Auburn Water District and Lewiston Water Division, Maine

Turbidity and Bacteria Study Update 2005 Summary

February 2006

Report

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Section 1

1.1 Background and Study Organization

In 1993, the State of Maine, Department of Health Engineering Drinking Water Program (MDWP) and United States Environmental Protection Agency (USEPA) granted the Auburn Water District (AWD) and the Lewiston Water Division (LWD) a waiver of the filtration requirement of the Surface Water Treatment Rule (SWTR). Although the historical data collected by the water systems indicated that the source water met the source water requirements of the rule, AWD and LWD commissioned a study of bacteria and turbidity occurrence in Lake Auburn in preparation for the submittal of application of a waiver of the filtration rule. The intention of the study was to get a better understand the potential bacteria and turbidity and to help site a new intake that would provide consistently high water quality. As a result, AWD/LWD engaged CDM to conduct a study with the following goals:

1. To understand the processes that cause elevations of coliform bacteria in certain locations, and to identify, on a preliminary basis, the major sources of coliform bacteria and to consider mitigation of the sources.

2. To characterize the relationship between intake location and turbidity.

3. To identify ways, including the consideration of a potential new intake siting area(s) to improve the likelihood of long term compliance with both the coliform bacteria and the turbidity criteria of the SWTR.

Prior to the start of the study, AWD/LWD had been collecting data as part of their efforts to improve water quality and to implement a Watershed Control Program. These efforts included establishment of a weather station at Lake Auburn to digitally record data on wind velocity and direction, temperature, precipitation, barometric pressure and relative humidity. In addition, in 1991, a program was already underway to continuously monitor "in the lake" turbidity and bacteria at alternate intake locations and to perform periodic water sampling on tributaries to Lake Auburn. In 1992, a detailed color aerial photograph was taken of the lake and its watershed to aid in researching watershed areas of concern. In June 1993, the Lake Auburn Watershed Protection Commission was formed to assure that the protection of the lake and watershed would be provided through a balanced governing of efforts and financial commitments.

The Turbidity and Bacteria Study was completed in June 1993. During the study, past efforts undertaken by the Watershed Protection Commission were reviewed, new data were collected, and analyses were performed. Since 1993, the study's recommendations have been implemented on an ongoing basis.

In November and December 2004, Lake Auburn experienced unusually high fecal coliform levels. As a result, AWD and LWD commissioned CDM to undertake an

update of the original 1993 Turbidity and Bacteria Study to address the issue. A report entitled, "Update of 1993 Turbidity and Bacteria Study" was completed in January 2005. The update recommended implementing new investigation and mitigation measures to be performed in 2005. This current study is a followup report summarizing the measures implemented in 2005 and presenting conclusions and recommendations regarding the fecal coliform issue.

1.2 Study Organization

This study is organized into six sections. Section 1 provides background about past turbidity and bacteria investigations and outlines the organization of this study. Section 2 provides a synopsis of the original 1993 Turbidity and Bacteria Study's findings and recommendations. Section 3 summarizes the investigations and conclusions of the "Update of 1993 Turbidity and Bacteria Study" completed in January 2005. Section 4 summaries the measures recommended in the latter study along with a summary of implementation efforts in 2005. Section 5 provides the findings based on the measures implemented in 2005. Finally, Section 6 provides new recommended Action Items.

Section 2

2.1 1993 Turbidity and Bacteria Report

The findings of the study reflected the ongoing efforts of the Watershed Control Program that included activities prior to and through completion of the report. The most notable of these efforts between 1991 and June 1993 included:

- Creation of a restriction zone in the lake around the location of the intakes.
- Adoption by the City of Auburn of the Phosphorus Control Ordinance.
- Closing of the Ice House Boat landing, thus limiting landings to only one other public location; the Route 4 boat launch.
- Closure and stabilization of Spring Road.
- Posting, in the outlet stream from the Basin area, signage and siltation fencing along the shore to discourage waterfowl.
- Updating of the sanitary survey database for the watershed.
- Posting of many no trespassing signs.
- Implementation of public education programs.
- Purchase of watershed properties.
- Establishment of annual watershed program activities and reporting.

The 1993 study findings included the following:

- The largest source of total and fecal coliform entering Lake Auburn was on the downstream section of its largest tributary that begins at Little Wilson Pond and flows down through "the Basin" and into the lake. A large duck population existing in the stream area leading from the Basin spillway to the lake (between the North Auburn Road Bridge and the inlet from the Basin to the lake) was the apparent source.
- The "duck" source of coliform impacted the lake between June and September each year but did not directly impact coliform reported in the intakes on the opposite side of the lake.
- During the mid to late fall, coincident with turnover events, lake coliform levels rise and circulate through the water column, particularly in the deepest part of the lake. Coliform levels also rose in the shallow areas, but not to levels seen in the deeper waters. It was hypothesized that sediments

in the deep parts of the lake harbored coliform that were resuspended during turnover.

- An increase in the turbidity of the lake during wind events was most pronounced in the near shore, shallow areas. A new intake extending between 600 and 1000 feet from shore could achieve consistently low turbidity while minimizing the impact of elevated coliform in deeper waters during the fall turnover.

The report recommended that several ongoing long-term programs be continued and that several new programs be established. The on-going programs and their status since 1993 (through 2004) are briefly described below:

1. Continuous operation of and data collection from the Lake Auburn weather station.

   Status: Station operation and data collection has been continuous through 2004.

2. Sampling 2-3 times per month (during warm weather) of in-lake and perimeter stations 1-5, 8, 10, 13-18 and 21-23. These sites include in–lake locations and major tributaries to Lake Auburn. (Reference the 1993 report for descriptions).

   Status: Sampling at 13 discrete sites in the lake and on tributaries continues on a weekly, bi-weekly or monthly basis depending on the parameter being sampled.

3. Counts of ducks and other waterfowl.

   Status: Initial duck population was significantly reduced in 1993 – 1994. No annual quantitative accounting of waterfowl population and activity has taken place since 1994. Other than annual loon counts, only qualitative assessments are performed on an as needed basis. No unusual waterfowl population changes have been noticed.

4. Tracking of the thermocline and turnover using temperature and dissolved oxygen profiles.

   Status: Tracking and profiles have been continuous through 2004.

5. Annual intensive fall sampling program in the lake before, during and after turnover for Total and Fecal Coliform to characterize the possible elevated levels.

   Status: Routine in lake sampling is timed so that at least one sampling set falls within the fall lake turnover period. Since the improvement in water

quality afforded by the new intake, which went into operation in late 1996, the intensive sampling has not been deemed necessary.

6. Waterfowl control program including signs, public education, and low fencing in critical feeding areas to make the habitat less desirable.

   Status: After initial success in the stream area leading from the Basin to the inlet into the lake, no new areas have been targeted for control. Existing controls and public education programs in place have been maintained.

New programs that were recommended by the 1993 report included:

1. Initiation of Giardia and Cryptosporidium sampling at the intakes.

   Status: For both parameters, three samples were collected and analyzed in 1993 and again in 1994 with none detected. Since 1996, sampling frequency has been one each per annum through 2004 with none detected.

2. Mitigation of additional sources of bacteria and turbidity as they are identified. In particular, increased outreach activity should be initiated targeting farms and stables.

   Status: Farms and stables in the watershed were initially contacted. Annual watershed surveys look for sources.

3. If high levels of bacteria persist in the fall turnover period despite present and future source control mitigation measures, additional measures could be considered, including alum treatment of the lake sediments.

   Status: Alum treatment has not been considered necessary based on the excellent lake water quality to date.

4. In addition to the above programs, it was also recommended that a new intake be located near sampling Station 12 (about 800 feet offshore near existing intakes) subject to another season of monitoring for springtime turbidity events.

   Status: Results were satisfactory in subsequent source water monitoring and a new 48-inch HDPE intake extending approximately 900 feet into Lake Auburn was designed and constructed. The new intake went online in late 1996.

In addition to the recommendations of the 1993 report, the Watershed Protection Commission initiated a series of activities that have either been completed or are still ongoing:

- Closed and revegetated Lunn Road.

- Continued ongoing mitigation efforts, such as the installation of sanitary stations at the boat launch.
- Developed an extensive GIS database on the watershed and the lake that is continually updated and improved.
- Developed overlay district ordinances.
- Adopted the City of Auburn Gravel Mining ordinance specifically protecting land in the watershed.
- Updated the Forest Management Plan.
- Supported a United States Geologic Survey Water Budget for Lake Auburn.
- Coordinated a Source Water Assessment with the Maine Drinking Water Program
- Closed and removed the North Auburn Store.
- Removed boat launches at Lake Shore Drive (at Maple Hill Rd.), Holbrook Road (Basin Launch), North Auburn, Ice House on West Auburn Rd. and improved the Route 4 launch, leaving only one public landing in service.
- Increased land protection efforts through ownership, conservation easements, and life estates. The Commission currently controls approximately 1800 acres within the Lake Auburn Watershed; the control level in 1993 was equal to 726 acres, the control level in 2004 was equal to 1865 acres, or a 1139 acre increase (156% increase).
- Supported the Auburn Land Lab to enhance environmental education and public awareness.
- Supported the Volunteer Lake Monitoring Program and the Maine Center for Invasive Aquatic Plants.
- Implemented erosion control and enhanced Lake Shore Drive Turnout and North Auburn Corner at Lake Shore Drive.
- Participated with Bates College promoting studies and projects for Lake Auburn.
- Supported a University of Maine, Farmington (UMF) project, mapping the bathymetry of Lake Auburn.

Section 4

4.1 Turbidity and Bacteria Recommendations for 2005

The short term rise in fecal coliform levels in late November 2004 and December 2004 was unusual in its magnitude and frequency based on a comparison to data from past years, but has been part of a recurring late fall cycle. The exact mechanisms causing this phenomenon, and in particular, the higher 2004 levels are not fully understood. There does not seem to be a direct correlation with elevated turbidity, weather conditions, or changes in lake level or turnover timing. In addition, direct influence by biogrowth in the intake and clearwell is unlikely, but cannot be ruled out at this time. What is known from past observations and investigations performed in December 2004 is the following:

- Higher coliform levels typically occur in November and December and correspond with the post turnover period.
- Just after turnover, the water column is mixed and there is a general increase in turbidity, although still relatively low, presumed to be from resuspended bottom sediments. Turbidity and coliform appear to increase at all depths during this period, but fecal coliform are found at higher levels with depth.
- In 2004, the increases in fecal coliform persisted past mid-December, well past the turnover.
- Based on one round of sampling in December 2004, the deeper sections of the lake have higher coliform levels than the intake area during this period.
- The tributaries, with fecal coliform levels less than or equal to 4/100 ml during this period, are not contributing any significant coliform loads to the lake.
- There have been roosting gulls and migratory waterfowl observed on the lake during this period.
- E. coli data indicates a source from the intestines of warm blooded animals.
- Speciation data from fecal coliform samples taken in December indicate that the predominant species are Escherichia coli (E. coli) and Escherichia sp.
- The coliform levels subside before the end of December which usually corresponds with less turbid lake water, cold weather, and the beginning of ice formation on the lake. Lake Auburn had complete ice cover on December 28, 2004.

Based on the above, it would appear that a likely cause is a direct input of fecal coliform from fecal matter deposited in the lake away from shore by roosting gulls

and waterfowl that becomes mixed in the water column and transported toward the intake, induced by the withdrawal of water. In addition, the full-depth mixing of the lake water during and after turnover will tend to spread the coliform throughout the lake's depth, whether initially found near the water surface or at the lake bottom. In addition, sediments, which may harbor fecal coliform from previous source inputs to the lake may also be contributing to observed fecal coliform levels in the water column, but this is questionable. This would lead to the finding that source mitigation, in particular, birds (gulls) in the fall season, could provide the greatest future reduction in fecal coliform occurrence by reducing source inputs directly to the lake and subsequently into the sediments.

A wide range of possible investigations and control measures for the mitigation of fecal coliform sources are described in Appendix A (Tables 2 and 3 respectively), along with discussion of their applicability and priority with respect to the current coliform issue. From the tables, the activities with moderate and high priority were recommended for implementation in 2005. Accordingly, the following outlines the 2005 recommended action plan, updating the 1993 report recommendations and providing a summary on the implementation of the various measures that AWD/LWD undertook in 2005.

4.1.1 2005 Action Plan and Follow Up Summary

CDM recommended that AWD/LWD should continue implementing the recommended and ongoing programs as outlined in the numbered bullets in Section 2.0 of this report, as modified and supplemented by the action plan measures discussed below. These measures, which were implemented throughout 2005, were developed with the input and support of MDWP. AWD/LWD provided updates and held meetings quarterly with MDWP to discuss the Action Plan progress. The following implementation summaries provide the details of the progress made during 2005 on the Action Plan with supporting documents within the appendices.

Measure No. 1 – Review GIS mapping and orthophoto of lake/watershed

The established GIS system should be updated during 2005 to include the results of various investigations. The GIS can then be used to assist in analyses. The orthophoto should be reviewed and areas of concern targeted for field investigation.

Schedule for Implementation
GIS implementation: 2005. Field investigations: Spring 2005

Implementation Summary
The Lake Auburn Watershed GIS Mapping system was updated with 2001 MEGIS. Electronic copies have been provided to field inspection teams. Tax map parcel information including current owners and parcel ID's within the Town of Turner near Little Wilson Pond and Mud Pond were updated from records at the Turner Town Office. This information was utilized for the completion of sanitary surveys around Little Wilson Pond, The Basin, and Townsend Brook tributary, as well as lake and

tributary sampling efforts. GIS mapping was also modified to include zones on Lake Auburn for recording the location of birds and waterfowl observed on the lake.

Measure No. 2 - Inventory gulls and waterfowl and make observations.

This program should include daily visits and notation of the approximate number, type, and location of gulls and waterfowl including nesting and roosting areas. Information collected can be compiled in GIS.

Schedule for Implementation
Observation, recording, and field investigations: Spring 2005 and Fall 2005.

Implementation Summary
Periodic bird monitoring efforts were initiated on May 2, 2005, by AWD/LWD water utility personnel. Bird monitoring efforts were conducted early morning and late evening, seven days a week until May 19th.

Subsequently, AWD/LWD enlisted the assistance of members of the Stanton Bird Club to assist us with the bird identification and monitoring efforts. Experienced members of the bird club provided periodic monitoring at key locations near the water intake structure. They were provided with utility security passes and initiated efforts on May 23rd. They prepared observation reports documenting the type, number, and location of birds (gulls/ducks/geese etc.).

The bird monitoring efforts completed through mid August, 2005 revealed no significant bird activity. Minimal to no sightings of ducks and gulls were made near the intake at sunrise and sunset; gulls observed on the lake were generally less than 100. Half a dozen to a dozen loons have been seen around the lake through the year and comerants have been present in varying numbers from a dozen to 3 dozen. Loons, ducks and swallows have been observed near the intake structure at sunrise and sunset.

Stanton Bird Club efforts were increased in September with a greater monitoring effort at dusk. Since the end of August the number of birds observed increased dramatically. Around 500 seagulls were observed for about a week on-water, during night and morning inspections and water quality personnel observed varying numbers during the day. Wood duck have been seen in numbers as low as a couple and up to a dozen in addition to the 3 dozen comerants.

A bird harassment program was implemented on September 7, 2005 by water utility personnel and is described in Measure No. 8. Bird presence was recorded in excess of 1,000 gulls beginning November 20, 2005.

A detailed tabulation of the bird monitoring efforts was prepared and is attached as Appendix B. Bird counts have also been identified in the tables by location or zone on the lake. Accordingly, a map the lake showing the zones is contained within Appendix B. Also within Appendix B, are e-mails from the Stanton Bird Club

member Stan DeOrsey dated 10-27-05 and 11-08-05 that outline an increased bird presence on Lake Auburn and surrounding land.

A lethal bird harassment program with the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) Wildlife Service (WS) was instituted on November 21, 2005 and continued through December 13, 2005. Non-lethal and lethal gull harassment program is further described in following Measure No. 8.

Measure No. 3 - Survey near shoreline subsurface disposal systems

From GIS, identify all systems within a 500 foot setback from the lake shore, review City of Auburn records of all upgrades and replacements to determine older systems. Perform physical inspection. Determine frequency of pump out.

Schedule for Implementation
Survey systems: Spring 2005.

Implementation Summary
The Lake Auburn Watershed encompasses nearly 15.3 square miles of land in the City of Auburn, and portions of the Towns of Turner, Minot, Hebron and Buckfield. Of this land area, Lake Auburn itself covers a surface area of approximately 2,290 acres and is located entirely within the City of Auburn. Other significant surface water bodies with the Watershed include Townsend Brook, The Basin, Little Wilson Pond, and Mud Pond.

In late Spring of 2005, the engineering firm of Wright-Pierce was hired to perform sanitary surveys throughout key portions of the Watershed. Given the vast land area of the Watershed, the primary focus for the sanitary surveys was on properties located within 500 feet of Little Wilson Pond and Mud Pond in the Town of Turner as well as Townsend Brook in Auburn.

Wright-Pierce began their effort by reviewing GIS data to identify which land parcels fell within the 500 foot setback limit that had been established to define the scope of the survey work. Once property parcels were identified, further investigation was conducted to determine whether there were any structures (residence, seasonal camp, business, etc.) located on the property. If so, City and Town records were examined to find the appropriate HHE-200 for any on-site wastewater disposal system.

Data obtained from the HHE-200 forms was input and linked to the GIS data. Field crews then began actual on-site reconnaissance of each parcel. Field visits were conducted at various times (day, evening, weekends) to increase the likelihood of meeting face-to-face with the property owners.

Field personnel investigated the private disposal systems for any apparent failures. They also remained vigil for any other potential problems such as point discharges to the water bodies, improper erosion control methods, poor farming practices, etc. No incidental issues such as erosion, improper farming or point sources were observed.

In addition to the Wright-Pierce efforts, personnel from the Auburn Water District and Lewiston Water Division conducted field inspections around the perimeter of Lake Auburn. Due to an aggressive land acquisition program, only 12 parcels that are homes/camps are located within 250 feet of the water. These septic systems were inspected last year (winter) by AWD/LWD personnel.

In the areas around Little Wilson Pond, 88 parcels were inspected within 500 feet of the water. Of these, only three problematic wastewater disposal structures were identified adjacent to the Little Wilson Pond shoreline. AWD/LWD staff met with the local Code Enforcement officials to discuss follow-up actions.

Appendix C includes a map that delineates the sanitary survey findings from Little Wilson Pond and Mud Pond.

Wright-Pierce Engineers also completed a field survey of septic system inspections within the Townsend Brook area for the Lake Auburn Watershed Protection Commission. The study included 56 properties within 500 feet of Townsend Brook and on the western side of Route 4 (Turner Road).

The survey indicated the need for further attention at five properties. Findings were discussed with local Code Enforcement officials to ensure that any required corrective measures are addressed.

Appendix C also includes a map that delineates the sanitary survey findings from the Townsend Brook Area.

In summary, with the efforts of inspecting over 150 parcels, the sanitary survey indicated that no problems were found immediately in and around Lake Auburn. In the rest of the watershed, the survey results did not turn up any widespread problems. A few localized issues were identified that triggered corrective measures. The sanitary survey verified the overall good health of the watershed and did not indicate any problems related to the private wastewater disposal systems.

Measure No. 4 – Establish new watershed tributary sampling schedule and protocols

Sample watershed tributary locations identified in the 1993 study. Sample monthly except for inflow from the Basin tributary, which should be sampled biweekly; increase the frequency to weekly from October to ice-in. Sample during dry weather and target sampling during wet weather after 3-day minimum antecedent dry period. When a value greater than source water criteria is obtained, perform additional follow-up sampling along tributary to try to isolate source. Sampling parameters to include: Total and fecal coliform, all relevant microbiological parameters, temperature, dissolved oxygen, turbidity, color, pH, and conductivity. Once per month sample for Total Phosphorous; Soluble Reactive Phosphorous; Nitrate; and Ammonia.

Schedule for Implementation
Spring 2005

Implementation Summary

The AWD/LWD Water Quality Team reviewed and expanded our watershed tributary sampling schedule. In summary, the new "Tributary Samples Sites" are as follows:

Tributary Sample Site # 1 (Lake Auburn Outlet @ E. Auburn Dam)
Tributary Sample Site # 26 (Townsend Brook at Tot Lot)
Tributary Sample Site # 25 (Lake Shore Drive @ 1st Culvert)
Tributary Sample Site # 2 (Lake Shore Drive @ Townsend Brook)
Tributary Sample Site # 23 (Lake Shore Drive @ Merritt Pond inlet)
Tributary Sample Site # 3 (Lake Shore Drive @ brook near Tabors)
Tributary Sample Site # 4 (Lake Shore Drive at culvert)
Tributary Sample Site #13 (North Auburn Road bridge)
Tributary Sample Site # 16 (The Basin before Dam)
Tributary Sample Site # 27 (Johnson Road)
Tributary Sample Site # 18 (Inlet to Little Wilson Pond)
Tributary Sample Site # 17 (Outlet of Little Wilson Pond)
Tributary Sample Site #28 (McCafferty Farm – Hebron)
Tributary Sample Site #5 (Spring Road)

A map of the tributary sample locations is located in Appendix D. The map also shows four watershed control levels. These levels consist of the following area and restrictions:

Level 1 - Intake Restricted Zone - Consisting of the shoreline of Lake Auburn upland to the closest roadway and the surface of the Lake encompassed by a line between "Point of Pines" and a point southerly of the Route 4 boat launch. This zone is restricted. Absolutely no trespassing on District land, year-round.

Level 2 - Shoreline Protected Zone - Other remaining surface of the Lake and shoreline areas and direct tributaries of the Lake. This zone provides limited access, no fires, and no trespassing after dark.

Level 3 - Lower Watershed - The remainder of the watershed of Lake Auburn located within the city limits of the City of Auburn. This area is protected by the Lake Auburn Overlay Zoning District (adopted by the City of Auburn) and the Auburn Water District Land Use Policy already in place, as from time revised and amended.

Level 4 - Upper Watershed - The watershed of the Lake outside the jurisdiction of the City of Auburn.

In 2005, 360 samples were collected and analyzed for the following Tributary Sampling Parameters: Total coliform, Fecal coliform, Enterococci, Temperature, Dissolved Oxygen, Turbidity, Color, pH, Total Dissolved Solids, Total Phosphorus, OrthoPhosphate, Nitrate/Nitrite, Ammonia. The frequency of sampling at all sites for most parameters was weekly. Additional parameters were sampled only on a

monthly basis. In addition, another feature of the tributary sampling program was sampling during and after rainfall events.

The largest tributary called "the Basin" is measured at the sampling location called Lakeshore Drive Bridge. The second largest tributary is Townsend Brook. All other tributaries are much smaller by comparison. Townsend Brook is especially important since it is the closest major tributary to the intake, located due north of the intake location. Fecal values in tributary during dry weather flows were generally very low. Input from tributary sources were low during the period of high coliform at the intake in November and December. Fecal coliform input from the tributaries generally increased with increasing rain volume and antecedent dry period. Rain intensity was not reviewed. The fecal coliform input from the tributaries is discussed further below.

Following 6.3 inches of rain on October 8 and 9, the Basin tributary was sampled at Lakeshore Drive bridge and had a fecal colifom level of 400 while Townsend Brook fecal coliform levels reached 200, the highest values of the year at these tributary locations. Yet, as discussed above, at about the same time the intake had a peak fecal coliform of only 12 on October 10. Other lesser rainfall events from May to October produced fecal levels in the Basin (Lakeshore Drive Bridge) tributary between 120 and 240 on four occasions. Similarly, in the same period prior to October 10, Townsend Brook tributary fecal coliform levels ranged from 84 to 135 on three occasions. In contrast, in November 2005 with four storms between 1 and 2 inches of total precipitation, at the Basin tributary fecal coliform levels were consistently below 25 with the exception of November 30 when the high value for the period, 94, was reached. Similarly, in the Townsend Brook tributary, fecal coliform values were generally under 40 with a high value of 52 reached on November 8.

Measure No. 5 - Update and increase frequency of on-lake sampling

Biweekly sampling should include the deep hole, a near shore location, the online intake location, the standby intake location and previous sampling stations 9 and 11. Increase frequency to weekly from October to ice-in. Sampling parameters to include: Total and fecal coliform, all relevant microbiological parameters, temperature, dissolved oxygen, turbidity, color, secchi disk, pH, and conductivity. Once per month sample for Total Phosphorous; Soluble Reactive Phosphorous; Algae; Chlorophyll a; Nitrate; and Ammonia.

Schedule for Implementation
Spring 2005 (when ice is out)

Implementation Summary
The AWD/LWD Water Quality Team reviewed and enhanced our on-lake water quality sampling program. In summary, the new "Inlake" Sample Sites are as follows:

Lake Sample Site # 8 (Deep Hole 120 foot depth)
Lake Sample Site # 9 (at 90 foot depth)
Lake Sample Site # 11 (at 60 foot depth)
Lake Sample Site # 12 (current Intake at 19 ft)

Lake Sample Site 10 (Standby Intake)
Lake Sample Site # 6 (150 ft off shoreline near LAPS)
Lake Sample Site # 7 (off Bird Island)

In addition, three new wetlands sample sites W-1, W-2, W-3, and W-4 were added to the sampling program, but were not sampled as frequently as the above sites.

A map of the inlake sample sites is located in Appendix D.

In 2005 over 300 samples were collected and analyzed for the following Inlake Sampling Parameters: Total coliform, Fecal coliform, Enterococci, Clostridium perfrigens, Temperature, Dissolved Oxygen, Turbidity, Color, Secchi Disk, pH, Total Dissolved Solids, Total Phosphorus, OrthoPhosphate, Algae, Chlorophyll a, Nitrate/Nitrite, Ammonia. The frequency of sampling at all sites (except wetland sites) for most parameters was weekly. Additional parameters were sampled only on a monthly basis.

Inlake sampling data was compiled and evaluated. For the entire summer period inlake sampling stations had fecal coliform values of generally 5 or less. Beginning about mid-October there was a clear upward trend in fecal coliform at all sites approaching an average of just over 10. The Bird Island site (Site 7) exhibited very high fecal coliform levels from October 31, 2005 to November 28, 2005. During the latter period, the Bird Island site data began with a high fecal coliform value of 246 on October 31, 2005 and ended with a fecal coliform value of 100 on November 28, averaging 136. The Bird Island area is of significant concern with periodic high fecal coliform levels since it seems to have a direct influence on fecal coliform levels observed at the intake. When compared to input from the two major tributaries in the month of November, the inlake fecal levels were much higher, indicative of the direct input of fecal contamination from gulls roosting on the lake. In December, all inlake sites had much lower fecal coliform levels.

Fecal coliform levels at the intake for the period through October 2005 were generally in the low single numbers or zero nearly all the time with occasional rain related spikes as high as 13. Elevated fecal coliform levels, however, began to exceed 10 more frequently in October. In the period November 9, 2005 through November 30, 2005, fecal coliform levels were equal to or greater than 20 twelve times. After November 30, 2005 levels dropped dramatically and remained very low through the end of December. This reduction coincided with the observed reduction in gulls resulting from the USDA lethal/non-lethal harassment program. Table 1 in Appendix E provides a summary of fecal coliform results at the Intake location for October 2005 through January 2006.

Measure No. 6 – Sample lake bottom sediment for total and fecal Coliform analysis

With sufficient ice thickness in place on the lake, initiate a sediment sampling program using a VanVeen sediment sampler to collect samples of bottom sediments. Test sediments for fecal and total coliform, and all relevant microbiological parameters. Additional testing to include Total Organic Carbon, conductivity, pH,

Total Phosphorous, and Soluble Reactive Phosphorous. Obtain sampling locations with GPS.

Schedule for Implementation
Winter 2005

Implementation Summary
This measure was intended to evaluate sediment in the lake as a possible source of bacteria contamination, and to determine if bacteria can lay dormant in the lake sediment. Samples were initially collected at 7 sites around the lake in the spring to establish a base line, and get a sense of sediment contamination in the lake after spring turnover. Throughout the year, monthly sediment samples were taken at the intake location. Then in the fall before turnover, another set of samples at the 7 sites around the lake were taken.

Sediment samples from the lake bottom adjacent to the 48" intake were collected by utility personnel on February 9, 2005, April 25, 2005, and then monthly through November 21, 2005. Testing parameters included Total coliform, Fecal Coliform, Enterococci, and Clostridium perfrigens.

The first round of samples at 7 sites around the lake occurred on May 17, 2005, when the diving inspection company of Underwater Solutions Inc. of Mattapoisett, Massachusetts was hired to collect bottom sediment samples and water samples at locations in Lake Auburn. The sample locations were identified with a GPS unit and are indicated on the sediment map within Appendix D. Sample sites include:

Sample Location # 1. Sample collected a depth of 118 feet in lake bottom described "as soft, silty bottom, free of obstructions or marine growth".

Sample Location # 2. Sample collected at depth of 98 feet in lake bottom described "as soft, silty bottom, free of obstructions or marine growth".

Sample Location # 3. Sample collected at depth of 33 feet in lake bottom described as having a good deal of "colonial/filamentous cyanobacter (blue-green algae).

Sample Location # 4. Sample colleted at depth of 30 feet in lake bottom described as "very silt with numerous colonial/filamentous cyanobacter (blue-green algae).

Sample Location # 5. Sample collected at depth of 30 feet In lake with bottom described as "a hard bottom having a soft silt layer measuring 2" in depth with several clams witnessed in the area".

Sample Location # 6. Sample collected at depth of 22 feet with lake bottom described as a hard bottom having marine growth measuring 6" in depth with several colonial/filamentous cyanobacter found within the area.

Sample Location # 7. Sample collected at depth of 17 feet with the bottom described as a hard mud bottom having 2" of soft silt and algae growth.

Please note that these Sample Site locations are different than the "Inlake" sample sites and "Tributary" sampling sites previously discussed. These sediment sample sites around the lake were selected based on several criteria; the sites near tributaries were tested because AWD/LWD experienced high coliform counts during heavy rainfall events, the deep water sites were tested because of suspected bird roosting, and bacteria was measured in the deep hole in an earlier study, the Bird Island area was sampled because of the large bird population casually observed on and around the rocks, and the intake was sampled because that is the point of control.

Sediment and water samples were processed by Analytical Services, Inc. of Williston, Vermont. Testing parameters include Total coliform, Fecal Coliform, Enterococci, and Clostridium perfrigens. The lab results are attached in Appendix E.

During the week of October 10th, 2005, Underwater Solutions returned to take sediment and water samples at the same locations as in the spring. The lab results are appended in Appendix E. The earliest lake turnover in the last five years was the last week of October and AWD/LWD wanted to make sure samples were collected before turnover. As was hypothesized earlier, this information should help determine what is going on in the water column when experiencing an event of high coliform bacteria counts. All the sediment sampling results are summarized in Appendix E.

A review of the results indicates that bacteria exist in the sediments at various depths and locations in the lake and are higher near the tributaries and the bird island location. The concentrations of total coliform and E. Coli in sediments tended to increase between spring and fall. The concentrations, however, are relative and no substantive conclusions can be made about their contribution to the water column. Furthermore, the concentrations are not high enough to suggest that they contribute much to elevated fecal coliform at the intake during different seasons and weather conditions during the year.

Measure No. 7 - Chemical and mircrobiological testing for E. coli source

Collect samples regularly and analyze for enterococci, sulphite reducing clostridia, and campylobacters. These organisms will be speciated to help determine if the source of these fecal markers is avian. Subject to availability of a suitable laboratory, samples will analyzed for fecal sterols to help pinpoint the animal source of the fecal material.

Schedule for Implementation
Winter 2005

Implementation Summary
Dr. Colin Fricker of ASI consulted with the AWD/LWD and Camp Dresser McKee on the available data and recommended a sampling program which included analysis for enterococci, sulfite-reducing clostridia and campylobacters. The critical determinant within this sample regimen was analysis for campylobacters. Other parameters were included as possible indicators of avian contamination should culture fail to reveal the presence of campylobacters. Per the 2005 protocol, if E coli in lake water samples become elevated, AWD/LWD initiated collecting samples and performed analyses for

enterococci, sulphite reducing clostridia, and campyplobacters to help determine if the source of these fecal markers is avian.

Fecal coliform levels began increasing in the lake samples, while other bacteria levels at tributaries began decreasing toward the end of October. On October 18, two samples were collected at the inlake site 12, the intake, for Campylobacter species. Within the water column at 4 meters Campylobacter lari was detected in both samples. No Campylobacter was recovered from the sediment at the intake location. Campylobacter lari was also detected in samples collected on November 15 and December 5, 2005. The occurrence of Campylobacter spp. in surface waters is an indicator of the presence of waterfowl.

Dr. Fricker concluded that there is strong circumstantial evidence that birds were responsible for the increased levels of fecal coliforms in the lake, which can be summarized as follows:

Coliform levels began to rise when the numbers of roosting birds increased during late fall and early winter. Microbiological examination of the water for the presence of campylobacters demonstrated the presence of *C. lari*, which is particularly associated with gulls. The reduction in the numbers of roosting gulls caused by the harassment program and the concomitant reduction in fecal coliforms is also good evidence that the contamination events were caused by birds and not fecal material from humans, livestock or feral animals.

Dr. Fricker states that he feels that the increases in fecal coliforms within Lake Auburn were as a result of fecal contamination of the lake by roosting gulls and as such the contamination presents a low risk to public health for consumers of water abstracted from this source. A letter summarizing Dr. Fricker's microbiological assessment of Lake Auburn, with regard to fecal contamination is presented in Appendix F.

Measure No. 8 - Additional gulls and waterfowl roosting control measures

Federal law prohibits harassment of wildlife; however, water suppliers can obtain special permits allowing harassment of certain problematic bird species. Within New England, there has been a growing awareness of the significant water quality effect of birds such as gull, Canada geese, and cormorants. These birds can travel in large flocks, and will roost overnight in open water. Lethal and non lethal means should be considered. The harassment could include firing blank rounds, pyrotechnic devices or other noise makers from shore or boat. Amplification of recorded gulls and waterfowl distress calls may also be effective. Personnel must be ready to act on a daily basis and to conduct surveillance and harassment at twilight. If it becomes impractical to police the entire lake, establish a "no waterfowl zone" that includes the intake area and a portion of the lake. On land harassment can include nets and wires, silt fencing in shallow waters, and scare crow type devices. It will be particularly important to be vigilant during the October to ice-in period.

Schedule for Implementation
Fall 2005 (or as soon as gulls and waterfowl roosting activity is anticipated)

Implementation Summary

After observing over 500 seagulls roosting through the night for a week in late August on Lake Auburn a very basic bird harassment program was established and implemented. After researching several techniques and other programs, the goal of the 'bird harassment program' was to discourage the seagulls and possibly other water foul that may be roosting on Lake Auburn and affecting water quality of the lake.

On September 7, 2005, water utility personnel got on the water with a boat and patrolled around the lake to locate and then discourage the large populations of seagulls and comerants. Utility personnel used pyrotechnic loads with starter pistols to create loud 'bangs' in the birds' general direction to scare off the seagulls and comerants. Loons and duck have not been harassed and will not be harassed as they are not in the large numbers to affect the water quality of the lake. The bird harassment starts in the afternoon around 5:00 pm and goes until dusk. The harassment program objective was to discourage the birds from roosting on Lake Auburn through the night. By not allowing them to be there just before dusk, it was expected that it would eventually modify the birds' habits.

After September 7, 2005, AWD/LWD patrolled and harassed birds on a regular basis. Early results (prior to early November) indicated some reductions. Observations were made twice daily and recorded. The following is an example of a daily report:

- Seagulls have decreased from 500+ to approximately 200
- Approximately 16 loons reside on Lake Auburn
- Several (less than 5) hooded mergansers live on the lake
- Approximately 12 wood ducks live on the lake
- There are approximately 24 comerants on the lake
- Approximately 50 geese reside on a farm next to Taber's Golf and have not been observed on the water
- The birds roost in different areas on the lake and those locations are dependant upon wind direction.

AWD/LWD discussed bird harassment techniques with the Massachusetts Water Resources Authority (MWRA) to learn from their program and adjusted the AWD/LWD program to continue to decrease the large population of birds that may be roosting on Lake Auburn. MWRA recommended that consistent application of harassment and frequently changing methods would yield the best results. Overtime, they had found that pyrotechnics and firearms shooting whistling shells were most effective.

Until the November 8th observations, the harassment efforts were somewhat successful at decreasing the number of seagulls that are roosting on the water at night. However, as a result of a significant increase in the number of gulls after November 8, 2005, AWD/LWD met representatives from the United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Wildlife Service (WS) during the week of November 14th. With the support of USDA, a lethal/non lethal bird harassment program was instituted on November 21, 2005. Attached in Appendix G is a copy of a Cooperative Service Agreement with USDA for services between November 21, 2005 and December 31, 2005 and a letter detailing WS activities during this time.

As detailed in the letter, WS' conducted harassment and shooting activities on Lake Auburn from November 21, 2005 to December 13, 2005. WS' involvement in this project was to be present on Lake Auburn during approximately 0500 hrs to 0800 hrs, and from 1400 hrs to 1700 hrs. WS' role was to provide an Integrated Wildlife Damage Management Program (IWDMP) that included the use of pyrotechnics and watercraft to harass gulls away from the affected area, as well as, lethal control (shooting) to reinforce and enhance the effectiveness of non-lethal methods. This work was in direct cooperation with the harassment efforts that were simultaneously being conducted by AWD and LWD.

On November 21, 2005, WS noted that a substantial number of gulls were present, with a maximum number estimated at 2000 individuals. WS noticed a gradual decline of gulls throughout the duration of the project, and on several days nearing the end of the project, less than five gulls were observed throughout the day. This gradual decline in the numbers of gulls that were identified on Lake Auburn was the measure used to determine that the program was successful. Climatic conditions such as high winds and ice formation caused limitations to the timing and duration of the program, and ultimately caused the work to conclude (ice), despite the presence of a small flocks of gulls using Lake Auburn. Overall, WS believes that the decline of gull presence was directly related to the active management during the four week period, and that this success clearly demonstrates the effectiveness of the program.

Measure No. 9 – Conduct hydraulic circulation pattern investigation

A field study to assess circulation patterns in the lake would be to drop drift floats, each labeled with the date and time of deployment (and even a GPS tracking device depending on expense), into the major tributary mouth (Basin spillway). This data will assist with determining a range of travel time from coliform sources to the intake. Deploy a large number on several occasions with a variety of wind and runoff conditions. Watch for them to turn up at the intake, and note the date and time of retrieval.

a) A possible drift card would be a wood Venetian blind slat 2 or 3 ft long, weighted at one end and buoyant at the other. Not all of it would float at the surface, but a significant fraction would be immersed in the water a foot or so below the surface.

b) A less expensive drift card would be a stub of a 2 x 4 (maybe only 3 inches long). This option is less expensive than the Venetian blind slat, and less likely to snag on the bottom, but more representative of just the very surface layer.

Schedule for Implementation
Spring 2005

Implementation Summary
AWD/LWD had initially planned to conduct only a surface water flow study of the Lake by deploying floating "markers" at various points around the Lake. In-house personnel would have then monitored the disbursement of the markers across the Lake, and also tracked their arrival at on-shore locations. AWD/LWD abandoned that proposal in favor of a more comprehensive, three dimensional modeling approach.

The firm of J.E. Edinger Associates, Inc. (JEEAI) of Wayne, Pennsylvania conducted a computational hydrodynamic model of Lake Auburn. JEEAI (now known as ERM) is an international consulting firm specializing in modeling and analysis of watersheds, rivers, lakes, reservoirs, estuaries and coastal waterbodies.

Bringing JEEAI aboard allowed AWD/LWD to conduct a hydrodynamic study of the lake and its flow conditions. The modeling work incorporates existing bathymetric data of the lake along with data gathered from the U.S. Geological Survey Report titled "Water Budget for Lake Auburn, Maine, May 1, 2000 through April 30, 2003". The model also incorporates past climate information such as wind speed, rainfall intensity, and lake temperature. With all the data input into the Model, the model tracks flow and temperature patterns, as well as fecal coliform concentrations throughout the lake.

A three-dimensional (3-D) hydrodynamic and water quality model, GEMSS (Generalized Environmental Modeling System for Surfacewaters) was used to study the flow patterns in Lake Auburn for the time period April 2002 to November 2002. The model was calibrated for water surface elevation (the "water balance") and for temperature, and then used to study the fecal coliform transport within Lake Auburn for stratified and non-stratified time periods using data from 2002. GEMSS as applied to Lake Auburn, shows good calibration for water balance and water temperatures based on the available input data. The model results also indicate different types of circulation patterns within Lake Auburn, which are affected by frequently varying wind directions, the Lake's bottom contours, and the presence or absence of temperature stratification.

Since coliform concentrations at intake are of concern, an investigation of possible sources and source strengths was conducted. Simulations were made with GEMSS for a total of nine fecal coliform source locations including three tributary source locations, three sediment source locations and three bird source locations. These source locations were examined for high inflow, high outflow, and runoff event conditions. The simulations show that fecal coliform concentrations at the intake

during the summer stratified time period are much smaller than those during the fall non-stratified time period.

Among each of the coliform source locations (tributary, sediment and bird), sources near the Townsend Brook and in the vicinity of bird island yield higher concentrations at the intake. This result may be due to the short distance between the source location and the intake and the driving force of Townsend Brook inflows.

For the tributary source locations, the highest coliform intake concentration occurred under the high inflow rate condition for the non-stratified period. For the sediment source locations, much higher intake coliform concentrations occurred in the non-stratified time period than in the stratified time period. The bird sources also show a similar result.

Runoff events, particularly in non stratified condition and in Townsend Brook, can influence intake.

A draft of the full model report is attached as Appendix H.

Measure No. 10 – Implement standby intake switching

The standby intake is 36-inch in diameter and has been out of service since 1996. If testing shows significantly better fecal coliform results closer to shore at the standby intake location, then it would be worthwhile to construct improvements necessary to bring the intake on line on short notice. Since the standby intake does not go directly to the clearwell, improvements would be needed to set up alternative chemical injection points and sampling points.

Schedule for Implementation
Not determined

Implementation Summary
The standby 36" intake structure has not been used since 1996. The diving inspection company of Underwater Solutions Inc. of Mattapoisett, Massachusetts was hired to undertake an inspection of the 36" Cast Iron Pipe intake structure to determine the condition of the intake and pipeline. If water quality testing indicated better water quality available closer to the shoreline in shallower water during certain times of year, the two utilities may be able to use the shallower 36" intake instead of the current deeper 48" intake structure.

The inspection, completed on May 18th by Underwater Solutions Inc. revealed the standby intake to be in usable condition. "It is the opinion of Underwater Solutions Inc. that this entire 36" inside diameter intake remains in very good condition and without abnormalities at this time. The end of this intake is 45 inches above the lake floor and 13 feet below the water surface."

Sampling at inlake site 10 (emergency intake) showed that fecal coliform levels closely followed data from the inlake intake site 12. In the November period, values at site 10

were sometimes slightly lower and at other times slightly higher than site 12. Therefore, there was no apparent advantage in operating the emergency intake.

AWD/LWD also had the 48″ intake inspected at the same time with the following report: The end of the 48″ intake consist of a 48″ inside diameter (T) which measures eight feet from opening to opening. A long 4 foot 45 degree section of plastic pipe extends down and ties into the 48″ pipeline with a bolted flange. No obstructions were found within the "T", although a 1/8″ layer of marine growth algae was found on all surfaces. The end of the pipe is located 960 feet out from the face of the pump building. No obstructions or debris were found in or around this pipe. The end of this intake is five feet above the lake floor and 17 feet below the water surface.

Section 3

3.1 Update of 1993 Turbidity and Bacteria – Summary through 2004

The installation of a new intake along with follow-up on the Turbidity and Bacteria Study recommendations and the ongoing Watershed Protection Program have resulted in excellent source water quality and a track record of compliance with the source water criteria of the SWTR.

A brief review of water quality at the intake since 1997 is shown in Table 1, below, based on monthly reporting (1997 was selected based on availability of data from the new intake). Turbidity has never exceeded 3 NTU in the period 1997 to 2004; the maximum turbidity allowed is 5 NTU. Note that coliform reporting switched from total coliform to fecal coliform in May of 2001. Based on approximately five coliform samples per week, in any six month period up to 13 coliform values exceeding the limit (100/100ml for total and 20/100 ml for fecal) are allowed. It should also be noted that the track record for meeting the CT treatment requirements and for maintaining a bacterially safe distribution system has also been excellent over the period.

	Coliform No. of Days Exceeding limit	Turbidity No. of Days with Turbidity >1 & <3
1997	0	2
1998	2	1
1999	0	4
2000	0	10
2001	1	31
2002	4	9
2003	2	14
2004	18	6
AVERAGE PER YEAR	3.4 days	9.6 days

Table 1
Coliform and Turbidity History

In the late fall of 2004, short-term fecal coliform levels increased abruptly in Lake Auburn. In the first ten months of the year, no daily fecal coliform sampling values exceeded 20/100 ml, with the highest value being an 8 count in October 2004. On November 4, 9, and 10, 2004, fecal coliform rose above 20 colonies/100 ml. Again on November 29, 2004, fecal coliform rose over 20/100 ml, but remained above 20/100 ml for the next 14 consecutive samples (through December 15, 2004). After December 15, fecal coliform exceeded 20/100 ml only once more on December 19, 2004 and has been below 20/100 ml through early January 2005. In early December, when AWD/LWD realized that a "consecutive" exceedance was underway, they took immediate steps to attempt to track and mitigate the source. On Monday, December 6, 2004 they engaged CDM to assist and began an intensive sampling program. Elements of the program included:

- December 6 –
  - Conducted in-lake sampling at the deep hole location, intake, and clearwell.
- December 7 –
  - Conducted lake and tributary sampling at 13 predetermined sites for analysis.
  - Split samples with laboratories (HETL and Portland Water District).
  - Initiated extra distribution sampling plan.
  - Raised chlorine dosage by .5 mg/L.
  - Contacted Underwater Solutions for emergency inspection of intake and clearwell.
- December 8 -
  - Shut down pumps for both systems all day.
  - Conducted "grid" sampling and analysis in vicinity of intake.
  - Inspected the intake structure using divers.
  - Surveyed the entire shoreline.
  - Checked shoreline septic systems for failures.
  - Collected a sample of intake pipe biofilm.
- December 9 – Contacted Nancy Beardsley, Maine Drinking Water Program, to update and arrange a meeting.
- December 13 - Collected a sample for Giardia, Cryptosporidium, and Virus for analysis while coliform levels were elevated.
- December 14 – Met with Nancy Beardsley and Jennifer Hitchcock of the Maine Drinking Water Program.

Other Activities:

- Obtained speciation results for coliform.
- Compiled data on temperature/turnover/turbidity/wind etc.
- Observed gulls and waterfowl activity on the lake.

As a result of these intensive efforts, several initial conclusions were formed as follows:

- Turnover occurred approximately on November 4, 2004.
- The duplicate data collected and analyzed indicated that laboratory error was not a cause of the elevated readings.
- The coliform levels were present in a large portion of the lake and at higher levels in the deeper locations.
- Biofilm in the intake pipe and/or clearwell was not considered a likely source, but biofilm test results are still pending.
- Tributaries were not conveying any significant amount of fecal coliform (values all less than 4/100 ml) into the lake at the time when elevated levels were observed in the lake.
- The intake seems intact, as designed, although a small leak (air bubbles) was observed in a small fitting on the pipe, about 150 feet from shore.
- High levels of E. coli were present in 14 of 14 samples analyzed when corresponding fecal coliform readings were over 20/100 ml.
- Results of testing for Cryptosporidium and Giardia Lambia indicated that none were detected.
- The initial results on speciation of the fecal coliform samples indicated the following species appearing in more than one sample/isolate.
    - Escherichia coli
    - Escherichia sp.
    - Serratia fonticola
    - Serratia liquefaciens/grimesii
    - Rahnella aquatilis
- Gulls were observed roosting on the lake in the vicinity of the deep hole. Other migrating waterfowl were also observed on the lake. The lack of a fecal coliform contribution from the tributaries suggests further investigation of a seasonal in-lake source.
- A review of the possible correlation of the higher coliform levels to various parameters including turbidity, rainfall, wind, lake water level and lake water temperature, and turnover timing did not seem to show any correlations. It was observed by a visual review of the lake water

temperature data that temperature in the fall of 2004 through November was approximately one-half to one degree Celsius higher than in any of the previous three years.

- A review of turnover timing indicates a similarity to recent previous years.
- Data for turbidity and coliform were reviewed and compared to the same period in the previous three years for the months of October, November and December (Note: data back to 2001 was included since reporting was switched to fecal coliform at that time.) In 2001 and 2003, fecal coliform levels showed only a minimal increase in the fall/early winter period. In 2002, there were only four times fecal coliform levels that were over 20/100ml; all occurred in a four day period in December. In 2004, much more elevated levels appeared during the same period. No apparent correlation was observed between elevated turbidity levels and elevated fecal coliform.
- This unusual event may be the result of a series of small events that led to it rather than one single event.
- Water balance changed in 2002 with the repair of the East Auburn dam.

Based on the above findings, it was concluded that weather, lake level, water temperature, turnover and turbidity factors were similar to past years and did not correlate well with the elevated coliform levels. It is possible that sediments disturbed by turnover distributed previously deposited coliform back into the water column, but this was not supported by a direct correlation of turbidity with fecal coliform levels.

Section 5

5.1 2005 Turbidity and Bacteria Study Findings

The investigations and progress made within 2005 to identify and reduce the accumulation of fecal coliform bacteria in Lake Auburn has resulted in the following findings:

Field data indicates that during November when intake fecal coliform levels were up and fecal coliform levels at all inlake sampling sites as measured at intake depth were also up including extreme values at the Bird Island sampling site, the fecal coliform input measured at the tributaries was very low. This reinforces the major influence of the direct input of fecal to the lake from gulls and other water fowl. Accordingly, without the massive fecal coliform input to the lake from roosting gulls in November, **tributary inflow alone is not likely to cause fecal coliform levels to approach 20.**

When an effective gull harassment program by USDA was underway from November 21 to December 13, 2005, including lethal measures, gull population roosting on the lake declined from 2000+ to about 5. There was a steady and remarkable corresponding decline in fecal coliform levels observed at the intake and at the inlake sampling sites during this period. From December 6 to December 22 (on December 22 there was a brief ice over of the lake), fecal coliform levels were consistently less than 5 as opposed to the month of November which had only 2 days under 5 and 11 days over 20. **Effective gull harassment resulted in remarkable decrease in fecal coliform.**

Speciation of fecal coliform samples point to gulls as the source. The microbiological examination of the water samples for the presence of campylobacter, reviewed by Dr. Colin Fricker, demonstrated the presence of *C. lari*, which is particularly associated with gulls, in four gull samples collected between October 18, 2005 and December 5, 2005.

There has been no Giardia or Cryptosporidium detected in Lake Auburn in the history of sampling for these constituents. In the last nine months since April 2005, samples have been taken each month for both Giardia and Cryptosporidium with none detected. Prior to April 2005, samples for both the latter constituents were taken annually since 1996 with none detected. In 2004, an extra sample taken while fecal coliform levels were high also yielded none detected. These results are extremely supportive with respect to the high quality of water in Lake Auburn.

When the lake is not stratified (e.g. after turnover) fecal coliform from tributary sources for large rainfall/runoff events have a greater impact on fecal coliform levels at the intake than in the stratified period. This was apparent based on the modeling comparison of August conditions (stratified) with November conditions (non stratified) under the same fecal loading and rainfall conditions. Based on the water quality modeling results, the hydraulic pattern in the lake is altered after turnover

allowing full depth uni-directional flow patterns to occur as opposed to a multi-directional pattern when the lake is stratified.

Modeling also showed that all sources including bird input, sediment and tributaries in the vicinity of Townsend Brook and Bird Island have a more direct influence on fecal coliform at the intake than other locations around the lake.

Field data for rainfall/runoff events during the stratified period of 2005 indicated that storms with total volume in excess of 1-inch generally had little effect on fecal coliform at the intake, raising levels by 2 or 3.

The impact of rainfall/runoff on the intake is also dependent on other factors. Factors such as antecedent dry period, rainfall intensity and the rate of deposition of bacteria on the watershed are also significant, but were not considered in this analysis. In addition, wind direction and speed, currents and sunlight can affect what amount of fecal coliform reaches the intake.

A secondary impact of rainfall/runoff, especially from the Townsend Brook watershed is its ability to move fecal coliform that have been deposited in the lake by gulls and other waterfowl toward the intake. This was confirmed by lake water quality modeling.

Exceptional storms including the 6.5 inches of rain that fell from April 20 through April 28 (in addition to snow melt) and the 6.3 inches of rain that fell on October 8 and 9 seemed to raise fecal coliform levels to 12 and 13, respectively, at the intake for short periods of time. In the case of the October 8 and 9 storms it is not clear how much of the fecal coliform at the intake was contributed by inlake sources such as the gulls as opposed to runoff.

During the non stratified lake period after October, there is a correlation between heavy rainfall exceeding one inch in volume, the presence of gulls roosting on the lake and the level of fecal coliform at the intake. In November of 2005, there is evidence that the roosting gull population was increasing and thus, the fecal coliform levels in the lake were also increasing. As discussed above, after turnover, fecal coliform deposited in the lake by gulls is more likely to be transported toward the intake by wind and rainfall. In addition, when the lake is stratified, gull feces can drop below the thermocline where the temperature stratification prevents further fecal coliform release from reaching the shallow intake.

For the entire 2005 summer period the inlake sampling stations had fecal coliform values of generally 5 or less, measured at approximately the intake elevation. Beginning about mid-October there was a clear upward trend in fecal coliform at all sites approaching an average of just over 10. The Bird Island site (Site 7) exhibited very high fecal coliform levels from October 31, 2005 to November 28, 2005. During the latter period, the Bird Island inlake site data began with a high fecal coliform value of 246 on October 31, 2005 and end with a fecal coliform value of 100 on November 28, averaging 136.

The examination of sediments at up to seven sites around the lake on two occasions, May and October 2005, and monthly samples taken at the intake from April through November 2005 indicates that total coliform and E. Coli increase as the seasons progress from spring to fall. In addition, bacteria levels in the sediments were not considered to be very high. The latter combined with the exceptionally low and stable turbidity levels in the lake, which were always less than 1 NTU, would indicate very little transport of sediments that might harbour bacteria.

Fecal coliform level at inlake sampling sites 8 (deep hole), 9 and 11 showed and increase in bacteria levels at all depths by mid-October prior to turnover due to direct fecal coliform input to the lake. Samples taken at the deepest sampling depths (16 to 32 meters) at the three sites showed additional fecal coliform increases after fall turnover.

Section 6

6.1 2006 Turbidity and Bacteria Study Recommendations

Based on the findings as discussed in Section 5, the recommendations outlined below include steps to enhance the gull management program that started in 2005 in order to appropriately address the future presence of gulls on Lake Auburn and a continued approach to lake sampling efforts. AWD/LWD plans to continue involving USDA Fish and Wildlife Service (WS) as part of the gull management program. A letter detailing their recommendations and a proposal attached are as Appendix G. The recommendations outlined by WS are included as part of the Recommendations summarized as Action Item No. 1 below.

Action Item No. 1 – Conduct a comprehensive survey of water birds in the vicinity of Lake Auburn, continue bird inventory and roosting control measures, and conduct bird food habits study

A comprehensive survey of water birds in the vicinity of Lake Auburn will provide data that can be analyzed to support any necessary management decisions. Initially, regional population trends must be documented, and basic population dynamics must be understood. These objectives may be best achieved through local surveys. The timing and frequency of these surveys are typically designed to best encounter bird activity during daytime hours (i.e. early morning, late afternoon) and to identify seasonal and weather related variations in bird activity. A standardized survey design is used, and this is based upon the United States Fish and Wildlife Service's (WS) Breeding Bird Survey (BBS). Routine bird surveys will provide answers to many questions including:

- Where are gulls feeding?
- Are gulls nesting locally?
- When gulls are dispersed from Lake Auburn, where do they go?
- What is the species composition and relative abundance of the local gull populations?
- To what degree does the gull migration effect gull presence on Lake Auburn in the spring and fall?
- Do other area lakes harbor gulls, and if so, how is gull use of those water bodies related spatially and temporally to Lake Auburn?
- Do climatic or environmental patterns exist relative to gull use on Lake Auburn?
- Do daily movement patterns exist in the local gull population, and if so, what are they?

- What are the current natural and man-made habitat features that effect the gull population, and can efforts be made to alleviate nearby gull attractants?

While the bird surveys are underway, direct management activities, such as harassment or shooting may need to continue. The direct management activities will be dictated by the numbers of gulls (therefore, the bird inventory will need to continue on a daily basis and be coordinated and implemented by WS in conjunction with AWD/LWD direction.

An additional source of information is often attained through stomach content analysis of the birds. In order to study local gull food habits, a collection of sample of birds taken under the USFWS depredation permit would be analyzed. This analysis could prove useful to document the daily activity patterns and foraging locations of gulls at Lake Auburn.

Action Item No. 2 - Implement new sampling program protocols

For the inlake sampling program, approximate weekly sampling should include Bird Island and a new site termed Salmon Point (the peninsula of land on the north side of the lake jutting out between tributary sample sites 3 and 23) and all previous sampling stations. This site will provide more inlake information in the area north of the intake and west of Bird Island which has been a hot spot for gull activity in the past. Frequency will be increased to weekly for all inlake sites from September to ice-in, similar to what AWD/LWD completed in 2005. Surface sampling should be added to the sampling routine at all sites. Sampling parameters to include: Total and fecal coliform, all relevant microbiological parameters, temperature, dissolved oxygen, turbidity, color, secchi disk, pH, and conductivity. Once per month sample for Total Phosphorous; Soluble Reactive Phosphorous; Algae; Chlorophyll a; Nitrate; and Ammonia. Enterococci and Clostridium should be dropped from the weekly program.

Perform a more intensive examination of the fecal material of the gulls and the microorganisms found in the lake, focusing particularly on campylobacter. The link between birds and contamination could be demonstrated using profiling of the Campylobacter species without the necessity of using much more expensive procedures such as microbial source tracking.

For tributary sampling, sampling frequency should be the same as 2005 and parameters should include: Total and fecal coliform, all relevant microbiological parameters, temperature, dissolved oxygen, turbidity, color, pH, and conductivity. Once per month sample for Total Phosphorous; Soluble Reactive Phosphorous; Nitrate; and Ammonia.

Wet weather sampling at the tributaries and the inlake stations should target several rainfall events during the year, focusing on expected rainfall volumes of 1-inch or more and an antecedent dry period of three days. If possible, sampling should be done just prior to the rain, during the rain and for three consecutive days following the rain. Sampling parameters at a minimum should include temperature, dissolved

oxygen, turbidity, total coliform and fecal coliform. Significant rainfall events after fall turnover should be given a priority.

A monthly schedule for all routine raw water sampling is depicted as Appendix I.

Action Item No. 3 - Design flow measuring capabilities to estimate the impacts of each tributary.

Reactivate USGS flow measurement stations for the "Basin" tributary and for Townsend Brook. Contact USGS and arrange to replicate past gaging methods used on these two tributaries. Obtain USGS rating curves. Purchase or lease the equipment and data loggers as needed.

Action Item No. 4 – Investigate removal of Bird Island.

If feasible, remove Bird Island by excavating and removing it down below the water level to a depth that will not be a hazard to watercraft. A boring/rock coring will likely be needed to determine an appropriate method for removal. In the interim, install deterrent devices on the island to make it unattractive for waterfowl and birds.

Based upon the success of the bird management program employed during the fall of 2005 on Lake Auburn and expertise from WS and others who have successfully managed a bird management program on drinking water sources, it is expected that the proposed recommendations above can significantly reduce the number of gulls and other water birds using Lake Auburn to help ensure low levels of bacteria at the intake. These measures will also continue to provide data regarding the quality and condition of the lake and its tributaries so future threats can be mitigated in a timely manner.

TABLE 2 - Possible Investigations for Coliform Source Mitigation

Source Investigations	Comments on Applicability to Current Issue	Relative Priority
o Inventory birds and waterfowl and make observations	Regular observations, during day and night periods, including location and approximate count will help with further mitigation efforts. Both roosting and nesting areas should be considered on the lake and along the shore.	High
o Update and increase frequency of on-lake sampling	Sample Deep Hole, Near Shore, Standby Intake, Outlet, and stations 9 and 11 locations from 1993 study biweekly. Increase frequency to weekly during October to ice-in period.	High
o Review GIS mapping and orthophoto of lake/watershed	Review photo from areas of concern such as expanded farms, lumber activities, etc., for followup investigation. Use GIS to display data gathered under other activities	Moderate
o Survey near shoreline subsurface disposal systems	Identify all systems within 500' of lake shore, review Auburn records of all upgrades and replacements to determine older systems. Perform physical inspection. This is good practice and should be implemented but is applicable to human waste issues only.	Moderate
o Initiate new watershed tributary sampling schedule and protocol. Repeat sampling locations from 1993 study. Track sources by sampling upstream along Townsend Brook and Basin tributary, the largest surface water inflow source.	Thirteen locations are sampled regularly. Increase frequency of coliform sampling to bi-weekly at basin tributary and weekly during October to ice-in period. Include dry weather and first flush wet weather sampling. Followup high levels of coliform with upstream sampling to help find source. Recent sampling did not reveal significant sources of coliform in tributaries.	Moderate
o Sample lake bottom sediment for fecal and total coliform	Sampling bottom sediments from on top of ice cover will provide information on survival of fecal coliform in bottom sediments. It will help to determine how responsive sediment coliform is to source control.	High
o Hydraulic Circulation Pattern Investigation	Physical investigations of current and circulation could consider travel times from tributaries or roosting areas to intake. This would allow consideration of lag time from mitigation activity to intake withdrawal.	Moderate
o Survey farms with livestock/animal waste disposal practices	Visit farms and stables and obtain livestock count. Review BMPs for waste control. Doesn't address waterfowl issue, since this is applicable to livestock issues only.	Low
o Survey Basin sediment build up to assess possible scour	Obtain bottom sediment readings from access on top of ice cover along basin and downstream of the basin dam and compare to last survey in late 1980s. The basin helps with natural treatment so this is applicable to the control of bacteria and turbidity in the lake's largest tributary. Prior testing, however, has shown the basin to be a low source of fecal coliform.	Low

TABLE 2 - Continued - Possible Investigations for Coliform Source Mitigation

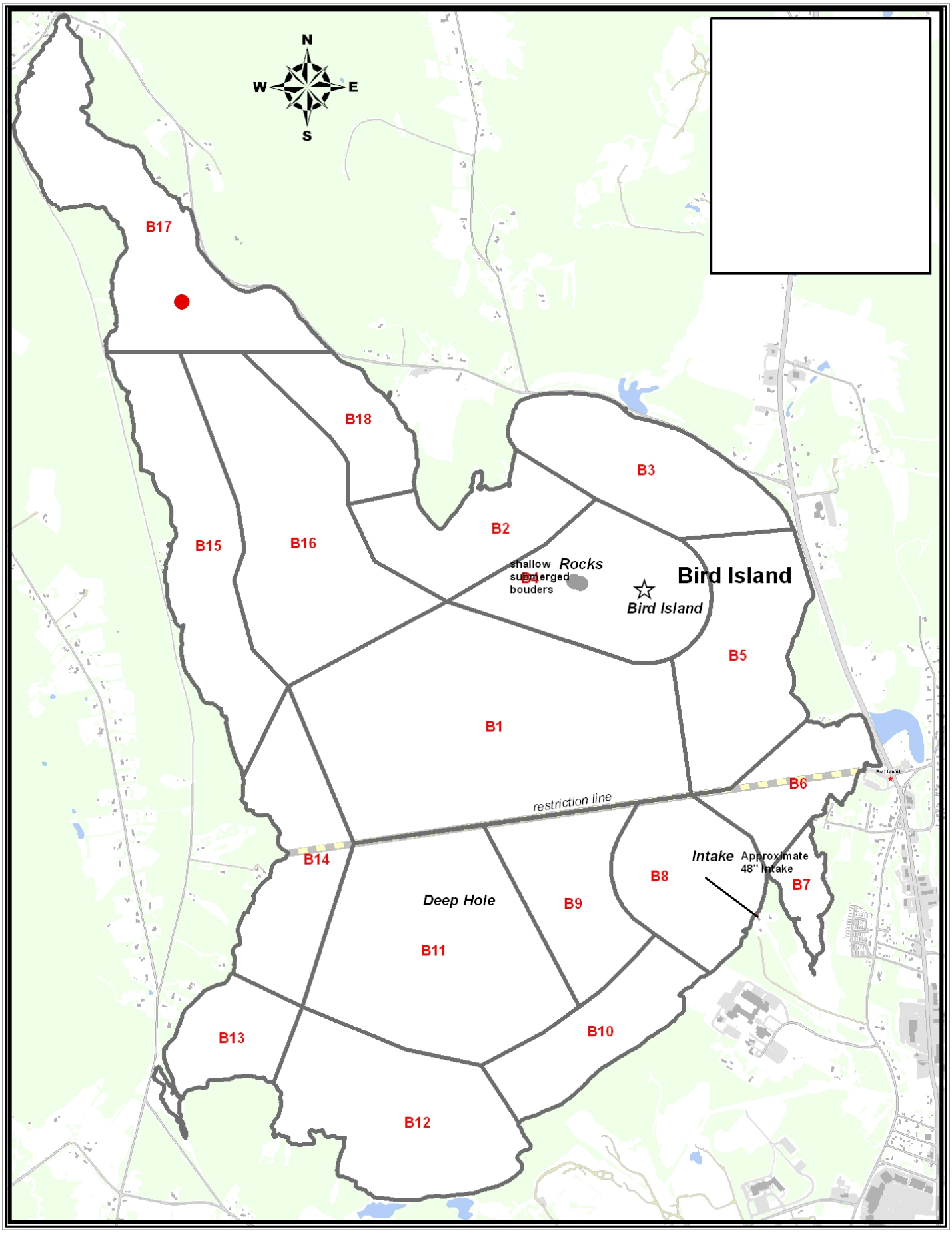
Source Investigations	Comments on Applicability to Current Issue	Relative Priority
o Survey wildlife habitats to estimate density	Counting of wildlife and habitats is difficult. Focus should be on beavers and aquatic mammals. Doesn't address waterfowl issue, since this is applicable to wildlife waste issues only	Low
o Assess recreational impacts (boating, hiking, etc)	Daily boat counts already taken. Review sanitary facilities and use of trails near the shore including dog walking and horse riding activities.	Low
o Microbiological Source Tracking Program	Several methods are available. Some, such as ribotyping, have been used successfully to identify a predominant source, but require establishment of a local data base of organisms collected from fecal material from targeted organisms (e.g. birds, humans, cattle). Bird material will only be available during the fall. The tests are expensive to perform and will only be used if other methodologies fail to establish the source of the *E. coli.*	Low
o Chemical and microbiological tests to establish the source of *E.coli*	Definitive identification of the source of fecal contamination is difficult, but the use of a variety of microbiological and chemical markers can help establish a source. Regular samples will be taken and analyzed for enterococci, sulphite reducing clostridia and campylobacters. These orgainisms will be speciated in order to help deterimine if the source of these fecal markers is avian. In addition, if a suitable laboratory can be found to perform the analysis, samples will be taken for fecal sterol analysis. Sterols can help pinpoint the animal source of fecal material.	High
o Investigate intake pipe leak	Initial investigation revealed that a fitting on a future chemical injection line on the intake pipe is leaking slightly. Not believed to be contributing to coliform problem.	Low

TABLE 3 - Possible Control Measures for Coliform Source Mitigation

Source Control Measure	Comments on Applicability to Current Issue	Relative Priority
o Additional waterfowl and bird roosting control measures	Measures might include establishing a No Waterfowl Zone and harrassing waterfowl day and night.	High
o Standby Intake Switching	Past sampling has indicated that better bacterial water quality might be obtained in nearer shore standby intake. However, near shore intake has a greater risk of turbidity event. After 2005 sampling, assess potential of use.	Moderate
o Additional waterfowl and bird nesting control measures	Curtail nesting by removal or destruction of eggs and nesting areas. Past inspections have shown only minimal nesting around the lake.	Low
o Additional BMPs for runoff control	BMPs such as retention ponds for culverts and filter strips can be considered to delay runoff. However, fecal coliform from direct runoff and culverts are not considered a significant source.	Low
o On-site storage/treatment for livestock on watershed	Livestock on watershed less than 50 head at individual locations. Review ACSC guidelines with owners. Consider store and treat of wastes or filter strips. No ordinance in place to require treatment.	Low
o Septic System Upgrades/holding tanks at lake shore	No cesspools in operation. Only 12 shore properties with subsurface disposal. This will not address waterfowl issue. Suggest review of survey data when collected and reassess. Possibly offer vouchers to encourage annual pump outs.	Low
o Management of trails and bridle paths	There are few estalished trails. Abandoned Spring Road is used like a trail. Provide additional postings about manure and litter near lake shore.	Low
o Buffer zone around lake shore prohibiting dogs and horses	Appears to be a minor source. Suggest establishing a protection zone with new signage and enforcement by patrols	Low
o Retention of water during fall turnover	Preliminary indications are that even without a release from the lake during turnover, intake is still a major withdrawal and attracts coliform. Lake circulation investigations may confirm this condition.	Low
o Alum Treatment	If sampling of sediment determines that coliform survival is short term, then controllinig sources of coliform entering sediments will be a more effective approach. Priority to be reassessed after sampling program.	Low
o Intake Repair	Leak is very small on fitting. Repair can be by diver in warmer weather. Not judged to be contributing to the problem.	Low
o Biofilm removal	Based on sampling program during fall of 2004, biofilm not likely to be contributing to the problem.	Low

DATE	OBSERVER	LOC_ID	LOCATION	TIME	WIND_MPH	WIND_DIR	AIR_TEMP_C	BIRD_TYPE	COUNT	COMMENTS
7/7/2005	MLAUZE	B6		430	NA	NA	NA	DUCKS	4	
7/7/2005	MLAUZE	B8		430	NA	NA	NA	GULLS	1	
7/7/2005	MLAUZE	B4		430	NA	NA	NA	GULLS	40	
7/8/2005	MLAUZE	B6		430	NA	NA	NA	DUCKS	6	
7/8/2005	MLAUZE	B3		430	NA	NA	NA	DUCKS	6	
7/8/2005	MLAUZE	B4		430	NA	NA	NA	GULLS	24	
7/15/2005	MLAUZE	B6		700	NA	NA	NA	DUCKS	4	
7/15/2005	MLAUZE	B4		700	NA	NA	NA	GULLS	60	
7/26/2005	KGAGNE	B6		1440	NA	NA	NA	GULLS	10	
7/28/2005	MLAUZE	B6		730	NA	NA	NA	DUCKS	2	
7/28/2005	MLAUZE	B3		730	NA	NA	NA	GULLS	12	
9/1/2005	JPLEAU	B6		1600	NA	NA	NA	GULLS	10	
9/1/2005	JPLEAU	B6		1600	NA	NA	NA	DUCKS	2	
9/1/2005	JPLEAU		OUTLET	1600	NA	NA	NA	GULLS	3	
9/1/2005	JPLEAU		OUTLET	1600	NA	NA	NA	DUCKS	3	
9/5/2005	DRICHARDSON	B8		1800	NA	NA	NA	DUCKS	6	
9/5/2005	DRICHARDSON	B6		1800	NA	NA	NA	DUCKS	15	
9/5/2005	DRICHARDSON	B18		1800	NA	NA	NA	GULLS	83	
9/5/2005	DRICHARDSON	B17		1800	NA	NA	NA	DUCKS	1	
9/5/2005	DRICHARDSON	B17		1800	NA	NA	NA	BEAVER	2	
9/5/2005	DRICHARDSON	B4		1800	NA	NA	NA	GULLS	52	
11/12/2005	RLEVASSEUR	B15		1350	NA	NA	NA	DUCKS	6	
11/12/2005	RLEVASSEUR	B18		1350	NA	NA	NA	GULLS	100	
11/12/2005	RLEVASSEUR	B4		1350	NA	NA	NA	GULLS	30	
11/12/2005	KGAGNE/MLAUZE	B12		530				DUCKS	12	
11/12/2005	KGAGNE/MLAUZE	B14		530				DUCKS	20	
11/12/2005	KGAGNE/MLAUZE	B16		530				GULLS	20	
11/12/2005	JBEAULE	B5		1400				GULLS	75	
11/12/2005	JBEAULE	B3		1400				GULLS	40	
11/12/2005	JBEAULE	B18		1400				GULLS	20	
11/12/2005	JBEAULE	B15		1400				GULLS	2	
11/12/2005	JBEAULE	B15		1400				DUCKS	4	
11/12/2005	JBEAULE	B17		1400				DUCKS	5	
11/12/2005	JBEAULE	B17		1400				GULLS	1	
11/12/2005	JBEAULE	B18		1400				GULLS	40	ON LAND
11/13/2005	RLEVASSEUR	B18		1350	NA	NA	NA	GULLS	100	
11/13/2005	JBEAULE	B1		600				GULLS	50	
11/14/2005	AWD		CMMC	1405	28	NA	50	GULLS	60	ON LAND
11/14/2005	AWD		MALL	1415	28	NA	50	GULLS	0	ON LAND
11/14/2005	AWD		SHAWS	1418	28	NA	50	GULLS	170	ON LAND
11/14/2005	AWD		WALLMART	1426	28	NA	50	GULLS	50	ON LAND
11/14/2005	AWD		LONGHORN	1427	28	NA	50	GULLS	20	ON LAND
11/14/2005	AWD		KHOLS	1432	28	NA	50	GULLS	10	ON LAND
11/14/2005	AWD		BJS	1438	28	NA	50	GULLS	60	ON LAND
11/14/2005	AWD		TABERS	1509	28	NA	50	GULLS	40	ON LAND
11/14/2005	AWD		BASIN	1540	28	NA	50	DUCKS	10	ON LAND
11/14/2005	AWD		BATES MILL	1635	28	NA	50	GULLS	150	ON LAND
11/15/2005	AWD	B11		A.M.	NA	NA	NA	GULLS	20	
11/15/2005	AWD	B9		A.M.	NA	NA	NA	GULLS	50	
11/15/2005	AWD	B1		A.M.	NA	NA	NA	GULLS	20	
11/15/2005	AWD	B4		A.M.	NA	NA	NA	GULLS	150	
11/15/2005	AWD	B9		P.M.	NA	NA	NA	GULLS	135	
11/15/2005	AWD	B16		P.M.	NA	NA	NA	GULLS	60	
11/15/2005	AWD	B4		P.M.	NA	NA	NA	GULLS	30	

DATE	OBSERVER	LOC_ID	LOCATION	TIME	WIND_MPH	WIND_DIR	AIR_TEMP_C	BIRD_TYPE	COUNT	COMMENTS
11/16/2005	AWD	B9		A.M.	NA	NA	NA	GULLS	30	
11/16/2005	AWD	B16		A.M.	NA	NA	NA	GULLS	75	
11/16/2005	AWD	B4		A.M.	NA	NA	NA	GULLS	150	
11/16/2005	AWD	B11		P.M.	NA	NA	NA	GULLS	20	FOGGY
11/16/2005	MROBI/JPLEAU	B8		1400			43	GULLS	15	FOGGY
11/16/2005	MROBI/JPLEAU	B11		1400			43	GULLS	400-TNC	FOGGY
11/16/2005	MROBI/JPLEAU	B4		1400			43	DUCKS	10	FOGGY
11/16/2005	MROBI/JPLEAU	B2		1400			43	DUCKS	6	FOGGY
11/16/2005	MROBI/JPLEAU	B16		1400			43	GULLS	200-TNC	FOGGY
11/16/2005	MROBI/JPLEAU	B15		1400			43	GULLS	50	FOGGY
11/17/2005	MRMROBI/JPLEAU	B9		530	CALM		46	DUCKS	2	
11/17/2005	MRMROBI/JPLEAU	B8		530	CALM		46	GULLS	25	
11/17/2005	MRMROBI/JPLEAU	B5		530	CALM		46	DUCKS	4	
11/17/2005	MRMROBI/JPLEAU	B1		530	CALM		46	BEAVER	1	
11/17/2005	MRMROBI/JPLEAU	B18		530	CALM		46	GULLS	200	
11/17/2005	MRMROBI/JPLEAU	B16		530	CALM		46	GULLS	400	
11/17/2005	MROBI/PPLEAU	B3		1400		15 FROM WEST	47	GULLS	250	SUNNY
11/17/2005	MROBI/PPLEAU	B18		1400		15 FROM WEST	47	GULLS	250	SUNNY
11/18/2005	MROBI/DRICH	B11			WINDY		30	GULLS	100	CLEAR,COLD
11/18/2005	MROBI/DRICH	B6			WINDY		30	GULLS	50	CLEAR,COLD
11/18/2005	MROBI/DRICH	B16			WINDY		30	GULLS	250	CLEAR,COLD
11/18/2005	AWD		CMCC	700	NA	NA	NA	GULLS	200	ON LAND
11/18/2005	AWD		TJ MAX	700		NA	NA	GULLS	40	ON LAND
11/18/2005	AWD		SHAWS	700		NA	NA	GULLS	150	ON LAND
11/18/2005	AWD		WALLMART	700		NA	NA	GULLS	20	ON LAND
11/18/2005	AWD		LONGHORN	700		NA	NA	GULLS	9	ON LAND
11/19/2005	DFORTIN/MVACHON	B16		A.M.	NA	NA	NA	GULLS	500	
11/19/2005	DFORTIN/MVACHON	B4		A.M.	NA	NA	NA	GULLS	200	
11/19/2005	DRICH/RBASTIEN	B11		A.M.	CALM		21	GULLS	50	CLEAR,COLD
11/19/2005	DRICH/RBASTIEN	B16		A.M.	CALM		21	GULLS	200	CLEAR,COLD
11/19/2005	DRICH/RBASTIEN	B4		A.M.	CALM		21	GULLS	110	CLEAR,COLD
11/19/2005	DRICH/RBASTIEN	B6		A.M.	CALM		21	GULLS	35	CLEAR,COLD
11/19/2005	PPPLEAU/DRICH	B10		P.M.	NA	NA	38	GULLS	200	SUNNY, CLEAR
11/19/2005	PPLEAU/DRICH	B8		P.M.	NA	NA	38	GULLS	100	SUNNY, CLEAR
11/20/2005	PPLEAU/RBASTIEN	B11				0 CALM	40	GULLS	500	SUNNY, CLEAR
11/20/2005	RBOUCHER/MROBI.	B16				0 CALM	27	DUCKS	1	SUNNY, CLEAR
11/20/2005	RBOUCHER/MROBI.	B18				0 CALM	27	DUCKS	4	SUNNY, CLEAR
11/20/2005	RBOUCHER/MROBI.	B2				0 CALM	27	DUCKS	6	SUNNY, CLEAR
11/20/2005	RBOUCHER/MROBI.	B4				0 CALM	27	GULLS	20	SUNNY, CLEAR
11/20/2005	PPLEAU/RBASTIEN	B15				0 CALM	40	DUCKS	16	SUNNY, CLEAR
11/20/2005	PPLEAU/RBASTIEN	B17				0 CALM	40	GULLS	400	SUNNY, CLEAR
11/20/2005	PPLEAU/RBASTIEN	B16				0 CALM	40	GULLS	600	SUNNY, CLEAR
11/20/2005	PPLEAU/RBASTIEN	B6				0 CALM	40	GULLS	200	SUNNY, CLEAR
11/23/2005	DFORTIN/MVACHON	B16		A.M.	NA	NA	NA	GULLS	1000	
11/23/2005	DFORTIN/MVACHON	B4		A.M.	NA	NA	NA	GULLS	50	
11/26/2005	DFORTIN/MVACHON	B16		A.M.	NA	NA	NA	GULLS	4	
11/26/2005	DFORTIN/MVACHON	B4		A.M.	NA	NA	NA	GULLS	25	
11/27/2005	DFORTIN/MVACHON	B16		A.M.	NA	NA	NA	GULLS	1000	
11/27/2005	DFORTIN/MVACHON	B11		A.M.	NA	NA	NA	GULLS	1000	
11/29/2005	DFORTIN/MVACHON		RAINBOW BIKE	A.M.	NA	NA	NA	GULLS	100	ON LAND
11/29/2005	DFORTIN/MVACHON		CHURCH	A.M.	NA	NA	NA	GULLS	50	ON LAND
11/29/2005	DFORTIN/MVACHON		CMCC	A.M.	NA	NA	NA	GULLS	700	ON LAND



0 1,000 2,000 4,000 Feet

Lake Auburn

1 inch equals 2,000 feet

May 17, 18, 2005

Lewiston Maine
Selling the Pace

-----Original Message-----
From: Stan DeOrsey [mailto:jsmd@att.net]
Sent: Thursday, October 27, 2005 8:09 PM
To: Mary Jane Dillingham
Subject: Lake Auburn birds

Made another visit to the water intake area. No birds over the intake but many gulls on the lake in general, mostly towards the "middle" plus many overhead, 100+ total. Also a nice bald eagle. The gulls, mostly ring-billed and some herring gulls, continue to be numerous in the vicinity of the malls as well. We also had a few ducks but they were too distant to accurately identify or even count (possibly ruddy ducks?).

With the clock change this weekend we'll try some "night" stopping by in late afternoon. The time is basically here when we would expect rafts of ducks to form. Not many Canada Geese have been reported anywhere as of yet.

How have you done with your laser light approach? How is the water quality testing? While you may be starting to see a problem, we have yet to observe anything unusual or unique to Lake Auburn particularly at the intake area.
--
Stan DeOrsey jsmd@att.net

FW Lake Auburn birds

From: Stan DeOrsey [mailto:jsmd@att.net]
Sent: Tuesday, November 08, 2005 1:05 PM
To: Mary Jane Dillingham
Subject: Lake Auburn birds

Hi again. We were there yesterday as the sun set and after. There were no birds whatsoever near the intake area, or even in the middle of the lake. However ... the ring-billed gulls streamed in by the hundreds directly across and to the left (west, where the sun had gone down). They seemed to settle on the lake but on the far side which was calm as the wind was very strong from the west. If the wind direction changed I would bet they would all be around the intake side!!

We tried to estimate the number of gulls and we easily counted 500 in the sky streaming in, but they continued to stream and I am sure there were well over 1000, perhaps multiple thousands given that some came both before and after we left. Indeed this number of gulls is much larger than the number which frequent the mall area. I do not know how far they come but this might well be the only, or at least the major, roost in the Lewiston / Auburn area. I would think you can expect these gulls to continue to roost on Lake Auburn until it freezes. At that point they will likely go to the river and a few could continue further south, but they will not migrate further south without a bad winter (generally very cold with food sources frozen over).

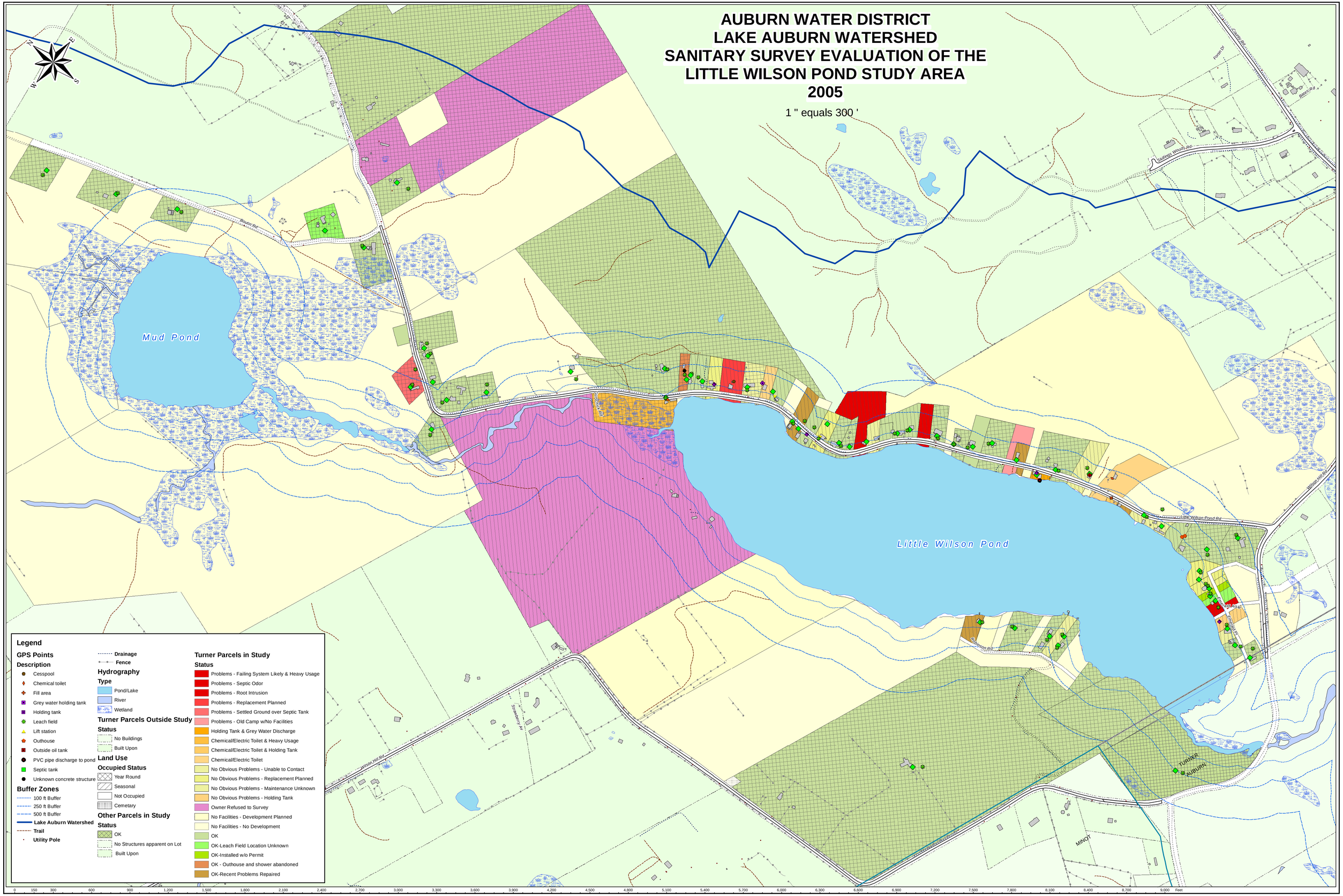
We did not see any crows near the water works area or even near Lake Auburn, however crows too were going to their roost from around 4 o'clock. The stream was headed south along the river and likely went to a spot south of the south bridge in lower New Auburn or neighboring Lewiston (generally near the landfill and a large beef farm near the turnpike bridge over the river). A good number of gulls are often there too.

We'll continue looking but I do not expect to see a large number of ducks such that they would be related to your problem. At one time I expected Canada Geese, but they seem to have left or at least are in very small numbers. In fact I have not heard of any large concentrations of Canada Geese anywhere in Maine this fall although a few are around but again not in huge flocks. But they could be back another year.

Hope this helps. More next time.
--
Stan DeOrsey jsmd@att.net

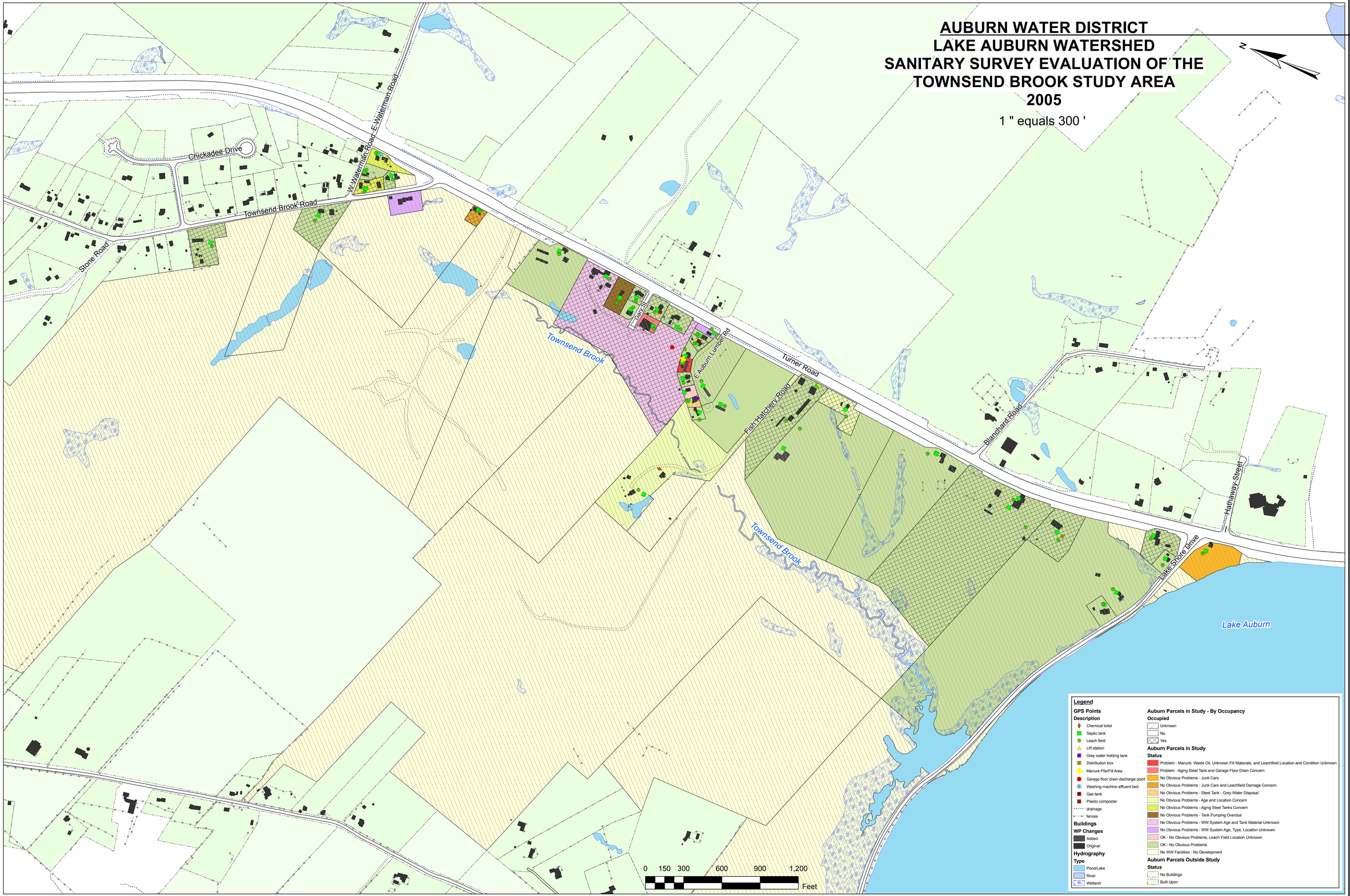
AUBURN WATER DISTRICT
LAKE AUBURN WATERSHED
SANITARY SURVEY EVALUATION OF THE
LITTLE WILSON POND STUDY AREA
2005

1 " equals 300 '

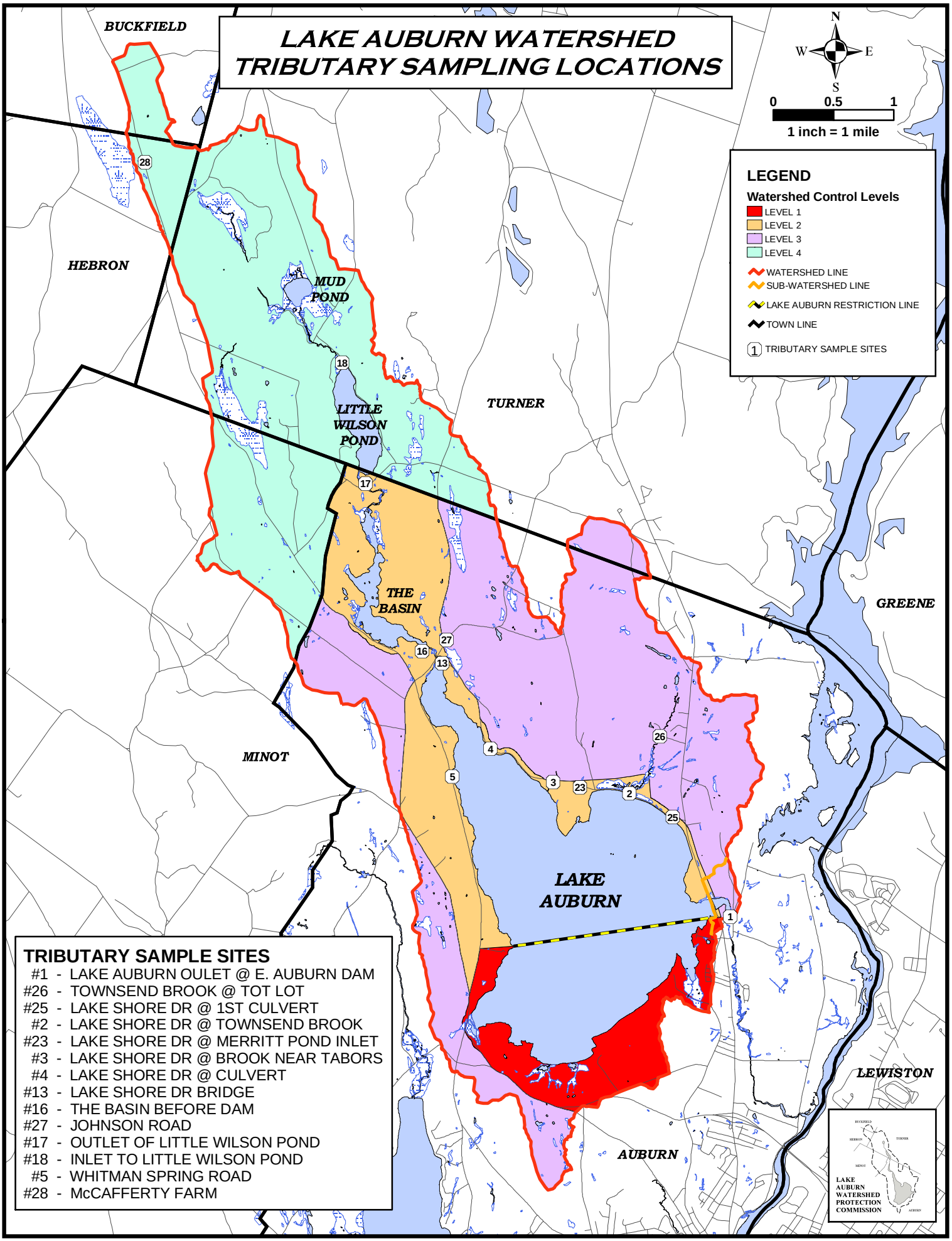


AUBURN WATER DISTRICT
LAKE AUBURN WATERSHED
SANITARY SURVEY EVALUATION OF THE TOWNSEND BROOK STUDY AREA
2005

1 " equals 300 '

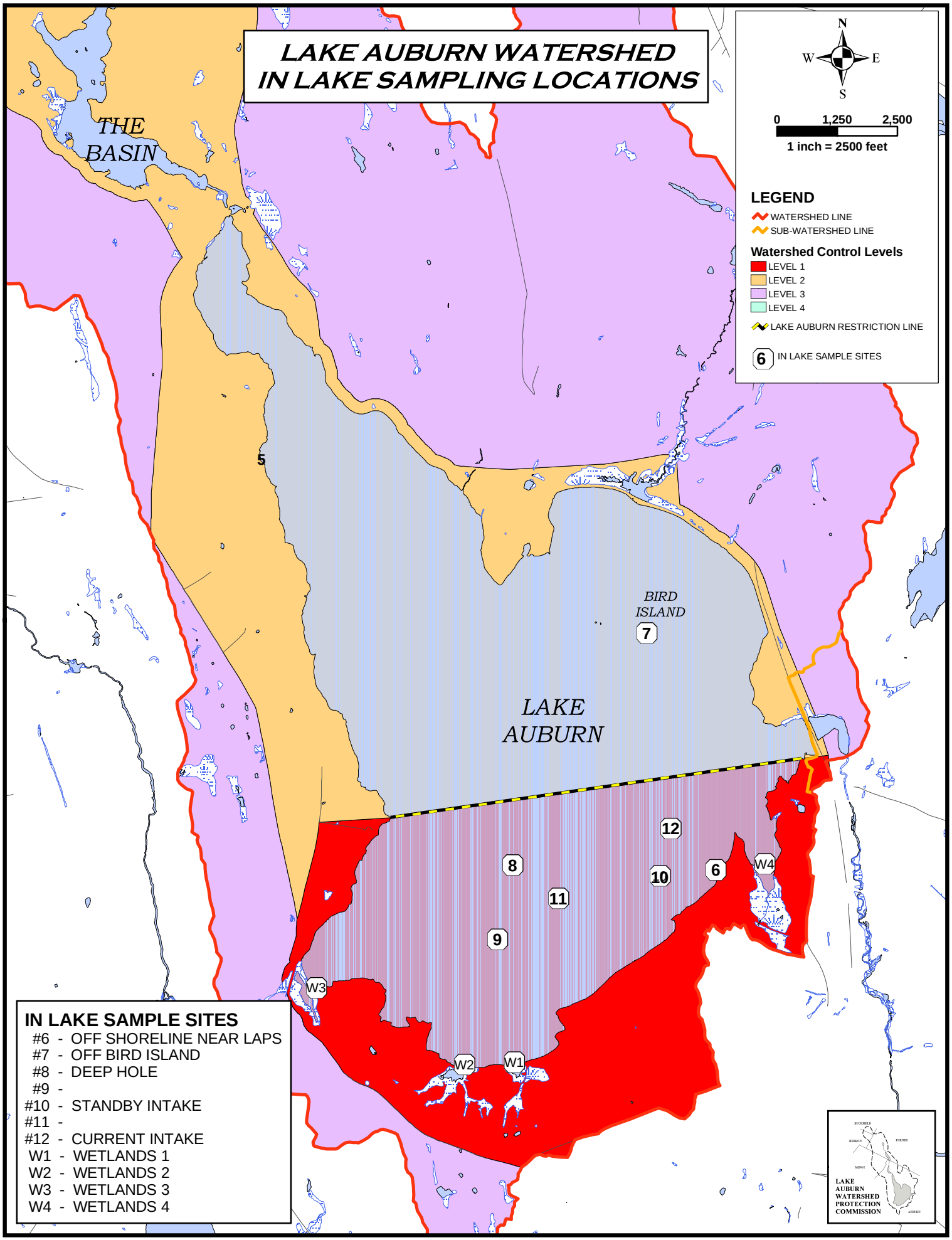


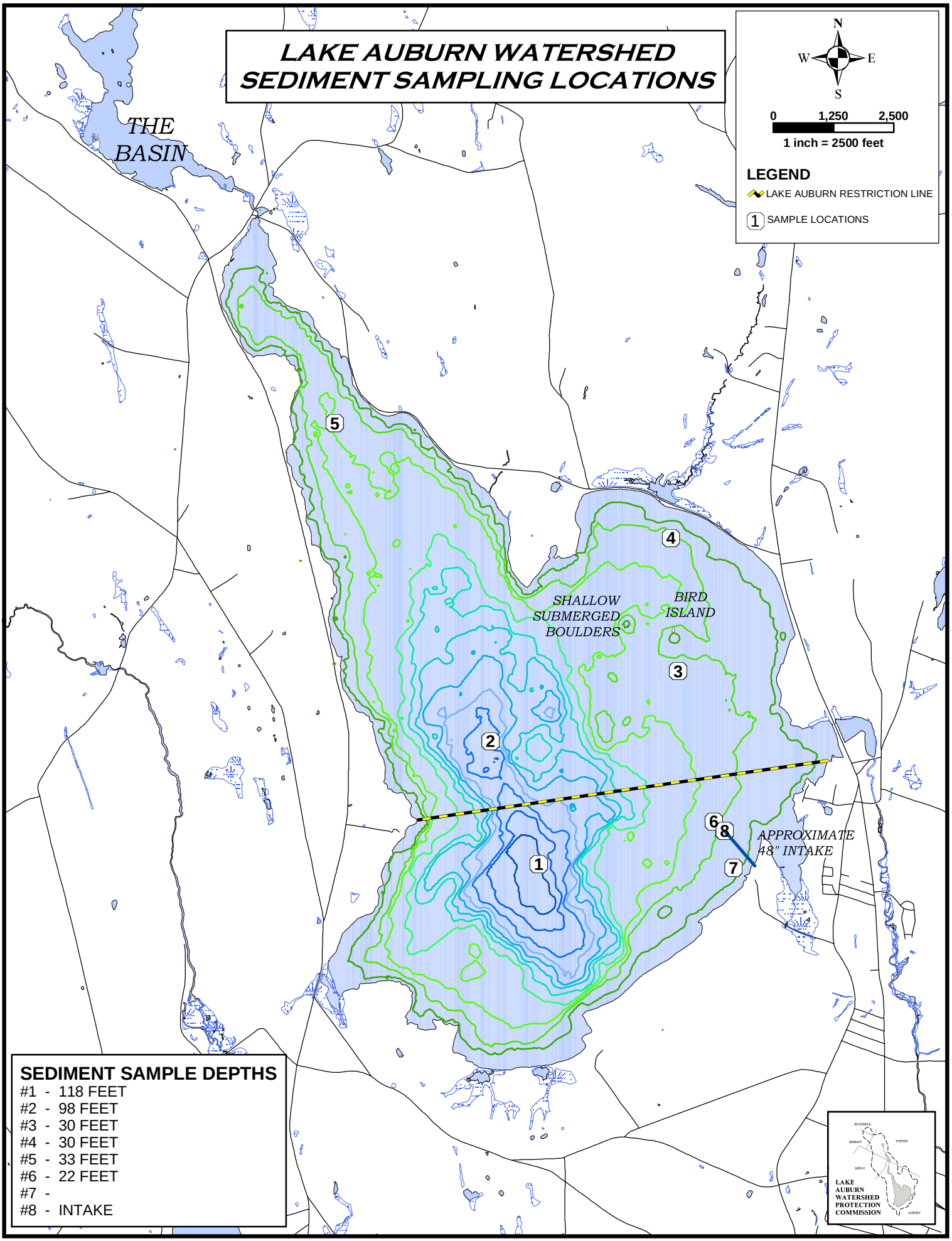
LAKE AUBURN WATERSHED TRIBUTARY SAMPLING LOCATIONS



TRIBUTARY SAMPLE SITES

- #1 - LAKE AUBURN OULET @ E. AUBURN DAM
- #26 - TOWNSEND BROOK @ TOT LOT
- #25 - LAKE SHORE DR @ 1ST CULVERT
- #2 - LAKE SHORE DR @ TOWNSEND BROOK
- #23 - LAKE SHORE DR @ MERRITT POND INLET
- #3 - LAKE SHORE DR @ BROOK NEAR TABORS
- #4 - LAKE SHORE DR @ CULVERT
- #13 - LAKE SHORE DR BRIDGE
- #16 - THE BASIN BEFORE DAM
- #27 - JOHNSON ROAD
- #17 - OUTLET OF LITTLE WILSON POND
- #18 - INLET TO LITTLE WILSON POND
- #5 - WHITMAN SPRING ROAD
- #28 - McCAFFERTY FARM


LAKE AUBURN WATERSHED
IN LAKE SAMPLING LOCATIONS
N
W
E
S
0
1,250
2,500
1 inch = 2500 feet
LEGEND
WATERSHED LINE
SUB-WATERSHED LINE
Watershed Control Levels
LEVEL 1
LEVEL 2
LEVEL 3
LEVEL 4
LAKE AUBURN RESTRICTION LINE
6 IN LAKE SAMPLE SITES
THE BASIN
5
BIRD ISLAND
7
LAKE AUBURN
12
8
10
6
W4
11
9
W3
W2
W1
IN LAKE SAMPLE SITES
#6 - OFF SHORELINE NEAR LAPS
#7 - OFF BIRD ISLAND
#8 - DEEP HOLE
#9 -
#10 - STANDBY INTAKE
#11 -
#12 - CURRENT INTAKE
W1 - WETLANDS 1
W2 - WETLANDS 2
W3 - WETLANDS 3
W4 - WETLANDS 4
LAKE AUBURN WATERSHED PROTECTION COMMISSION


LAKE AUBURN WATERSHED
SEDIMENT SAMPLING LOCATIONS
N
W
E
S
0
1,250
2,500
1 inch = 2500 feet
LEGEND
LAKE AUBURN RESTRICTION LINE
SAMPLE LOCATIONS
THE BASIN
SHALLOW SUBMERGED BOULDERS
BIRD ISLAND
APPROXIMATE 48" INTAKE
1
2
3
4
5
6
7
8
SEDIMENT SAMPLE DEPTHS
#1 - 118 FEET
#2 - 98 FEET
#3 - 30 FEET
#4 - 30 FEET
#5 - 33 FEET
#6 - 22 FEET
#7 -
#8 - INTAKE
LAKE AUBURN WATERSHED PROTECTION COMMISSION

DATE	TIME	LOCATION	Total Coliform MPN	TC Units of Measure	E.Coli MPN	E.coli Units of Measure	Enterococci MPN	Enterococci Units of Measure	Clostridium perfringens CFU	FECAL COLIFORM	CAMPLYLOBACTER sp	COMMENTS
2/9/2005	1100	INTAKE	13.4	per 100 mls	1	per 100 mls	140	per 100 mls	None Detected			
4/25/2005		INTAKE	8.6	per 10 grams	<1.0	per 10 grams	87	per 10 grams	180/ 1.1 mls			
5/17/2005		DS-1, 118'	<1.0	per 10 grams	<1.0	per 10 grams	9.6	per 10 grams	900/ 100mls			SOIL
		DS-2, 98'	3.1	per 10 grams	<1.0	per 10 grams	10.2	per 10 grams	1400/ 100mls			SOIL
		DS-5, 33'	5.2	per 10 grams	<1.0	per 10 grams	>2419.2	per 10 grams	1300/ 100mls			SOIL
		DS-5	44.1	per 10 grams	<1.0	per 10 grams	>2419.2	per 10 grams	2400 CFU/ 100g			SOIL
		DS-1, 118'	6.3	per 100 mls	<1.0	per 100 mls	1	per 100 mls	0			WATER
		DS-2, 98'	39.9	per 100 mls	23.1	per 100 mls	2	per 100 mls	2/ 100mls			WATER
5/18/2005		DS-3, 30'	20.3	per 10 grams	<1.0	per 10 grams	16.9	per 10 grams	0			WATER
		DS-4, 30'	8.2	per 10 grams	<1.0	per 10 grams	35.4	per 10 grams	800/100mls			WATER
		DS-6, 22'	1	per 10 grams	<1.0	per 10 grams	9.2	per 10 grams	100/ 100mls			WATER
		DS-7	10.8	per 10 grams	<1.0	per 10 grams	26.6	per 10 grams	0			WATER
		DS-3, 30'	35.8	per 10 grams	14.9	per 10 grams	210.5	per 10 grams	4000/100g			SOIL
		DS-4, 30'	13.4	per 10 grams	<1.0	per 10 grams	>2419.2	per 10 grams	5000/100g			SOIL
		DS-6, 22'	<1.0	per 10 grams	<1.0	per 10 grams	24.5	per 10 grams	0			SOIL
		DS-7	21.6	per 10 grams	<1.0	per 10 grams	114.5	per 10 grams	2000/ 100g			SOIL
5/23/2005		INTAKE	2	per 10 grams	<1.0	per 10 grams	690	per 10 grams	100/ 100g			
6/20/2005		INTAKE	19.8	per 10 grams	<1.0	per 10 grams	146.1	per 10 grams	Positive/ 1g			
7/18/2005		INTAKE	>2419.2	per 10 grams	7.4	per 10 grams	>2419.2	per 10 grams	30 CFU/ 1g			
8/22/2005		INTAKE	488.4	per 10 grams	1	per 10 grams	>2419.2	per 10 grams	Positive/ 1g			
9/19/2005		INTAKE	124.6	**per 1 grams**	<1	**per 1 grams**	243.6	**per 1 grams**	NA	NA		DWQM LAB
9/19/2005		INTAKE	461.1	per 10 grams	4.1	per 10 grams	>2419.2	per 10 grams	<1/1g	NA		ASI LAB
10/11/2005		DS-1, 118'	39.5	per 10 grams	1	per 10 grams	22.6	per 10 grams	1/1g	NA		
10/11/2005		DS-2, 98'	106.7	per 10 grams	10.8	per 10 grams	1011.2	per 10 grams	10/.1g	NA		
10/11/2005		DS-3, 30'	71.4	per 10 grams	<1	per 10 grams	24.3	per 10 grams	20/.1g	NA		
10/11/2005		DS-4, 30'	172.2	per 10 grams	7.5	per 10 grams	140.1	per 10 grams	10/.1g	NA		
10/11/2005		DS-5, 33'	172	per 10 grams	1	per 10 grams	1011.2	per 10 grams	30/.1g	NA		
10/11/2005		DS-6, 22'	344.8	per 10 grams	3.1	per 10 grams	72	per 10 grams	10/.1g	NA		
10/11/2005		DS-7	770.1	per 10 grams	4.1	per 10 grams	58.4	per 10 grams	Positive/ 1g	NA		
10/18/2005		INTAKE	648.8	per 10 grams	3.1	per 10 grams	172	per 10 grams	1/.1g	NA	NO GROWTH/5g	ASI LAB
11/21/2005		INTAKE	60.5	per 1 grams	<1	per 1 grams	37	per 1 grams	NA	3 per .5 grams		DWQM LAB
11/21/2005		INTAKE	686.7	per 10 grams	1	per 10 grams	>2419.2	per 10 grams	5/.1g	NA	NO GROWTH/5g	ASI LAB

YEAR	MONTH	DAY	TEMP	FECAL MFC
2005	OCTOBER	1	18.3	0
		2	18.3	1
		3	18.6	0
		4	18.7	0
		5	18.7	0
		6	18.3	0
		7	18.8	1
		8	19.1	4
		9	17.8	4
		10	17.1	12
		11	17	1
		12	16.6	4
		13	16.2	5
		14	16	3
		15	16.5	0
		16	13.6	8
		17	15.2	12
		18	14.7	3
		19	14.5	0
		20	13.9	2
		21	13.4	4
		22	13.5	7
		23	13.2	2
		24	13.1	5
		25	12.8	8
		26	12	9
		27	11.6	11
		28	11.3	4
		29	11.1	6
		30	11.5	11
		31	11.3	7
2005	NOVEMBER	1	11.4	10
		2	11.4	7
		3	10.6	17
		4	11.2	16
		5	10.7	15
		6	11.2	10
		7	10.7	8
		8	10.8	4
		9	10.5	39
		10	10.4	29
		11	9.5	19
		12	9.6	6
		13	9.4	8
		14	9.6	9
		15	9.4	22
		16	9.5	28
		17	9.5	23
		18	8.9	14
		19	8	20
		20	8.5	6
		21	8.5	5
		22	8.4	4
		23	8.2	53
		24	7.4	47
		25	7.2	29
		26	6.9	24
		27	6.8	13
		28	6.6	17
		29	6.8	7
		30	7.1	21
2005	DECEMBER	1	7	10
		2	7	10
		3	6.4	18
		4	6.4	6
		5	5.9	8
		6	5.5	0
		7	5.4	3
		8	4.7	5
		9	4.7	5
		10	3.6	1
		11	4.4	0
		12	4.4	0
		13	4	3
		14	3.6	6
		15	3.8	5
		16	3.4	3
		17	2.3	0
		18	1.9	2
		19	2.4	0
		20	2.7	1
		21	3	0
		22	2.8	0
		23	2.8	0
		24	2.8	0
		25	2.9	0
		26	3.2	0
		27	2.8	2
		28	2.9	9
		29	3	1
		30	3	2
		31	2.9	40

Appendix E
Table 1 - Fecal Coliform Results
October - December 2005

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02 February 2006

James J. Pescatore, P.E., DEE
Camp Dresser & McKee, Inc.
One Cambridge Place
50 Hampshire Street
Cambridge, MA 02139

Subject: Microbiological Assessment of Lake Auburn

Dear Jim:

As per your request, this letter summarizes the microbiological assessment of Lake Auburn, with regard to fecal contamination.

Routine sampling of Lake Auburn by the Auburn Water Department and Lewiston Water Department (AWD/LWD) has consistently demonstrated that the microbiological quality of the raw water is good, with low concentrations of fecal coliforms (mean less than 10 cfu/100 mL) being detected. In 2001 there were no samples shown to contain fecal coliforms at greater than 20 cfu/100mL whilst in recent years fecal coliform levels rose during fall and winter. Fecal coliforms were detected above 20 cfu/100 mL on four occasions in 2002, twice in 2003, seventeen times in 2004 and on eleven occasions in 2005.

The 2004 the AWD/LWD had developed a hypothesis that the increased levels of fecal contamination were due to the roosting of birds (particularly seagulls) on the Lake and in an effort to try to test this hypothesis they sought microbiological advice from Analytical Services Inc (ASI). Dr Colin Fricker of ASI consulted with the cities and with Camp Dresser McKee on the available data and recommended a sampling program which included analysis for enterococci, sulfite-reducing clostridia and campylobacters. The critical determinand within this sample regimen was analysis for campylobacters. Other parameters were included as possible indicators of avian contamination should culture fail to reveal the presence of campylobacters.

The so called "thermophilic" campylobacters include *C. jejuni, C. coli* and *C. lari*, which survive poorly (at least in a culturable state) outside of warm blooded animals (e.g. in water). Therefore, the presence of campylobacters in water is indicative of recent fecal contamination. Furthermore, the species of *Campylobacter* which are recovered can be indicative of the possible source of contamination. *C. jejuni* is the most commonly reported species, causing diarrhea in human beings, and consequently is found at high levels in domestic sewage. *C. coli* also infects

humans but at a lower frequency and is common in pigs. *C. lari*, as the species name suggests (c.f. of a gull) is common in birds and in fact was first described in fecal material from *Larus* gulls. It rarely causes disease in humans. Many subsequent reports have also demonstrated the frequent occurrence of this organism in avian faeces, particularly birds associated with water. Speciation of campylobacters found in water bodies can therefore be indicative of the potential source of contamination. Demonstration of the presence of *C. lari* in water, particularly if it is the only species detected, is good evidence that fecal contamination is of avian origin.

Samples of water and sediment were collected and sent to ASI for culture for the presence of campylobacters. No sediment samples were found to contain culturable campylobacters, perhaps due to their poor survival outside of their natural hosts. On four occasions however, campylobacters were detected in water samples collected from the lake. These samples were collected on 18 October (2 samples), 14 November and 5 December, which correspond to the time of year when bird roosting activity is high and when fecal coliform concentrations had been previously observed to increase (although the fecal coliform levels in the samples associated with the detection of *C. lari* were not elevated). This combination of events is good evidence that gulls were the source of the contamination.

During November of 2005 fecal coliform levels began to rise and a lethal bird harassment program was introduced. One week following the initiation of the program fecal coliform levels began to decline again providing good evidence that birds were responsible for the contamination events.

In conclusion, there is strong circumstantial evidence that birds were responsible for the increased levels of fecal coliforms in the lake, which can be summarized as follows:

1. Coliform levels began to rise when the numbers of roosting birds increased during late fall and early winter.
2. Microbiological examination of the water for the presence of campylobacters demonstrated the presence of *C. lari*, which is particularly associated with gulls.
3. The reduction in the numbers of roosting gulls caused by the harassment program and the concomitant reduction in fecal coliforms is also good evidence that the contamination events were caused by birds and not fecal material from humans, livestock or feral animals.

Whilst the data is not completely conclusive, it is my opinion that the increases in fecal coliforms within Lake Auburn were as a result of fecal contamination of the lake by roosting gulls and as such the contamination presents a low risk to public health for consumers of water abstracted from this source.

If more conclusive evidence is required then there are several potential approaches which can be used. Source tracking of the fecal coliforms using either biochemical or molecular procedures could be used. Alternatively a more intensive examination of the fecal material of the gulls and the microorganisms found in the lake could be undertaken, focussing particularly on campylobacters. The link between birds and contamination could be demonstrated using

profiling of the *Campylobacter* species without the necessity of using much more expensive procedures such as microbial source tracking. This has been used to good effect in the UK. Such a study would involve collection of samples of fecal material from gulls, other potential sources of campylobacters and a more intensive sampling regimen in the lake. Biochemical profiling and speciation should be adequate to demonstrate a conclusive link between bird use of the lake and the elevated indicators of fecal contamination without the need for molecular fingerprinting. Furthermore the collected fecal material could be used to demonstrate the low risk of contamination of the lake with organisms such as *Cryptosporidium.*

Please note that we have not performed an extensive review of the scientific literature for this letter. However, we believe that such a review with references cited would be beneficial with regard to presentation of this data interpretation to the regulatory authorities, as well as for considerations of future monitoring. If authorized, we can complete the review (anticipate less than 8 hours required) and report to you by Monday, 06 February 2006.

If you have questions about this summation, or if ASI may be of further assistance, please contact me at anytime (ColinFricker@aol.com).

Sincerely,

ANALYTICAL SERVICES, INC. (ASI)

Dr Colin Fricker
Senior Technical Advisor

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06 February 2006

James J. Pescatore, P.E., DEE
Camp Dresser & McKee, Inc.
One Cambridge Place
50 Hampshire Street
Cambridge, MA 02139

LETTER OF TRANSMITTAL: *Campylobacter* Literature Review

Dear Jim:

As per your request, enclosed please find a brief review of the scientific literature with regard to *Camplylobacter* spp. as it relates to the Auburn Water Department / Lewiston Water Department (AWD/LWD) project at Lake Auburn.

If you have questions about this summation, or if ASI may be of further assistance, please contact me at anytime (ColinFricker@aol.com).

Sincerely,

ANALYTICAL SERVICES, INC. (ASI)

Dr Colin Fricker
Senior Technical Advisor

Campylobacters in water, sources and potential implications

The recognition that campylobacters may be involved in enteric disease in humans occurred in the 1950s when Elizabeth King described their presence in blood cultures (King, 1957) and subsequently when Butzler recovered them from fecal samples using a selective filtration technique (Butzler et al., 1973), but it was not until 1977 that their significance as human pathogens became accepted. The description of a selective medium for the recovery of campylobacters (Skirrow, 1977) facilitated studies to determine their role in the etiology of human diarrheal disease and to investigate their presence in other animals and the environment.

Campylobacters are widely distributed and occur in most warm-blooded domestic, production and wild animals. They are prevalent in food animals such as poultry, cattle, pigs, sheep, ostriches and shellfish; and in pets, including cats and dogs. The main route of transmission is generally believed to be foodborne, via undercooked meats and meat products, as well as raw or contaminated milk. The ingestion of contaminated water or ice is also a recognized source of infection. Campylobacteriosis is considered to be a zoonosis, a disease transmitted to humans from animals or animal products. In animals, campylobacters seldom cause disease.

Campylobacter jejuni is the most common bacterial cause of gastroenteritis in the United Kingdom and in the rest of the developed world (Skirrow, 1994). Environmental waters are thought to be a significant source of human infection, and contaminated surface waters have been responsible for a number of outbreaks of *C. jejuni* infection (Vogt *et* al., 1982; Aho et al., 1989; Jones and Roworth, 1996). Campylobacters have been isolated from a variety of environmental water sources, including rivers (Bolton et al., 1987), lakes (Arvanitidou et al., 1995), and ponds and streams (Carter et al., 1987). The reported incidence of *Campylobacter* isolation from environmental waters varies between 16.3 and 82.1% (Arvanitidou et al., 1995; Koenraad et al., 1997). A study of campylobacters in a river system demonstrated that some of the serotypes of campylobacters isolated from river water were indistinguishable to those isolated from cases of human infection (Bolton et al., 1987). Infection can occur through ingestion during recreational water activity or by consumption of contaminated potable water (Koenraad et al., 1997).

There have many outbreaks of *Campylobacter* infection associated with consumption of contaminated water and in almost every case the source was untreated water. For example, in England and Wales between 1992 and 1995, there were six outbreaks of *Campylobacter* enteritis associated with consumption of water from private supplies, involving a total of 128 people (Furtado et al., 1998; Kemp et al., 2005). *Campylobacter* spp. have been isolated from a range of different water types, including sewage outflows, river water, groundwater, and seawater (Jones, 2001). In temperate climates, a consistent and marked seasonality is seen in human cases of *Campylobacter* enteritis, with a peak in late spring and early summer and a second, smaller peak in early autumn (Skirrow, 1987). The isolation of *Campylobacter* spp. from sewage effluent shows a similar trend. Conversely, the seasonality seen in water other than sewage effluent does not show the same pattern and may be the reverse of that seen in human cases (Jones et al., 1990). *Campylobacter* spp. are found commonly in the guts of many warm-blooded animals and

are not thought to replicate in the environment, so fecal contamination is considered the major source of *Campylobacter* spp. in water. The species of *Campylobacter* identified in these outbreaks was most frequently *C. jejuni* and only one outbreak has been described which has implicated *C. lari* (Broczyk et al., 1987). Since that time the taxonomy of the campylobacters has been modified extensively and it is by no means certain that the organism would now be classified as *C. lari*.

The vast majority of *Campylobacter* infections in human beings are associated with *C. jejuni*, *C. coli* and *C. upsaliensis* with very few infections being due to *C. lari*. Those infections with *C. lari* which do occur are often in developing countries or in the immunocompromised (Martinot et al., 2001). For example, only 0.2% of gastrointestinal infections in Argentina were due to *C. lari* (Notario et al., 2001) and in India, *C. lari* accounted for only 3% of all *Campylobacter* infections (Prassad et al., 2001). In a large investigation of *Campylobacter* infections in the UK, Lawson et al. (1999) found only a single case of *C. lari* infection from a total of 543 *Campylobacter* infections. Consequently, in sewage-contaminated water, *C. jejuni* is the most common species found whilst *C. lari* is extremely uncommon (Arimi et al., 1988). Similarly, the species most commonly found in poultry, which is thought to be the major source of infection for humans, is *C. jejuni*, with *C. lari* accounting for 1-2% of the organisms found (Osano and Arimi, 1999; Moore et al., 2002)

On the contrary, many studies have demonstrated the presence of *C. lari* in bird feces, particularly seagulls (Skirrow and Benjamin, 1980; Fricker et al., 1983; Benjamin et al., 1983; Whelan et al., 1988). In a study of 1794 birds examined in Sweden, Waldenstrom et al. (2002) found that shoreline feeding birds and opportunistic feeders had the highest carriage rates (76.8 and 50.0% respectively) and *C. lari* was the species most frequently identified. Further studies by the same group (Broman et al., 2002) showed that whilst *C. lari* could be detected in black-headed gulls (*Larus ridibundus*); they were not isolated from poultry or humans in the same area.

The intestinal environment of birds is favourable for the growth of campylobacters and consequently carriage rates are high and the number of organisms excreted is large (Jones, 2005). Use of phenotypic methods to investigate the types of campylobacters found in seawater, birds and mussels showed that the organisms were similar and unlike those found in human sewage (Jones, 2005), demonstrating that gulls can contaminate local water environments. More sophisticated techniques based on molecular methods can also be utilised to discriminate between strains of *C. lari* and several have proved useful including multiplex PCR of the *lpxA* gene (Werno et al., 2002), amplified fragment length polymorphism and protein profiling (Duim et al., 1999; Duim et al., 2004) and ribosomal RNA patterns (Owen et al., 1993).

The infrequent occurrence of *Campylobacter lari* in human feces and other animals and its prevalence in gulls makes it a good marker for fecal material originating from seagulls. In the recent investigation at Lake Auburn, campylobacters were isolated on four occasions and on each occasion the only species isolated was *C. lari.* This strongly suggests that the source of the contamination was seagulls. Whilst gulls can carry other types of campylobacters, it appears that they harbour *C. jejuni* that are species adapted and may not cause a significant risk to public

health. Water which is adequately disinfected should provide no risk of infection to human beings as campylobacters are susceptible to chlorine disinfection.

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WS-ER (10/05)

Agreement No.: 06 7223 8006 TF
Accounting Code: 683 7223 017
TIN: _____
Effective: 11/21/05 – 12/31/05
Agreement Amount: $24,754.00

COOPERATIVE SERVICE AGREEMENT
between
CITY OF LEWISTON (CITY)
and
UNITED STATES DEPARTMENT OF AGRICULTURE (USDA)
ANIMAL AND PLANT HEALTH INSPECTION SERVICE (APHIS)
WILDLIFE SERVICES (WS)

ARTICLE 1

The purpose of this Cooperative Service Agreement is to administer a cooperative program on behalf of the City of Lewiston, Department of Public Services, Water Division, who wishes to retain the professional services of APHIS Wildlife Services (WS) as a consultant for a Nuisance Bird Control Project at Lake Auburn, Auburn, ME. APHIS WS will provide technical assistance, operational assistance and consultation on control of gulls and other wildlife as deemed appropriate, subject to agreement by the City of Lewiston. WS activities are described in the attached Work and Financial Plans (Attachments A and B).

ARTICLE 2

APHIS WS has statutory authority under the Act of March 2, 1931 (46 Stat. 1468; 7 U.S.C. 426-426c) as amended, and the Act of December 22, 1987 (101 Stat. 1329-331, 7 U.S.C. 426c), to cooperate with States, local jurisdictions, individuals, public and private agencies, organizations, and institutions while conducting a program of wildlife services involving mammal and bird species that are reservoirs for zoonotic diseases, or animal species that are injurious and/or a nuisance to, among other things, agriculture, horticulture, forestry, animal husbandry, wildlife, and public health and safety.

ARTICLE 3

APHIS WS and the City of Lewiston (CITY) mutually agree:

1. The parties' authorized representatives who shall be responsible for carrying out the provisions of this Agreement shall be:

CITY: James Bennett, City Administrator
City of Lewiston
Department of Public Services, Water Division
101 Adams Ave
Lewiston ME 04240

APHIS WS: Edwin B. Butler, State Director
USDA APHIS Wildlife Services
Capitol West Business Center
79 Leighton Rd, Suite 12
Augusta ME 04330

2. To meet as determined necessary by either party to discuss mutual program interests, accomplishments, needs, technology, and procedures to maintain or amend the Work Plan, Attachment A. Personnel authorized to attend meetings under this Agreement shall be the City Administrator or his designee, the State Director or his designee, and/or those additional persons authorized and approved by the City Administrator and the State Director.

3. APHIS WS shall perform services more fully set forth in the Work Plan, which is attached hereto and made a part hereof. The parties may mutually agree in writing, at any time during the term of this Agreement, to amend, modify, add or delete services from the Work Plan.

ARTICLE 4

City of Lewiston agrees:

1. To authorize APHIS WS to conduct direct control activities to reduce human, health and safety risks and property damage associated with ring-billed gulls, herring bulls and great black-backed gulls. These activities are defined in Attachment A, Work Plan. The Wildlife Services' State Director will coordinate all APHIS involvement and designate staff as appropriate based on availability, needs and/or as requested by the CITY. WS will be considered an invitee on the lands controlled by the CITY and the CITY will be required to exercise reasonable care to warn WS as to dangerous conditions or activities in the project areas.

2. To deposit $24,754 with APHIS WS. Funds will be placed in a Trust Fund account and used to pay for costs of services provided under this Agreement up to but not exceeding the amount specified in Attachment B, Financial Plan. The contract amount shall include the costs of WS personnel in traveling from their regular duty stations to the temporary duty locations at Lake Auburn or other mutually agreed upon location for the purpose of participation in meetings and participation in technical assistance and/or operational assistance, and return to the regular duty stations, an amount equal to WS' actual costs for salary and benefits, equipment, supplies and travel costs incurred in accordance with WS' normal and customary travel rules and regulations. The Cooperator ensures and certifies that it is not currently debarred or suspended and is free of delinquent Federal debt.

3. To designate to APHIS WS the CITY authorized individual whose responsibility shall be the coordination and administration of activities conducted pursuant to this Agreement.

4. To notify APHIS WS verbally or in writing as far in advance as practical of the date and time of any proposed meeting related to the program.

5. APHIS WS shall be responsible for administration and supervision of the program.

6. All equipment purchased for the program is and will remain the property of APHIS WS.

7. To respond to all media requests.

8. To assist WS in obtaining the appropriate clearances necessary for using pyrotechnics, shotguns and/or other mutually agreed upon control techniques on properties under control of the CITY.

9. To provide appropriate specialized safety equipment needed for WS employees entering the CITY or approved WS-owned equipment for use at Lake Auburn.

10. To give WS employees access to all problem areas where control activities associated with this project will be conducted.

ARTICLE 5

APHIS WS Agrees:

1. To conduct activities at Lake Auburn as described in the Work and Financial Plans, and to provide all resources necessary for accomplishment of the program, except those items the CITY agrees to provide as specified in Article 4, including personnel, equipment, supplies and other support materials.

2. Designate to the CITY the authorized WS individual who shall be responsible for the joint administration of the activities conducted pursuant to this Agreement.

3. APHIS WS shall keep records and receipts of all reimbursable expenditures hereunder for a period of not less than one year from the date of completion of the services provided under this Agreement and the CITY shall have the right to inspect and audit such records.

4. To consult with the CITY prior to issuing any news release, advertisement, or literature of any kind or permitting the issuance of any news release, advertisement, or literature of any kind which refers to the CITY or other services performed under this Agreement. WS shall not issue any such release, advertisement, or literature without the express prior approval of the City Administrator or his designee.

5. The CITY shall have the right to use or permit the use of all estimates, reports, records, data, charts, documents, models, designs, renderings, drawings, specifications, computations and other papers of any type whatsoever, whether in the form of writing, figures, or delineations, or any ideas or methods represented by them, which are prepared or compiled in connection with this Agreement, for any purpose and at any time without other compensation than that specifically provided herein.

ARTICLE 6

This Agreement is contingent upon the passage by Congress of an appropriation from which expenditures may be legally met and shall not obligate APHIS upon failure of Congress to so appropriate. This Agreement may also be reduced or terminated if Congress only provides APHIS funds for a finite period under a Continuing Resolution.

ARTICLE 7

APHIS assumes no liability for any actions or activities conducted under this Cooperative Service Agreement except to the extent that recourse or remedies are provided by Congress under the Federal Tort Claims Act (28 U.S.C. 1346(b), 2401(b), and 2671-2680).

ARTICLE 8

Pursuant to Section 22, Title 41, United States Code, no member of or delegate to Congress shall be admitted to any share or part of this Agreement or to any benefit to arise there from.

ARTICLE 9

All activities will be conducted in accordance with all applicable Federal, State and local laws, rules, and regulations. Nothing in this Agreement shall prevent APHIS WS from entering into separate agreements with any other organization or individual for the purpose of providing wildlife damage management services exclusive of those provided for under this Agreement.

ARTICLE 10

The CITY certifies that wildlife damage management options, including the use of services provided by the private sector, have been carefully considered. After considering these options, the CITY requests that APHIS WS provide its services under the stated terms of this Agreement.

ARTICLE 11

The performance of wildlife damage management actions by APHIS WS under this Agreement is contingent upon a determination by APHIS WS that such actions are in compliance with the National Environmental Policy Act, Endangered Species Act, and any other applicable environmental statutes. APHIS WS will not make a final decision to conduct requested wildlife damage management actions until it has made the determination of such compliance.

ARTICLE 12

This Cooperative Service Agreement may be amended at any time by mutual agreement of the parties in writing. Also, this Agreement may be terminated at any time by mutual agreement of the parties in writing, or by one party provided that party notifies the other in writing at least 120 days prior to effecting such action. The length of notice for unilateral termination may be longer or shorter if necessary. Further, in the event the Cooperator does not provide necessary funds, APHIS WS is relieved of the obligation to provide services under this Agreement.

The CITY shall have the option to extend this Agreement, if desired, by notice in writing sent before the termination date. If the CITY exercises the option to extend this Agreement for the purpose of retaining WS direct control assistance, or contracts with APHIS WS in subsequent years or on an annual or periodic basis (as needed), it is understood by all parties that all serviceable equipment and nonexpendable materials purchased in connection with Agreement shall remain available for use as necessary in the conduct of such activities. Additional costs will be incurred only for personnel, travel (lodging and per diem), expendable supplies, program support fees, and any additional equipment deemed necessary by the CITY and APHIS WS.

In witness whereof, the City of Lewiston has caused this Agreement to be executed on its behalf by its City Administrator or his designee, and APHIS WS has caused this Agreement to be executed on its behalf.

(See the next page for signatures.)

City of Lewiston

BY: _____ Date: November 16, 2005

James Bennett, City Administrator
City of Lewiston
Department of Public Services
Water Division
101 Adams Ave
Lewiston ME 04240

In accordance with the Debt Collection Improvement Act of 1996, the Department of Treasury requires a Taxpayer Identification Number for individuals or businesses conducting business with the agency.

City of Lewiston Taxpayer Identification Number (TIN) #_____

United States Department of Agriculture
Animal and Plant Health Inspection Service
Wildlife Services

BY: _____ Date:

Charles S. Brown, Director, Eastern Region
USDA, APHIS, Wildlife Services
920 Main Campus Drive, Suite 200
Raleigh NC 27606

ATTACHMENT A

WORK PLAN

Introduction

The U.S. Department of Agriculture (USDA) is authorized to protect American agriculture and other resources from damage associated with wildlife. The primary authority for Wildlife Services (WS) is the Act of March 2, 1931 (46 Stat. 1468; 7 U.S.C. 426-426c) as amended. Wildlife Services activities are conducted in cooperation with other Federal, State and local agencies; private organizations and individuals.

The WS program uses an Integrated Wildlife Damage Management (IWDM) approach (sometimes referred to as IPM or "Integrated Pest Management") in which a series of methods may be used or recommended to reduce wildlife damage. IWDM is described in Chapter 1, 1-7 of the Animal Damage Control Program Final Environmental Impact Statement (USDA, 1994). These methods include the alteration of cultural practices as well as habitat and behavioral modification to prevent damage. However, controlling wildlife damage may require that the offending animal(s) are killed or that the populations of the offending species be reduced.

Purpose

A. Objective and Need for Assistance

To reduce fecal contamination to the public water supply at Lake Auburn by ring-billed gulls, herring gulls and great black-backed gulls.

B. Results or Benefits Expected

The bird population will be reduced to alleviate human health and safety concerns.

C. Approach

WS personnel will use an integrated wildlife damage management program relying on harassment with pyrotechnics and shooting with shotguns. Birds will be retrieved and disposed of by WS whenever possible as part of regular control activities.

D. Procurement

Purchase of supplies, equipment and miscellaneous needs including salary will be made by WS.

E. Resources Required

Harassment and shooting activities will begin on November 21, 2005 and continue for three weeks. Two shifts will be worked each day; one at dusk and one at dawn.

F. Assistance to be provided by the City of Lewiston

A WS vehicle will be authorized access to the work area to carry in equipment and to act as a base of operations for equipment and disposal of bagged birds.

G. Funding

WS involvement in the project will be funded through a Cooperative Service Agreement for approximately $24,754 to pay WS for expenses incurred in the purchase of bird control materials and in conducting bird control activities.

Planned USDA APHIS Wildlife Services Activities

1. Harassment using pyrotechnics and shooting of gulls using shotguns.

Effective Dates

The Cooperative Service Agreement shall become effective November 21, 2005 and shall expire on December 31, 2005.

ATTACHMENT B

FINANCIAL PLAN

Personnel Costs (Salary and Benefits): = $15,600.00
Shooting – WS employees (2 employees @ up to 5 hours each visit, 2 times per day). Includes travel time, over-time and night differential. ($700/trip weekdays and $850/trip weekends)

Vehicle Usage: = $ 2,037.00
Vehicle costs = 100 miles round trip @ $0.485 cents per mile = $48.50/trip X 42 trips.

Technical Assistance/Miscellaneous Consults: = $ 525.00
($175 per week up to 3 weeks)

Supplies/Equipment: = $ 3,150.00
($150 per trip up to 21 days)

Subtotal =$21,312.00

Plus Program Support Costs (16.15%) = $ 3,442.00

GRAND TOTAL = $24,754.00

Activities will be conducted with regular and overtime hours worked as necessary to accomplish the objectives of the program.

The distribution of the budget from this Project Financial Plan may vary as necessary to accomplish the purpose of this Agreement but may not exceed the total cost of $24,754.00.

Financial Point of Contact

CITY: x

Auburn:
Auburn email:

APHIS, WS: Susan M. Pepin, Budget Analyst - Phone: 207-622-8263 (Fax 622-5760)
Email: susan.m.pepin@usda.gov

USDA United States Department of Agriculture | Animal and Plant Health Inspection Service | Wildlife Services | 79 Leighton Road, Suite 12
Augusta, ME 04330
(207) 622-8263
(207) 622-5760 fax

February 6, 2006

John Storer
District Engineer
Auburn Water and Sewerage Districts
P.O. Box 414
268 Court Street
Auburn, ME 04212-0414

Dear John:

The purpose of this letter is to serve as an official report and evaluation of the USDA, APHIS, Wildlife Services' involvement with the Lewiston/Auburn gull harassment project that was conducted in the fall of 2005 on Lake Auburn. In addition to detailing the work that was conducted by Wildlife Services (WS), we will propose a future plan to help reduce the presence of gulls and other water birds that may be implicated in creating elevated bacteria counts within Lake Auburn. The scope of this proposal is based upon limited data that was collected during the 2005 project by both WS and your staff.

2005 Gull Management Project

Wildlife Services conducted harassment and shooting activities on Lake Auburn from November 21, 2005 to December 13, 2005. At the initiation of WS' involvement, the Auburn Water District (AWD) and the Lewiston Water District (LWD) had been conducting harassment efforts for several months. During that time, the AWD and LWD reported an increase in gull presence on Lake Auburn from approximately 300 gulls to 3000 gulls despite their harassment activities. Because of this increase, the AWD and LWD contacted WS for assistance.

WS' involvement in this project was to be present on Lake Auburn during approximately 0500 hrs to 0800 hrs, and from 1400 hrs to 1700 hrs. WS' role was to provide an Integrated Wildlife Damage Management Program (IWDMP) that included the use of pyrotechnics and watercraft to harass gulls away from the affected area, as well as, lethal control (shooting) to reinforce and enhance the effectiveness of non-lethal methods. As previously mentioned, this work was in direct cooperation with the harassment efforts that were simultaneously being conducted by the AWD and LWD.

On the initial day of work (11/21/05), WS noted that a substantial number of gulls were present, with a maximum number estimated at 2000 individuals. WS noticed a gradual decline of gulls throughout the duration of the project, and on several days nearing the end of the project, less than five gulls were observed throughout the day. This gradual decline in the numbers of gulls that were identified on Lake Auburn was the measure used to determine that the program was successful. Climatic conditions such as high winds and ice formation caused limitations to the timing and duration of the program, and ultimately

caused the work to conclude (ice), despite the presence of small flocks of gulls using Lake Auburn. Overall, WS believes that the decline of gull presence was directly related to the active management during the four week period, and that this success clearly demonstrates the effectiveness of the program.

Considerations for Enhancing the Integrated Wildlife Damage Management Program

Surveys

To appropriately address the future presence of gulls on Lake Auburn, and hence the associated damage thereof, several steps must be initiated in the future. Initially, regional population trends must be documented, and basic population dynamics must be understood. These objectives may be best achieved through local surveys. A comprehensive survey of water birds in the vicinity of Lake Auburn will provide data that can be analyzed to support any necessary management decisions. The timing and frequency of these surveys are typically designed to best encounter bird activity during daytime hours (i.e. early morning, late afternoon) and to identify seasonal and weather related variations in bird activity. A standardized survey design is generally used, and this is based upon the United States Fish and Wildlife Service's (USFWS) Breeding Bird Survey (BBS). Routine bird surveys will allow WS to answer many questions including:

- Where are gulls feeding?
- Are gulls nesting locally?
- When gulls are dispersed from Lake Auburn, where do they go?
- What is the species composition and relative abundance of the local gull populations?
- To what degree does the gull migration effect gull presence on Lake Auburn in the spring and fall?
- Do other area lakes harbor gulls, and if so, how is gull use of those water bodies related spatially and temporally to Lake Auburn?
- Do climatic or environmental patterns exist relative to gull use on Lake Auburn?
- Do daily movement patterns exist in the local gull population, and if so, what are they?
- What are the current natural and man-made habitat features that effect the gull population, and can efforts be made to alleviate nearby gull attractants?

Direct Management

Bird surveys can reveal some population parameters quickly, while some aspects may take several months or more to answer. At times when immediate problems are identified, direct management activities, such as harassment or shooting may be undertaken. Overall, the underlying premise of surveys is to provide baseline information that will lead to direct management of the gull population at Lake Auburn. Additional forms of management such as nest and egg destruction, habitat modification, or exclusion devices could become necessary as a result of data analyses.

Environmental Compliance

The National Environmental Policy Act mandates that all federal agencies perform environmental review of proposed projects to ensure no adverse effects to a species or the environment will occur. WS will prepare an Environmental Assessment for the proposed project that will encompass a wide host of considerations to protect environmental integrity. This public process will allow input from stakeholders and will further direct management objectives.

Food Habits Study
An additional source of information is often attained through stomach content analysis. WS may propose to conduct a study of local gull food habits by collecting a sample of birds taken under the USFWS depredation permit. This analysis could prove useful to document the daily activity patterns and foraging locations of gulls at Lake Auburn.

Project Proposal
Wildlife Services will submit a formal agreement and financial plan that will detail the terms and conditions of our proposed program. Please understand that this proposal is preliminary and is subject to change. Flexibility in the operational aspects of an Integrated Wildlife Damage Management Program will allow higher success of the intended goals.

Feasibility Statement
Based upon preliminary investigations, experience by WS operational and research staff, and the success of the management program employed during the fall of 2005, WS believes that the proposed program can significantly reduce the number of gulls using Lake Auburn. Furthermore, WS believes that the presence of gulls and other water birds that contribute to the accumulation of coliform bacteria in Lake Auburn can be reduced indefinitely, provided that the proposed Integrated Wildlife Management Plan is conducted accordingly.

Mission
The mission of Wildlife Services (WS) is to provide Federal leadership in managing problems caused by wildlife. WS recognizes that wildlife is an important public resource greatly valued by the American people. By its very nature, however, wildlife is a highly dynamic and mobile resource that can damage agricultural and industrial resources, pose risks to human health and safety, and affect other natural resources. The WS program carries out the Federal responsibility for helping to solve problems that occur when human activity and wildlife are in conflict with one another.

If you have questions or comments to the content of this letter, please feel free to contact me. I will be looking forward to discussing this project further.

Sincerely,

Edwin B. Butler

Edwin B. Butler
State Director

cc: Kevin Gagne, Deputy Director, Lewiston Department of Public Services

Computational Flow and Fecal Coliform Transport Modeling of Lake Auburn

Prepared for
Camp Dresser & McKee, Inc.
Cambridge, MA 02139

Prepared by
Angelene X. Huang
George Krallis
Edward M. Buchak

ERM Inc.
350 Eagleview Boulevard, Suite 200
Exton, PA 19341-1180

13 January 2006

DRAFT

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Summary

A three-dimensional (3-D) hydrodynamic and water quality model, GEMSS (Generalized Environmental Modeling System for Surfacewaters) was used to study the flow patterns in Lake Auburn for the time period April 2002 to November 2002. The model was calibrated for water surface elevation (the “water balance”) and for temperature, and then used to study the fecal coliform transport within Lake Auburn for stratified and non-stratified time periods in 2002.

GEMSS as applied to Lake Auburn shows good calibration for water balance and water temperatures based on the available input data. The model results also indicate different types of circulation patterns within Lake Auburn, which are affected by frequently varying wind directions, the Lake’s bottom contours, and the presence or absence of temperature stratification.

The Lake Auburn Water Treatment Facility (LAWTF) is managed by Auburn Water District (AWD) and the City of Lewiston Water Division (LWD) and is located on the south shore of Lake Auburn. Coliform concentrations at the LAWTF intake are of concern. To investigate possible sources and source strengths, simulations were made with GEMSS for a total of nine fecal coliform source locations (three tributary source locations, three sediment source locations and three Bird Island source locations).These source locations were examined for high inflow, high outflow, and runoff event conditions.

The simulations show that fecal coliform concentrations at the intake during the summer stratified time period are much smaller than those during the fall non-stratified time period. Among each of the coliform source locations (tributary, sediment and Bird Island), sources near the Townsend Brook yield higher concentrations at the intake. This result may be due to the short distance between the source location and the intake and the driving force of Townsend Brook inflows.

For the tributary source locations, the highest coliform intake concentration occurred under the high inflow rate condition for the stratified period. For the sediment source locations, much higher intake coliform concentrations occurred in the non-stratified time period than in the stratified time period. The Bird Island sources also show a similar result.

1. Introduction

The purpose of the three-dimensional (3-D) model application presented here is to provide a tool to analyze water circulation patterns and bacteria transport in Lake Auburn. The model chosen is the Generalized Environmental Modeling System for Surface Waters (GEMSS). GEMSS is an integrated system of 3-D hydrodynamic and transport models embedded in a geographic information and environmental data system. GEMSS includes a grid generator and editor, control file generator, 2-D and 3-D post processing viewers, and an animation tool. GEMSS was developed in the mid-80's as a hydrodynamic platform for transport and fate modeling. The hydrodynamic platform ("kernel") provides 3-D flow fields from which the distribution of various constituents can be computed. The constituents are grouped into modules. GEMSS modules include:

- Water quality
- Sediment transport
- Particle tracking
- Oil and chemical spills
- Entrainment
- Toxics

The theoretical basis of the hydrodynamic kernel of GEMSS is the three-dimensional Generalized, Longitudinal-Lateral-Vertical Hydrodynamic and Transport (GLLVHT) model was first presented in Edinger and Buchak (1980) and subsequently in Edinger and Buchak (1985). The GLLVHT computation has been peer reviewed and published (Edinger and Buchak, 1995; Edinger, et al., 1994 and 1997). The kernel is an extension of the well known longitudinal-vertical transport model written by Buchak and Edinger (1984) that forms the hydrodynamic and transport basis of the Corps of Engineers' water quality model CE-QUAL-W2 (U. S. Army Engineer Waterways Experiment Station, 1986). The constituent modules as well as the GIS, visualization, GUI, and post-processors have been developed by Kolluru et al. (1998; 1999; 2003a; 2003b).

GEMSS-based studies have been accepted by EPA as well as a number of state agencies. Most recently it has been published as a recommended three-dimensional dynamic hydrodynamic and water quality model in studies funded by EPA (HGL and Aqua Terra, 1999) and by WERF (2001).

A GEMSS application requires two types of data: (1) spatial data, primarily shoreline and depth, but also including locations of inflows and outflows and (2) temporal data, that is, time-varying data defining the forcing functions of inflow rate and temperature, outflow rate, and meteorological data. The latter is sometimes referred to as boundary condition data. All deterministic models, GEMSS among them, require continuous time-varying boundary condition data. There can be no long gaps in the record and all required datasets must be available during the span of the proposed simulation period. The application to Lake Auburn was based only on existing data; no new data were collected for this study, consequently complete time-varying boundary condition data needed to be found in the historical record.

The spatial data is used to construct the model grid and the time-varying data is used to build the time series input files for the chosen simulation period. Continuous data are available for Lake Auburn from January 2001 to July 2003. The study required using the most recent year and stratified and non-stratified time periods. The period of April 2002 to mid-November 2002

was chosen and will be referred to as the “study period”. Furthermore August 2002 was identified as the stratified time period and November the unstratified time period.

1.1 Bathymetry and model grid

Lake Auburn has a mean surface area of 3.53 mi^2, a mean depth of 40 ft, a maximum depth of 120 ft, and an approximate volume of 3,920 million ft^3 (Auburn Water District and the Lewiston Water Division, 2002; Maine Department of Environmental Protection, 2003). The Lake Auburn shoreline coordinates was provided as a shapefile by CDM, who also provide depth soundings in feet. The coordinate system used in this study is NAD 1983, State Plane West Maine in feet. Use of this common coordinate system facilitated transfer of spatial data as GIS files. Figure 1 (all figures are at the end of the text) shows a 3-D view of the bathymetry of Lake Auburn. 3-D color contours indicate the bottom elevation gradient of the lake. The deep portion of the lake and the scattered islands (“Bird Island”) along the eastern shore are clearly identifiable.

The 3-D grid generated by GEMSS for Lake Auburn and the data collection stations are shown in Figure 2. The LAWTF intake is located at Station 12. Station 8 is located at the deepest point in Lake Auburn. The grid cells sizes are uniform in the x- and y- (horizontal) directions and have a spacing of about 100 meters. The grid has a total of 38 layers with a layer thickness of 3 ft. There are 477 active cells in this 3-D grid. The grid water surface area at the normal pool elevation is 3.58 mi^2 with the mean depth of 40 ft and 3,972 million ft^3, less than 2% different compared with the values provide by AWD/LWD and the Maine DEP.

1.2 Time-varying boundary condition data

As mentioned above, the inflow rates, inflow water temperatures, LAWTF intake withdrawal rates, and meteorological data were the necessary time-varying boundary condition data. These boundary condition data are described in the following sections.

Tributary inflow data

Figure 3 shows the location of the three USGS gaging stations used in the GEMSS application, two of which are inflow stations. Daily flow rates for the Basin Outlet and the Townsend Brook are available from the beginning of 2000 to the summer of 2003 and can be downloaded from www.USGS.gov. Figure 4 shows the time series flow rates of the Basin Outlet and Townsend Brook. The Basin Outlet flow rates are relatively high before July 2002 and became smaller after that. The flow rates for these both tributaries were small during the fall of 2002.

Lake Auburn has a number of ungaged tributaries. According to Dudley, the total drainage area for Lake Auburn is 18.3 square miles. The Basin Outlet gage has a drainage area of 8.01 square miles, and the Townsend Brook gage has a drainage area of 1.88 square miles. Inflow rates for the remaining drainage area (8.41 square miles) were proportion to the Basin Outlet drainage area. The flows themselves were added to the Basin Outlet.

Outflow data

The outflow rates at the Bobbin Mill Brook near the southeastern side of the reservoir (Figure 3) were downloaded from the USGS website and the data were converted to GEMSS input format. Figure 5 shows the time series daily flow rates at the Bobbin Mill Brook gage.

AWD/LWD withdrawals

The LAWTF intake structure is a 48” diameter pipe approximately 10 ft to 12 ft from the bottom located on the south shore of Lake Auburn 900 ft out from the pumping station (Station 12 in Figure 2). A time series plot of the withdrawal rate is shown in Figure 6. The withdrawal rates

were predominately less than 10 cubic feet per second (cfs) with no large fluctuations during the entire study period.

Meteorological data

Meteorological data is required to quantify two processes: (1) surface heat exchange, including shortwave and longwave radiation, conduction, evaporation, and back radiation and (2) surface wind shear. The parameters necessary are dry and dew point temperatures, wind speed and direction, cloud cover and atmospheric pressure and are available from the Automated Surface Observing System (ASOS) station in Augusta (WBAN 14605), approximately 25 miles northeast of Lake Auburn. Local wind speed and wind direction data from a station 6 miles south of Lake Auburn were available and used instead of the wind speed and wind direction from the Augusta data. The final meteorology data file Aug_LAIF.met is the result of combining these two datasets. Figure 7 shows the time series plots for the meteorological data used in this study.

Response water temperature

As noted, the model requires the continuous (hourly or daily) water temperature for tributary inflows. For the Lake Auburn GEMSS application, inflow temperature time series need to be constructed for the Basin Outlet and for Townsend Brook. This type of data is often difficult to acquire, but a satisfactory inflow temperature time series can be generated from meteorological data and synoptic observations of the type available for some of the tributaries. The generated inflow temperature time series uses a simple water temperature model, called the response temperature model. Response temperature is defined as the temperature a column of fully mixed water would have if surface heat exchange were the only active heat transfer process (i.e., water temperature “responding” only to surface heat exchange).

The rate of change of response temperature can be written in terms of the net rate of surface heat exchange as

$$D\frac{dT}{dt} = \frac{R_n}{\rho c_p} \qquad \text{Eq. 1}$$

where

D	=	mean depth of the water column, m
T	=	water column temperature, C
t	=	time, s
R_n	=	net rate of surface heat exchange, W m^{-2}
ρ	=	density of water, 1000 kg m^{-3}
c_p	=	specific heat of water, 4186 J kg^{-1} $°C^{-1}$

The rate of surface heat exchange can be computed from air and dew point temperature, wind speed, cloud cover, solar radiation, and atmospheric pressure. All of these parameters are available in the composite meteorological dataset Aug_LAIF.met. The code necessary to compute response temperature is included in the GEMSS tool, MetGen, which is also used to format meteorological data for GEMSS itself.

The primary calibration parameter in Equation 1 is the waterbody depth, D, which controls the seasonal and diurnal amplitude of the response temperature. In addition, shortwave solar

radiation can be reduced to account for shading and the evaporative windspeed can be manipulated by adopting any one of several formulas to compute evaporative heat loss and by modifying the windspeed itself.

Hourly response temperatures were computed using MetGen and the synoptic temperature observations provided by CDM for the Basin Outlet and Townsend Brook. Figure 8 and Figure 9 show the calibrated response temperatures for each location and the water temperature observations. The best fit to the provided datasets was obtained with 20% solar radiation shading for the Basin Outlet and 0% for the Townsend Brook; and the Brady, Graves and Geyer windspeed function; an effective windspeed coefficient 100%, and a depth of 4 m for both locations.

1.3 Hydrodynamic setup data summary

All the boundary condition data described in the previous sections are summarized in Table 1. The file names, sources, frequency and available periods are indicated in this table. As mentioned in the previous section, the time period of 1 April 1 2002 to 15 November 2002 was chosen as the study period.

Table 1 GEMSS 3-D model input summary

Dataset	GEMSS Input Filename	Source Filename	Frequency	Start	End
Spatial data – bathymetry					
Shoreline polygon	Boundary_prj.dbf	Boundary.dbf by CDM			
Depth soundings	xyz_prj.shp	xyz.dbf by CDM			
Time-varying boundary condition data – tributary inflows					
Basin Outlet flow rate	BasinOutletFlow.hdg	USGS Station 01056400	Daily	Feb 2000	Jul 2003
Townsend Brook flow rate	TownsendBrookFlow.hdg	USGS Station 01056480	Daily	Apr 2000	Jul 2003
Bobbin Mill Brook flow rate	BobbinMillBrookFlow.hdg	USGS Station 01056505	Daily	Aug 1999	Jul 2003
Basin Outlet water temperature	BasinOutlet.wdg	Perimeter Sampling.xls and MetGen tool	Hourly	Jul 1995	Jul 2005
Townsend Brook water temperature	Townsend.wdg	Perimeter Sampling.xls and MetGen tool	Hourly	Jul 1995	Jul 2005
Time-varying boundary condition data – Lake Auburn Water Treatment Facility (LAWTF)					
LAWTF withdrawal rate	AWD-LWD-withdrawal rate.hdg	LWD AWD Daily Flow.xls by CDM	Daily	Jan 2001	Jun 2005
Time-varying boundary condition data – meteorological data					
Meteorological data at Augusta (WBAN 14605) with replaced local wind speed and wind direction data	Aug_LAIF.met	Augusta_DATSAV3.txt; LAIFwind speed2004.xls and LAIFwind speed2005.xls	Hourly	Jul 1995	Jul 2005

2. Model Calibration

Model calibration means comparing observed and computed values and adjusting model input data and parameters to obtain computed values that are closer to observed values. This process generally includes changing values of parameters that are not measured in the field (e.g., sediment heat exchange rates), but also using bathymetric and time series input data differently as the calibration simulations reveal a better understanding of the underlying processes.

2.1 Available field data for calibration

Daily observed water surface elevations from January 2001 to June 2005 were available and used for the water balance calibration. Vertical temperature profiles at Station 8 (The deepest portion of the Lake) were available from May 2001 to November 2004 at a weekly frequency. These data were used for water temperature calibration.

2.2 Flow balance and temperature calibration

Figure 10 shows the computed water surface elevations compared with the observed daily elevations. In this figure, blue triangles indicate the water surface observed elevations; the red solid line indicates the computed elevations.

According to the USGS report (Dudley, 2004), Lake Auburn evaporation was 24.1 inches in 2002. The model results showed a loss of 14 inches of water for the seven months of April 2002 to November 2002, exactly in proportion to the USGS value.

Observed water temperature profile data were available at Station 8 (Figure 2). These data were used for the water temperature calibration. For calibration, the wind sheltering, Secchi depth, sediment heat exchange coefficient, and the evaporative wind speed function were adjusted. The best fit of these parameters for the calibration was 100% for the wind sheltering coefficient, 5x10-7 W m-2 °C-1 for the sediment heat exchange coefficient, 8 meters for the Secchi depth, and the Brady, Graves and Geyer formula for evaporative heat exchange.

Figure 11, Figure 12, Figure 13, and Figure 14 display the comparisons of observed and computed water temperature profiles for the 2002 study period. Both the shapes and values of the computed water temperature profiles match well the observed shapes and values. The results indicate that turnover (the transition from stratified to non-stratified conditions) occurs earlier by two weeks in October in the model. After that, the model results again show the good agreement with the observed profiles.

2.3 Flow pattern analysis

The model results indicate that the circulation patterns in Lake Auburn are a function of the complex bottom bathymetry, frequently varying wind speeds and directions, and inflow and outflow rates. Three different circulation patterns at the surface layer are shown in Figure 15, Figure 16 and Figure 17. Figure 15 shows a strong surface flow direct north as a result of a strong south wind. Figure 16 shows the southwestern directed flow due to strong northeast winds. Figure 17 shows a clockwise flow pattern at the surface when the wind shifts direction from north to southeast. Figure 18 shows that regional clockwise and counter clockwise circulations occur at the same time at the intake layer. The model results also indicate that horizontal flow patterns in Lake Auburn differ from one layer to another during both stratified and the non-stratified periods. This phenomenon was investigated by plotting circulation patterns along a vertical plane (“slice”) of Lake Auburn.

Figure 19 shows the location of the vertical slice. Figure 20 shows an example of the multi-layer flow during the stratified time period; Figure 21 shows an example of two layer flow during the non-stratified period. These examples were selected when the wind was from north and the velocity patterns were clear. Additional circulation patterns at the other times can be viewed in the animation files in the accompanying CD.

3. Coliform Simulations

With the GEMSS application calibrated, the fecal coliform transport in Lake Auburn was modeled using nine coliform source locations and varying hydrodynamic conditions. The model setup and the results are included in this section of the report. The detailed animation files for the coliform simulations are also included in the accompanying CD.

3.1 Coliform model setup

To study the impact of nine source locations on the intake coliform concentrations, various factors such as inflow rates, LAWTF withdrawal rates, surface elevations and the coliform source locations were considered in the coliform analysis. Based on the previous calibration results, the time period of 1 August 2002 to 30 August 2002 was chosen for the stratified study; and the time period of 20 October 2002 to 20 November 2002 was chosen for the non-stratified study. These two time periods were modeled separately with the same coliform load for each coliform source location. Because coliforms decay linearly, the coliform concentrations shown in the model results are scalable to the initial concentrations.

Nine coliform source locations (three tributary sources, three sediment bed sources and three Bird Island sources) were included in the modeling. The location and name of each coliform source location are shown in Figure 22. “T” stands for tributary source location. “S” stands for sediment source location. “B” stands for Bird Island source location. Each coliform source was simulated separately and named CFM1 to CFM9 (Table 2). Because coliforms found in the Lake Auburn are generally fecal coliforms, model coliform parameters were taken from literature values for fecal coliform (Table 2. The fecal coliform loads for all the source locations were provided by CDM. The parameters and loads are listed in Table 3 (Borst and Selvakumar 2005).

Table 2 Coliform sources description

Coliform Name	Source Type	Location in Lake Auburn
CFM1	Tributary	The Basin Outlet
CFM2	Tributary	Townsend Brook
CFM3	Tributary	Southwest tributary
CFM4	Sediment	North
CFM5	Sediment	East near Townsend Brook
CFM6	Sediment	South lake
CFM7	Bird source	Northwest shore
CFM8	Bird source	North Central shore
CFM9	Bird source	South lake

Table 3 Coliform parameters used in the model
(Borst and Selvakumar 2005).

Source of coliform	Tributary	Sediment	Bird source
Concentration	2500 colonies/100 ml		
Load		100,000 colonies/second	1000 colonies/second
Coliform decay rate	1.44 / day	1.44 / day	1.44 / day
Coliform temperature coefficient	1.03	1.09	1.09
Coliform settling velocity	0.5 m/day	0.5 m/day	0.5 m/day

Table 4 shows that the scenarios conduced in this study were divided into the stratified group and the non-stratified group. The first scenario for each group was the base simulation with the average inflow rates, average LAWTF withdrawal rates and average water surface elevations. “Average” means the average value during the same time period for each variable. All the scenarios used the varying meteorological data as specified in Section 1.2.

Table 4 Coliform simulation scenarios

Scenario Name	Conditions	Inflow rate (cfs)	Initial surface elevation (ft)	Outflow rate (cfs)	LAWTF withdrawal rate (cfs)
Stratified time period 1 August 2002 to 30 August 30 2002					
Scenario A0	Baseline	Average	259.75	Average	15.16
Scenario A1	High inflow rate	38.5	259.75	Average	15.16
Scenario A2	High outflow rate	Average	259.75	38.5	15.16
Scenario A3	Runoff event	Hydrograph	259.75	Average	15.16
Non-stratified time period 20 October 2002 to 20 November 2002					
Scenario B0	Baseline	Average	259.2	Average	11.2
Scenario B1	High inflow rate	38.5	259.2	Average	11.2
Scenario B2	High outflow rate	Average	259.2	38.5	11.2
Scenario B3	Runoff event	Hydrograph	259.2	Average	11.2

For Scenarios A3 and B3 (runoff event), hydrographs for the two time periods were provided by CDM and are shown in Figure 23 and in Figure 24. The flow rates during the runoff event were distributed evenly based on sub-watershed areas to match the model configuration for tributary flows. For the stratified Scenario A3, the runoff event was arranged such that the peak runoff occurred on 6 August 2002 1:45PM to try to drive it toward the intake simultaneously with strong north winds. For non-stratified Scenario B3, the peak runoff was arranged on 28 October 28 2002 6:45PM for the same reason as the August runoff event.

The initial water surface elevation was provided by CDM (Table 4). The initial concentrations for all the source locations were zero. The analysis focused on the intake coliform concentrations. The LAWTF intake (Station 12) is located 900 ft out from the pumping station. The depth at Station 12 is 22 ft. The top of the 48” diameter intake is at a depth of approximately 10 ft to 12 ft from the bottom. Because the layer thickness is 3 ft, the intake vertical location in the model is at the fourth layer from the bottom. The intake coliform concentrations for each of the nine source locations were compared using GEMSS time series plotting and horizontal constituent contouring features.

3.2 Coliform study summary

The model results demonstrate different impacts of the nine coliform source locations on the intake concentrations under the three conditions of high inflow, high outflow and runoff event. Selected time series plots and plume contour plots are shown in this section. The animation files of selected coliform simulations are included in the accompanying CD.

Table 5 shows the maximum coliform concentrations due to all the source locations for the stratified and non-stratified time periods. The results indicate that higher concentrations occurred during the non-stratified time period than in the stratified time period. The sediment and Bird Island source locations yielded much higher intake coliform concentrations in the non-stratified time period than in the stratified time period. The sediment source locations yielded the

highest intake coliform concentrations among all the other source locations in the non-stratified time period.

The model results also show that in the stratified time period, the runoff event had little impact on the intake coliform concentrations. But in the non-stratified time period, the tributary source location CFM2 and sediment source locations CFM5 and CFM6 yielded significant higher intake coliform concentrations during the runoff event.

Table 5 Maximum model result of the intake coliform concentrations
(units are number of colonies/100 ml)

Scenarios	Tributary source locations			Sediment source locations			Bird Island source locations		
	CFM1	CFM2	CFM3	CFM4	CFM5	CFM6	CFM7	CFM8	CFM9
Stratified time period									
Scenario A0	0.000	0.009	0.000	0.001	0.032	0.000	0.004	0.167	0.030
Scenario A1	0.010	0.049	0.001	0.002	0.045	0.000	0.004	0.189	0.030
Scenario A2	0.000	0.008	0.000	0.000	0.024	0.000	0.005	0.190	0.030
Scenario A3	0.000	0.007	0.001	0.000	0.012	0.000	0.007	0.220	0.030
Non-stratified time period									
Scenario B0	0.002	0.156	0.120	21.135	258.093	7.080	1.170	2.916	0.845
Scenario B1	0.028	0.651	0.120	25.088	258.731	9.956	1.254	2.851	0.838
Scenario B2	0.001	0.144	0.101	18.039	257.205	4.719	1.095	2.756	0.783
Scenario B3	0.023	8.295	0.120	28.071	263.617	11.884	1.339	2.599	0.837

Stratified time period

The model results show the high inflow rate condition caused higher intake coliform concentrations from the tributary and sediment source locations. The Bird Island source locations yielded the higher intake coliform concentrations for the runoff event. CFM2, CFM5 and CFM8, three source locations near Townsend Brook, yielded higher intake coliform concentrations due to the short distance to the intake.

Bird Island source location CFM8 yielded the highest intake coliform concentrations for the runoff event for the stratified time period. Figure 25 shows the time series plots of all the Bird Island source locations. The peak concentration of runoff event occurred on 7 August 2002 7AM after the runoff happened on 6 August 2002. Figure 26 shows the peak coliform concentration plumes at the intake layer from CFM8. The contour plot provides a good visualization on the impact of CFM8 in Lake Auburn.

Non-stratified time period

As noted in Table 5, the model results show much higher intake coliform concentrations from all the source locations during the non-stratified time period than during the stratified time period. The runoff event condition caused significant high intake coliform concentrations from all source locations. Among all the source locations, sediment source locations yielded the highest intake coliform concentrations. The sediment source location CFM5 yielded significantly high intake coliform concentrations (>250 colonies/100 ml) under all flow conditions, possibly due to the short distance to the intake as well as the inflow driving force from Townsend Brook. For similar reasons, CFM2 and CFM8 (two locations close to the Townsend Brook) yielded higher intake coliform concentrations than the others.

Figure 27 shows the time series plots of intake coliform concentrations from the sediment source locations under the runoff event condition. The model results indicate the peak intake coliform concentration during the runoff event occurred on 29 October 9 PM after the peak runoff in the morning of 28 October 2002. Figure 28 to Figure 36 show the color contour coliform concentrations at the intake layer from each coliform source location on 29 October 9PM. The color and the size of the plumes in these figures provide the information on the impact of each coliform location for the runoff event. More detailed contour animations are included in the accompanying CD ROM provided by ERM.

4. Conclusions

The 3-D hydrodynamic model GEMSS is a good tool to model the circulation patterns and coliform transport in Lake Auburn. The model results show a good calibration for water balance and water temperatures. Different circulation patterns in Lake Auburn were evident in the model results and occurred due to frequently varying wind and wind directions, the complex bottom bathymetry, and the presence or absence of stratification.

The coliform analysis shows that the fecal coliform concentrations at the intake during the stratified time period are much smaller than the concentrations during the non-stratified time period. Among all the coliform source locations, the sources near the Townsend Brook yield higher concentrations at the intake. This result may be due to the short distance between the source location and the intake location, and the driving force from the Townsend Brook inflows. The sediment source near Townsend Brook yielded the highest coliform concentrations at the intake among all the coliform source locations.

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6. Contents of the CD

The folders and their contents are listed below:

- **BoundaryCondition**
  - Flow rate files for tributaries and withdrawals (.hdg GEMSS input format)
  - The water temperature files for tributaries (.wdg GEMSS input format)
- **Client**
  - The original files provided by CDM, including the withdrawal rate file, sampled water temperature files, elevations files
  - *Not used* subfolder contains the data were not used in this study
  - *Processed* subfolder contains data files that were processed for GEMSS input
- **Control**
  - The GEMSS control files for all the scenarios. Those files are ready to use for obtaining the simulation results. The description of each control file is as follows:
    - Run056 is the final calibration for the time period of April 2002 to November 2002
    - RunA0, RunA1, RunA2 and RunA3 correspond to ScenarioA0, ScenarioA1, ScenarioA2 and ScenarioA3 in Table 4 of the report.
    - RunB0, RunB1, RunB2 and RunB3 correspond to ScenarioB0, ScenarioB1, ScenarioB2 and ScenarioB3 in Table 4 of the report.
- **Doc**
  - The final report file and the downloaded reference papers related to this study (.pdf files).
- **Field**
  - Observed database (.mdb) for calibrations including the vertical water temperature profiles and water surface elevations
- **GIS**
  - Maps, shape files and soundings for developing the 3D grid
- **Grid**
  - The GEMSS 3D grid for model simulation
- **Meteorology**
  - Meteorological data source files, GEMSS input file and the meteorological data analysis file. Aug_LAIF.met is the final met file used in the model that combined Augusta and local airport wind data.
- **Output**
  - If GEMSS is running, the model results will automatically be placed in the folder in text formats and .mdb final model results database.
  - This folder contains the examples of model results. Since the model results contain the contour data for animation purpose, they are very large files.
- **PostProcessing**
  - The plots, animations from the model results
  - The animation files are in .avi format. This CD includes the following animations:
    - Base line condition Bird Island source near Townsend Brook tributary during the non-stratified time period Scenario B0 – CFM8
    - High flow condition Townsend Brook tributary coliform source during the non-stratified time period Scenario B1 – CFM2
    - Runoff event condition Sediment source near Townsend Brook during the non-stratified time period Scenario B3- CFM5

7. Figures

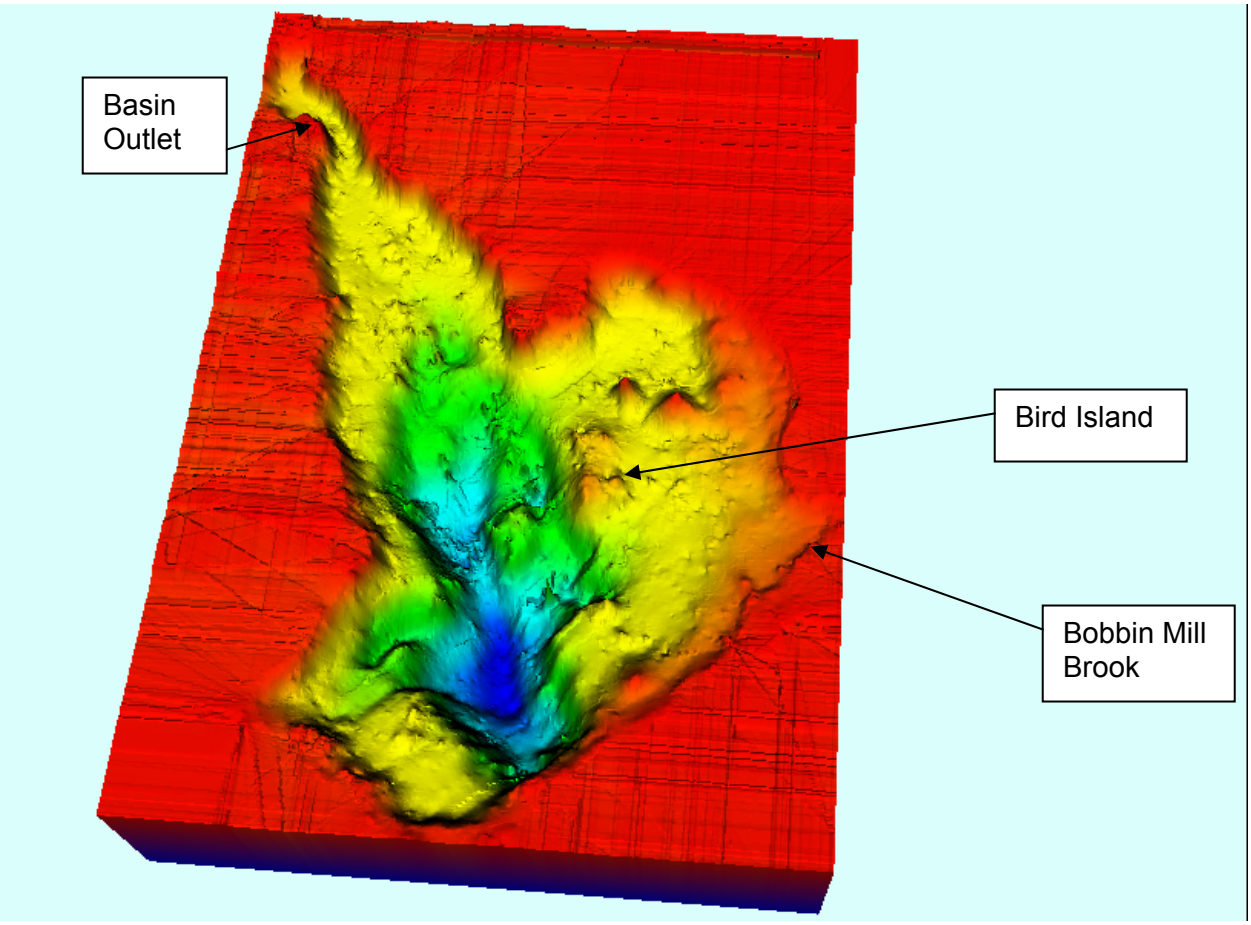

Figure 1 3-D view of Lake Auburn's bathymetric data
The dark blue color represents the deepest area, with gradations from blue to red representing shallower areas. The red color represents the land surface.

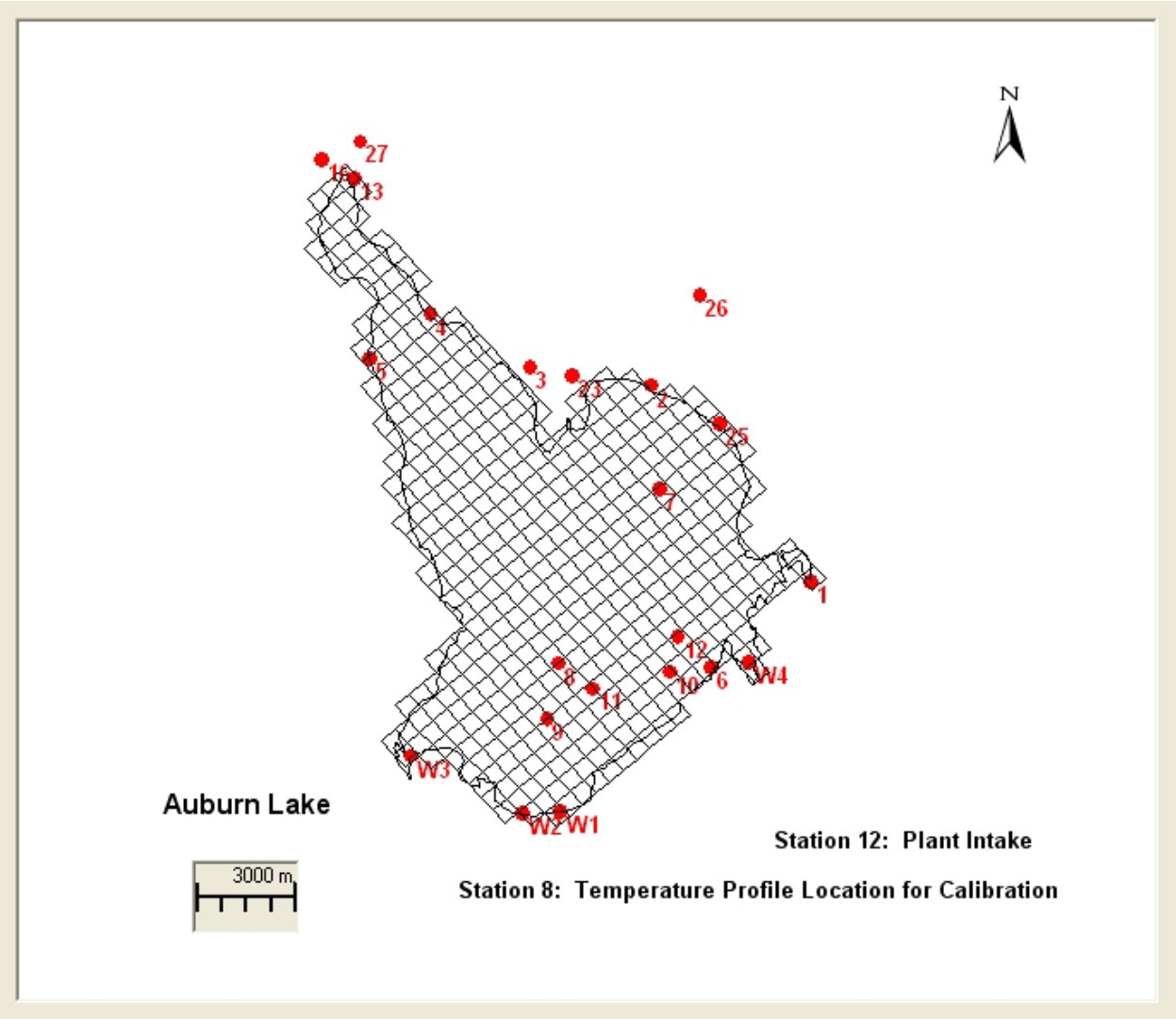

Figure 2 GEMSS grid for Lake Auburn and data collection stations
The numbers shown in the figure are data collection stations. Station 12 is the LAWTF intake, and Station 8 is located at Lake Auburn's deepest point.

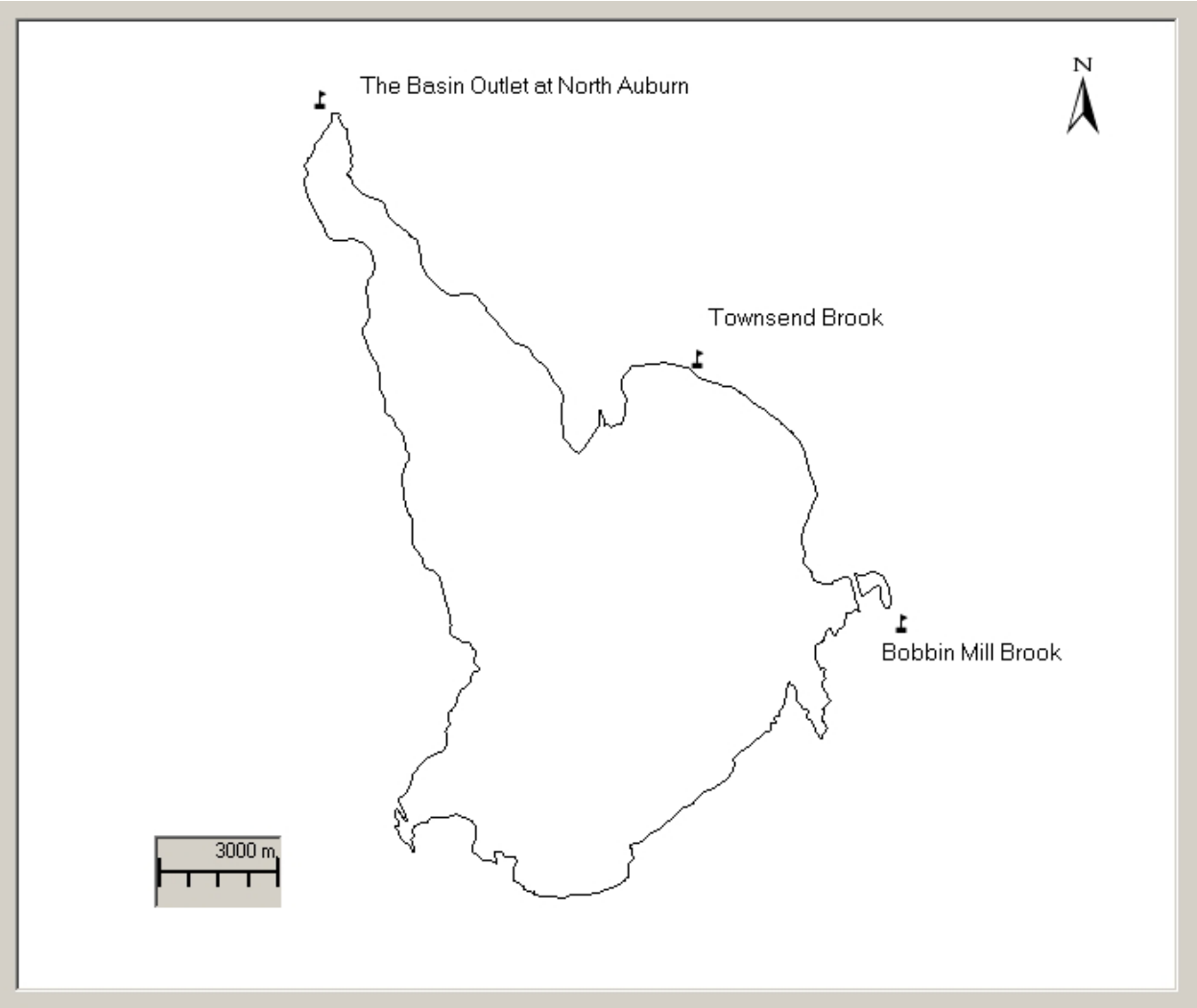

Figure 3 USGS gaging stations in the Lake Auburn drainage basin

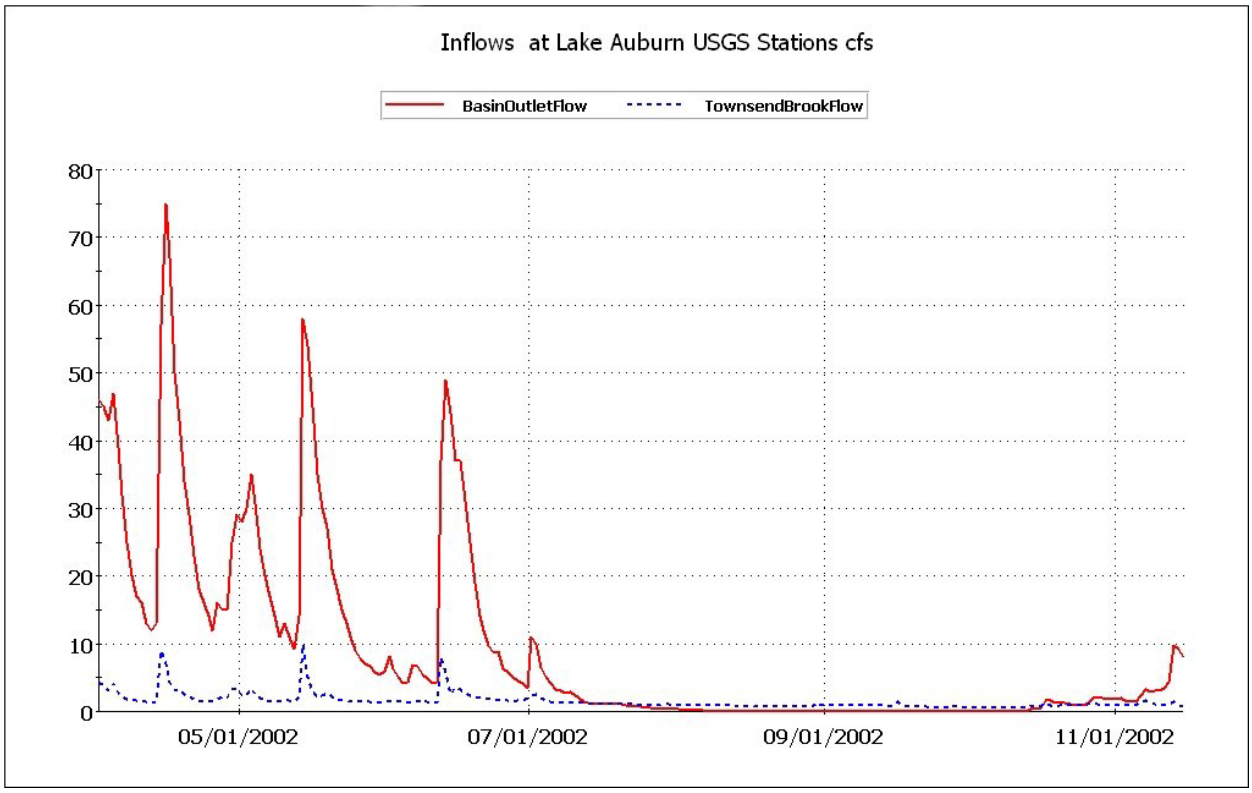

Figure 4 Time series inflow rates for the Basin Outlet and Townsend Brook

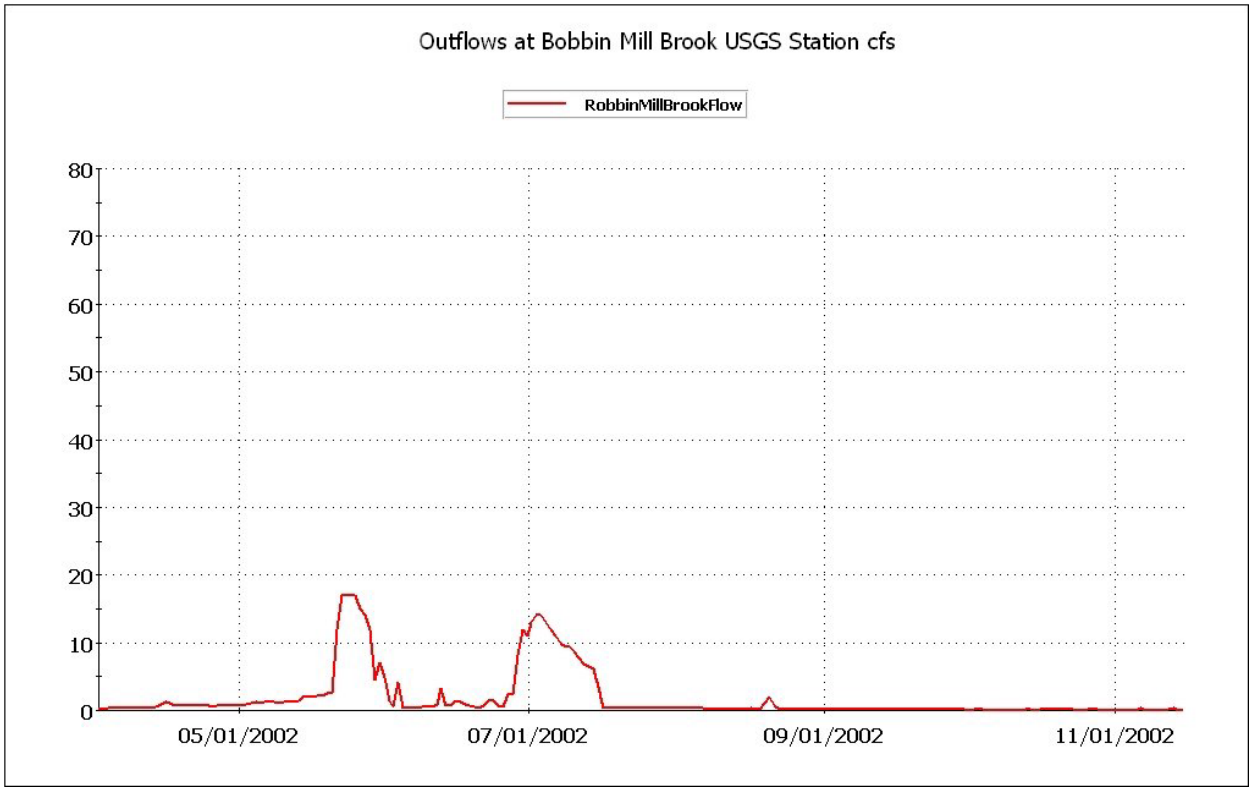

Figure 5 Time series outflow rates for Bobbin Mill Brook

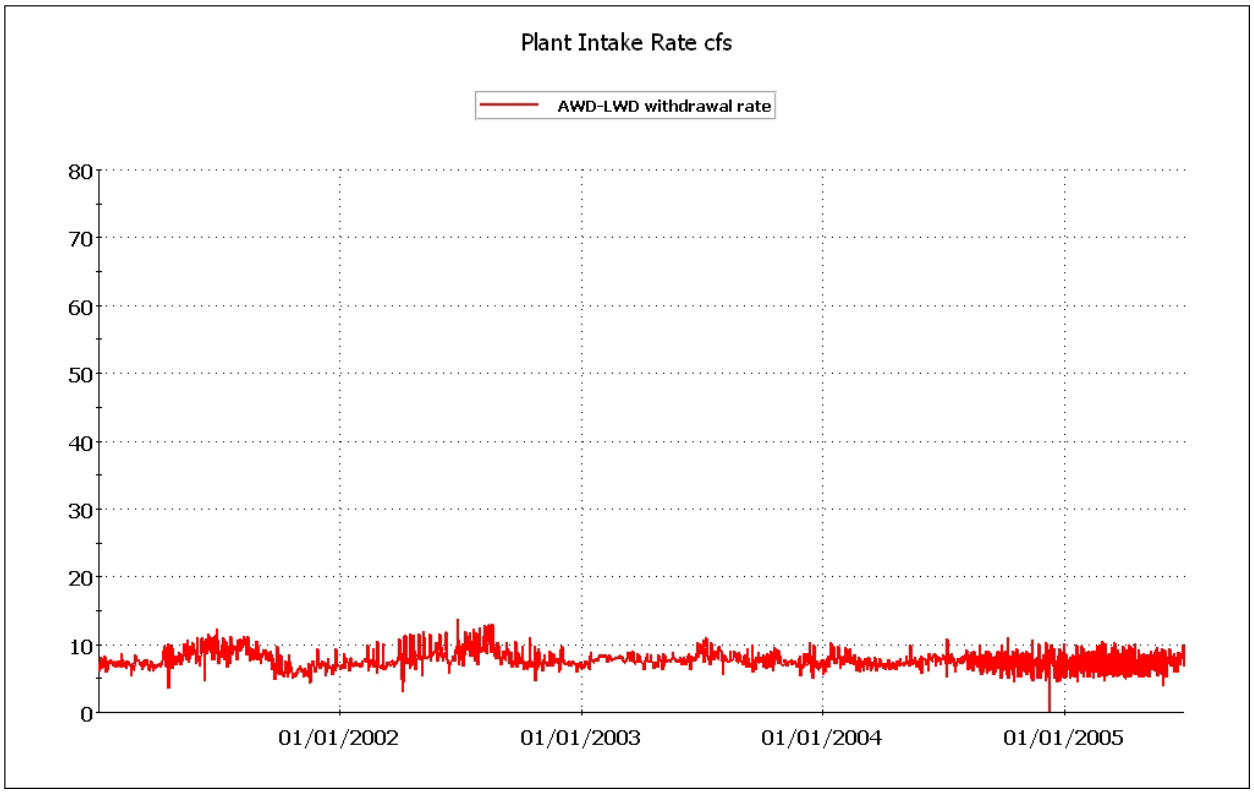

Figure 6 Time series LAWTF withdrawal rates

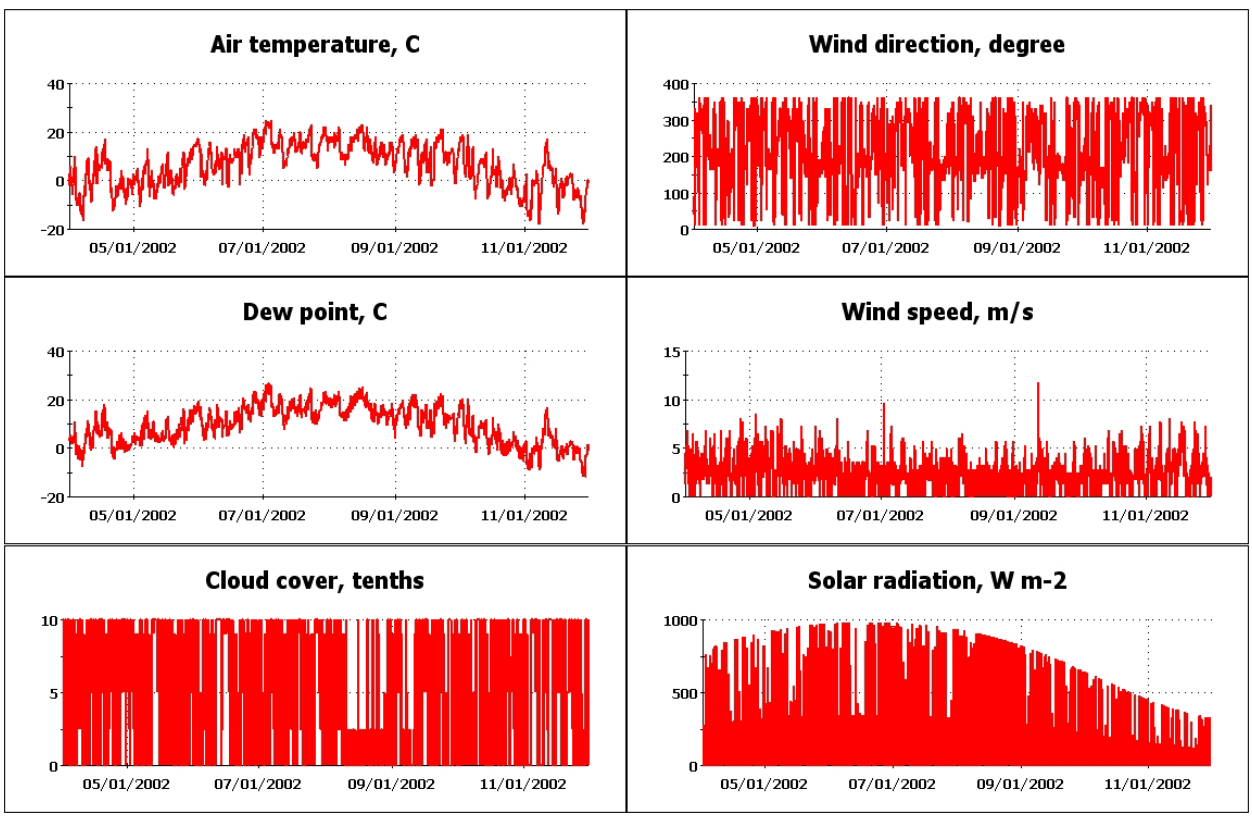

Figure 7 Time series meteorological data

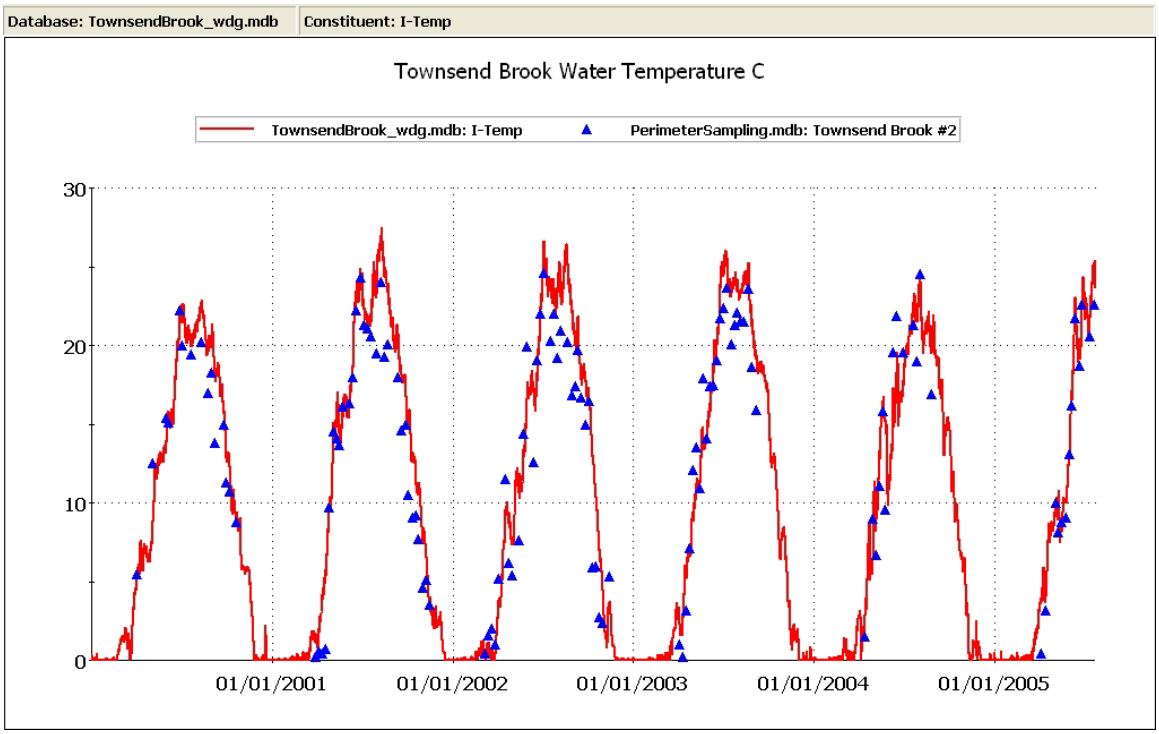

Figure 8 Calibration of response temperature to synoptic observations at Townsend Brook

Red solid line is computed response water temperature; blue triangles are sampled water temperatures.

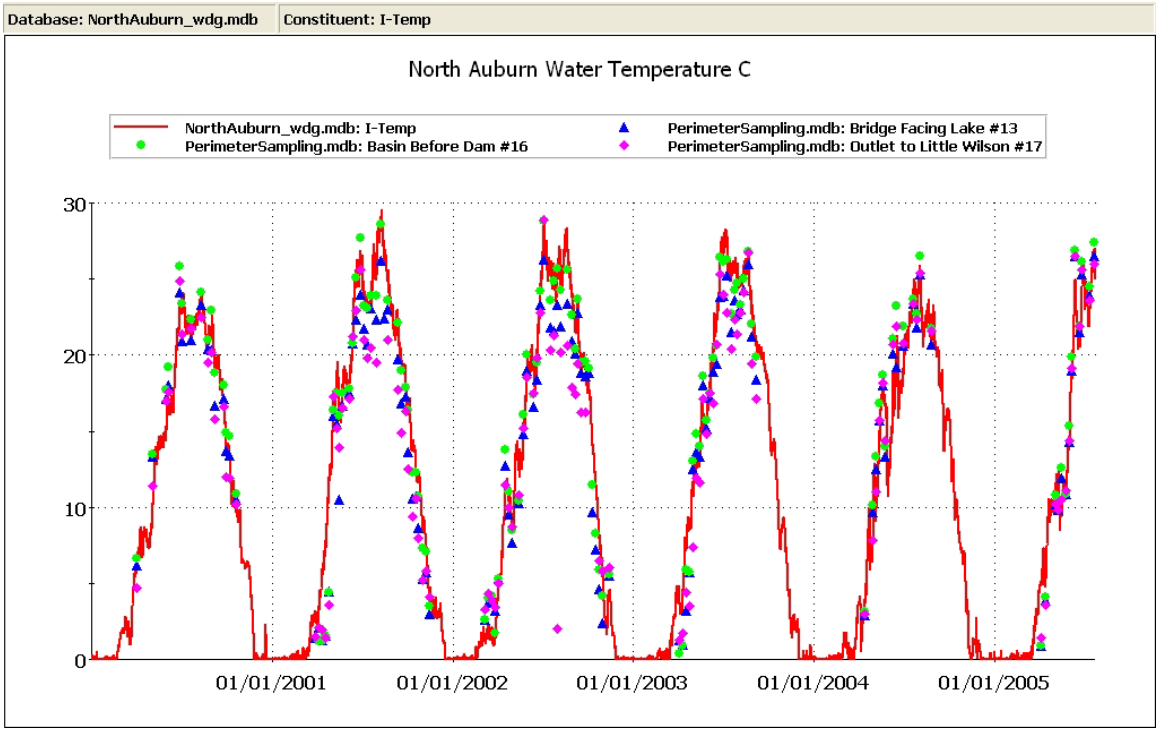

Figure 9 Calibration of response temperature to synoptic observations at the Basin Outlet

Red solid line is computed response water temperature; shapes are various sampled water temperatures.

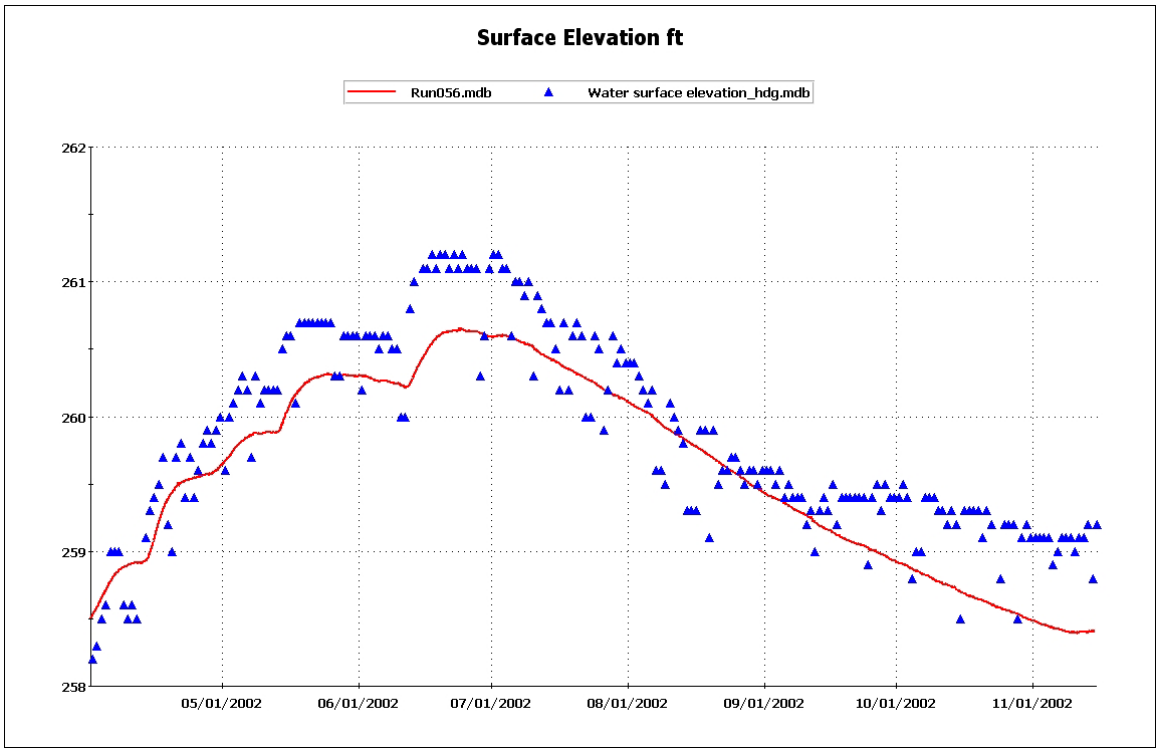

Figure 10 Calibration of surface water elevations

Blue triangles indicate the observed water surface elevations; the red solid line indicates the computed elevations.

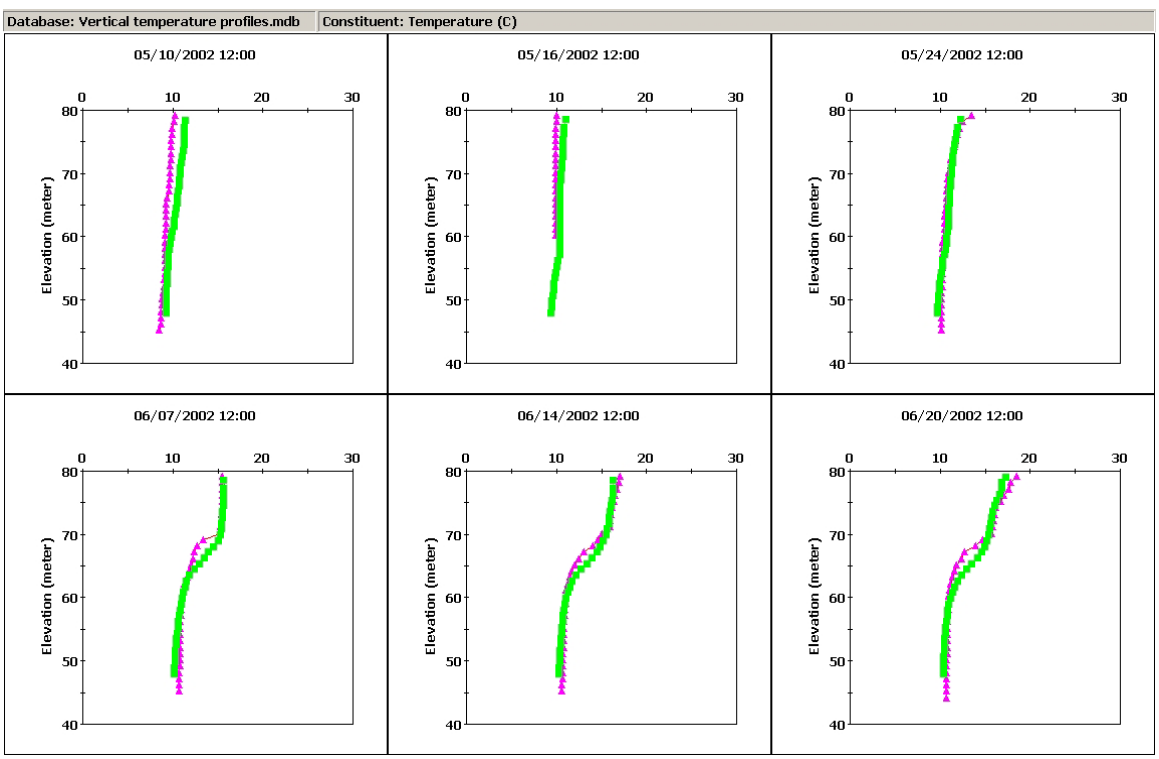

Figure 11 Observed and computed water temperatures at Station 8 (April – May 2002)

Purple triangles are observed values; green squares are computed values.

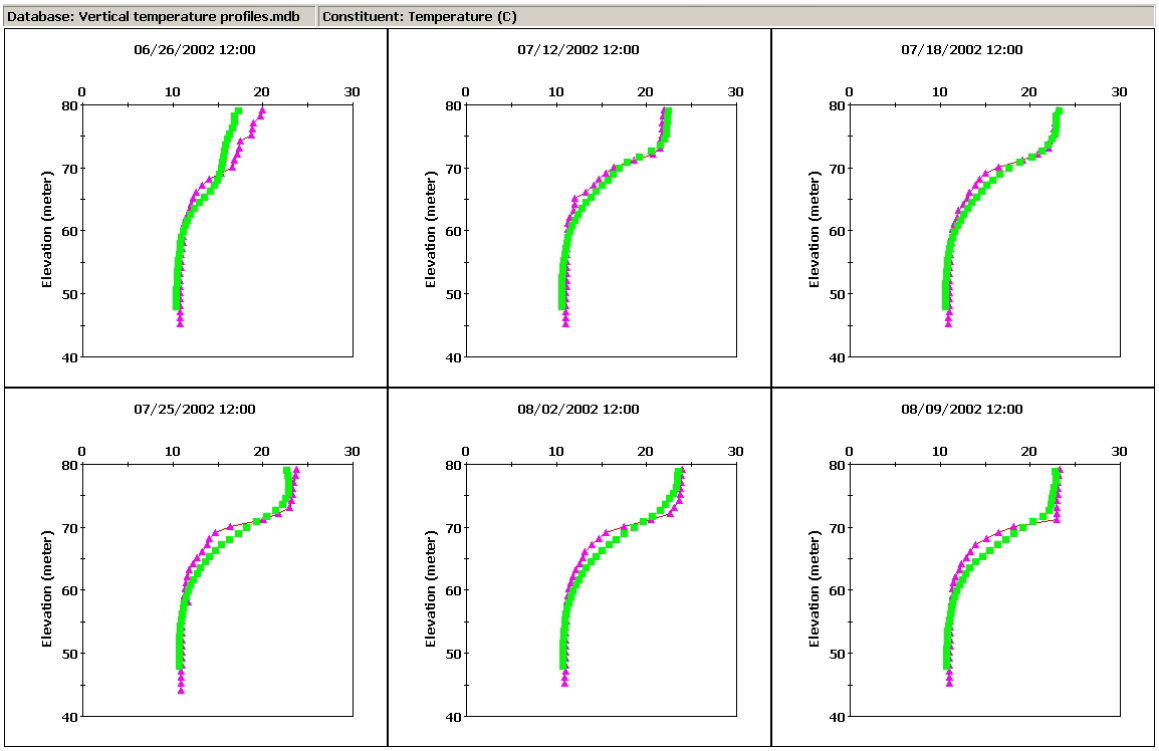

Figure 12 Observed and computed water temperatures at Station 8 (June – July 2002)
Purple triangles are observed values; green squares are computed values.

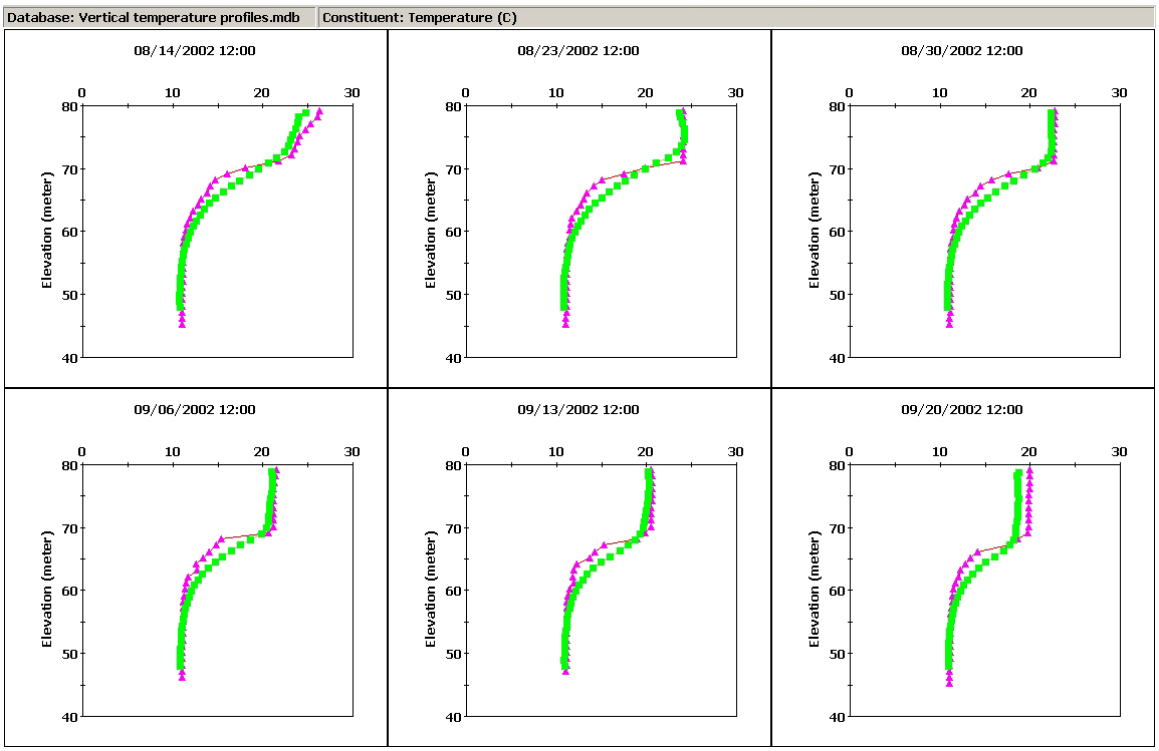

Figure 13 Observed and computed water temperatures at Station 8 (August 2002)
Purple triangles are observed values; green squares are computed values.

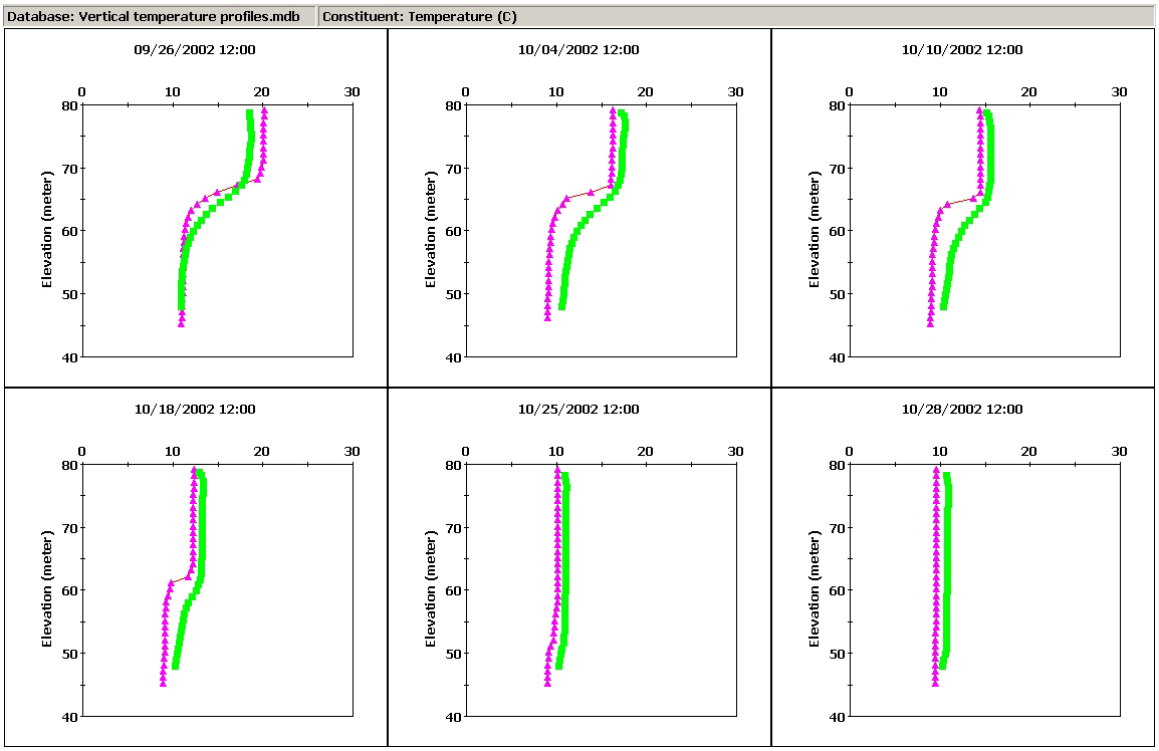

Figure 14 Observed and computed water temperatures at Station 8 (September – October 2002)

Purple triangles are observed values; green squares are computed values.

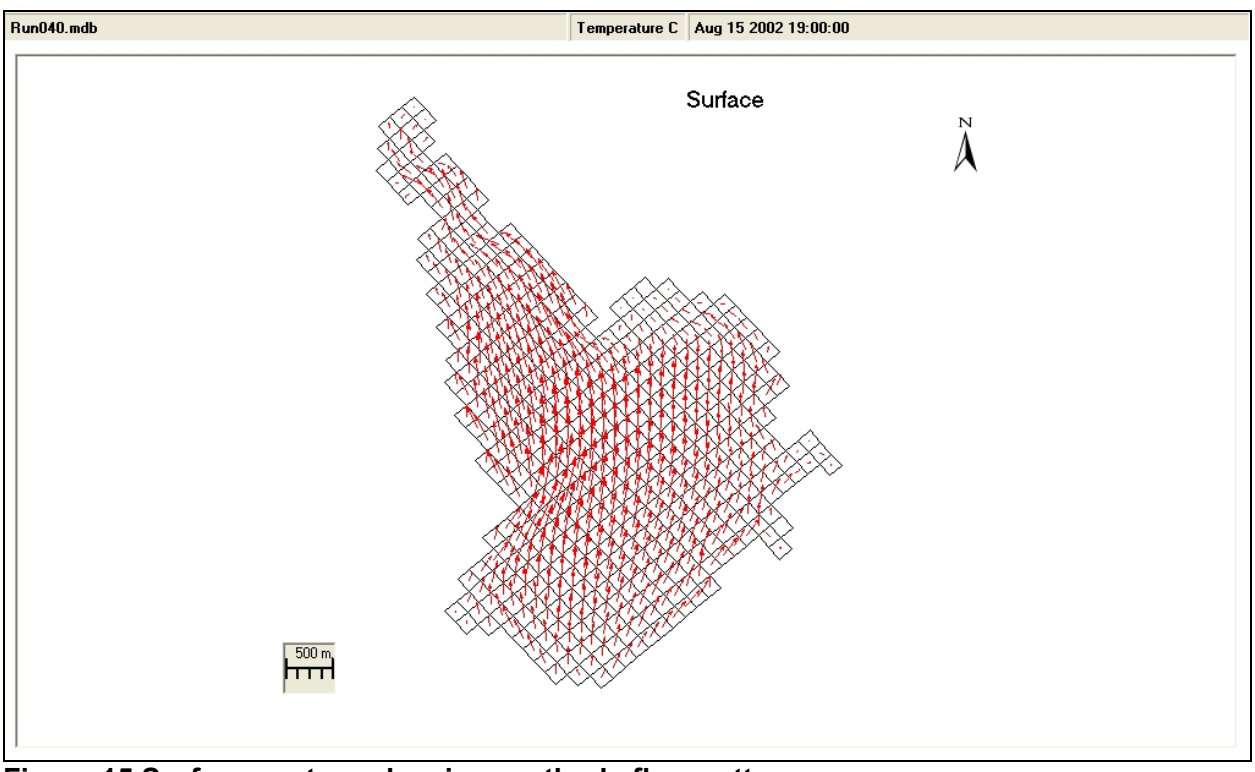

Figure 15 Surface vectors showing northerly flow pattern

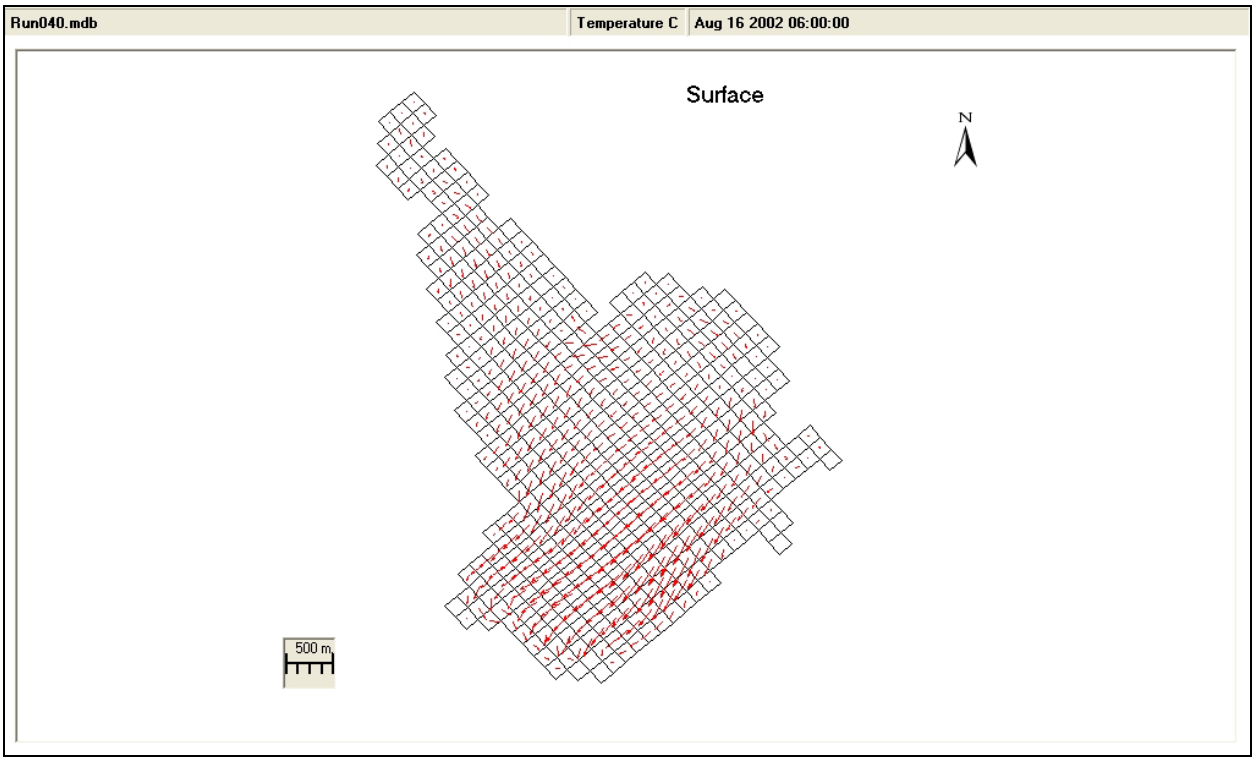

Figure 16 Surface vectors showing southwestern flow pattern

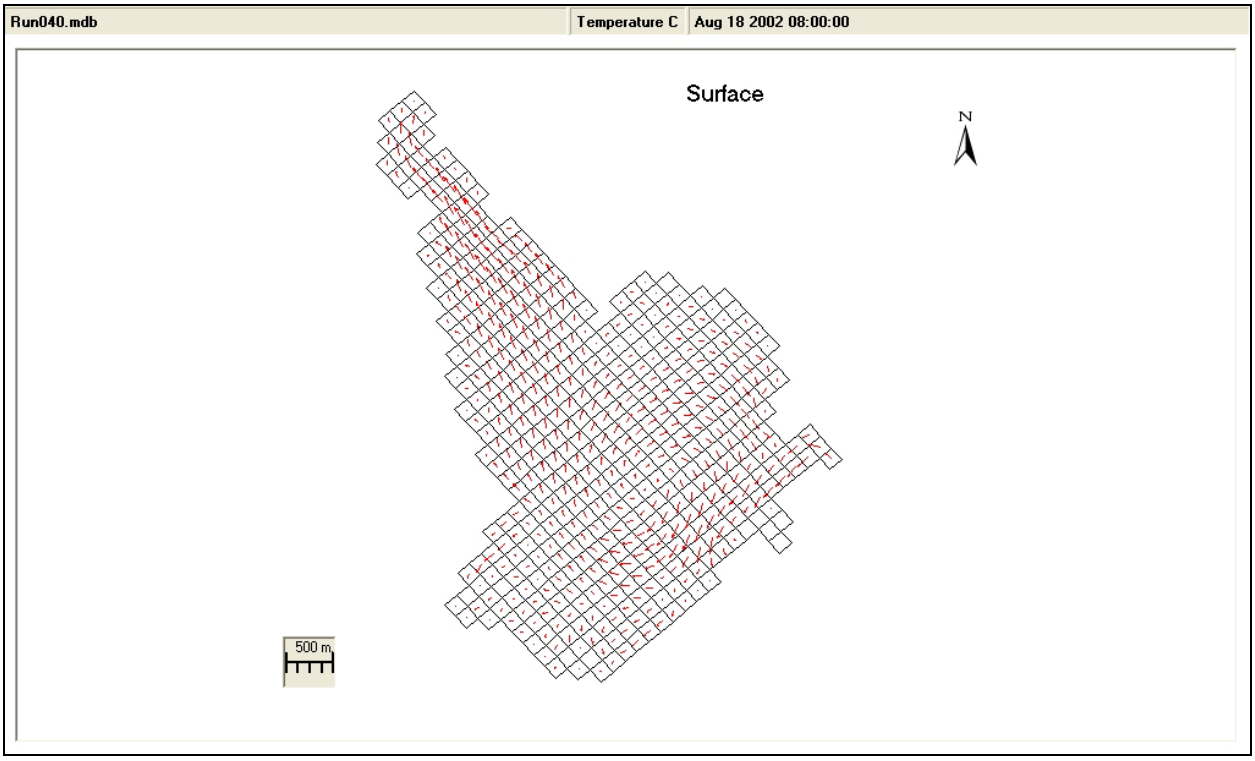

Figure 17 Surface vectors showing clockwise flow pattern

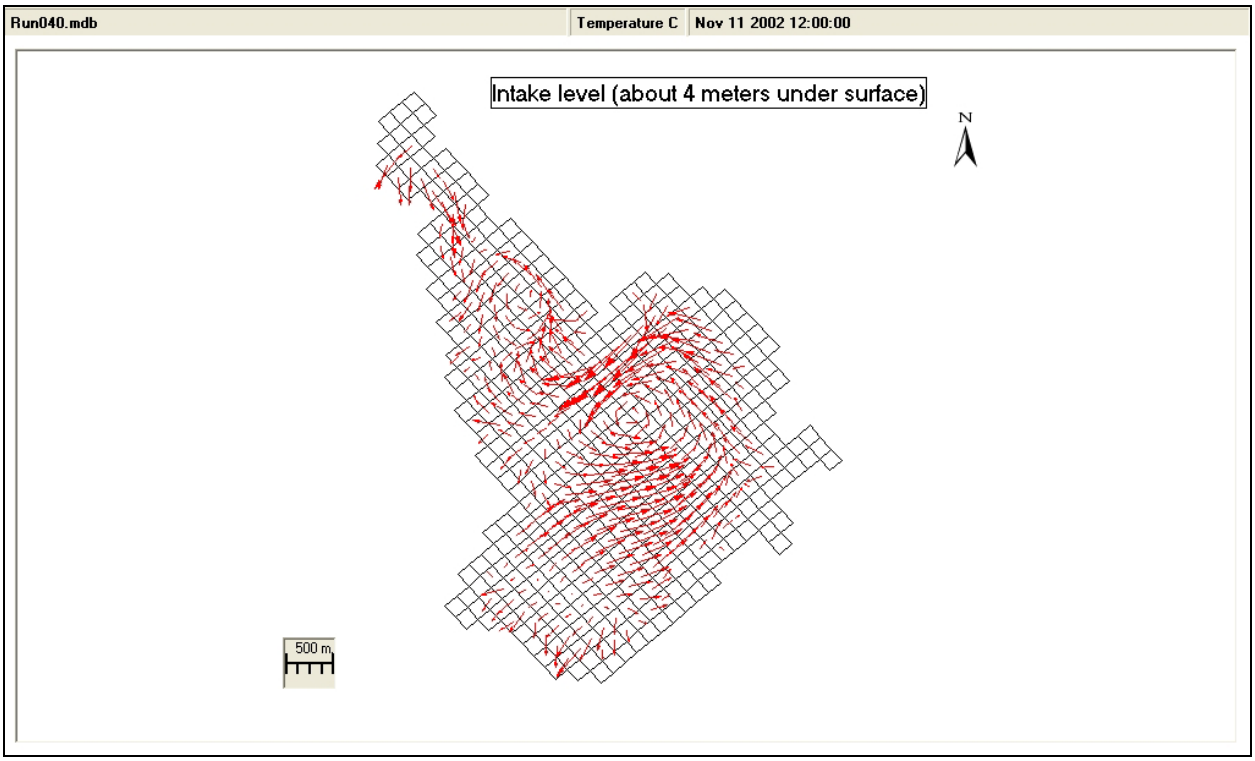

Figure 18 Vectors showing multiple counter clockwise flow patterns at the intake layer

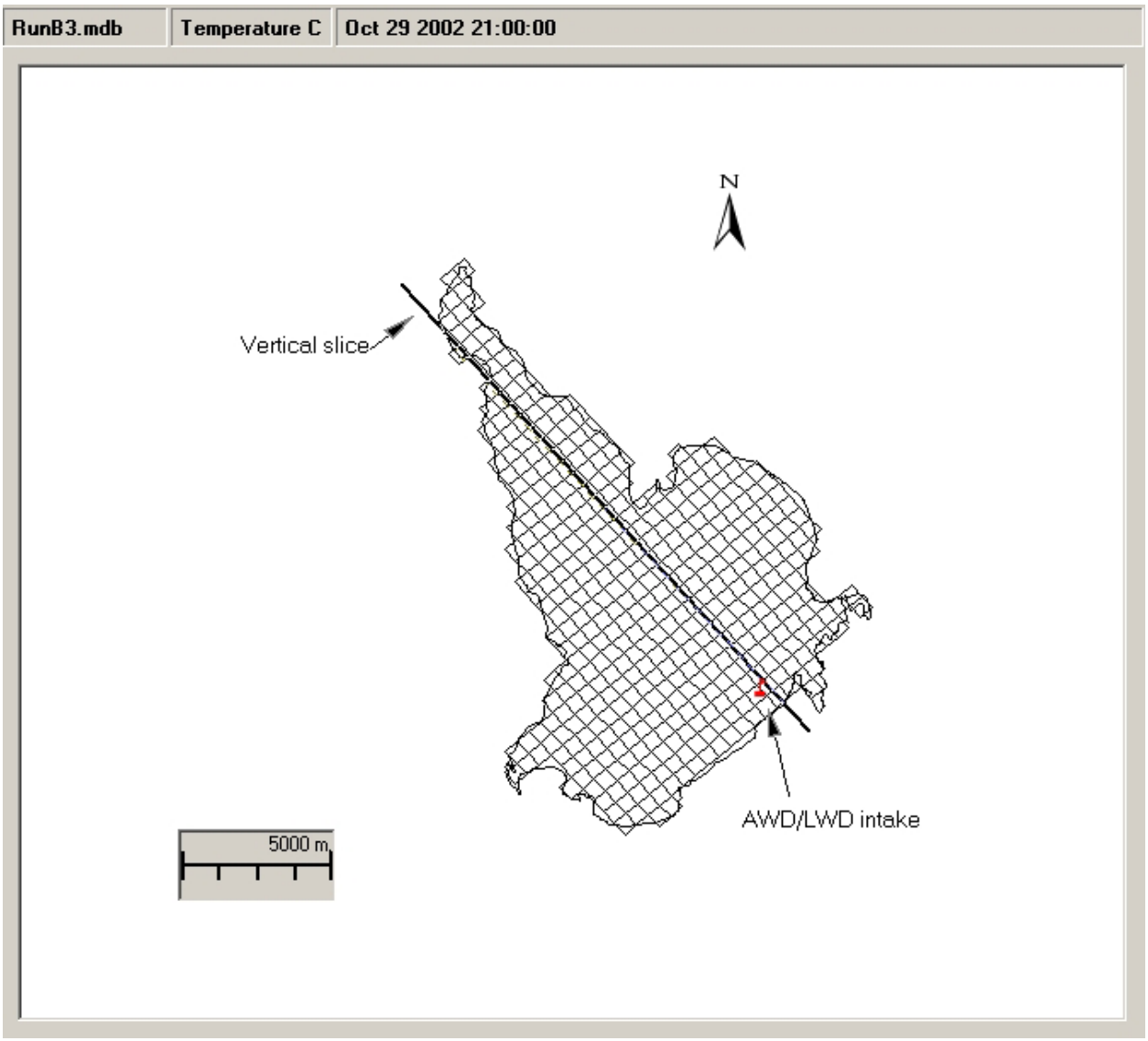

Figure 19 Location of the vertical slice

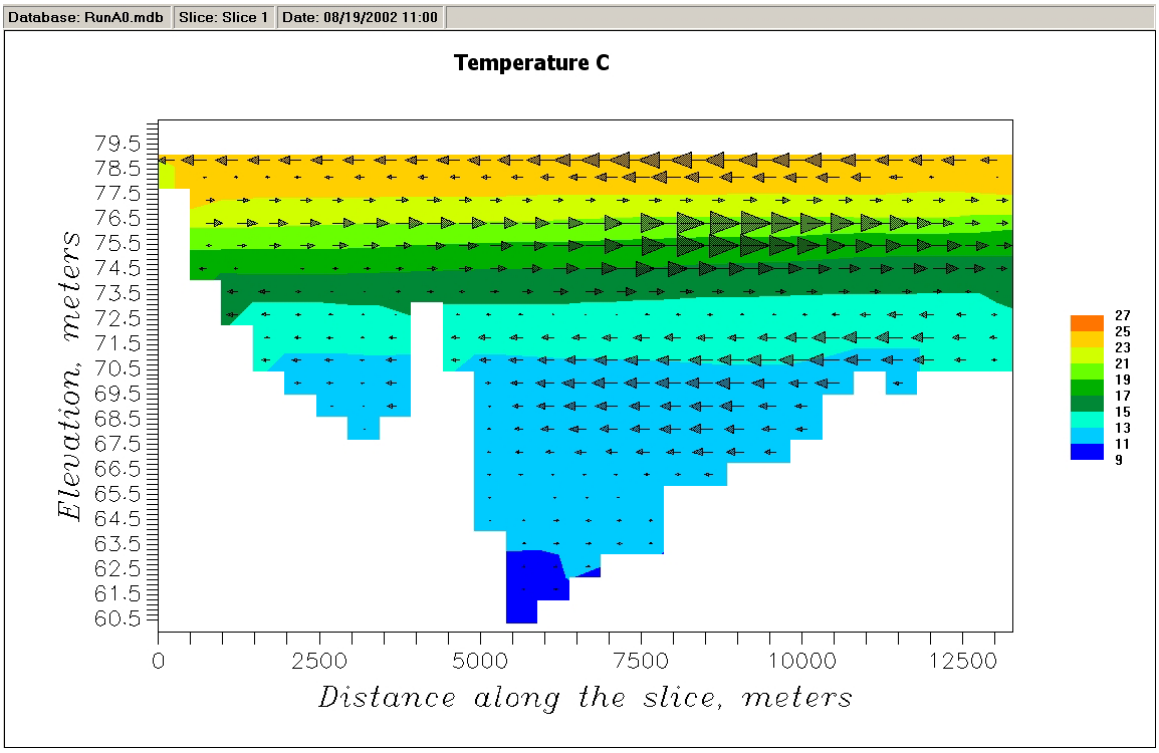

Figure 20 Multi-layer flow patterns during a stratified period
The slice is south to north from left to right; the LAWTF intake is on the left.

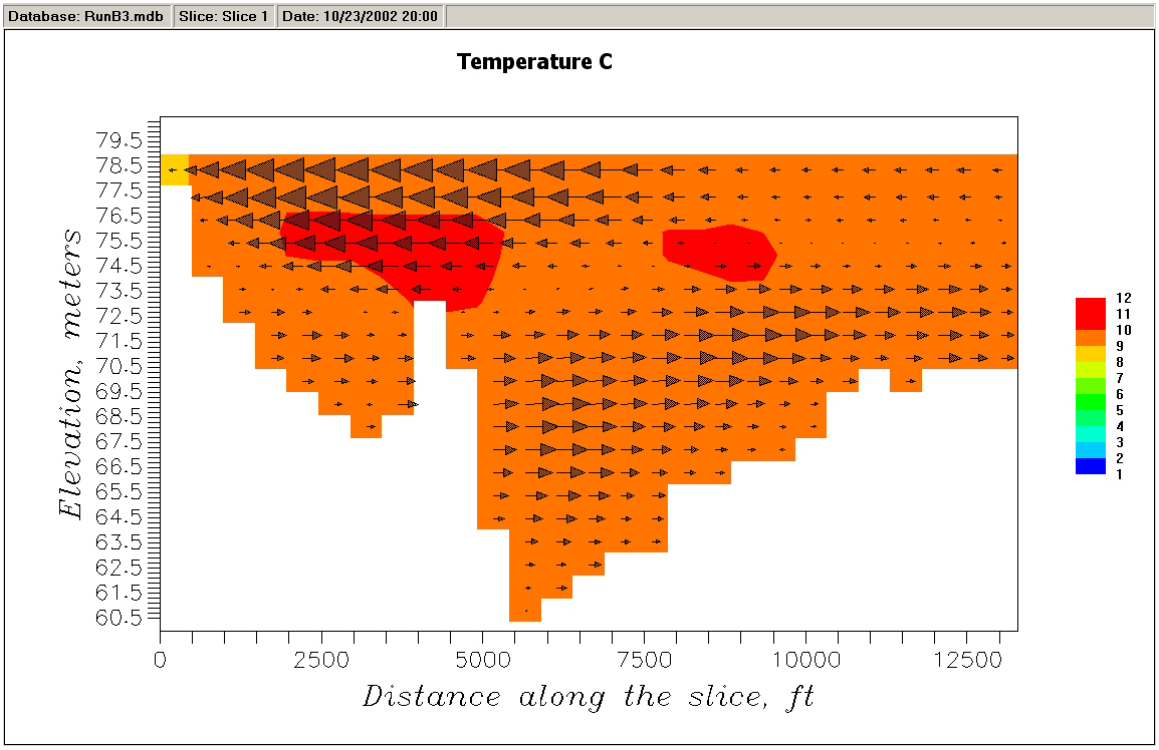

Figure 21 Two layer flow patterns during a non-stratified period
The slice is south to north from left to right; the LAWTF intake is on the left.

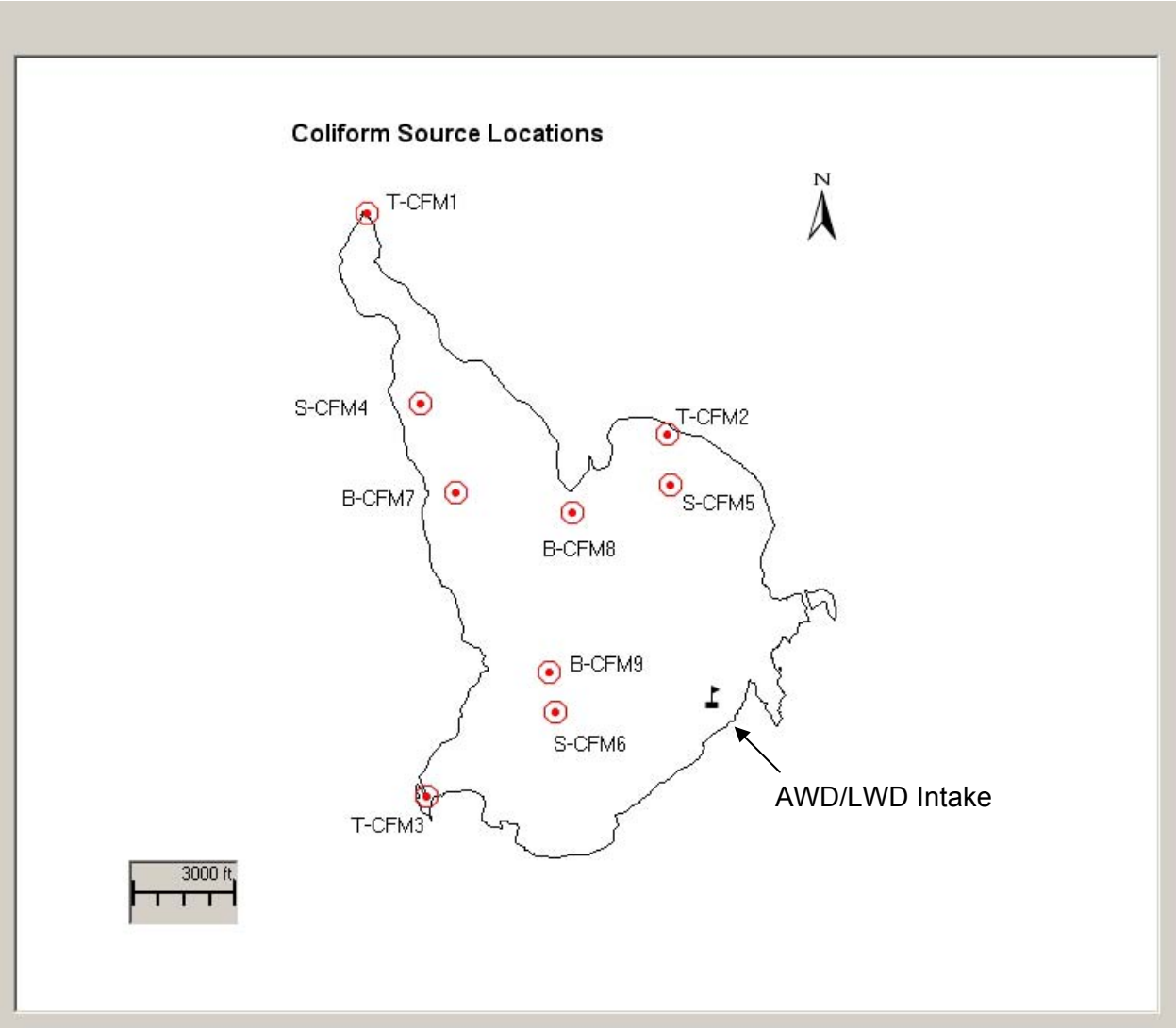

Figure 22 Nine fecal coliform source locations in Lake Auburn

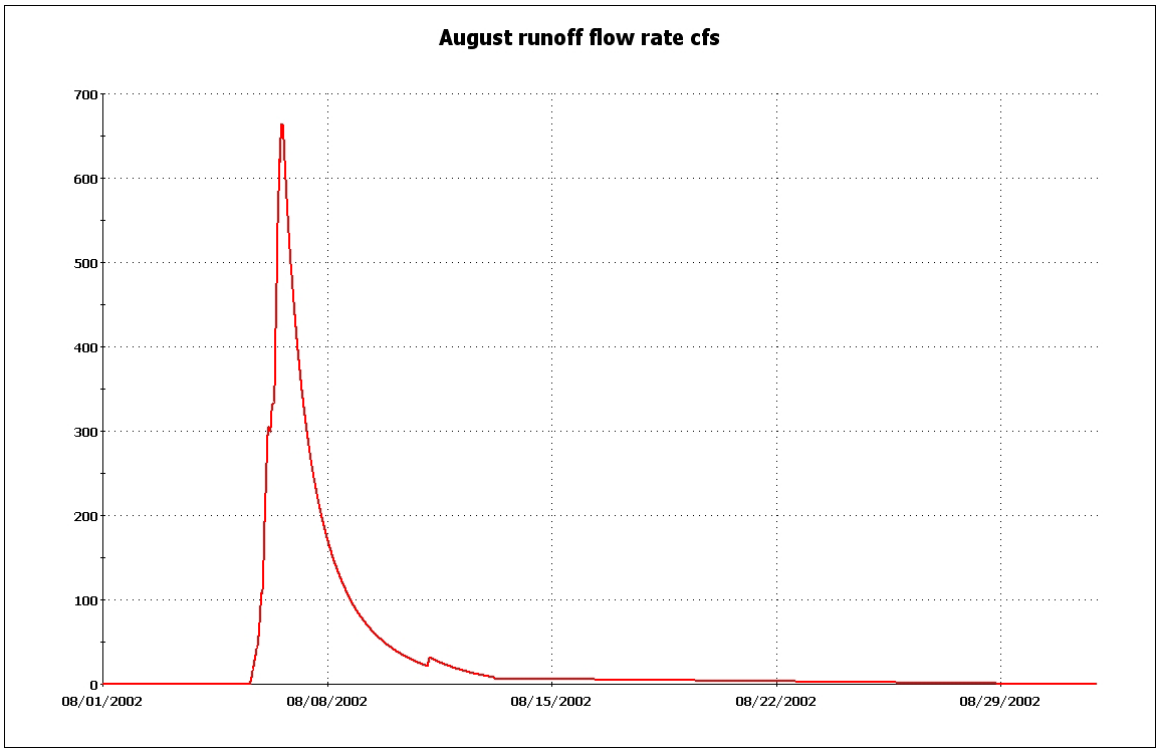

Figure 23 Hydrograph for runoff event condition in August 2002

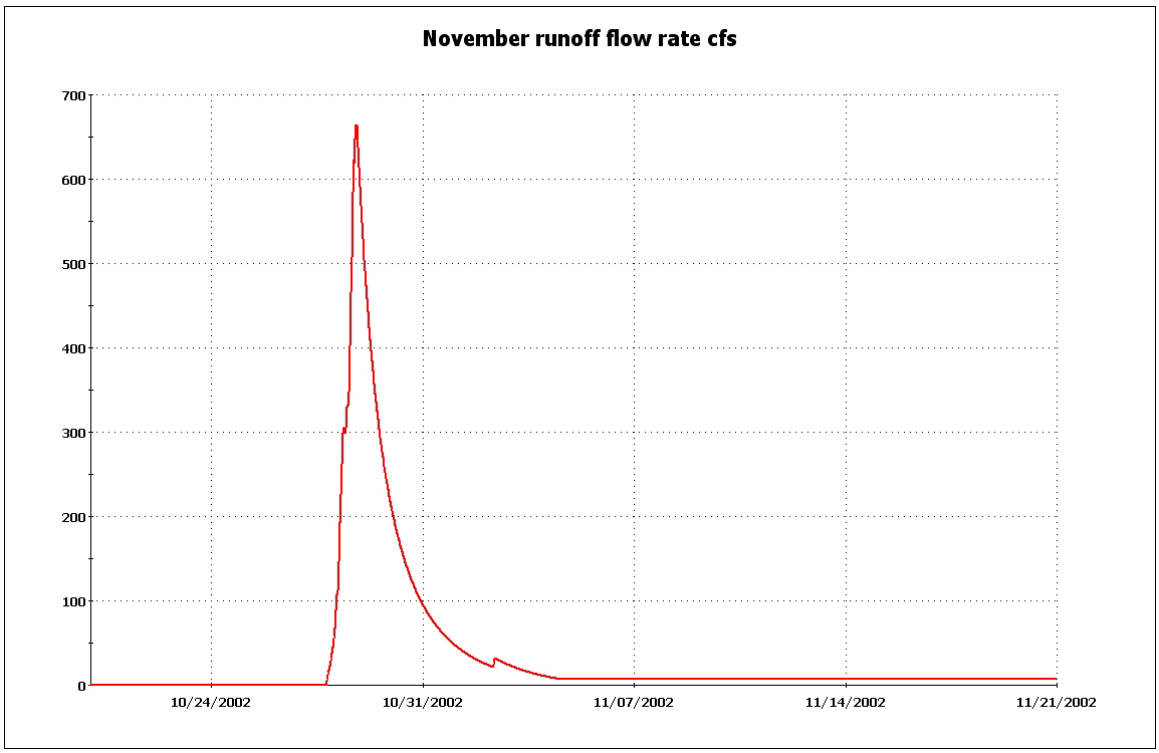

Figure 24 Hydrograph for runoff event condition in November 2002

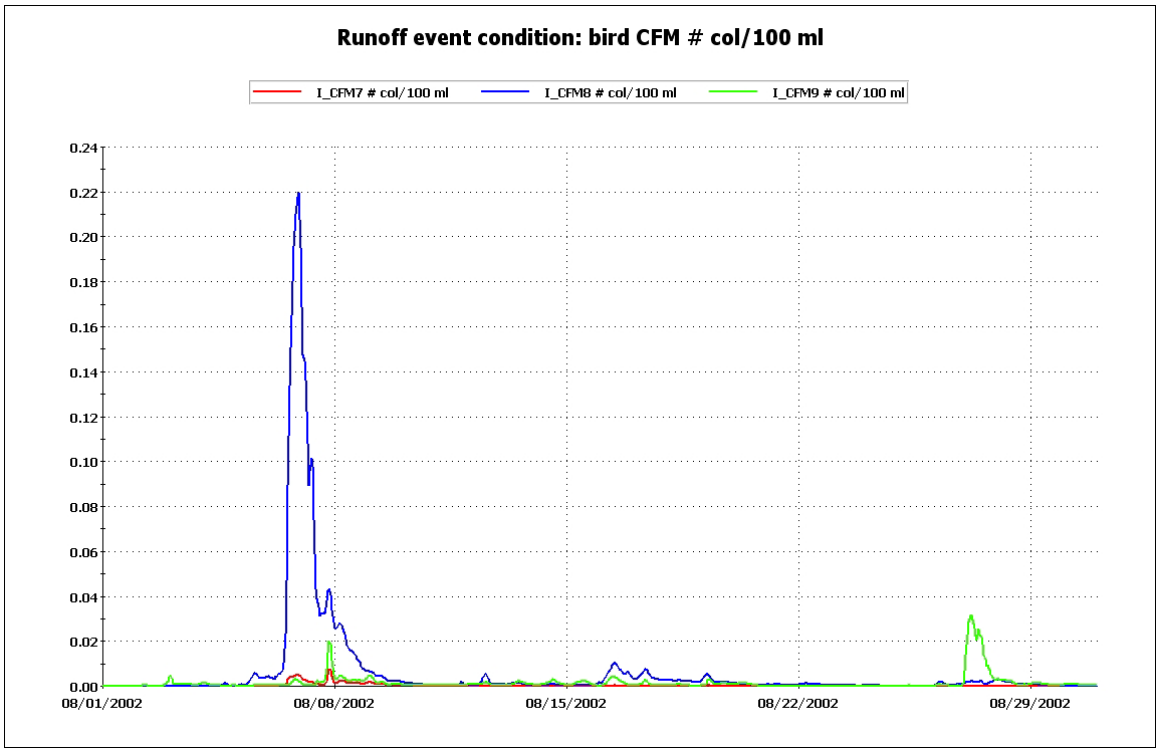

Figure 25 Time series intake coliform concentrations from Bird Island for the runoff event

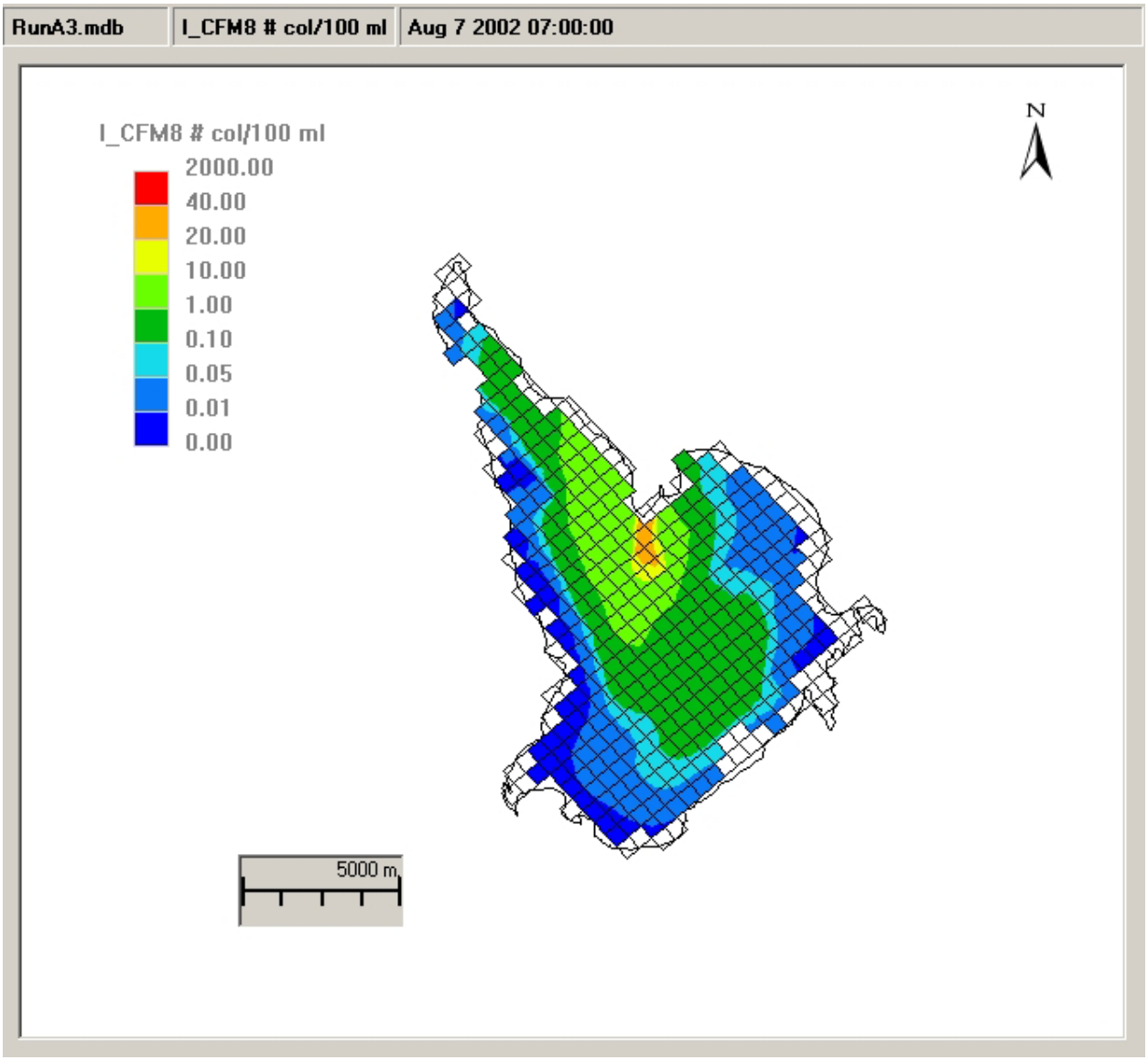

Figure 26 Intake layer contour plot for CFM8 for the runoff event – stratified time period

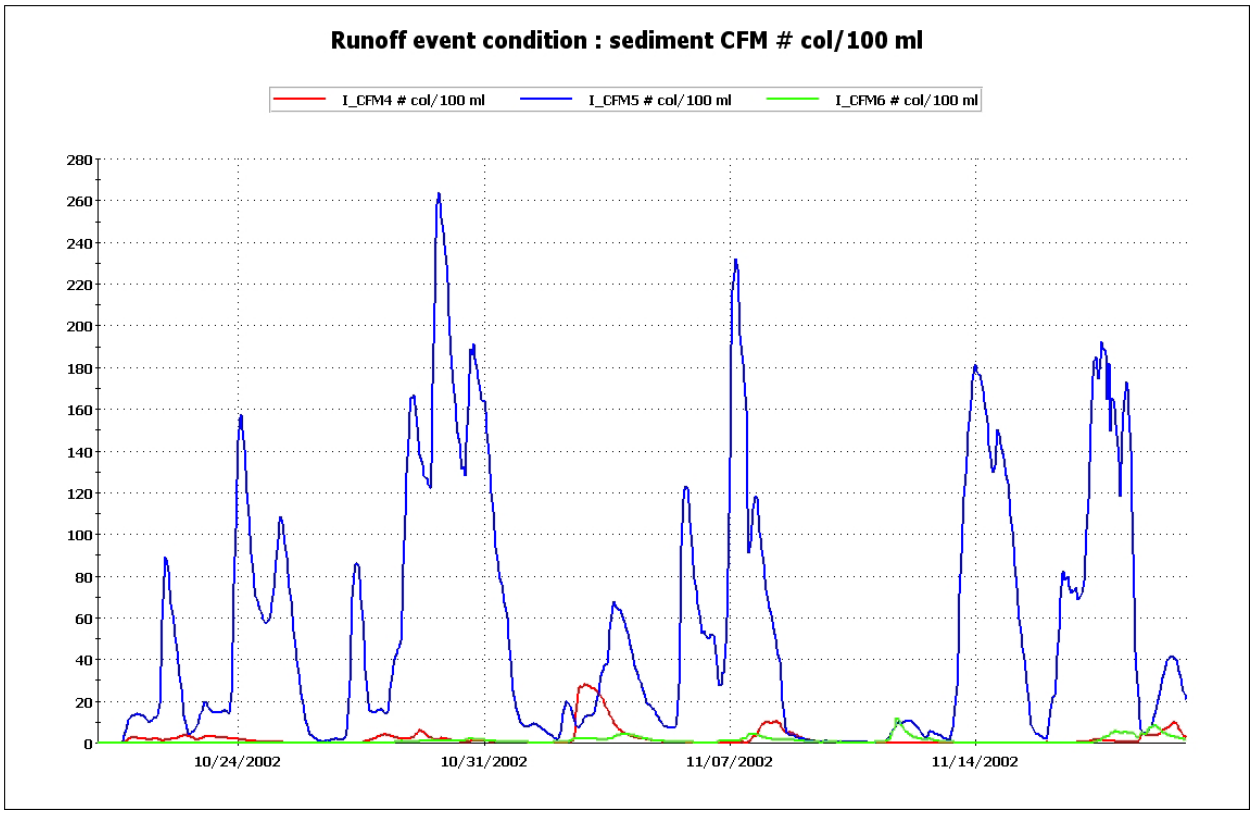

Figure 27 Time series intake coliform concentrations from sediment sources for the runoff event

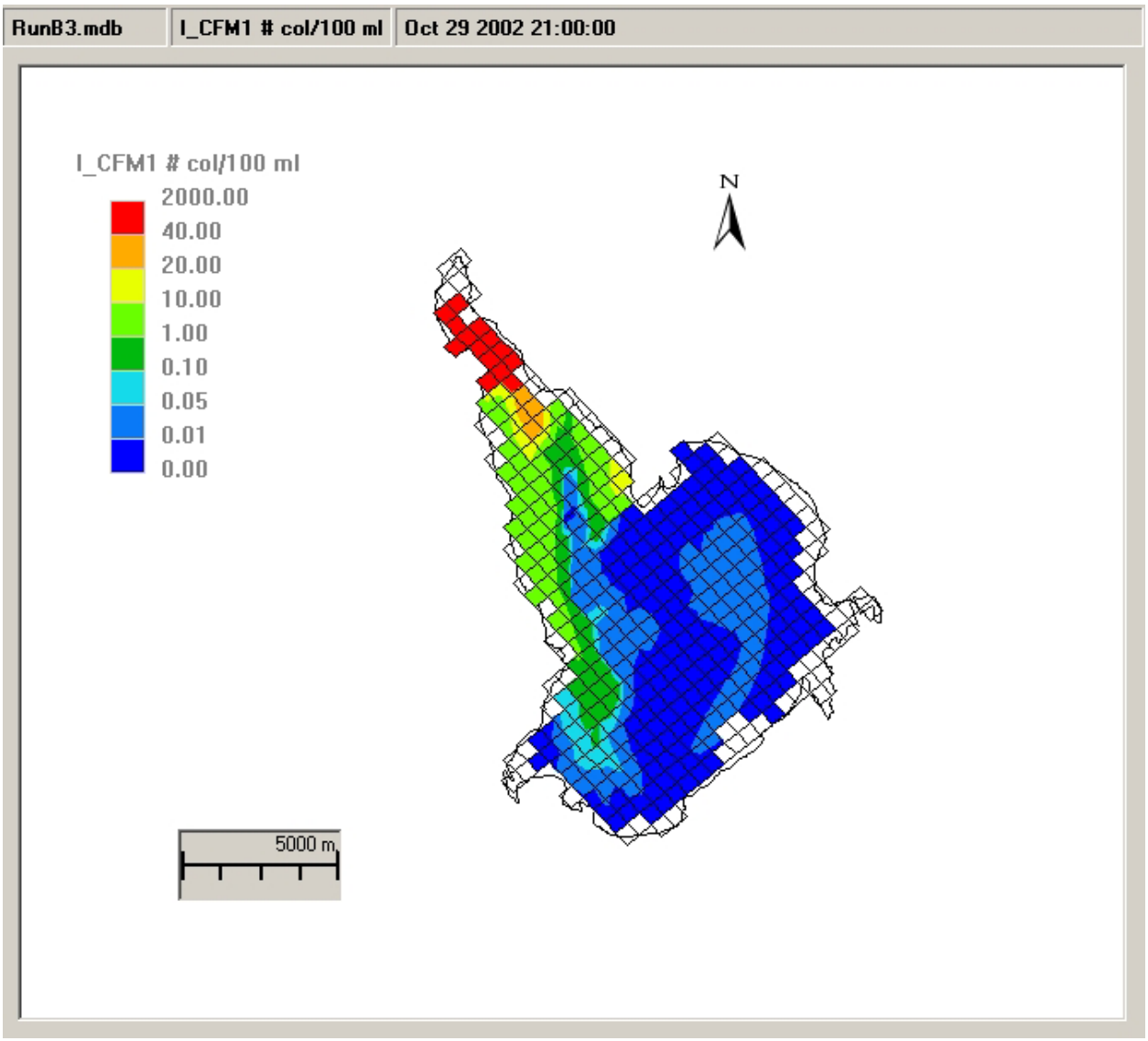

Figure 28 Intake layer contour plot for CFM1 for the runoff event – non-stratified time period

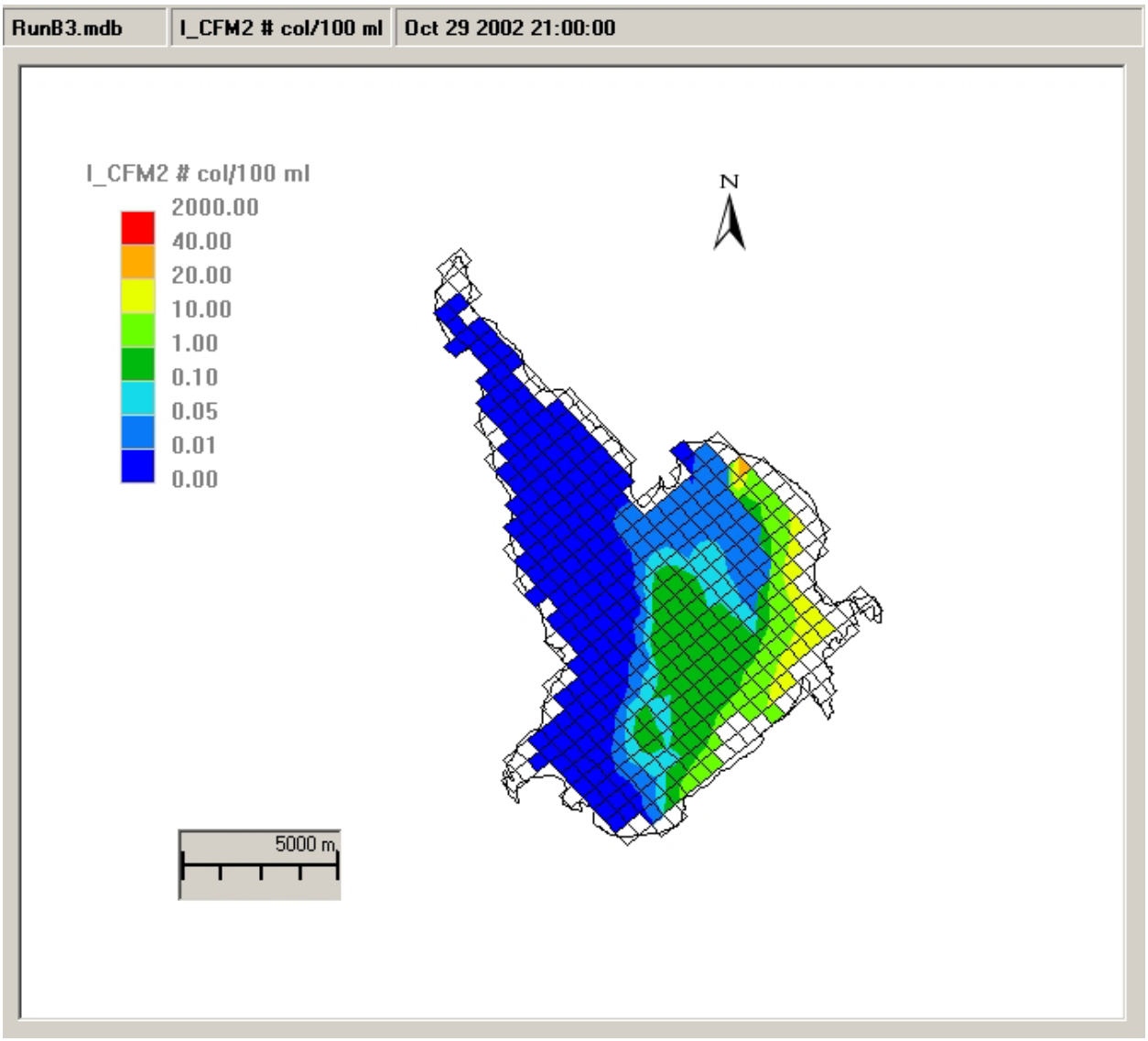

Figure 29 Intake layer contour plot for CFM2 for the runoff event – non-stratified time period

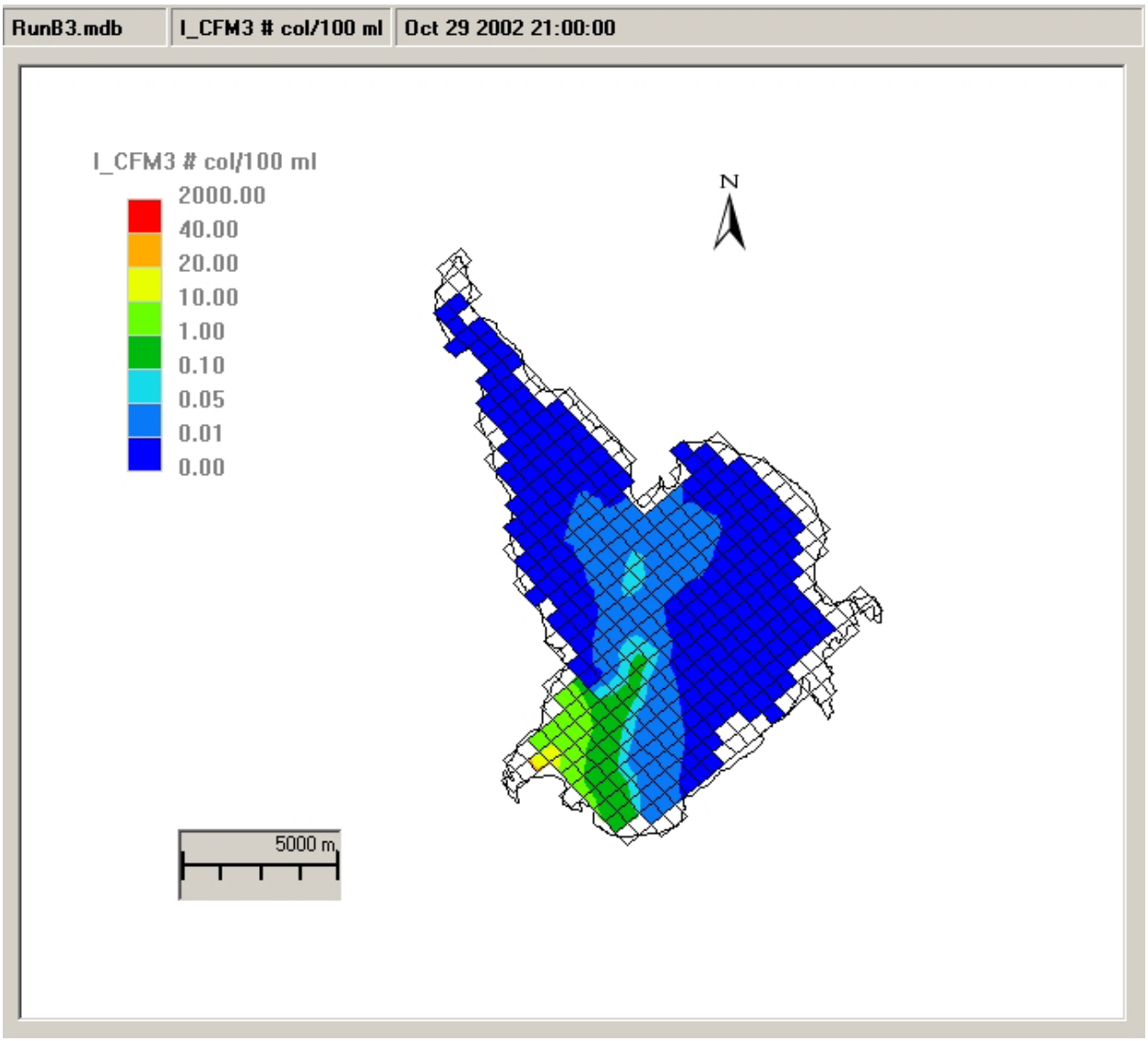

Figure 30 Intake layer contour plot for CFM3 for the runoff event – non-stratified time period

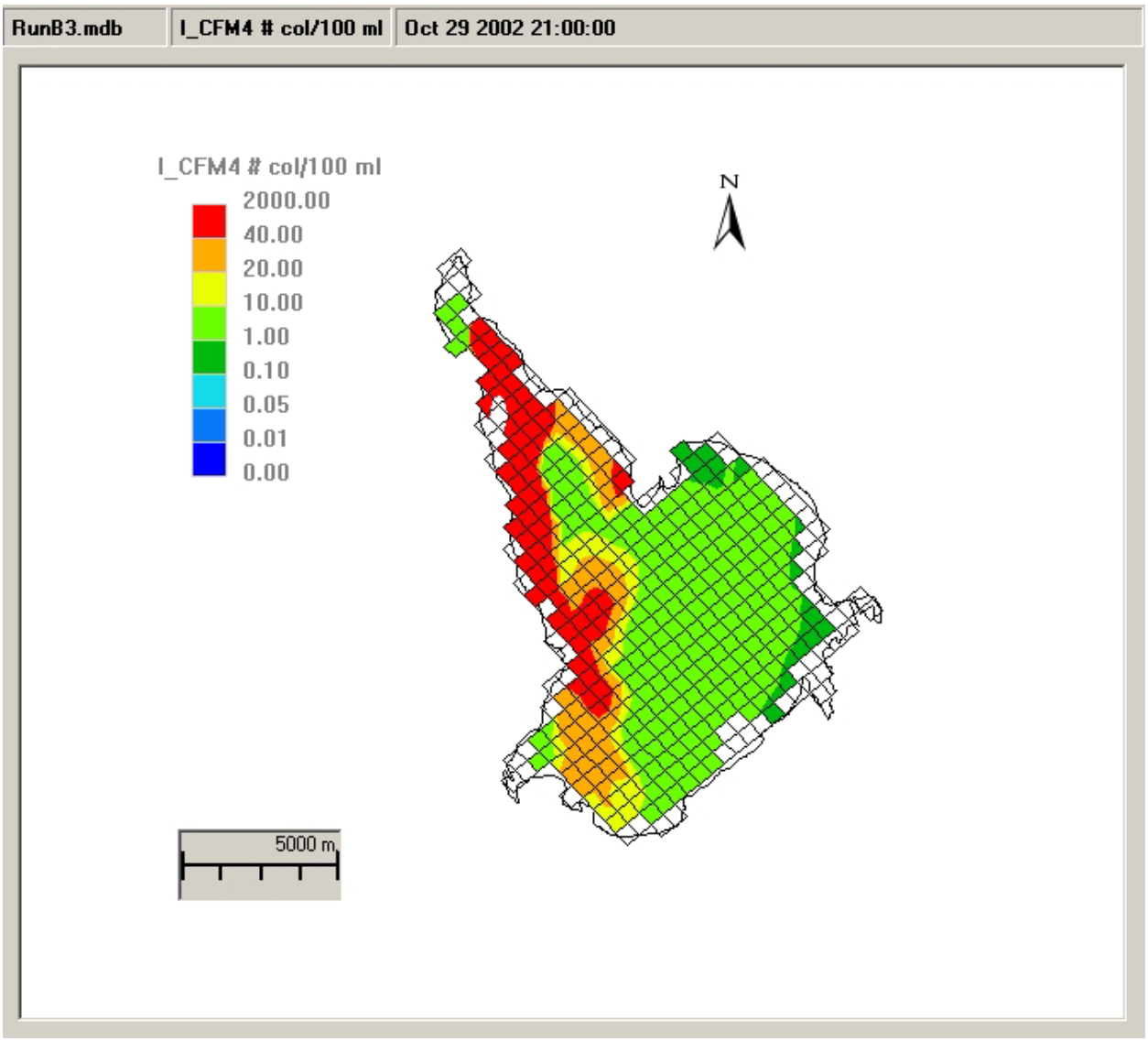

Figure 31 Intake layer contour plot for CFM4 for the runoff event – non-stratified time period

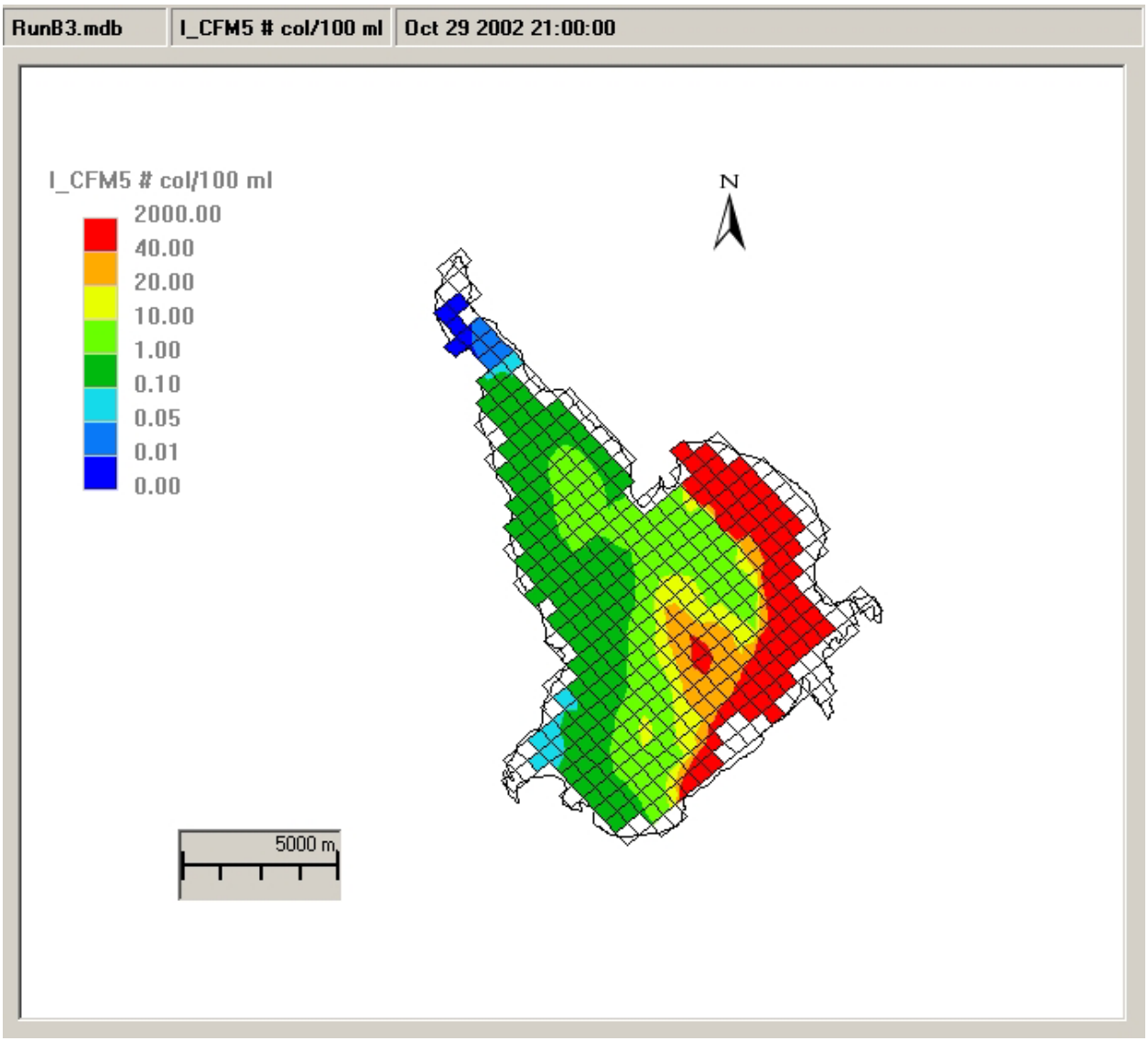

Figure 32 Intake layer contour plot for CFM5 for the runoff event – non-stratified time period

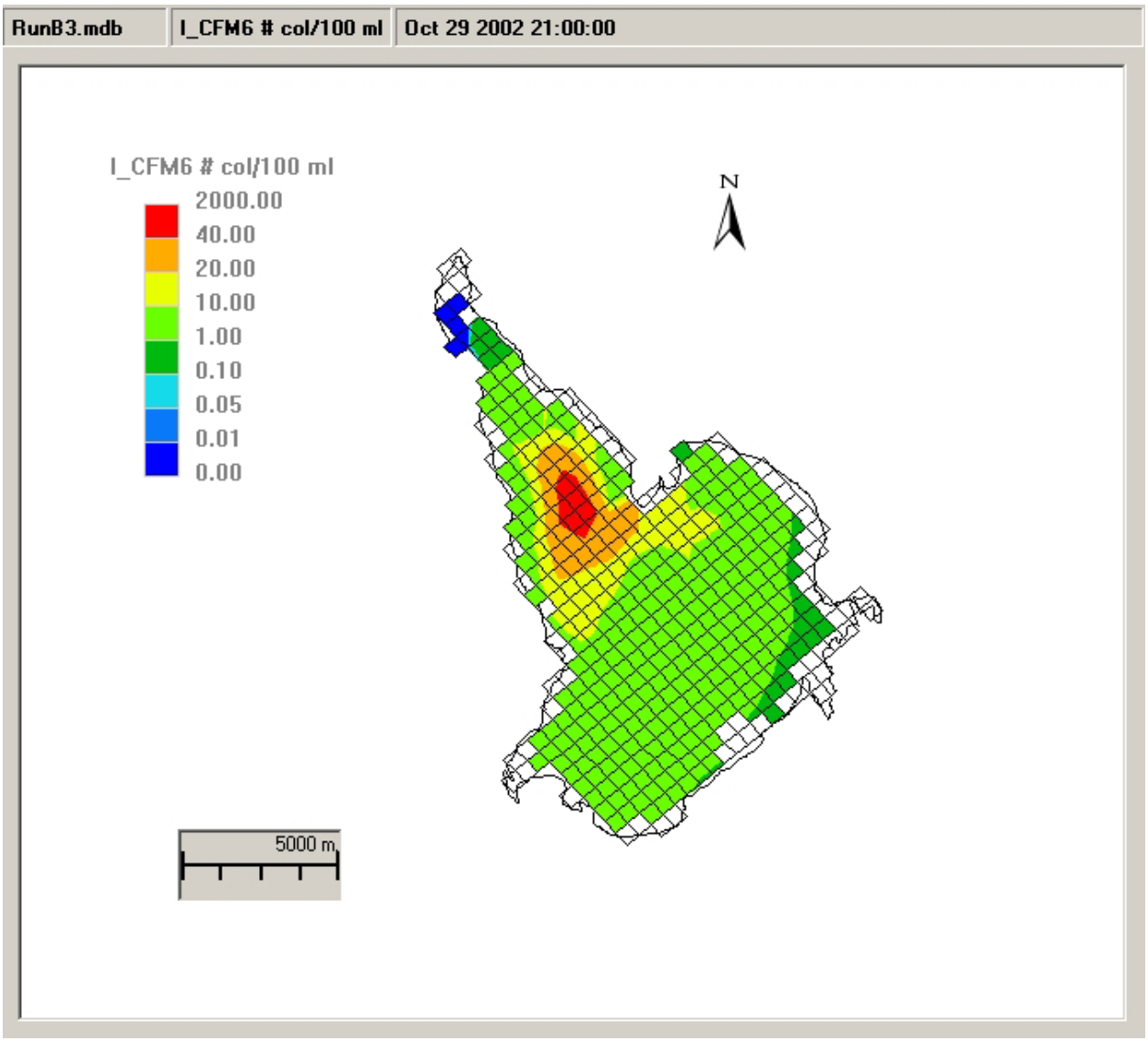

Figure 33 Intake layer contour plot for CFM6 for the runoff event – non-stratified time period

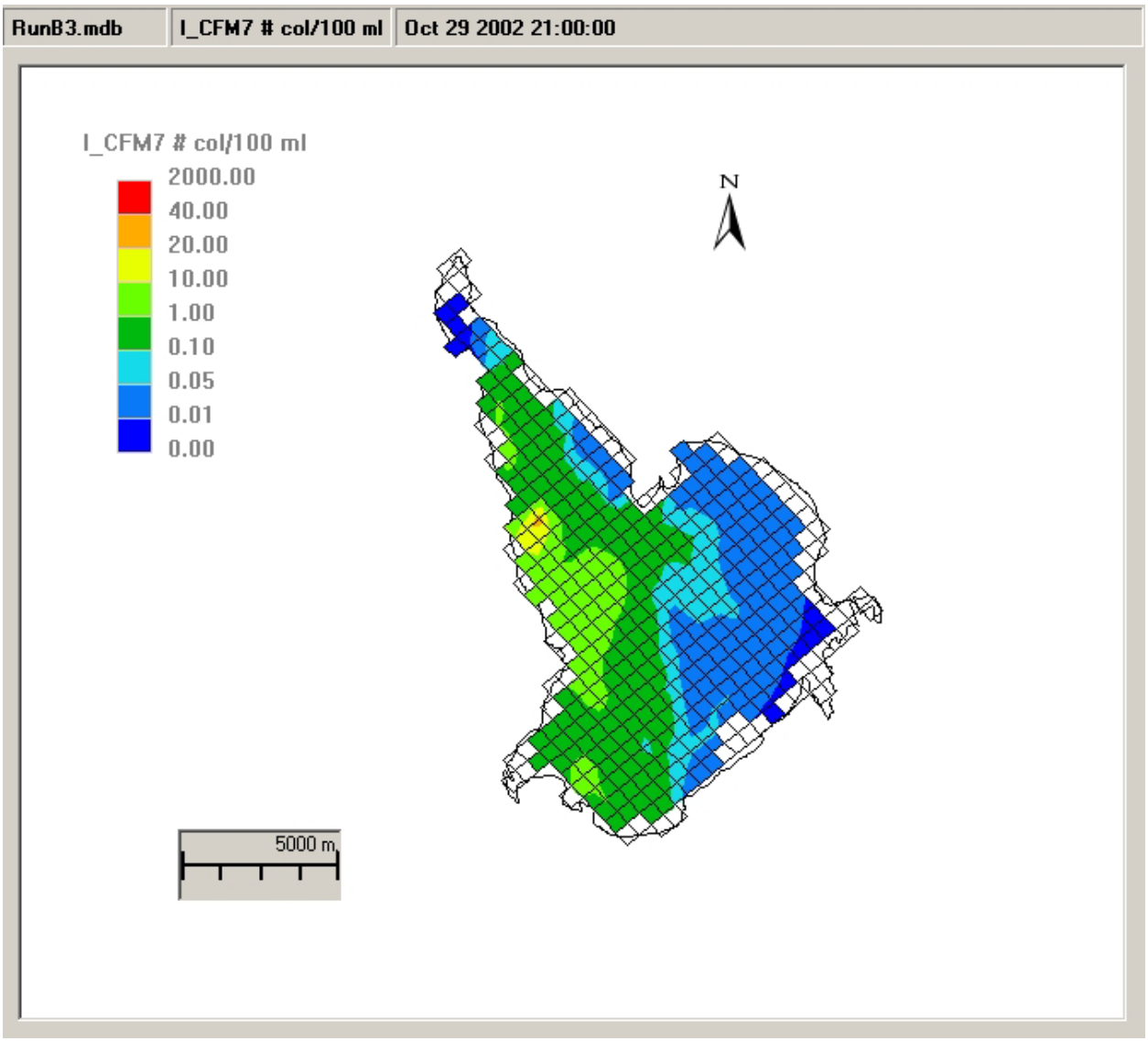

Figure 34 Intake layer contour plot for CFM7 for the runoff event – non-stratified time period

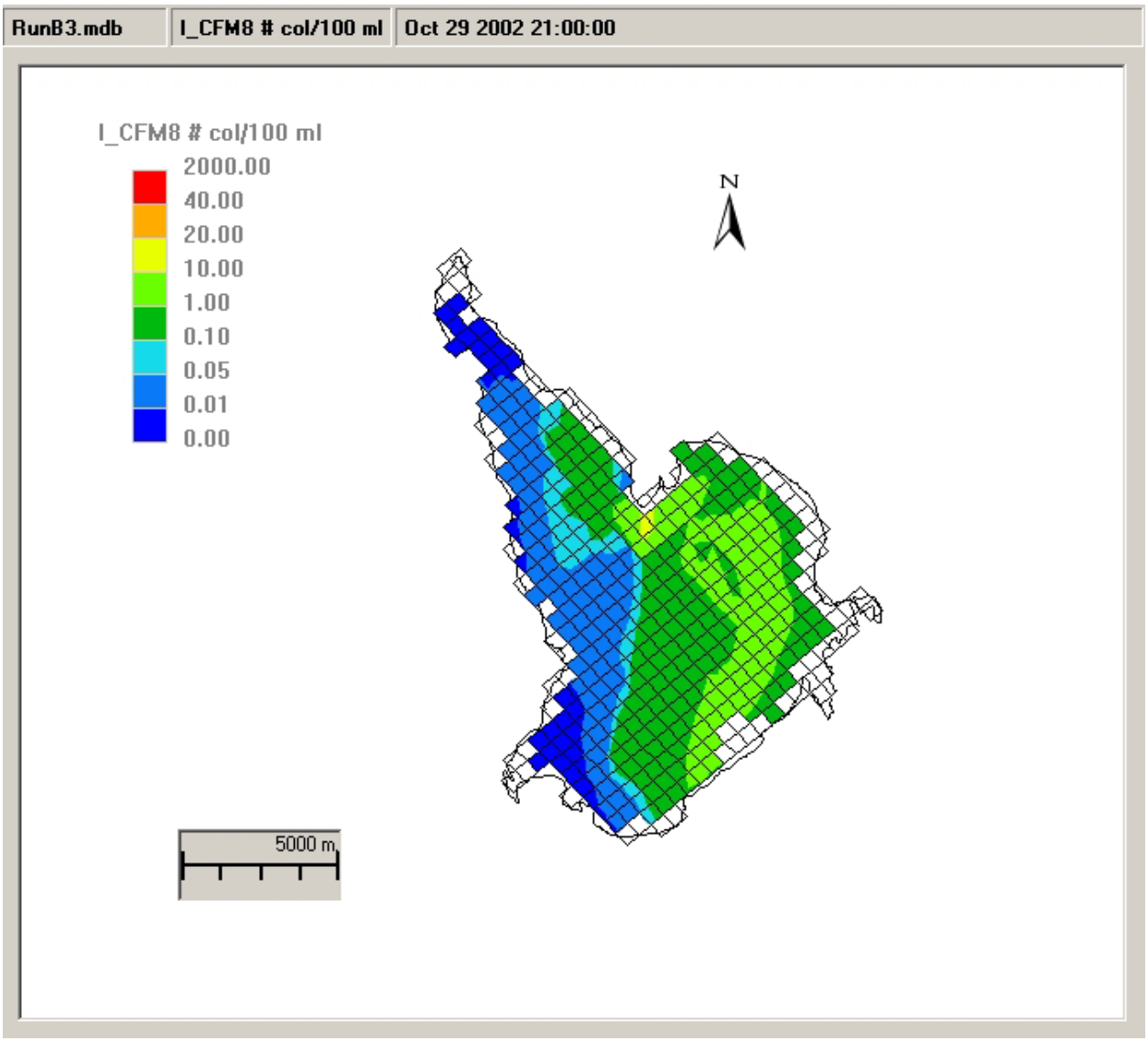

Figure 35 Intake layer contour plot for CFM8 for the runoff event – non-stratified time period

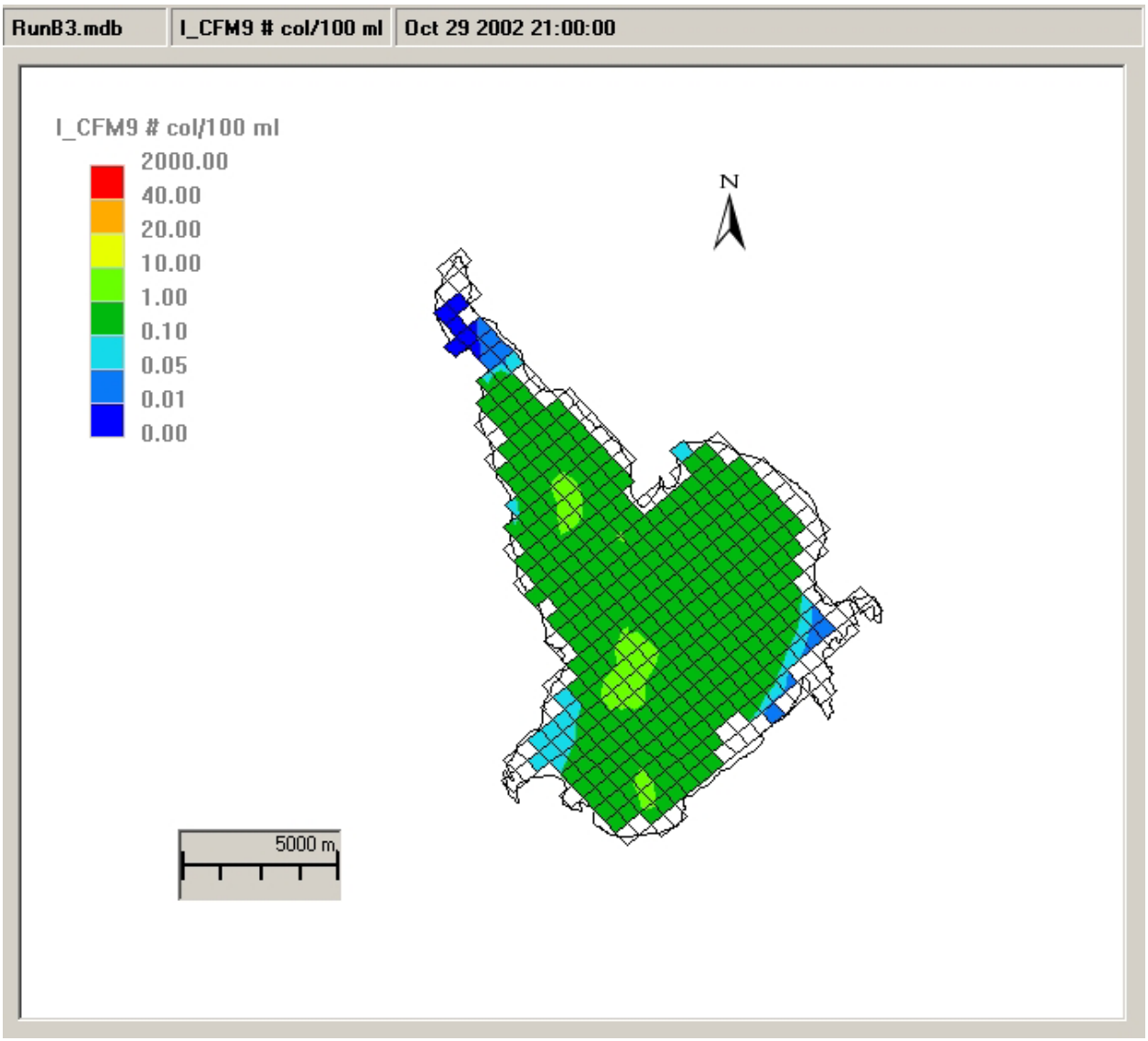

Figure 36 Intake layer contour plot for CFM9 for the runoff event – non-stratified time period

	MONTHS											
Sampling Parameter	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
TOC /DOC (intake)												
ALKALINITY (intake)												
Giardia & Crypto												
Entrance to system Fecal coliform, pH, Temp, Turbidity - 7/wk												
TE2 - Inorganics screen testing												
TSH - Inorganics screen testing, NO3N												
TE3 - Inorganics screen testing												
Bird counts daily												
InLake Samples: Sites 6,10,12,8,9,11,7,Salmon Point (new); Deep Hole: Secchi disk, DO & temp at each meter; All sites: pH, Turbidity, Conductivity, TC/FC/EC/Enterococci at 4m. TC/ FC/EC/Enterococci/Campylobacter, Color, Total P, algae, Chlorophyll												
Perimeter - Weekly: TC/FC/EC/Enterococci, temperature, DO, turbidity, color, pH, coductivity												
MTBE (intake & boat launch) Early in Month												
CORE (Color, Nitrate/ite, Total Phosphorus, Ortho P, TOC, Chl a, Algae, Ammonia N)												
TOC at Milfoil area North Auburn												

APPENDIX I
2006 Lake Auburn Raw Water Testing Schedule