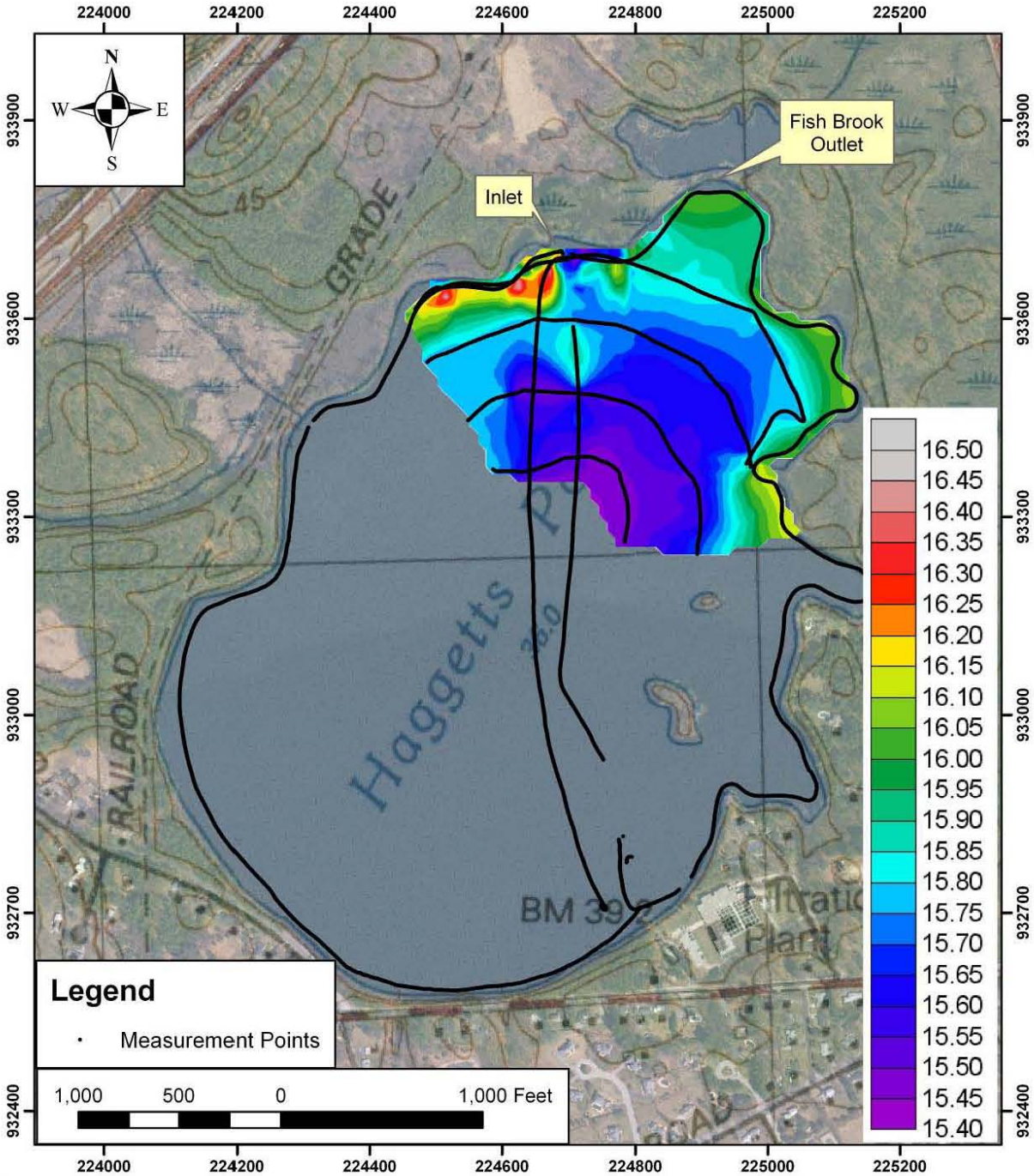
FIGURE 9

Near Bottom Temperature Towed CTD Data
Haggetts Pond, Andover, MA
(0.05 degrees C contour interval)



Notes:

1. Survey conducted by CR Environmental, Inc. on October 18, 2007 using a YSI 6600 Sonde and DGPS positioning.
2. Grid: MA Mainland State Plane, NAD83, metric.

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FIGURE 10

Typical Temperature Profile
Haggetts Pond, Andover, Massachusetts
October 18, 2007

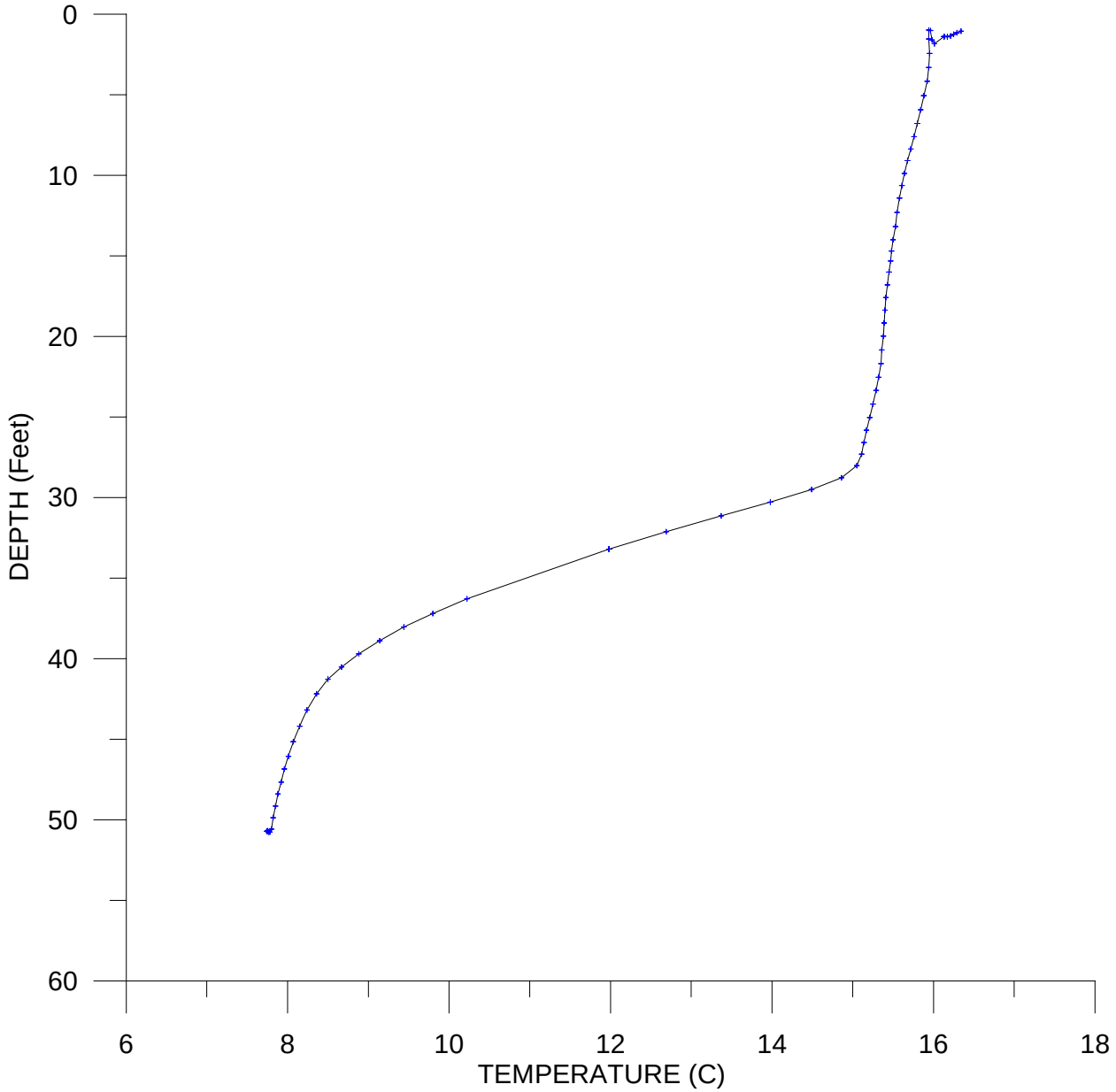
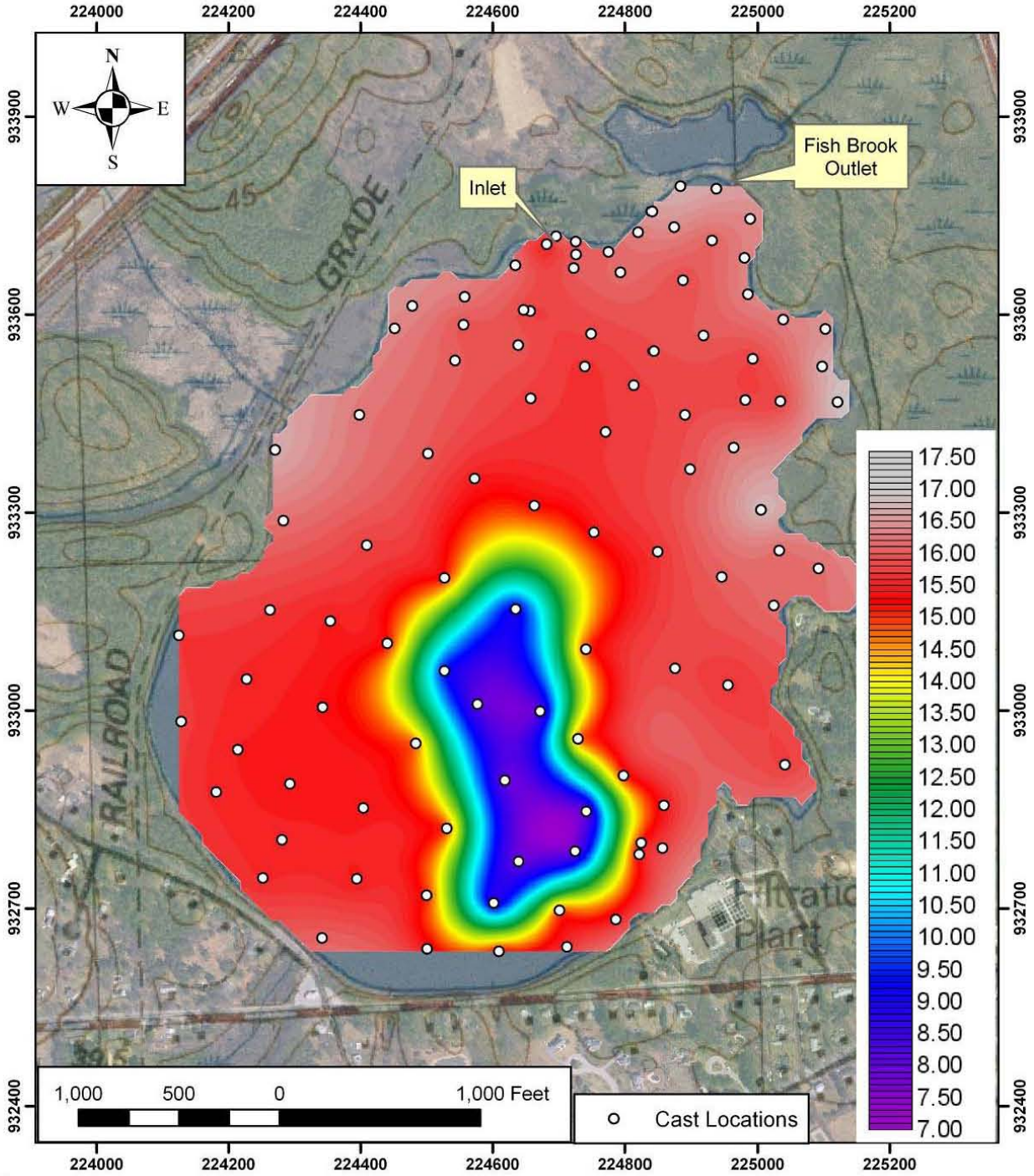


FIGURE 11

Contour Map of Lakebed Temperature
Haggetts Pond, Andover, MA
(0.1 degree contour interval)



Notes:

1. Survey conducted by CR Environmental, Inc. on October 18, 2007 using a YSI 6600 Sonde and DGPS positioning.
2. Grid: MA Mainland State Plane, NAD83, metric.

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FIGURE 12

Typical Conductivity Profile Adjacent to Water Treatment Plant
Haggetts Pond, Andover, Massachusetts
October 18, 2007

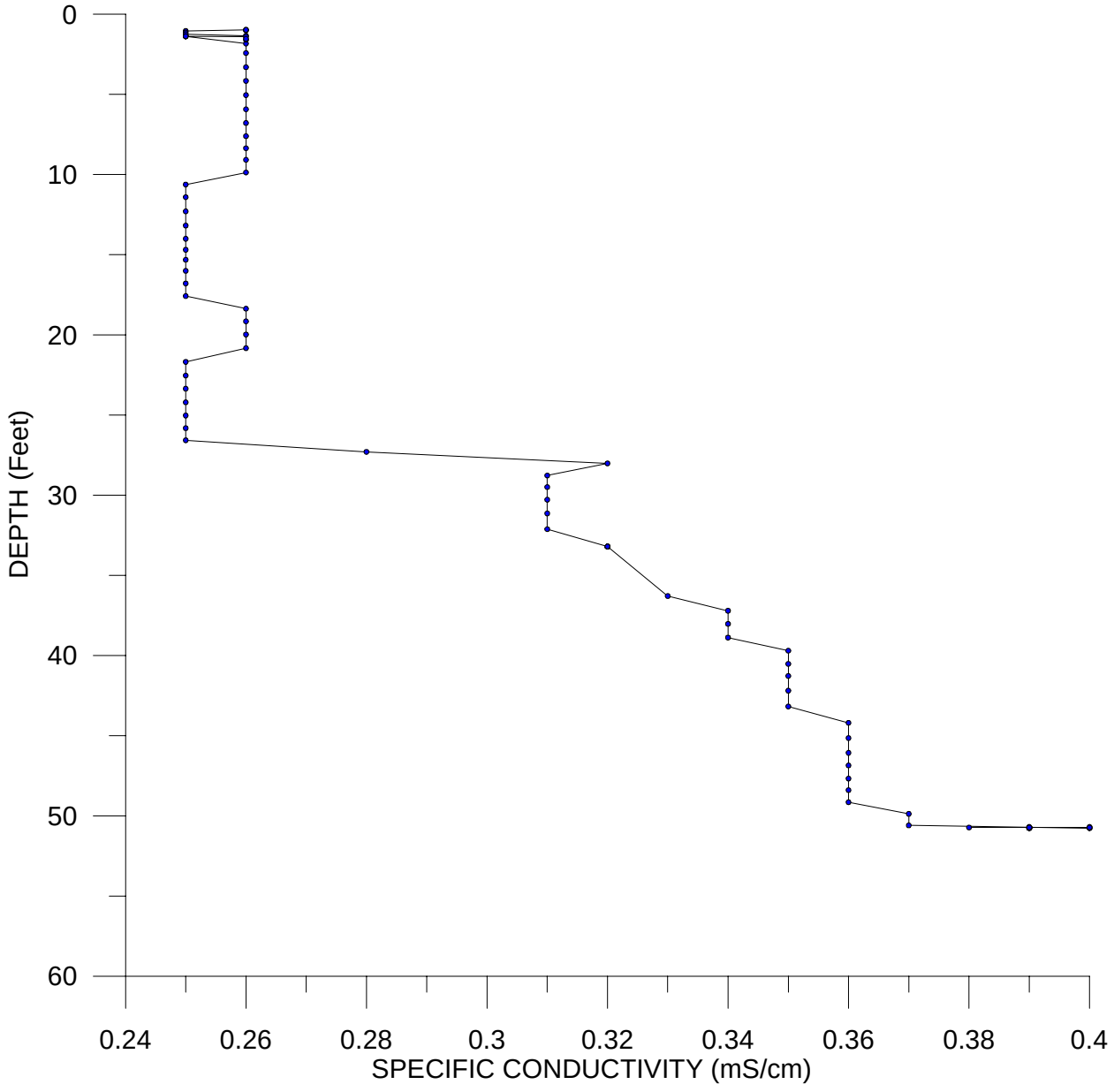


FIGURE 13

Scatter Analysis of Specific Conductivity Measurements
Haggetts Pond, Andover, Massachusetts
October 18, 2007

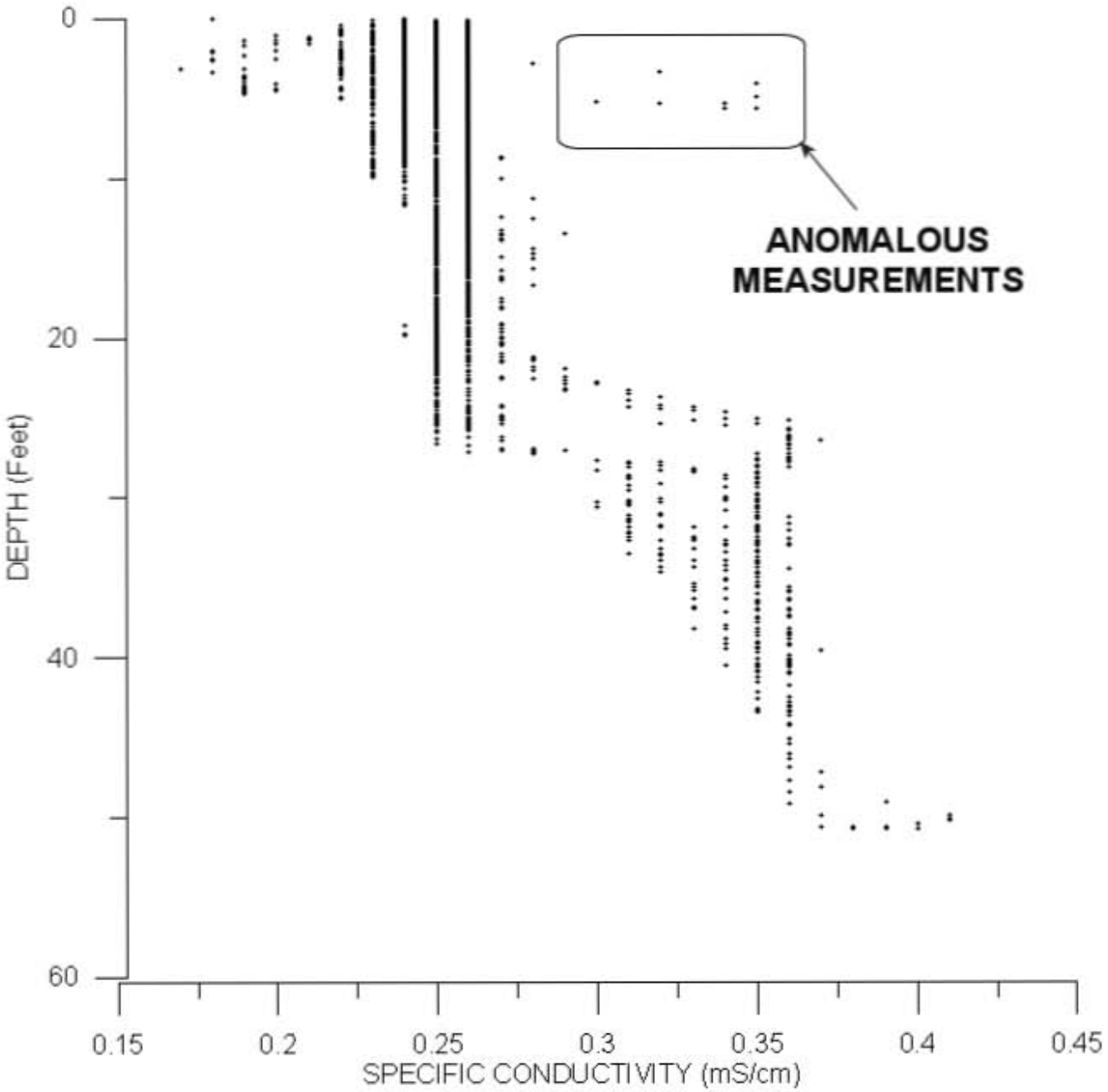
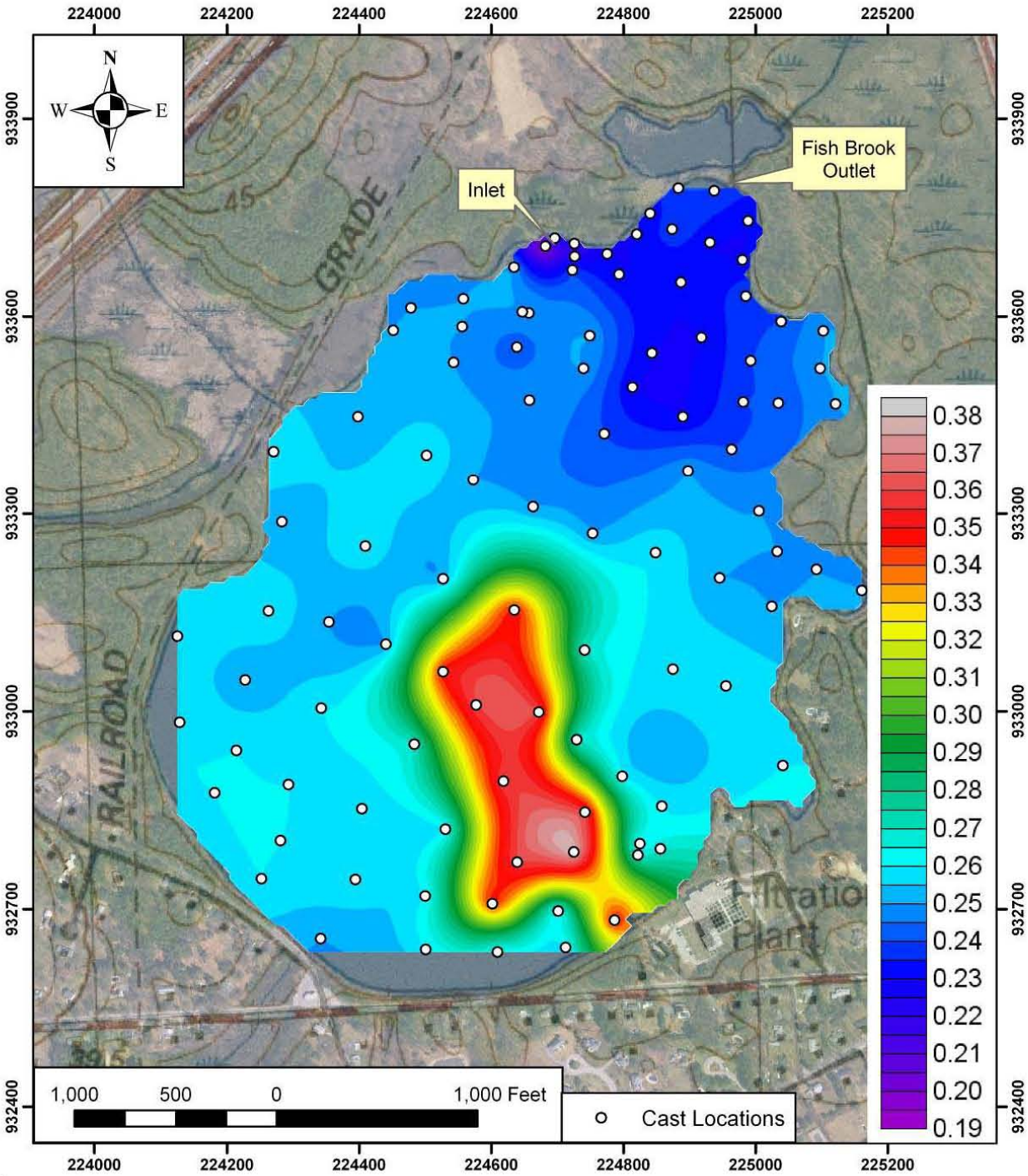


FIGURE 14

Contour Map of Lakebed Conductivity
Haggetts Pond, Andover, MA
(0.005 mS/cm contour interval)



Notes:

1. Survey conducted by CR Environmental, Inc. on October 18, 2007 using a YSI 6600 Sonde and DGPS positioning.
2. Grid: MA Mainland State Plane, NAD83, metric.

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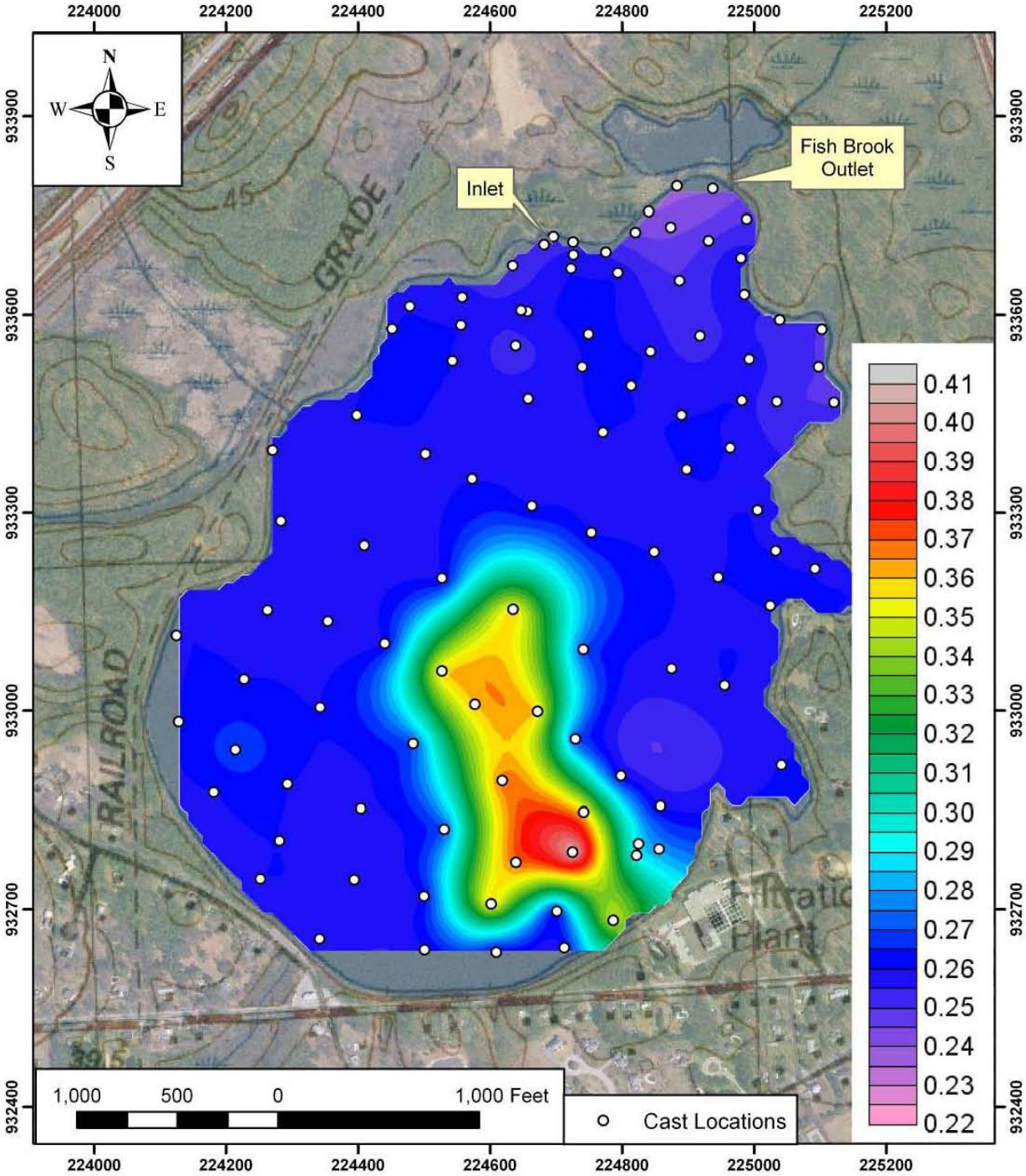
FIGURE 15

Contour Map of Conductivity – Maximum Value Per Cast
Haggetts Pond, Andover, MA
(0.005 mS/cm contour interval)



Notes:

1. Survey conducted by CR Environmental, Inc. on October 18, 2007 using a YSI 6600 Sonde and DGPS positioning.
2. Grid: MA Mainland State Plane, NAD83, metric.

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C

Appendix

SECTION 8.0. SPECIAL DISTRICT REGULATIONS

8.1. **WATERSHED PROTECTION OVERLAY DISTRICT**

8.1.1. Purpose. The Watershed Protection Overlay District (WPOD) is established in the Town of Andover for the following purposes:

1. To preserve and protect surface and ground water resources in the Fish Brook/Haggetts Pond Watershed Protection Overlay District (WPOD) for the health, safety and welfare of its people;

2. To protect the community from the detrimental use and development of land and waters within the WPOD.

3. The WPOD does not limit the existing authority of the Conservation Commission pursuant to G.L. c. 131, s. 40.

4. This Bylaw is adopted under authority granted by the Home Rule Amendment of the Massachusetts Constitution, the Home Rule statutes, and pursuant to the regulations of the federal Clean Water Act found at 40 CFR 122.34.

8.1.2. Establishment. The WPOD includes all the lands which create the catchment or drainage areas of Fish Brook or Haggetts Pond as part of their natural or man-made drainage system. The district includes all areas designated on the plan titled "Fish Brook/Haggetts Pond Watershed Protection Overlay District", dated December 1985, prepared by the Town Engineer, as amended, and also as amended by the plan titled "Topographic Plan Requested Revision to Watershed Protection Overlay District River Road, Andover, MA, dated January 19, 2006" prepared by Dana F. Perkins, Inc., for Richard and Kay Pelletier, 176 River Road, Andover, MA 01810, which plans are on file in the office of the Town Clerk and which are hereby made part of the Town Zoning Maps. [Amended 4-24-2006 ATM, Art. 50]

Within the WPOD, Priority Zones 1 and 2 shall be designated to identify areas where permitted uses and design standards shall apply based upon, in part, the linear distances from surface waters and tributaries. Priority Zone 1 shall include land areas up to 400 feet from the annual high water levels of Haggetts Pond, its tributaries, and Fish Brook, respectively. Priority Zone 2 shall include land areas exceeding 400 feet and extending out to ½ mile from the edge of Priority

Zone 1(Priority Zones 1 and 2 shall apply to Fish Brook and any other Class A water source that is tributary to surface water supplies within the WPOD to a distance of 200 feet from the source).

1. Burden of Proof. When a property owner seeks town approval for any work done on a lot which is partially contained within the WPOD boundary, the owner must include with his or her application a map on a scale of one inch equals forty feet prepared by a registered professional surveyor, stamped by a Registered Professional Engineer specializing in Civil Engineering, and approved in writing by the Town Engineer, showing the boundary of the WPOD with respect to the owner's property limits. The Planning Board may, upon review of the application, determine what portion, if any, of such lot is contained within the WPOD. The Planning Board may issue an order approving said plan if the Planning Board determines that land on such lot shown outside the WPOD is not part of the catchment or drainage areas of Fish Brook or Haggetts Pond or part of their natural or man-made drainage system.

8.1.3. Overlay District. The WPOD is an overlay district and shall be superimposed on the other districts established by this by-law. Land in the WPOD may be used for any purpose otherwise permitted in the underlying district, subject to the additional restrictions which follow herein.

8.1.4. Permitted Uses. The following uses are permitted within the WPOD, subject to the design standards set forth in Section 8.1.7:

1. Conservation of soil, water and plants;

2. Outdoor recreation and nature study;

3. Boat docks and landings, except on Haggetts Pond and Fish Brook, pedestrian and bicycle paths and bridges; and horse paths and bridges;

4. Operation and maintenance of dams, splash boards and other water control, supply and conservation devices;

5. Residential development, as permitted in the underlying district;

6. Farming, gardening, nursery, conservation, golf courses, forestry, harvesting and grazing, subject to restrictions set forth in Section 8.1.5.3;

7 Earth removal as defined in Sections 6.3.2, 6.3.3, and 6.3.4, where such removal will not endanger ground or surface water quality and where non-construction excavation or grading shall not come closer than four feet above maximum groundwater elevation. The angle of graded slopes shall be no greater than that which can be held by existing or planned vegetation;

8. Construction, alteration, repair and maintenance of municipal infrastructure, including water system, sewer systems, drainage, roadways and public utilities;

9 .Storage of heating oil within a building, provided that all necessary state and local approvals have been obtained.

10. Existing on-site sewage disposal and treatment systems within 400 feet of Haggetts Pond, provided that on-site disposal and treatment systems are maintained in accordance with requirements set forth in 310 CMR 15.300 et seq.

8.1.5. Special Permit Uses. The Planning Board may allow the following uses within the WPOD upon the grant of a special permit and subject to any additional conditions the Planning Board may impose:

1. Ponds or other changes in water bodies or watercourses, created for recreational use or drainage improvements;

2. The creation of ponds not subject to Conservation Commission jurisdiction under the Wetlands Protection Act

3. The storage, manufacture or use of hazardous or toxic substances other than those prohibited in Section 8.1.6 as long as there is minimal risk to health, safety, and the environment as provided for in 310 CMR 40 Massachusetts Contingency Plan and would not exceed any state or federal water quality criteria or standards if spilled, discharged or otherwise released.
All reasonable and necessary measures shall be taken to prevent spills, discharges or other releases of the hazardous or toxic substances to the environment.

8.1.6. Prohibited Uses. The following uses are prohibited within the WPOD, except as otherwise noted within this By-Law:

1. The bulk storage of salt and other road de-icing chemicals;

2. Landfills and open dumps as defined in 310 CMR 19.006;

3. Automobile graveyards and junkyards, as defined in M.G.L. c. § 140B, 1;

4. The discharge of stormwater into Fish Brook, Haggetts Pond, or any other surface water body or tributary stream within Priority Zones 1 or 2 for which oil/water separation devices have not been installed and regularly maintained at the nearest upstream manhole structure before the outfall;

5. Any new building, structure, land-disturbing activities, excavation or fill within fifty feet of all water bodies and watercourses as defined in this by-law; except for that which is necessary for the operation, modification, repair, replacement or expansion of the town's public drinking water supply system, and foot, bicycle and/or horse paths and bridges and said systems which will be consistent with the purposes set forth in Section 8.1.1.

6. The storage, management, or disposal of solid waste or refuse as defined in Massachusetts regulations at 310 CMR 19 ;

7. Gasoline service station, repair garage or body shop for motorized vehicles;

8. The stockpiling, or disposal of snow within the WPOD boundaries from any sources either within or outside the boundaries of the WPOD;

9. Unless otherwise exempted or excluded under federal, state, or local requirements, the storage, management, or disposal (including septic systems and floor drains) of hazardous materials as defined in Massachusetts regulations cited at 310 CMR 40.1600 (Oil and Hazardous Materials List) and Federal regulations cited at 40CFR Part 355 (Extremely Hazardous Materials List).

10. Petroleum, fuel oil, and heating oil bulk stations and terminals including, but not limited to, those listed under Standard Industrial Classification (SIC) Codes 5171 and 5983. SIC Codes are established by the US Office of Management and Budget and may be determined by referring to the publication, Standard Industrial Classification Manual and any other subsequent amendments;

11. Discharge to the ground of non-sanitary wastewater including industrial and commercial process wastewater;

12. Landfills receiving only wastewater and/or septage residuals including those approved by the Department pursuant to M.G.L. c. 21, §§ 26 through 53; M.G.L. c. 111, § 17; M.G.L c. 83, §§ 6 and 7, and regulations promulgated there under;

13. Unless otherwise exempted or excluded under federal, state, or local requirements, facilities that generate, treat, store, or dispose of hazardous waste that are subject to M.G.L. c. 21C and 310 CMR 30.00;

14. Unless otherwise exempted or excluded under federal, state, or local requirements, the storage of liquid hazardous materials, as defined in M.G.L. c. 21E, and/or liquid petroleum products;

15. Storage of commercial fertilizers, as defined in MGL c 128, § 64;

16. Storage of sludge and septage;

17. Storage, stockpiling, or spreading of animal manure within Priority Zone 1;
18. Earth removal, consisting of the removal of soil, loam, sand, gravel or any other earth material (including mining activities) to within four feet of historical high groundwater as determined from monitoring wells and historical water table fluctuation data compiled by the United States Geological Survey, except for excavations for building foundations, roads, or utility works;

19. Any new on-site sewage treatment and disposal systems within 400 feet of a surface water supply as provided for in 310 CMR 15.211 and within 200 feet of one or more rivers, streams, or swales which are tributary to the surface water supplies;

20. Prohibitions not otherwise specified herein, but provided for in 310 CMR 22.20B, Surface Water Supply Protection.

21. For lots constructed after June 1, 2009 in addition to the above named prohibited uses the following shall apply: Any new building, structure, land-disturbing activities, excavation or fill within Priority Zone 1 as defined in this by-law; except for that which is necessary for the operation, modification, repair, replacement or expansion of the town's public drinking water supply system, and foot, bicycle and/or horse paths and bridges and said systems which will be consistent with the purposes set forth in Section 8.1.1.

8.1.7. Design Standards. Any development of land within the WPOD, except as provided for in 8.1.4 and 8.1.6 above, and modifications/changes to previously existing buildings or structures within Priority Zone 1 shall meet the following design standards in addition to all standards imposed by the underlying zoning district. Where a lot is partially contained within the WPOD boundary, these standards shall apply to that portion of the lot which is determined to be within the WPOD:

1. Slopes which exceed an average of fifteen percent (15%) over a distance of ten feet or more shall remain undisturbed;

2. Where a lot is partially outside the WPOD, the site plan shall, to the greatest extent possible, locate pollution sources, such as subsurface sewage disposal systems, outside the district;

3. Vegetation on the lot shall be planted and located in such a way as to maximize groundwater recharge, absorb and filter runoff and reduce erosion;

4. All construction activities as allowed within the WPOD shall be designed or sited to minimize erosion and runoff, by such practices as minimizing the construction period, slope stabilization, ditch maintenance, filtering, sedimentation basins and re-vegetation. A Sedimentation and Control Plan, prepared and stamped by a Massachusetts Registered

Professional Engineer, and approved by the Town Planning Board and other local agencies as may be needed, shall be required for all construction and land-disturbing activities within the designated Priority Zone 1 of water bodies and tributaries to the water supply as defined in Section 8.1.2. In addition, a Planting and Re-vegetation Plan prepared by a licensed Landscape Architect and approved by the Town shall be required as part of all construction and land disturbing activities within the WPOD.

5. The renovation, expansion, and/or upgrade of existing on-site sewage treatment and disposal systems shall be conducted in accordance with requirements set forth in 310 CMR 15.000 et seq., unless otherwise specified herein.

8.1.8. Special Permit Procedures.

1. Filing of the Application. Twelve complete copies of the application for a special permit for land use within the WPOD shall be filed with the Planning Board on a form approved by the Planning Board.

2. Review by Other Boards and Agencies. Before acting upon the application, the Planning Board shall submit it to the following boards and agencies which may review it jointly or separately: the Board of Health, the Conservation Commission, the Department of Public Works and other boards or agencies that the Planning Board may deem appropriate. Any such agency to which petitions are referred for review shall submit such recommendations as it deems appropriate to the Planning Board and the applicant.

3. Further Requirements for Information. After the opportunity for review by other boards and agencies, the Planning Board may require the applicant to supply more specific information about the proposed development as per questions and comments of the reviewing boards and agencies.

8.1.9. Decision. The Planning Board may grant a special permit for land use within the WPOD hereunder only if it finds that the applicant has met the general requirements of Sections 8.1 and 9.4, and that the applicant has demonstrated the following:

1. That the plan will preserve and protect the surface and ground water resources in the WPOD for the health, safety and welfare of the town's people;

2. That the plan will protect the community from the detrimental use and development of land and waters within the WPOD;

3. That the design standards of Section 8.1.7 have been met.

4. That Special Permits Procedures 8.1.8 (2.) have been met.

8.1.10. Conditions and Restrictions. The Planning Board may impose any conditions and restrictions required to mitigate any potential damage to surface and ground water resources and, in reaching its decision, will consider the simplicity, reliability and effectiveness of these mitigating measures and the damage likely to result if these measures were to fail. If the Planning Board disagrees with the recommendations of the Conservation Commission or the Board of Health, the reasons shall be stated in writing.

8.1.11. Severability. If any provision, paragraph, sentence, or clause of this By-law shall be held invalid for any reason, all other provisions shall continue in full force and effect.