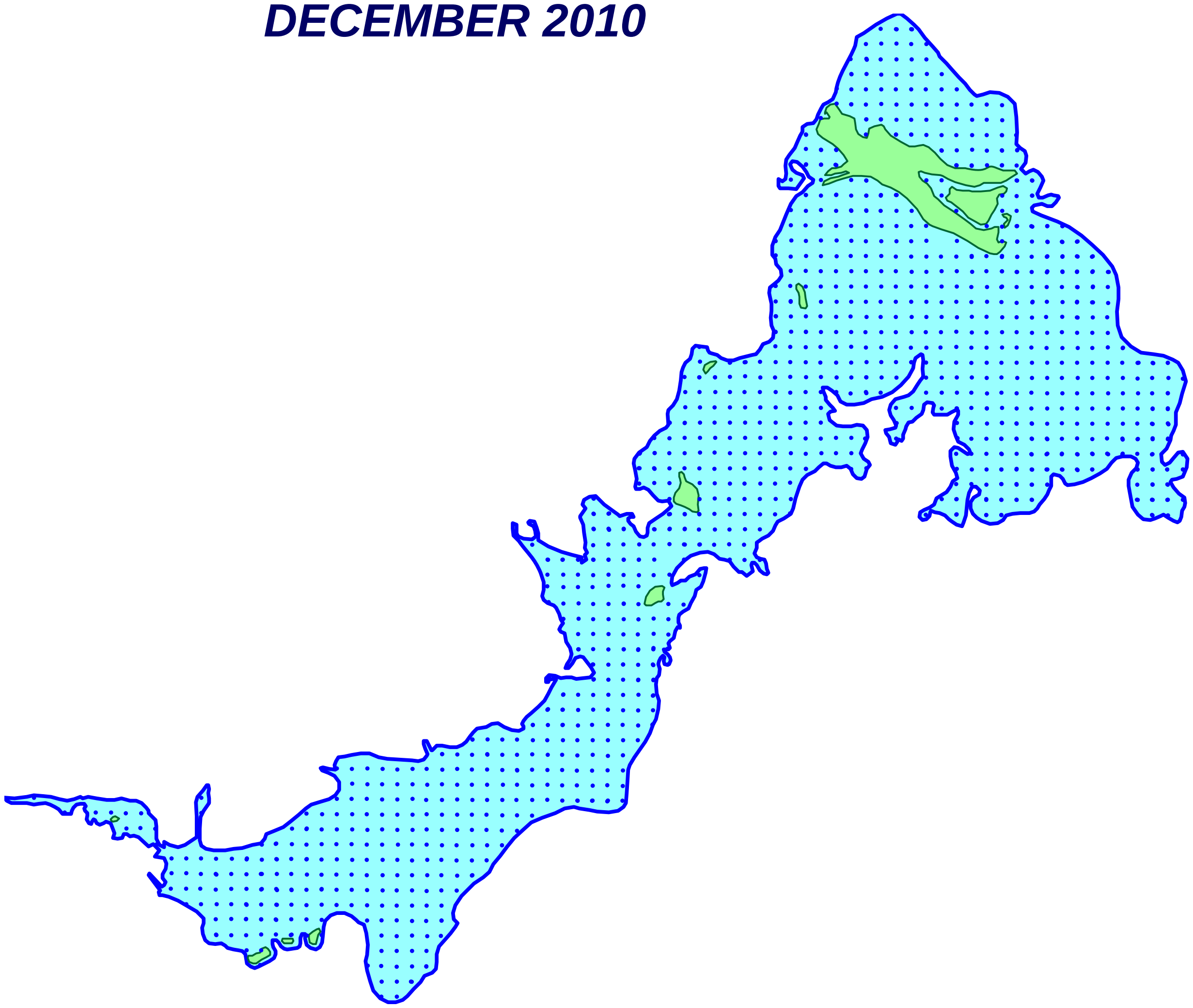
LAKE MANAGEMENT PLAN
LAKE BEULAH
WALWORTH COUNTY
WISCONSIN

DECEMBER 2010



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RJN Project Number 09-201

Submitted to:

Lake Beulah Management District

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1 INTRODUCTION

Lake Beulah is an 834-acre drainage (flow-through) lake, situated within U.S. Public Land Survey Sections 4, 5, 8, 9, 17, and 18, Township 4 North, Range 18 East, Town of East Troy, Walworth County, Wisconsin. The Lake Beulah Outlet Channel drains the lake into the middle reaches of the Mukwonago River, a Wisconsin Administrative Code Chapter (Wis. Admin. Code Ch.) NR 102 Exceptional Resource Water of the State. Figure 1 shows the lake, and its watershed.

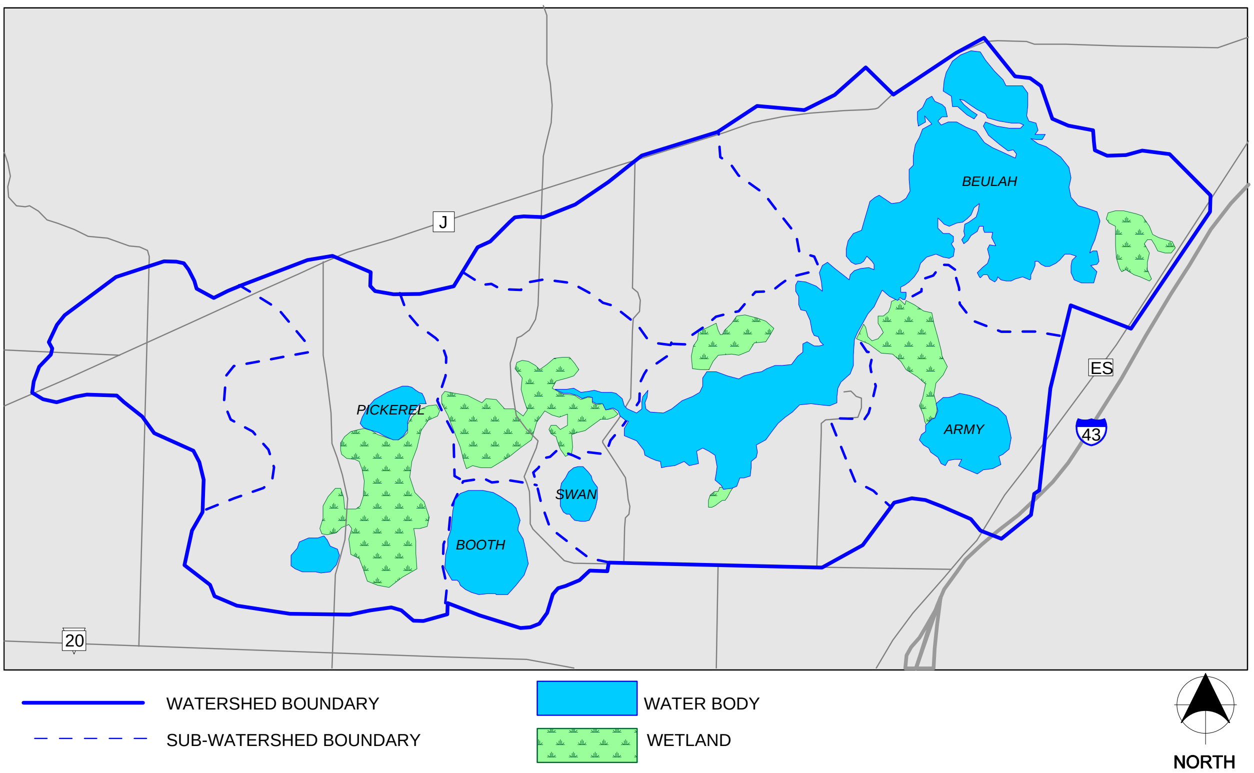


Figure 1. Lake Beulah watershed.

The Lake Beulah Management District (LBMD) was formed by the conversion of a town sanitary district, as a special purpose governmental unit to conduct studies and undertake other lake management activities with respect to Lake Beulah. Although the LBMD territory includes only properties near Lake Beulah, the LBMD is charged with the protection of the lake and its environments, and therefore assumes certain regulatory authority for all areas within the watershed.

The LBMD has undertaken a program of study that has included watershed, water quality, and lake management planning investigations, funded in part under the Wis. Admin. Code Ch. NR 190 Lake Management Planning Grant Program. The Wisconsin Department of Natural Resources (WDNR) awarded the LBMD's first Planning Grant in 2004. The grant funded a water balance study of the lake, which demonstrated the strong reliance of the lake's ecosystem on the flow of groundwater into the lake, particularly in the southern half of the lake.

Significant work is currently being conducted to develop an understanding of the complex environments of the Lake Beulah watershed. Some of this work is being funded in part by an earlier Lake Management Planning grant; some is being entirely funded by the LBMD, and lake residents. This work includes:

- Lake water quality monitoring
- Citizen lake monitoring
- Groundwater elevation monitoring
- Stream flow monitoring below the Highway J dam
- Aquatic plant survey

Water quality monitoring conducted in 2007 and 2008 by the USGS has identified Lake Beulah as a high-quality, hard-water lake. Because Lake Beulah has adequate public recreational boating access as defined in Wis. Admin. Code Ch. NR 1, there are also opportunities for non-residents to enjoy recreational activities on the Lake, adding to the economic base that the lake sustains.

The development of this management plan is being funded in part by a Lake Management Planning Grant and will provide protection of Lake Beulah and its watershed, which will in turn contribute to the management and protection of downstream water resources, in light of the combined stressors of pumpage and development. Existing geochemical and groundwater elevation data, and supplemental trophic state index data will be utilized to assess possible long-term response of the lake to development in the watershed and pumpage from the well. Additionally, an aquatic plant survey and surrounding wetlands survey are proposed to assess the health and quality of current lake ecology, and to determine the appropriate care and protection practices. The results of the studies will be incorporated into this lake management plan, the preparation of which was recommended in the Southeast Wisconsin Regional Planning Commission (SEWRPC) Regional Water Quality Management Plan.

2 MANAGEMENT GOALS

The ultimate goal of the lake management plan is to preserve Lake Beulah and its watershed as an environmental and recreational resource for lake residents and anyone wishing to enjoy its scenic natural beauty, as well as to protect the integrity of the lake's ecosystem.

Specific goals include:

- Maintenance of the environmental integrity of the lake ecosystem;
- Protection of the aesthetic value of the lake; and
- Maintenance of recreational opportunities.

3 IDENTIFICATION OF NEEDS AND PROBLEMS

Discussions with local residents and lake users identified several areas of concern, including:

- Impact of high-capacity well on lake
- Nutrient loading
- Water quality
- Area development and growth
- Shoreline erosion
- Invasive species management
- Weed management
- Fisheries management
- Endangered resources protection
- Sensitive area protection

3.1 IMPACT OF HIGH-CAPACITY WELL ON LAKE

To meet the increasing water supply needs of the growing surrounding population, the Village of East Troy installed a high-capacity water supply well near the southwestern shoreline of the lake. Previous studies have indicated that this is the primary area for groundwater discharge into the lake. Removal of water through the new well in the shallow aquifer intercepts groundwater and reduces the amount of groundwater entering the lake. It also reduces the amount of water in streams entering the lake, which will alter the lake's water budget. As a result, the lake's flushing rate will be reduced and seasonally low water levels, especially during drought periods, may be aggravated.

Additionally, groundwater discharge to the lake increases the hardness of the water and results in the lake being classified as a hard-water lake. In 2007, autumnal turnover concentrations of calcium and magnesium were 55.2 mg/L and 33.6 mg/L, respectively, with a water hardness of about 276 mg/L. A reduction in groundwater inputs to the lake over time could result in a reduction of water hardness in the lake, which, in turn, could degrade water quality. Recent studies by the USGS on nearby Nagawicka Lake have demonstrated that hard-water lakes often have better water quality than would be expected based upon phosphorus loadings because of the co-precipitation of phosphorus with calcium and magnesium that limits the availability of phosphorus for algal production. Combined with the likelihood of increased loading of phosphorus to the lake from increased development in the watershed, a decreased ability of the lake to assimilate phosphorus through co-precipitation could result in significant reduction in lake quality. Consequently, lake-area residents and property owners are concerned that operation of the well could have an adverse influence on the lake and downstream reaches of the Mukwonago River.

3.2 NUTRIENT LOADING

Nutrient loading is a major concern for many of Wisconsin's surface water bodies, and Lake Beulah is no exception. Nitrogen and phosphorus entering the lake from soil erosion and fertilizer applications within the watershed lead to growth of excess vegetation and a degradation of water clarity. There is currently a phosphorus ordinance prohibiting the use of phosphorus-containing fertilizers within the Lake Beulah Management District. However, cultivated farmland is also present within the watershed, where fertilizers containing phosphorus can still be used. Consequently, phosphorus can still enter the watershed's hydrologic system.

Dr. Jeff Thornton of the Southeastern Wisconsin Regional Planning Commission was provided with lake water quality analytical data collected by the United States Geological Survey. Using shallow water data (from a depth of 1.5 to 2 feet), Dr. Thornton estimated the potential nutrient loading to Lake Beulah, utilizing the OECD/Vollenweider equation to back calculate the loading rates to Lake Beulah.

The equation is [P] = L/qs(1+ sqrt Tw), where [P] is the forecast phosphorus concentration—in our case the known, L is the P loading rate in mg/m2 , qs in the water loading rate in m/yr or the mean depth divided by the water residence time, and Tw is the water residence time.

A volume of 14,279 acre-feet was used for the lake, assuming a mean depth on 17 feet and a surface area of 834 acres, with a watershed area of 5,283 acres.

Using the USGS long-term runoff value for the Mukwonago River gauge of 9.97 inches/year, the inflow to Beulah is estimated at 4,389.3 ac-ft per year. Dividing the volume of the lake by this figure, a water residence time of 3.25 years is estimated.

The 17 feet mean depth is converted to meters, with a result of 5.18 meters.

Working the lower half of the OECD equation, qs(1+sqrt Tw) is equal to 1.59(1+1.8) = 4.45/m.

To calculate the value of L, both sides of the equation are mulitplied by qs(1+sqrt Tw), or the high value (22 mg/m3) and low value (11 mg/m3) by 4.45.

Therefore, L = 98 mg/m2 as a high rate and L = 49 mg/m2 as the low value.

Because Lake Beulah has a surface area of 834 acres, this is equal to 3.375 x 10E6 square meters. At 49 mg/square meter, the low end loading rate would be 165,375,000 mg/year, and the high end would be 330,750,000 mg/year.

These loads translate into 165 kg and 330 kg per year, or about 365 to 730 pound of phosphorus per year.

3.3 WATER QUALITY

Water quality in the lake is dependent on the level of nutrients such as nitrogen and phosphorus, hardness, concentration of dissolved oxygen, lake temperature, vegetation and sedimentation. Studies by the USGS and lake volunteers have shown the lake to have very good water quality.

3.4 AREA DEVELOPMENT AND GROWTH

Lake Beulah is located in a rapidly developing area in Walworth County. Between 1990 and 2000, the Village of East Troy experienced a population growth of 33.8% (Village of East Troy, 2008). Residential development within the Lake Beulah watershed is subject to the Village of East Troy Comprehensive Plan, adopted in June 2008. Under the plan, areas along the southern and eastern shores of Lake Beulah are identified for planned residential development and expansion of City sewer utilities. As discussed in Section 3.1 above, increased development coupled with a change in water chemistry in the Lake caused by pumpage of the high-capacity municipal well near the lake could significantly degrade water quality in the lake.

3.5 SHORELINE EROSION

Shoreline erosion leads to excess sedimentation and a degradation of the water quality in the lake. Shoreline erosion is exacerbated by wave action caused by boats wakes, as well as removal of natural vegetation from the lake shore.

3.6 INVASIVE SPECIES MANAGEMENT

Invasive species are aggressive non-native species that disrupt the lake ecosystem by displacing native species. Lake Beulah has been impacted by invasive species such as the rusty crayfish, zebra mussels and Eurasian milfoil. Some occurrences of curly-leafed pondweed and purple loosestrife have also been observed.

3.7 WEED MANAGEMENT

Excess vegetation in the lake caused by nutrient loading from poor land management practices can make boating difficult and affect other recreational opportunities, such as fishing. Additionally, fish native to Lake Beulah thrive in a variety of habitats, and some may be displaced by an overabundance of vegetation.

3.8 FISHERY MANAGEMENT

Lake Beulah provides year-round enjoyment for anglers. Sport fish present in the lake include bluegill, brown trout, largemouth bass, northern pike and rainbow trout. The parking lot on the south side of the lake is frequently full during the peak fishing season, and protection and maintenance of the Lake Beulah fishery is essential to ensure the future of this recreation opportunity on the lake.

3.9 ENDANGERED RESOURCES PROTECTION

The WDNR defines a threatened species as "any species which appears likely, within the foreseeable future, on the basis of scientific evidence to become endangered." An endangered species is defined as "any species whose continued existence as a viable component of this state's wild animals or wild plants is determined by the Department to be in jeopardy on the basis of scientific evidence."

RSV Engineering, Inc. requested a WDNR review of threatened/endangered species within the Lake Beulah watershed area. The review was conducted in December 2008 and identified 25 rare species and communities that exist within and in close proximity to the Lake Beulah watershed boundary. The rare communities include oak opening, bog relict, calcareous fen, emergent marsh, southern sedge meadow, southern tamarack swamp and northern wet forest. The rare plant species include common bog arrow-grass, kitten tails, beaked spikerush, lesser fringed gentian, tufted club-rush, Ohio goldenrod, showy lady's slipper, pale green orchid and sycamore tree. The rare animal species include mulberry wing, double-striped bluet, lake chubsucker, banded killfish, least darter, starhead topminnow, pugnose shiner, bullfrog and blanding's turtle. Additionally, 48 rare species and communities were identified within the one-mile buffer zone surrounding the watershed, which may be present within the watershed if suitable habitat is present. Many of the rare species (mussels, dragonfly, fish, butterfly and plants) are dependent on lake and wetland habitat for their survival.

Three State Natural Areas (SNAs) are also located within the watershed or one-mile buffer zone. SNAs protect outstanding examples of Wisconsin's native landscape of natural communities and are valuable for research and educational use, the preservation of genetic and biological diversity and for use as benchmarks for determining the impact of use on managed lands.

To summarize, the Lake Beulah watershed area contains a variety of rare ecological communities providing habitat for several species of plants and animals rare in Wisconsin. If land disturbing projects are proposed in any of the ecological communities previously discussed, it is important that endangered resource surveys be conducted to determine the presence/absence of such species.

3.10 SENSITIVE AREA PROTECTION

The WDNR also completed an assessment of sensitive areas within Lake Beulah in 1994. These areas support a diverse community of native plants with limited areas of Eurasian milfoil and offer spawning and nursery areas for several fish species, nesting habitat for animals, act as sediment and nutrient traps and help protect the shoreline from erosion. Eight such areas are located within the lake, and specific recommendations were made by the WDNR for their protection. The WDNR document is included with the Aquatic Plant Management Plan, which is provided in Appendix A of this document.

The sensitive areas are as follows:

- Area 1 – along the eastern shore of Jesuit Island in the northeastern part of the lake.
- Area 2 – a small cove located across from Jesuit Island.
- Area 3 – around a small island along the northeastern shore of the lake.
- Area 4 – along the southern shore of the lake in the area also known as Mueller's Cove.
- Area 5 – in the south shore cove area, located on the southern shore of the eastern end of the lake.
- Area 6 – in the narrows between the two basins of the lake.
- Area 7 – in the bay near the inlet from Pickerel Lake in the southwestern part of the lake.
- Area 8 – just southeast of the East Troy boat launch on the southwestern shore of the lake.

4 CURRENT UNDERSTANDING

The physical characteristics of a lake and its watershed are important factors in any evaluation of existing and likely future water quality conditions and lake uses, including recreational uses. Characteristics such as watershed topography, lake morphometry and local hydrology, ultimately influence water quality conditions and the composition of plant and fish communities within the lake. This section provides pertinent information on the physical characteristics of Lake Beulah, its watershed, and on the climate and hydrology of the Lake Beulah drainage area.

4.1 WATERBODY CHARACTERISTICS

The Lake Beulah watershed is situated in the Towns of Troy and East Troy. Due to recent annexation, a portion of the Village of East Troy is also within the watershed. The lake occupies a central position within the Mukwonago River Basin. The Mukwonago River is a tributary stream to the Fox River, which ultimately drains into the Mississippi River. Lake Beulah is 834 acres with a mean depth of 17 feet and a maximum depth of 58 feet. It is a drainage lake, which is a lake that is fed by streams, groundwater, precipitation and runoff and drained by a stream. According to *A Comprehensive Plan for the Fox River Watershed – Volume 2* prepared by SEWRPC, the lake has approximately 15.3 miles of shoreline and a volume of 14,489 acre-feet. Approximately 13 percent of the lake area is less than 3 feet deep, 53 percent has a water depth between 3 and 20 feet, and about 34 percent of the lake has a water depth of more than 20 feet.

The level of the lake is maintained by a fixed berm, which includes a concrete spillway. The spillway was reportedly constructed in the 1840's and was initially used to power a flour mill. The berm forms the northernmost boundary of Lake Beulah and serves as the road bed for CTH J. The Lake discharges through this control structure to the Lake Beulah outlet, which in turn drains in a northerly direction to the Mukwonago River.

The lake has two public access points. One public access with two boat ramps is located on the southern portion of the lake, off Wilmers Landing Road. The second access point is a public beach located on the northeastern portion of the lake, off East Shore Road.

The shoreline of Lake Beulah is mostly developed for residential uses, with a few scattered commercial facilities comprised primarily of restaurants and businesses catering to lake users. Additionally, several camps are present for young people and families, such as Camp Edwards (YMCA) and Camp Charles Allis. Three significant wetland areas are present along the lake's shoreline: a large emergent wetland complex between Lake Beulah and Army Lake along the east central shoreline, a large forest/shrub/emergent wetland complex between Beulah Heights Road and Lake Beulah along the west central shoreline, and a variety of wetland types along the southern portion of the lake, north of Booth and Swan Lakes. In addition, numerous other smaller, yet valuable, wetland communities also exist along the shore of the lake.

4.2 DATA COLLECTION

As part of the grant project, Lake Beulah has continued to monitor surface water and groundwater conditions. Most of the monitoring is producing long-term data; however, some of the monitoring has been hampered by potential vandalism, weed cutting, and activities of riparian owners. Data are presented in Appendix B. Monitoring tasks have included:

Stream flow over the Highway J dam: Outflow has been monitored at Lake Beulah for several years. Data files, in Excel format, are provided on CD for the years 2007 and 2008. Winter flows (December through April) are not provided, because ice buildup on the data logger produced anomalous results.

Lake bed temperatures: Lake bed temperatures are provided in graphical format for 2007. Subsequent attempts to record data were interrupted either due to the removal of data loggers (tethered to shore by a cable), or due to weed cutting activities.

Groundwater quality monitoring: An attempt was made to monitor groundwater quality. Arrangements were made with various property owners in the fall of 2008. Upon the first attempt to collect water samples, it was found that all property owners had shut off their water supplies for the winter. Because the purpose of this task was to observe changes in water quality due to the start up of East Troy well 7, resuming the sampling at a later time was not considered. Consequently, the funds for this task were redirected toward lake quality monitoring.

Groundwater level monitoring: Groundwater levels have been monitored at eight locations around the lake. Water levels were measured by volunteers at five drive point nests around the lake. Additionally, in cooperation with the Village of East Troy, water levels have been monitored at three pairs of well nests around the lake. Results of this monitoring are presented in Appendix B, along with a map showing the well locations.

4.3 WATERSHED CHARACTERISTICS

The drainage area which drains directly into the lake totals approximately 10.2 square miles. Lake Beulah is fed by surface water flow, mainly from the southwestern portion of the watershed, and by groundwater. The watershed is an area of rolling hills on the southeastern edge of the southern Kettle Moraine, with numerous short surface water and groundwater flow systems draining into Lake Beulah and on to the Mukwonago River.

Much of the watershed is underlain by the Troy Bedrock Valley, a southwest-to-northeasterly-trending buried valley. The valley is filled with glacial outwash consisting of clay, silt, sand and gravel, and is a valuable aquifer.

4.4 WATERSHED LAND USE AND POPULATION

Human activity within the drainage area of a waterbody can deteriorate the natural environments within and ultimately impact water quality. This is especially true with respect to lakes, which are highly susceptible to deterioration from human activities and because of the variety of conflicting uses to which lakes are subjected. Development pressure is often concentrated in watershed areas, around the shorelines of lakes, where there are no intermediate stream segments to attenuate pollutant runoff and loadings. Land uses and population levels within the watershed of a lake must be important considerations in lake management planning effort. This section discusses land usage and population distributions within the Lake Beulah watershed, including their relevance to water quality and lake management.

4.4.1 Population

According to the SEWRPC Community Assistance Planning Report No. 288, the Town of Troy's population based on a 1980 census was 1,794. The Department of Administration estimated the 2006 population at 2,409, an approximate 42 percent increase between 1980 and 2006. SEWRPC's trend based population estimate for the year 2035 is 3,419, a potential 42 percent increase between 2006 and 2035. As for the Town of East Troy, the population based on the 1980 census was 3,583. The Department of Administration estimated the 2006 population at 3,915, an approximate 9 percent increase between 1980 and 2006. SEWRPC's trend based population estimate for the year 2035 is 5,378, a 37 percent increase between 2006 and 2035.

SEWRPC's regional land use plan recommends that much of the future increase in population and households within the County be accommodated in urban service areas that provide sanitary sewer and other urban services. Therefore, the 2035 trend based population estimates for the Town's of Troy and East Troy may be slightly on the high end. Regardless of the predicted percent population increase for the future, it can be assumed that the population within the Lake Beulah watershed will significantly increase over the next 25 years.

4.4.2 Current and Future Land Use

Current Land Use

The various land use types within the Lake Beulah watershed play an integral role in the overall water quality and recreational use demands. Current and planned land use patterns should be important considerations in any lake management planning effort for Lake Beulah. Table 1 displays the different land use types within the Towns of Troy and East Troy and the overall percentage of each land use.

Land Use Category	Town of East Troy		Town of Troy	
	Acres	Percent	Acres	Percent
Urban				
Single-Family	1,472	7.8	915	4.0
Multi-Family	7	0.03	-	-
Commercial	16	0.1	12	0.1
Industrial	17	0.1	30	0.1
Streets and Highways	712	3.8	498	2.2
Railroads	82	0.4	-	-
Other Transportation/Utilities	16	0.1	7	0.03
Governmental/Institutional	68	0.4	13	0.1
Recreational	271	1.4	135	0.6
Unused Urban	71	0.4	10	0.04
Urban Subtotal	2,732	14.5	1,620	7.1
Non-Urban				
Surface Water	1,193	6.3	475	2.1
Wetlands	2,275	12	2,474	10.9
Woodlands	1,916	10.1	2,364	10.4
Extractive/Landfill	180	1.0	-	-
Agricultural	9,945	52.5	14,860	65.4
Unused Rural	689	3.6	934	4.1
Non-Urban Subtotal	16,198	85.5	21,107	92.9
Total	**18,930**	**100**	**22,727**	**100**

Source: SEWRPC Community Assistance Planning Report No. 288

Table 1. Land use in the Towns of Troy and East Troy.

The percentage of land within the watershed that is developed as impermeable surface, whether for buildings, roads, parking lots, etc., directly affects the amount of water that recharges the lake and associated wetlands through infiltration and groundwater flow. Additionally, it has become increasingly apparent that non-point sources such as stormwater flow and runoff from agricultural fields have a significant effect on the quality of water in surface water bodies, and can contribute heavy loads of nutrients from fertilizers, sodium and other salts from road salt, which are particularly harmful to wetlands, as well as contaminants such as heavy metals and volatile organic compounds.

Future Land Use

The Village of East Troy initially adopted a “Smart Growth” plan, the 2030 Comprehensive Community Plan, on July 14, 2008. The plan addresses future land use in the areas surrounding Lake Beulah, including a significant portion of the Lake’s watershed.

The plan was promulgated pursuant to the State of Wisconsin’s “Smart Growth” legislation, and the primary objective of the legislation is the incorporation of community input into local land use planning. Due to widespread public dissatisfaction with the plan, the Village has reconsidered the plan.

The Lake Beulah Protective and Improvement Association (LBPIA) raised several objections regarding the plan, including:

- Plans for extensive residential development in areas that are currently agricultural lands south of the lake;
- Plans for additional high-capacity municipal wells in areas adjacent to the lake;
- Preference for high-density development along lakeshores;
- Plans for the Divine Word Seminary property along the southern shore of Lake Beulah;
- Statement within the plan that only the Swan Lake Wetland Complex within the planning area "contains rare, threatened or endangered species..." and
- Lack of adequate study of the potential impacts of Well #7 on public rights, surface and ground water, wetlands or the ecosystem in general.

The Village of East Troy was invited to take part in the creation of the Lake Management Plan for Lake Beulah and asked to address the above comments in the final "Smart Growth" plan.

4.5 GROUNDWATER MODELING AND WATER BUDGET

A water budget study was completed by RSV Engineering, Inc. in 2006. This study was conducted utilizing data collected on site, published information, and a three-dimensional groundwater flow model. This study showed that the lake relied a great deal on groundwater. A summary of the water budget conclusions is summarized in Table 2.

COMPONENT	ACRE-FEET/YEAR[1]	
	INFLOW	OUTFLOW
Evaporation		2,208
Precipitation	2,295	
Surface flow	3,941	5,683
Groundwater	1,699	44
Totals	7,935	7,935

1 One acre-ft/year is equal to approximately 325,830 gallons per year.

Table 2. Summary of water budget calculations for Lake Beulah.

Although Table 2 shows that groundwater accounts for only 21 percent of the total inflow, most of the surface flow comes from the upgradient lakes, including Booth, Swan and Pickerel. Groundwater is a major component to inflow for those lakes. Together, surface flow and direct groundwater discharge provide approximately 71 percent of the lake's water budget.

A groundwater flow model was developed in 2007 and 2008 by Ms. Kalina Dunkle at the University of Wisconsin Department of Geoscience, under the supervision of Drs. Mary Anderson and Dave Mickelson. This model was developed to observe the relationship between surface water and groundwater in the Troy Bedrock Valley. The Lake Beulah area of the model was calibrated utilizing groundwater and surface water data collected as part of this grant project, and Robert Nauta of RJN Environmental Services, LLC was one of the reviewers of the model.

This model produced water budget figures comparable to those estimated in 2006. However, because the lake was simulated in a manner in which additional parameters could be observed, it was found that groundwater pumping, at the location and rates approved for East Troy well 7 would result in up to a 30 percent loss in groundwater discharge to the lake.

4.6 SOIL TYPES AND CONDITIONS

Soil type, topography, and land use are among the most important factors determining lake water quality conditions. Soil type, topography, and vegetative cover are also important factors affecting the rate, amount, and quality of stormwater runoff. Soil texture and land slope influence the permeability and infiltration rate of stormwater runoff and erosion potential of soils. The potential for erosion can be reduced with vegetative growth.

According to the Walworth County Soil Survey, the soils within the Lake Beulah watershed consist primarily of the Casco-Rodman and Casco-Fox soil associations. The Casco-Rodman association consists of loam and silt loam soils that are well-drained and somewhat excessively drained that have a subsoil of clay loam and gravelly sandy loam. The Casco-Fox association consists of loam and silt loam soils that are well-drained and have a subsoil of clay loam.

Casco soils have a water erosion hazard on sloping areas. They have a low available moisture capacity making them droughty during dry periods. The nearly level to sloping Casco soils are good to fair for cropland. Rodman soils are very droughty and sloping areas have a water erosion hazard. They are very poor cropland soils. Fox soils also have a water erosion hazard on sloping areas as well as being droughty during prolonged dry periods. The nearly level to moderately steep soils are suitable for cropland.

Utilizing the NRCS Web Soil Survey, an approximate Lake Beulah watershed boundary was delineated to determine an estimate of non-hydric vs. hydric soils within the watershed. Approximately 73 percent of the soils within the watershed boundary consist of upland soils and 27 percent consist of water or hydric soils.

4.7 WETLANDS

A wetland defined by the State of Wisconsin is: "an area where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic (water-loving) vegetation and which has soils indicative of wet conditions."

Wetlands cover a wide variety of landscapes and provide habitat for more species of plants and animals than any other landscape type in Wisconsin. In addition, wetlands also store water to prevent flooding, purify water, protect lakes and stream shores from eroding and provide recreational opportunities for wildlife viewers, anglers, hunters and boaters. Unfortunately, Wisconsin only has about half of the 10 million acres of wetlands that were present in 1848 due to farm drainage and filling for development and roads. Wetland regulations have slowed their loss; however, wetlands continue to be destroyed and degraded from human activities. Invasive plants such as purple loosestrife and reed canary grass are invading wetland habitats and crowding out native plants. Overuse of groundwater and increasing stormwater runoff from development either starves or drowns wetland plants.

Three significant wetland areas are present along the lake's shoreline; a large emergent wetland complex between Lake Beulah and Army Lake along the east central shoreline, a large forested/shrub/emergent wetland complex between Beulah Heights Road and Lake Beulah along the west central shoreline, and a variety of wetland types along the southern portion of the lake, north of Booth and Swan Lakes. In addition, numerous other smaller, yet valuable, wetland communities also exist along the shore of the lake.

Beulah Bog, owned by the WDNR and dedicated as a State Natural Area in 1975, is located approximately 1,200 feet north of Lake Beulah (within the lake watershed boundary) and is considered a rare southern bog community. Beulah Bog lies in a series of four kettle holes and features an undisturbed bog with many unusual plants more typical of northern bogs. Undisturbed bogs in southeastern Wisconsin are rare and support a number of regionally rare plants including dense cotton grass, large and small cranberry, and small bladderwort. The site harbors at least six species of insectivorous plants and the state-threatened plant, kitten tails, is also found there. The bog also provides habitat for several dragonfly species and other invertebrates. Beulah Bog is located within the lake watershed boundary and is considered a valuable resource to the lake.

Pickerel Lake Fen, owned by the Wisconsin Chapter of The Nature Conservancy, and dedicated as a State Natural Area in 1986, is located just west of Booth Lake (within the lake watershed boundary). Pickerel Lake Fen is a diverse alkaline fen that originates at the base of a glacial ridge from seeps and springs. The fen has a rich flora including these common species: shrubby cinquefoil, pitcher plant, sedges, bulrushes, blue-joint grass, marsh blue violet, swamp milkweed, Joe-Pye weed, boneset and several goldenrods.

As part of this grant project, Richard Jirsa, former Staff Scientist for RSV Engineering, Inc., observed wetlands from a boat in June 2008. Due to restrictions from property owners, actual on-site inspections were not possible. However, Mr. Jirsa made observations of wetland areas relative to the mapping found in the May 1994 WDNR Sensitive Area Report, and relative to wetlands mapped by the WDNR (Surface Water Data Viewer, WDNR website). Mr. Jirsa observed conditions comparable to those represented in the documents, with some apparent degradation of species in the wetlands located on either side of the public boat landing, at the south end of the lake

4.8 LAKE CHEMISTRY

Judging the water quality of a lake can be difficult because lakes display problems in many different ways. One indicator of water quality is a lake's trophic status. Lakes are divided into three categories based on their trophic status; oligotrophic, eutrophic, and mesotrophic, defined below:

- **Oligotrophic** lakes are generally clear, deep and free of weeds or large algal blooms. Though beautiful, they are low in nutrients and do not support large fish populations; however, oligotrophic lakes often develop a food chain capable of sustaining a very desirable fishery of large game fish.

- **Eutrophic** lakes are high in nutrients and support a large biomass (all the plants and animals living in a lake). They are usually either weedy or subject to frequent algal blooms, or both. Eutrophic lakes often support large fish populations, but are also susceptible to oxygen depletion. Small, shallow, eutrophic lakes are especially vulnerable to winterkill which can reduce the number and variety of fish. Rough fish are commonly found in eutrophic lakes.

- **Mesotrophic** lakes lie between the oligotrophic and eutrophic stages. Devoid of oxygen in late summer, their hypolimnions limit cold water fish and cause phosphorus cycling from sediments.

Lakes naturally change over time and shift from oligotrophic to eutrophic status. Human beings accelerate the eutrophication process by allowing nutrients from agricultural fields, lawn fertilizers, streets, septic systems and urban storm drains to enter lakes.

There are three water quality parameters that have traditionally been used to determine a lake's trophic status in Wisconsin. These include total phosphorus, chlorophyll-a, and secchi disk transparency.

- **Phosphorus** is a nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. In more than 80 percent of Wisconsin's lakes, phosphorus is the key nutrient affecting the amount of algae and weed growth.

- **Chlorophyll-a** is the green pigment present in all plant life that is necessary for photosynthesis. The amount present in lake water depends on the amount of algae, and is therefore used as a common indicator of water quality.
- **Secchi disk transparency** is a measurement of water clarity, and of all limnological parameters is the easiest for non-professionals to understand. Secchi disc readings are taken using an 8-inch diameter weighted disc painted black and white. The disc is lowered into the water until it disappears from sight, then raised until it is visible. The average of the two depths is recorded.

The water quality parameters described above are all interrelated. Phosphorus controls algae abundance, which is measured by chlorophyll-a levels. Water clarity, as measured by secchi disk transparency, is directly affected by algal abundance.

4.8.1 Citizen Lake Monitoring Program

Lake Beulah water quality data (secchi disk clarity, chlorophyll-a, total phosphorus) was obtained from the WDNR's Citizen Lake Monitoring Program (formerly Self-Help Lake Monitoring) database. This database contained water quality data dating back to 1973 and was reportedly collected from Station 1 (deep hole) of the lake. Other stations on the lake have been monitored by citizen volunteers since 1991; however, for discussion purposes, only water quality data collected from Station 1 was evaluated. The Citizen Lake Monitoring began in 1986, and any data prior to 1986 was collected by WDNR staff.

A technical bulletin titled *Limnological Characteristics of Wisconsin Lakes* (Lillie and Mason, 1983) was used to compare water quality from Lake Beulah with water quality data collected from other Wisconsin Lakes. This document provides a source for comparing lakes within specific regions of the state. Lillie and Mason divided the state's lakes into five regions, each having lakes of similar nature or apparent characteristics. These regions include northwest, northeast, central, southwest and southeast. Walworth County lakes were included within the study's southeast region and were among 61 lakes randomly picked from the region that were analyzed for water clarity (Secchi disk), chlorophyll-a, and total phosphorus.

<u>Secchi Disk Clarity</u>
Secchi disk clarities in Lake Beulah have generally been very good and higher than mean values for other natural lakes in the state and for lakes in the southeast region of Wisconsin. The overall average secchi disk clarity based on the Citizen Lake Monitoring database was 11.8 feet. This value was based on sampling events during the growing season, May through October.

<u>Chlorophyll-a</u>
Chlorophyll-a levels in Lake Beulah have generally been very good and significantly lower than mean values for other natural lakes in the state and for lakes in the southeast region of Wisconsin. The low chlorophyll-a levels are related to the high secchi disk clarities. The overall average chlorophyll-a value based on the Citizen Lake Monitoring database was 5.45 µg/L. This value was based on sampling events during the growing season, June through October.

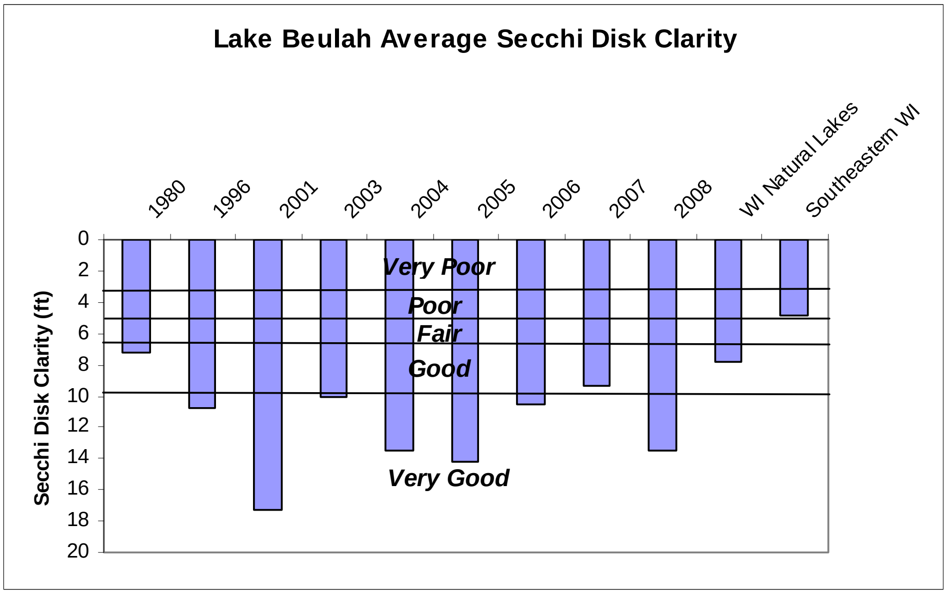


Figure 2. Lake Beulah Average Secchi Disk Clarity Values. The mean secchi values from random natural lakes in Wisconsin and lakes in Southeastern Wisconsin were derived from Lillie & Mason (1983).

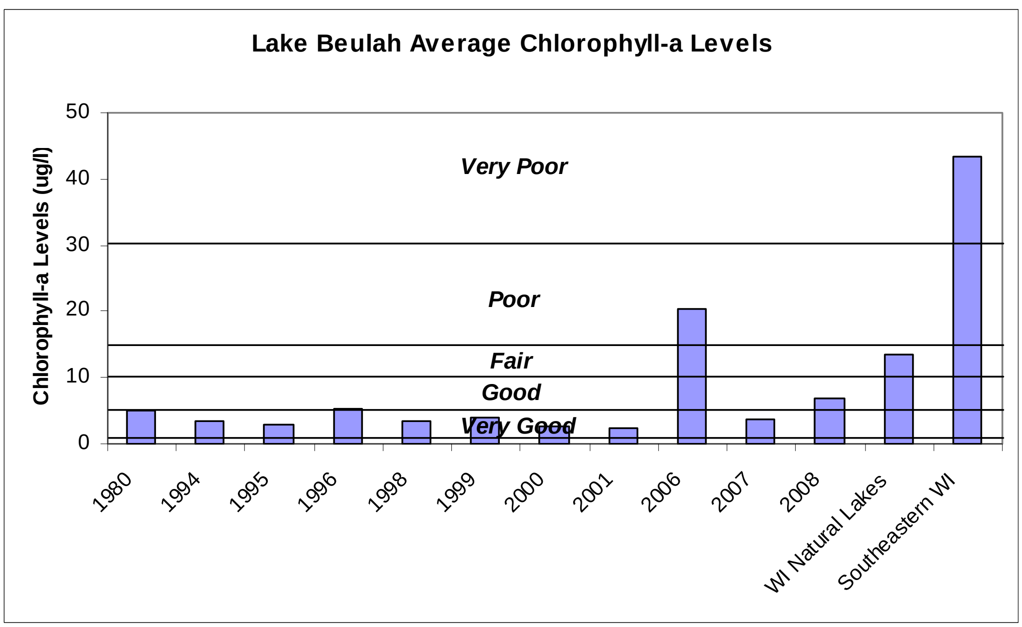


Figure 3. Lake Beulah Average Chlorophyll-a Levels. The mean chlorophyll-a values from random natural lakes in Wisconsin and lakes in Southeastern Wisconsin were derived from Lillie & Mason (1983).

Total Phosphorus

Total phosphorus values in Lake Beulah, plotted on Figure 4, have generally been good and lower than mean values for other natural lakes in the state and for lakes in the southeast region of Wisconsin. The overall average total phosphorus value based on the Citizen Lake Monitoring database was 14.54 µg/L. This value was based on sampling events during the growing season, May through October.

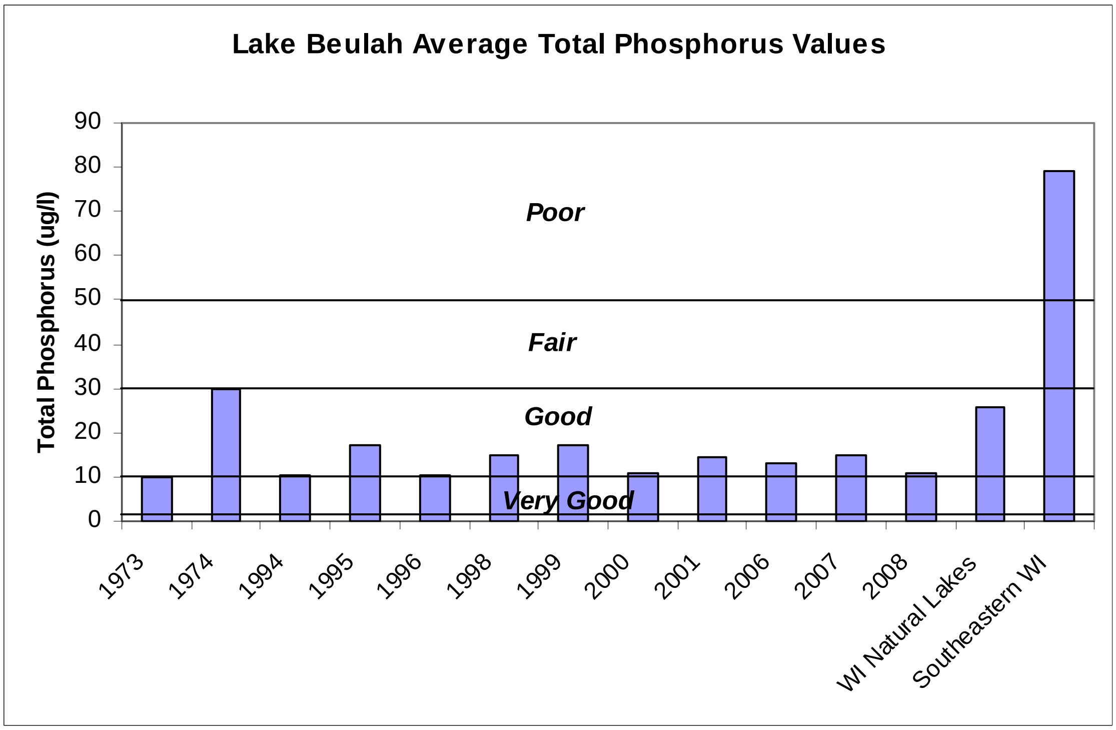


Figure 4. Lake Beulah Average Total Phosphorus Values. The mean total phosphorus values from random natural lakes in Wisconsin and lakes in Southeastern Wisconsin were derived from Lillie & Mason (1983).

4.8.2 USGS Monitoring

The USGS conducted water quality monitoring in 2007 and 2008 from three Lake Beulah monitoring stations, one of which was the deep hole. Only water quality data (secchi disk transparency, chlorophyll-a, total phosphorus) collected from the deep hole was evaluated and will be discussed in this section. Refer to Appendix C for a complete set of water quality data from all three monitoring stations.

The 2007 monitoring was conducted during the months of August and December. The 2008 monitoring was conducted in March, April, and August. In 2007, the average secchi disk clarity was 16 feet, compared to 10.6 feet in 2008. The two-year secchi disk average is 13.3 feet, slightly higher than the 11.8 feet average for the Citizen Lake Monitoring. According to Lillie and Mason (1983), a secchi disk clarity of 13.3 indicates very good water quality.

In 2007, the average chlorophyll-a value was 2.73 µg/L, compared to 6.23 µg/L in 2008. The two-year chlorophyll-a value average is 4.48 µg/L, slightly lower than the 5.45 µg/L average for the Citizen Lake Monitoring. According to Lillie and Mason (1983), a chlorophyll-a value of 4.48 ug/L indicates very good water quality.

In 2007, the average total phosphorus value was 18.3 µg/L, compared to 18.2 µg/L in 2008. The two-year total phosphorus average is 18.25 µg/L, slightly higher than the 14.54 µg/L average for the Citizen Lake Monitoring. According to Lillie and Mason (1983), a total phosphorus value of 18.25 indicates good water quality.

In addition the USGS analyzed for other water quality values including, but not limited to, turbidity, pH, specific conductance, calcium, magnesium, silica, sulfate, and iron. These parameters were all below any caution levels. The hardness concentration averaged 281 mg/L for 2007 and 2008 monitoring, indicating Lake Beulah is a very hard lake. According to limnology experts at the USGS, this hardness is a result of the strong groundwater component of the lake's water budget, and a reduction in groundwater flow could be detrimental to the lake's water quality.

4.8.3 Wisconsin Trophic Status Index

The Wisconsin Trophic Status Index (WTSI) is based upon the widely used Carlson Trophic Status Index (TSI), but is specific to Wisconsin. Secchi disk transparency, chlorophyll-a levels, and total phosphorus values can determine the trophic status or level of nutrient enrichment of a lake. Trophic state index is a continuum scale of 0 to 100, with 0 corresponding to the clearest and most nutrient poor lake possible, and being 100 the least clear and presumably most nutrient rich lake possible. As previously discussed, lakes can be divided into three main levels of nutrient enrichment categories: oligotrophic, eutrophic, and mesotrophic. Refer to Table 3 for a description of the TSI breakdown.

Figure 5 displays the WTSI (Lillie, et al. 1993) values calculated from average chlorophyll-a concentrations, total phosphorus concentrations, and Secchi disk transparencies measured during the growing season, May through October. Based on the WTSI, Lake Beulah is characterized as a mesotrophic lake. Mesotrophic lakes fall in the middle of the continuum from nutrient-poor to nutrient-rich. They have moderately clear water, and may experience low to now oxygen concentrations in bottom waters. Based on dissolved oxygen profiles conducted by the USGS while water quality sampling the deep hole of the lake in 2007 and 2008, the lake does stratify during the summer months and is essentially depleted of oxygen at approximately 20 feet in depth (Figure 6).

TSI	TSI Description
TSI < 30	Classical oligotrophy: clear water, many algal species, oxygen throughout the year in the bottom water, cold water, oxygen-sensitive fish species in deep lakes. Excellent water quality.
TSI 30-40	Deeper lakes still oligotrophic, but bottom water of some shallower lakes will become oxygen-depleted during the summer.
TSI 40-50	Water moderately clear, but increasing chance of low dissolved oxygen in deep water during the summer.
TSI 50-60	Lakes becoming eutrophic: decreased clarity, fewer algal species, oxygen-depleted bottom waters during the summer, plant overgrowth evident, warm-water fisheries only.
TSI 60-70	Blue-green algae become dominant and algal scums are possible, extensive plant overgrowth problems possible.
TSI 70-80	Becoming very eutrophic. Heavy algal blooms possible throughout summer, dense plant beds, but extent limited by light penetration (blue-green algae block sunlight).
TSI > 80	Algal scums, summer fish kills, few plants, rough fish dominant.

Table 3. Trophic Status Index Scale.

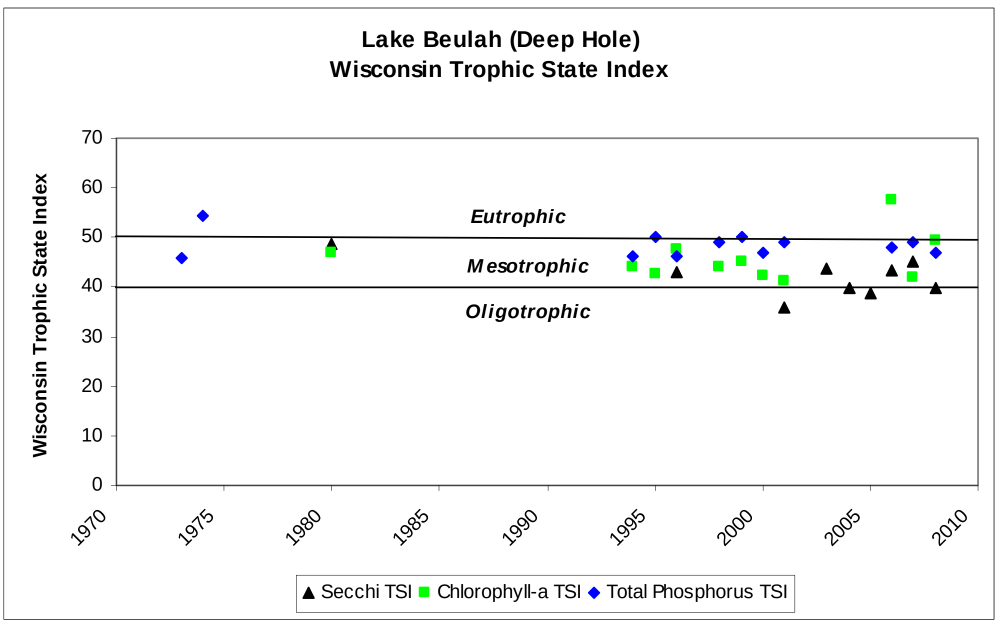


Figure 5. Lake Beulah Wisconsin Trophic State Index. *Calculations based upon Lillie, et al. (1993).*

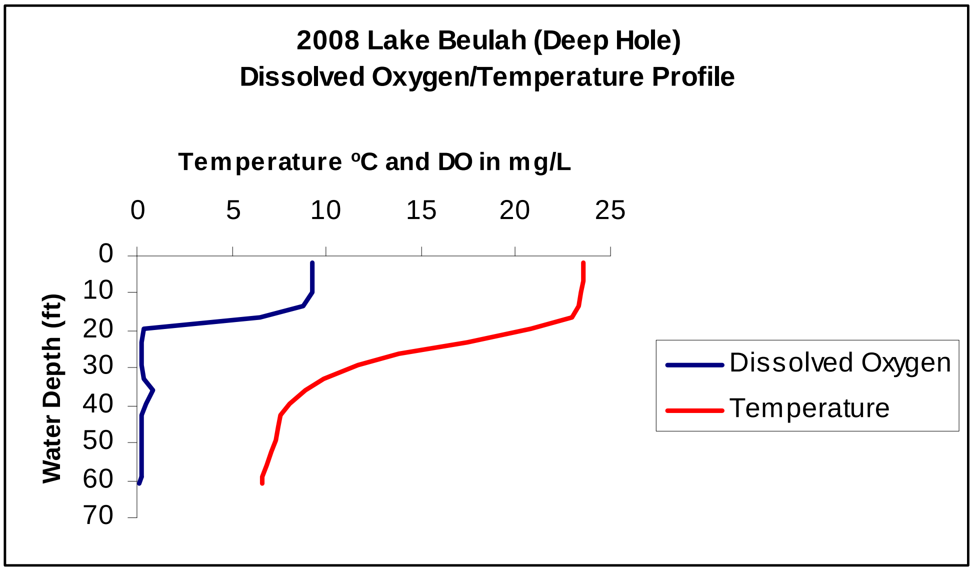


Figure 6. 2008 Lake Beulah (Deep Hole) Dissolved Oxygen and Temperature Profile.

4.9 AQUATIC PLANTS

An aquatic plant survey was completed for the LBMD in 2008 and 2009. In accordance with WDNR requirements, plant samples were collected based on a pre-determined grid pattern. Based on the WDNR's spacing requirements, this resulted in 996 sample locations. Numerous samples yielded healthy, native plants; however, many locations also yielded the invasive Eurasion water-milfoil. Several samples of Curly-leaf pondweed were collected, as well. Figure 7 shows the grid pattern, and sample locations yielding aquatic plants. An Aquatic Lake Management Plan is included on compact disk in Appendix A.

4.10 FISHERY

A fishery study was not included in the scope of this plan.

4.11 SHORELINE USE

A shoreline study was not included in the scope of this plan; however, with the exception of a few areas, most of the lake shore has been developed, either with single-family dwellings or by organizations (e.g., B'Nai Brith). Additionally, much of the lake is surrounded by steep slopes, giving the potential for erosional degradation of the shoreline.

5 SUMMARY AND MANAGEMENT RECOMMENDATIONS

Many data have been, and continue to be collected pertaining to the Lake Beulah environment. We understand it to be a very healthy lake, with some encroachment of invasive aquatic species, as is occurring in all lakes in the area. We also understand that the lake's environmental health relies a great deal on groundwater discharging into it. Groundwater modeling shows that high capacity wells, such as East Troy's well 7, can significantly reduce the flow of groundwater into the lake. Groundwater data collected from monitoring wells at the south end of the lake confirms this conclusion. This makes it even more necessary to control other factors, such as nutrient loading.

Many experts are available for consultation on specific issues relating to lake management. The Southeastern Wisconsin Regional Planning Commission has available experts on wetland and aquatics. Additional expertise is available through the University of Wisconsin and University of Wisconsin Extension system. Several important areas of lake management are discussed below.

<u>High Capacity Well</u>
Data collected from several monitoring wells around Lake Beulah show that, as predicted in 2003, that the Village of East Troy well 7 is preventing groundwater from entering the lake. As discussed above, the lake owes much of its aquatic health to the inflow of groundwater, and most of the groundwater that enters the lake is in the area of the well. Unfortunately, while it is clear that the well is having an adverse impact on groundwater flow into the lake, the impacts to the lake's water quality will take time to become apparent. By that time, significant damage will have been done, and remediation will be difficult.

The continued monitoring of the water levels in the monitoring wells will serve to provide a database, documenting the groundwater flow conditions. Additionally, the continued monitoring of critical aspects of the lake water (e.g., hardness parameters) will provide documentation of the gradual changes. It is possible, that along with positive changes to Wisconsin's groundwater use regulations and the establishment of a mitigation fund in the State's high capacity fee program, early detection of adverse impacts can be addressed with minimal cost to the LBMD.

<u>Nutrient Loading</u>
The LBMD has wisely restricted the use of fertilizers containing phosphorus. Although, to a great extent, the success of this ban relies on compliance by the residents of the Lake Beulah watershed, public education can be helpful in encouraging compliance.

Shoreline Erosion

It is often natural for riparian owners to desire a beautifully landscaped lawn extending to the shoreline. However, shoreline buffers are important for the prevention of shoreline erosion. They serve the important purposes of taking the energy out of water flowing over the ground surface, and can also intercept debris that can cause erosion. As with nutrient loading, education is an important aspect of keeping riparian owners in compliance with buffer requirements.

Invasive Aquatic Animal Species

As indicated in section 3.6, Lake Beulah has been infested with rusty crayfish and zebra mussels. Once aquatic animal species have invaded a lake, and become a self-sustaining population, their eradication is very difficult. However, efforts should be taken to enforce the requirements to properly clean and flush watercraft before entering the lake. Various options are available, from having staff monitoring the activities at public boat landings to specialized cameras that are positioned such that they monitor both the activities and boat identifications (e.g., registrations and license plates).

Management of Invasive Aquatic Plants

The most pervasive invasive aquatic plant is Eurasian milfoil. Various options are available for addressing this problem, based on water depth, equipment availability and water use. Clearly, efforts should be concentrated on the areas where significant milfoil was found. Most harvesters can go to 5 feet of depth and the larger ones to 7 feet.

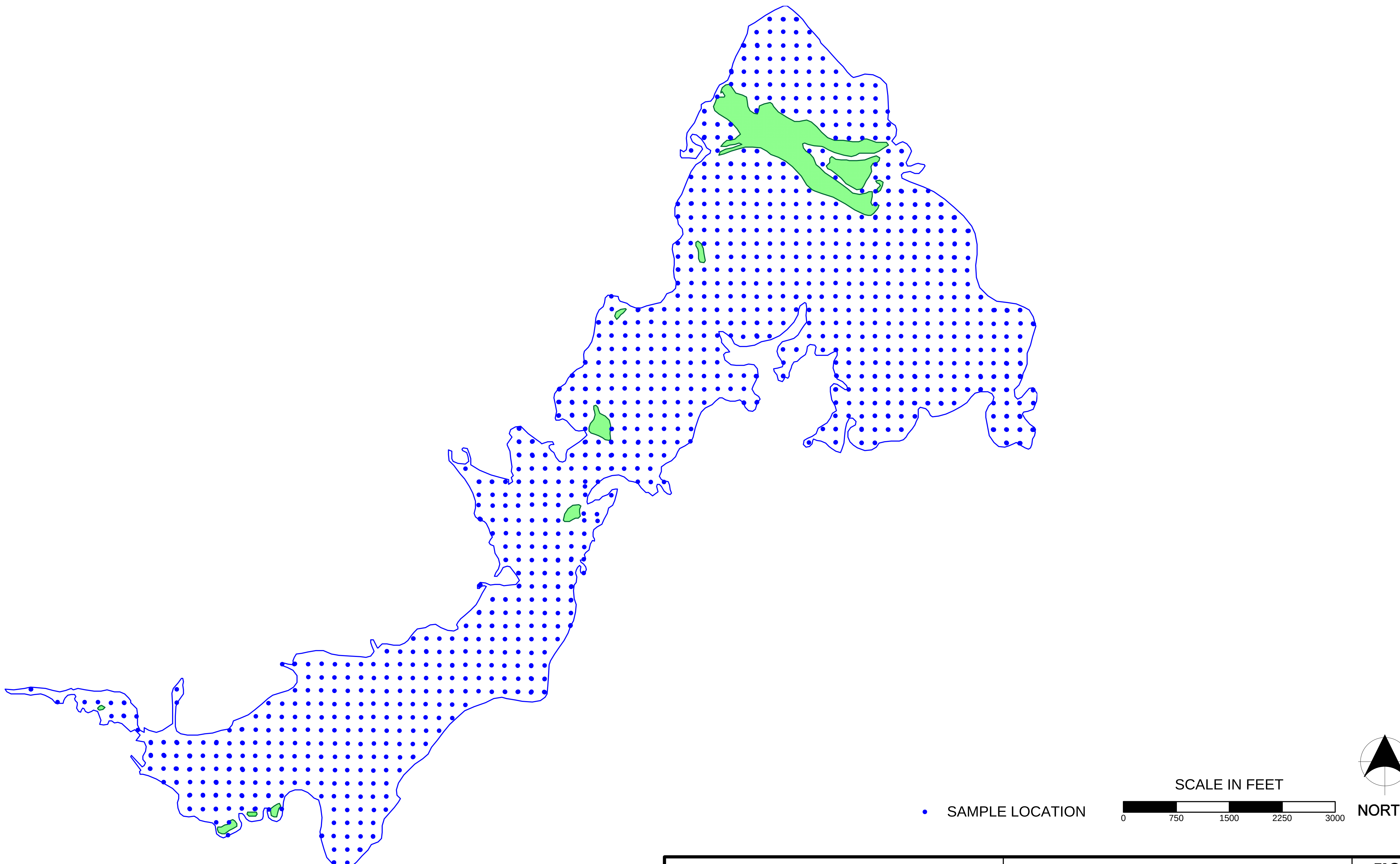
In lake management plans developed by SEWRPC, they typically recommend “top chopping” in deeper waters such that the harvester cuts to a depth that they are pulling up mostly milfoil. By removing the vegetative canopy of the plant, this allows sunlight to penetrate and native plants, which tend to be lower growing, to germinate and grow. We have found, however, that the harvesting/top chopping has to be repeated at about 3 to 4 week intervals through the summer to limit re-growth of the milfoil. In waters shallower than 3 feet depth, SEWRPC generally recommends that the individual homeowners manage milfoil by raking, although there will be some who prefer to use herbicide (granular 2,4-D is typically the herbicide of choice).

Habitat Protection

As discussed earlier, the WDNR has identified several areas around the lake as being environmentally sensitive. The LBMD should follow the recommendations provided in the WDNR’s report on this issue.

Public Information and Education

The LBMD has traditionally been strong supporters of providing information and education to the public with respect to various issues pertaining to the lake. It is recommended that these efforts be focused on the issues discussed in this document, such as nutrient control, shoreline erosion and habitat protection.



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LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
AQUATIC PLANT SAMPLE LOCATIONS

FIGURE
7

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	24 MAR 10	SAMP LOC

APPENDIX A

AQUATIC PLANT MANAGEMENT PLAN

(Provided digitally)

APPENDIX B

SURFACE WATER AND GROUNDWATER MONITORING DATA

APPENDIX B
SURFACE WATER AND GROUNDWATER MONITORING

Appendix B includes a summary of the data collected by the Lake Beulah Management District. Figure B-1 shows the locations of monitoring points. These include drive point nests, drilled well nests, temperature probes and stream flow.

Stream Flows

Figures B-2 through B-10 show stream flows for the months of March 2007 through November 2007; Figures B-11 through B-17 show flows for the months of May 2008 through November 2008. In general, flows are in the 20 to 30 cubic foot per second (CFS) range; however, some spikes occur due to precipitation. As Figures B-10 (November 2007) and B-17 (November 2008) show, ice caused anomalously high readings, so monitoring was discontinued during winter months.

Lake Bed Temperatures

Figure B-18 shows the lake bed temperatures at two locations for the period of November 10, 2006 through May 2, 2007. Temperatures were typically slightly lower at the Norton site than at the Camp site, likely due to greater groundwater discharge on the south side of the lake.

Groundwater Levels

Groundwater levels at five drive point nests have been monitored by lake volunteers for several years. The data collected are summarized in Table B-1.

Additionally, RJN Environmental Services, LLC has been monitoring water levels at three monitoring well nests in the Lake Beulah area. These data are plotted on Figures B-19 through B-21, for nests MW-1, MW-2 and MW-3, respectively.

Figure B-19 shows the vertical gradient. This is the separation between the water levels in the shallow well and the adjacent deep well. A higher water level in the deep well indicates an upward groundwater flow gradient, i.e., groundwater is discharging into the lake. Both Figures B-19 and B-20 show downward spikes, which are caused by the pumping of East Troy well 7. These spikes result in a reduction, and at times reversal of the upward vertical flow gradient. A reduced gradient indicates a reduction of groundwater flow into the lake; a reversed gradient indicates that lake water is discharging to the aquifer. This condition was predicted in 2003, when East Troy initially proposed well 7.

DRIVE POINT NEST
EAST TROY WELL NEST
TEMPERATURE PROBE
STREAM FLOW

NORTH

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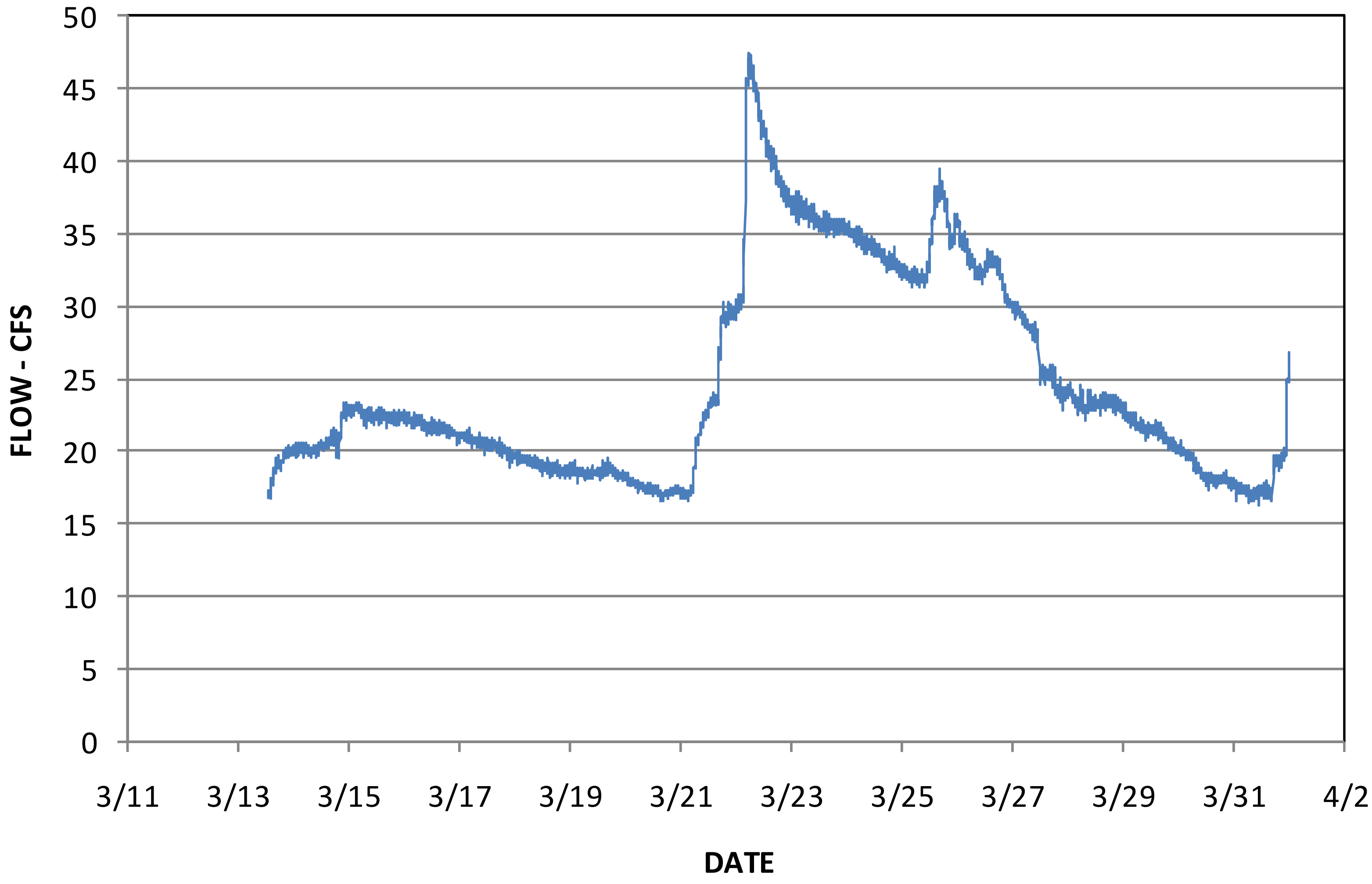
LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
MONITORING LOCATIONS

FIGURE
B-1

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	17 MAY 10	POINT LOC



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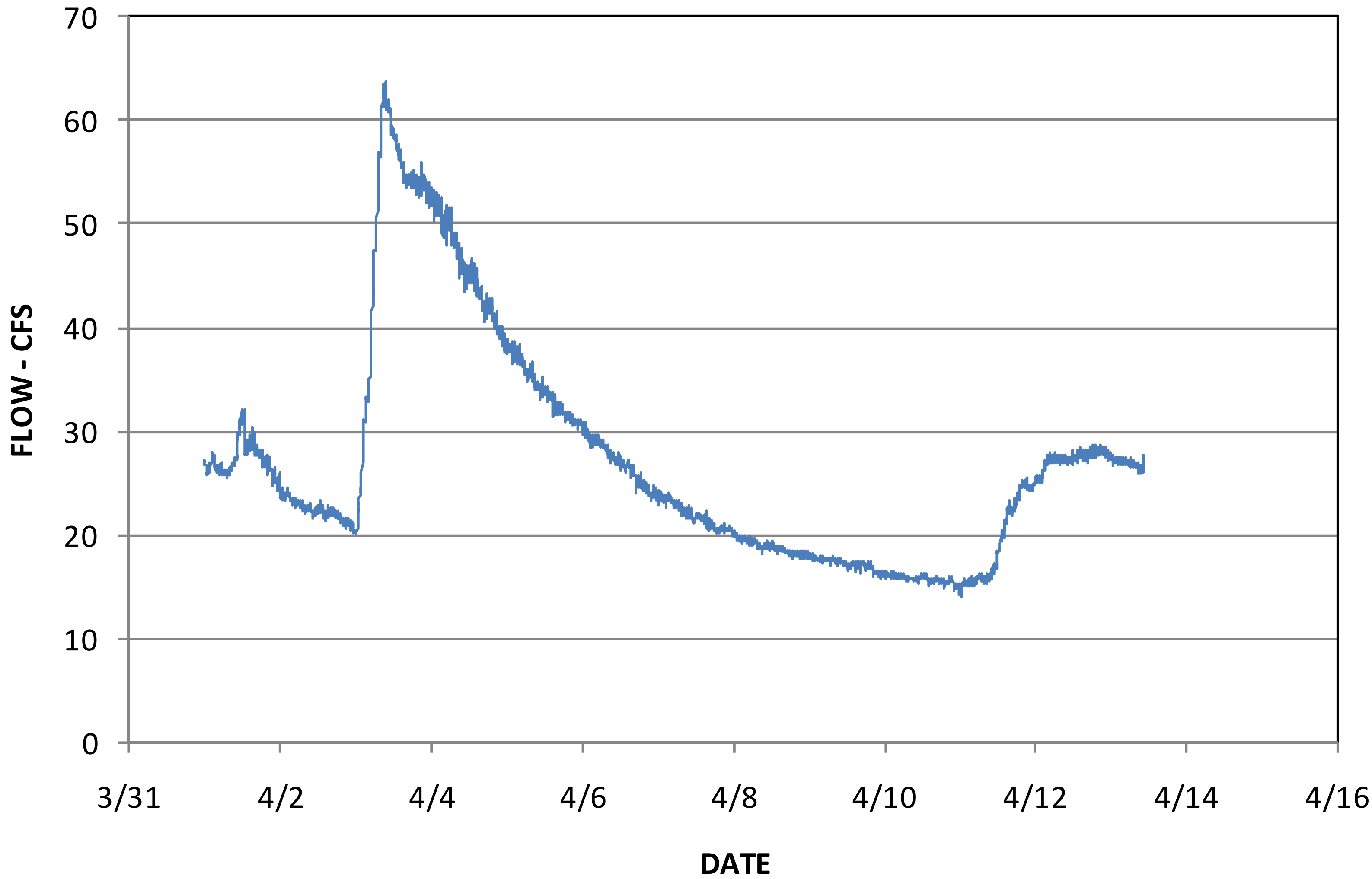
LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
STREAM FLOW - MARCH 2007

FIGURE B-2

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 0307



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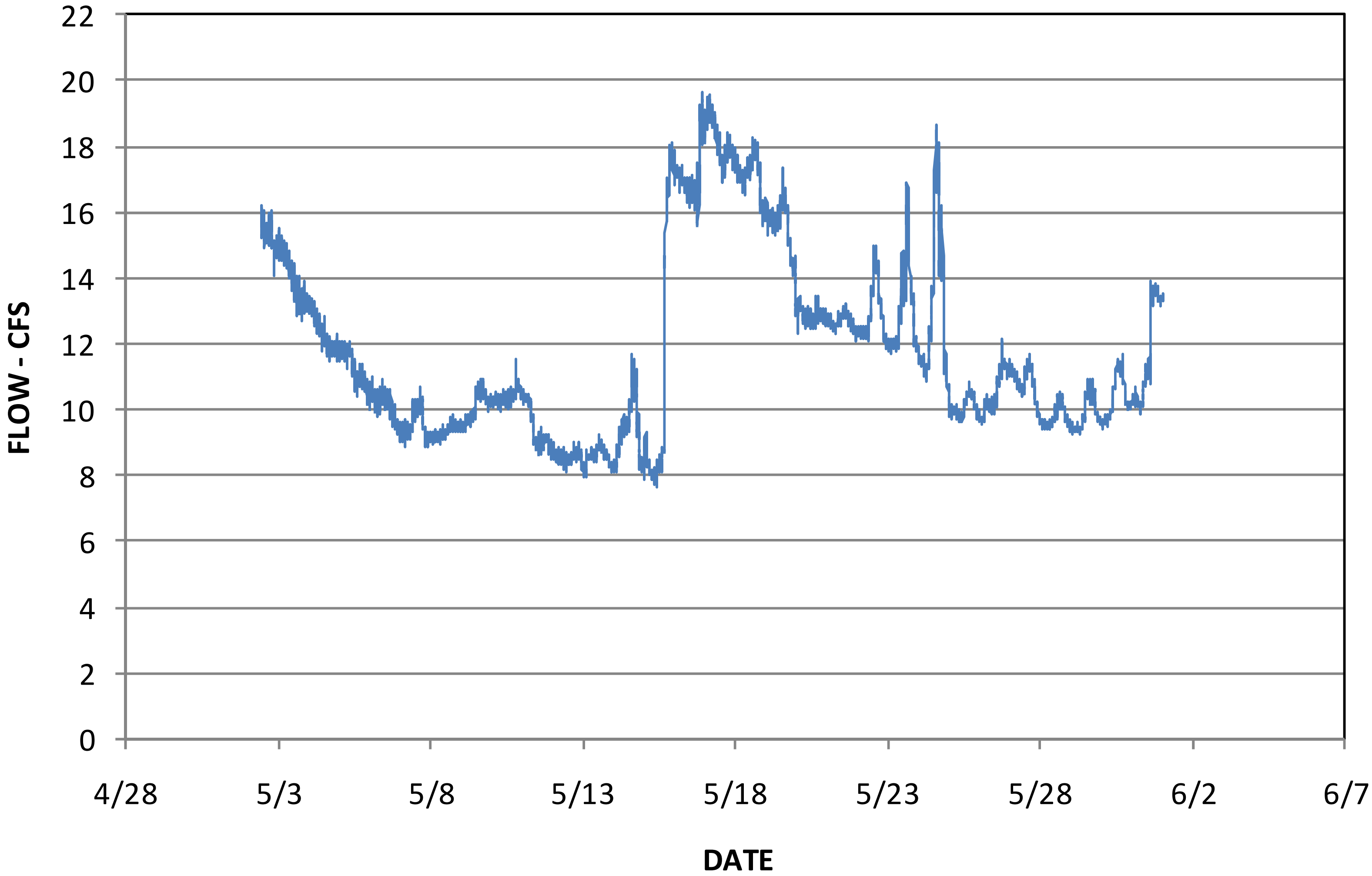
LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
STREAM FLOW - APRIL 2007

FIGURE B-3

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 0407



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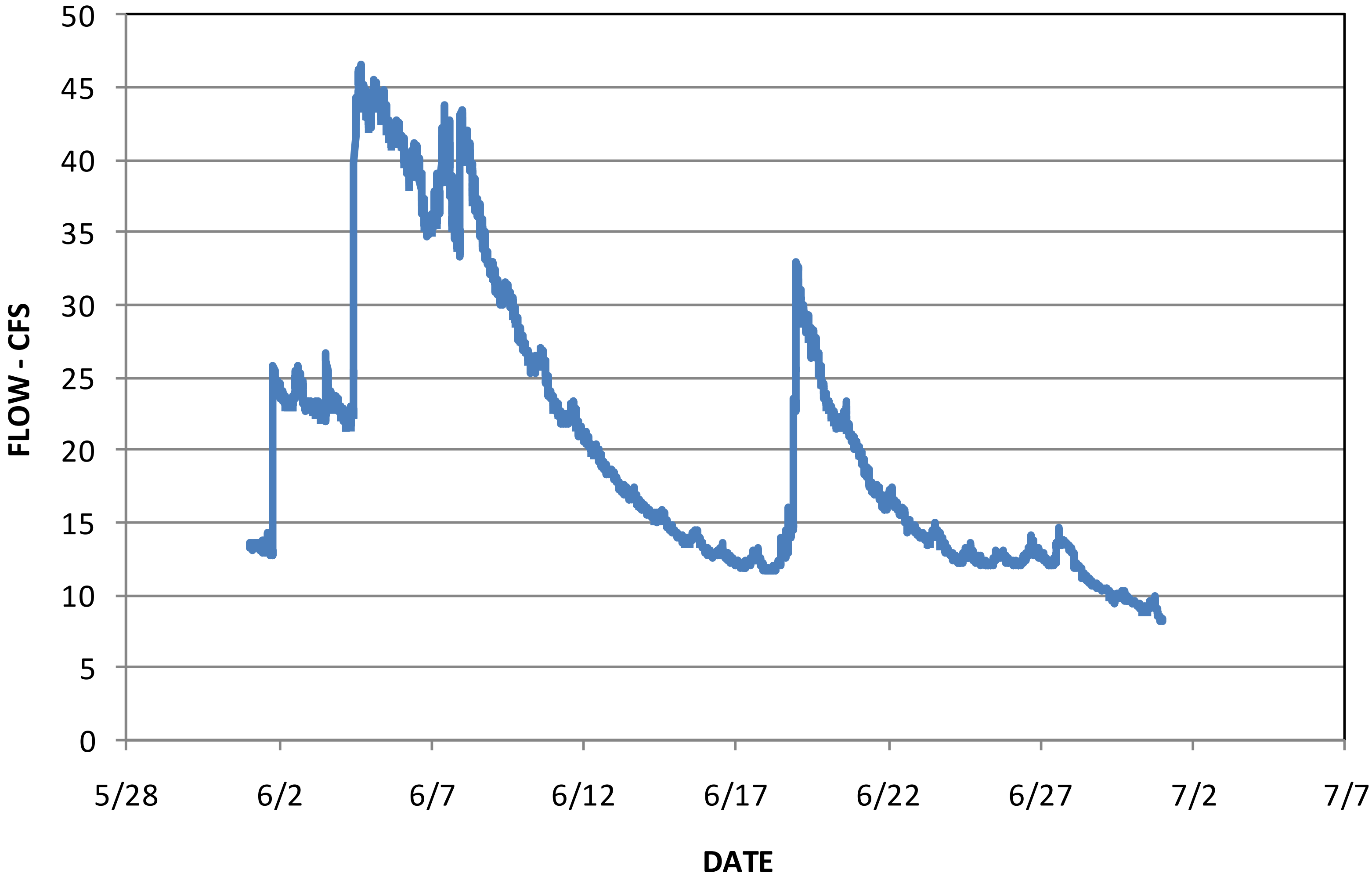
LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
STREAM FLOW - MAY 2007

FIGURE B-4

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 0507



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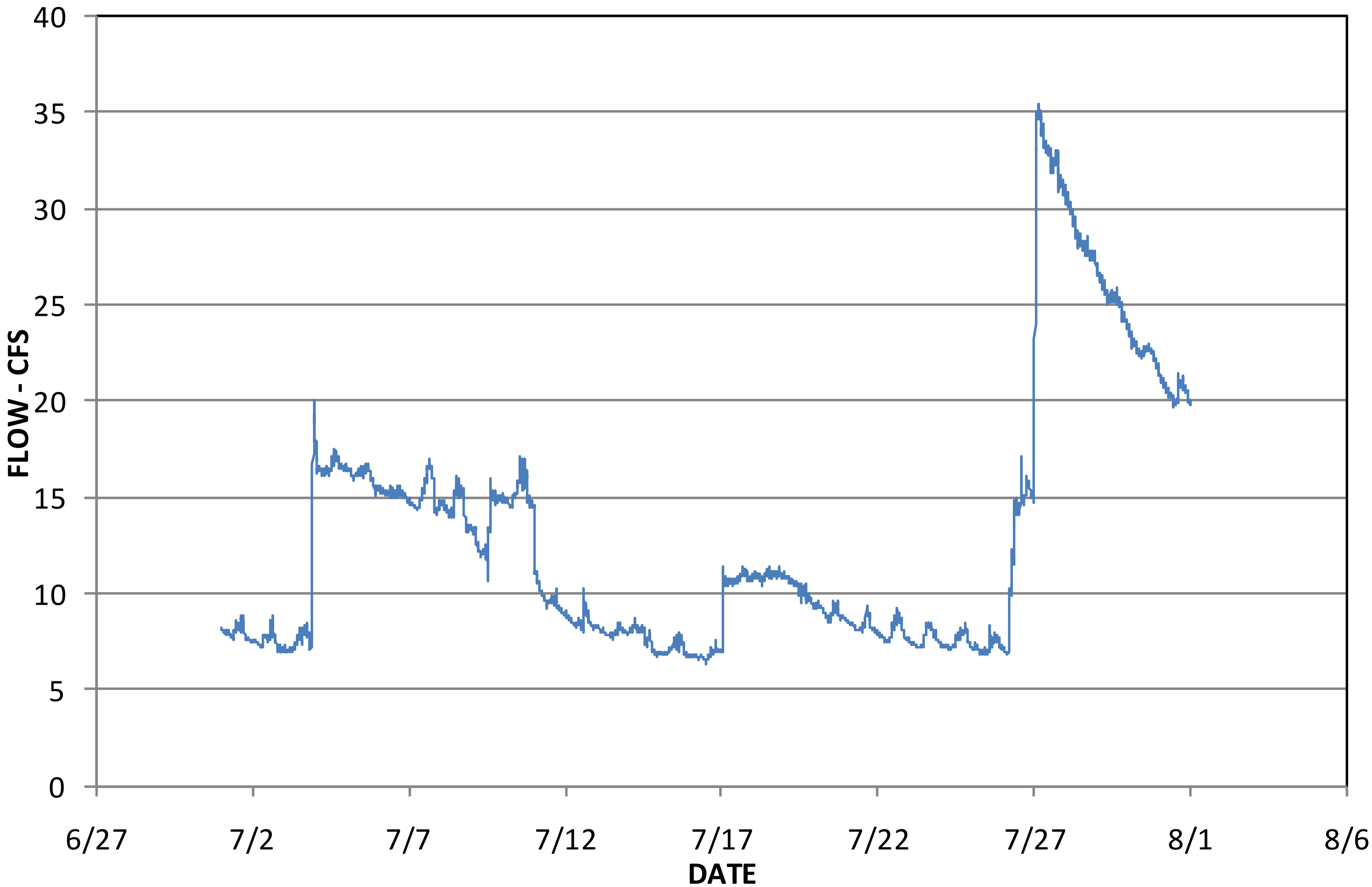
LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
STREAM FLOW - JUNE 2007

FIGURE B-5

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 0607



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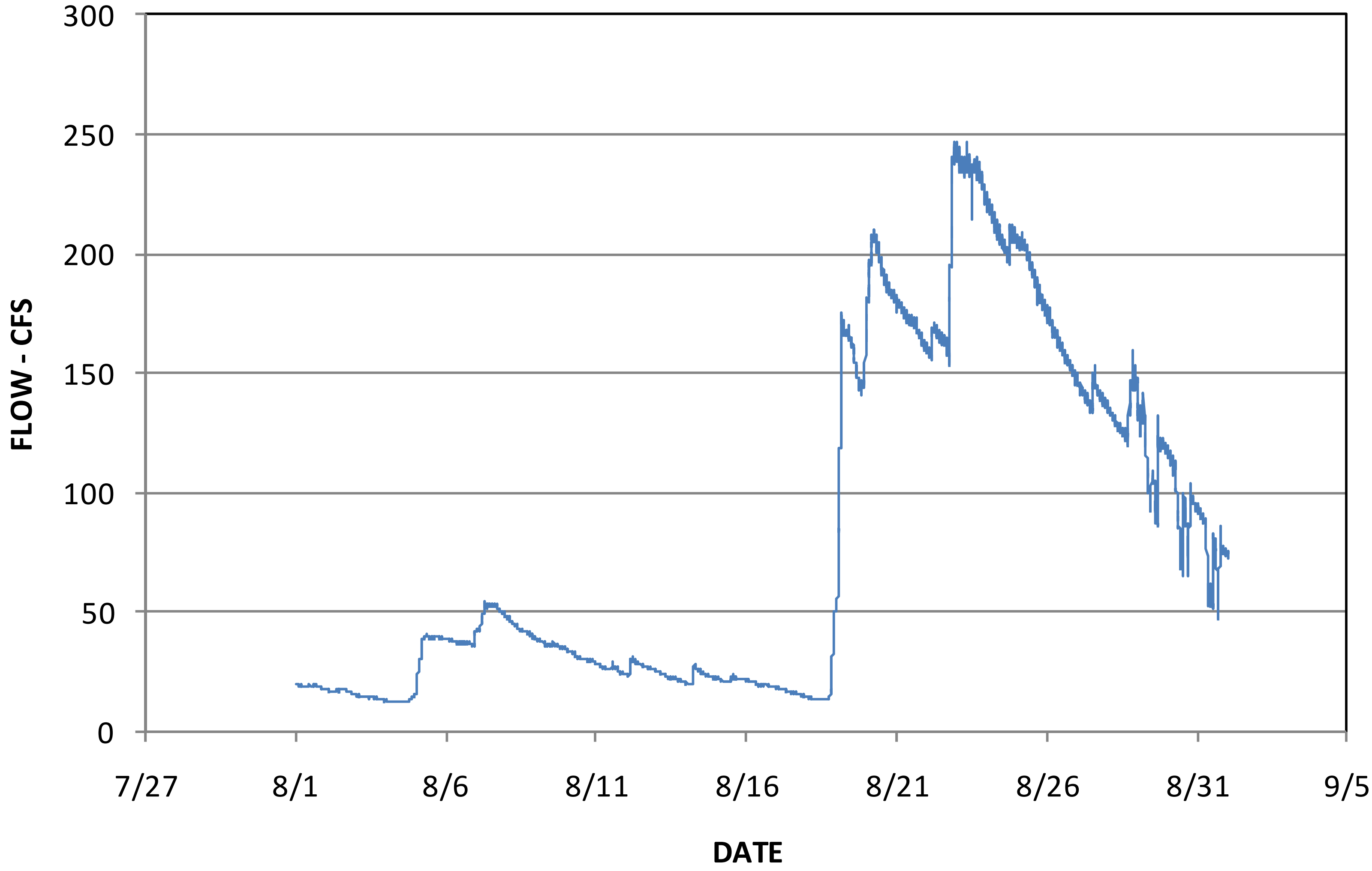
LAKE BEULAH, WISCONSIN
STREAM FLOW - JULY 2007

FIGURE
B-6

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 0707



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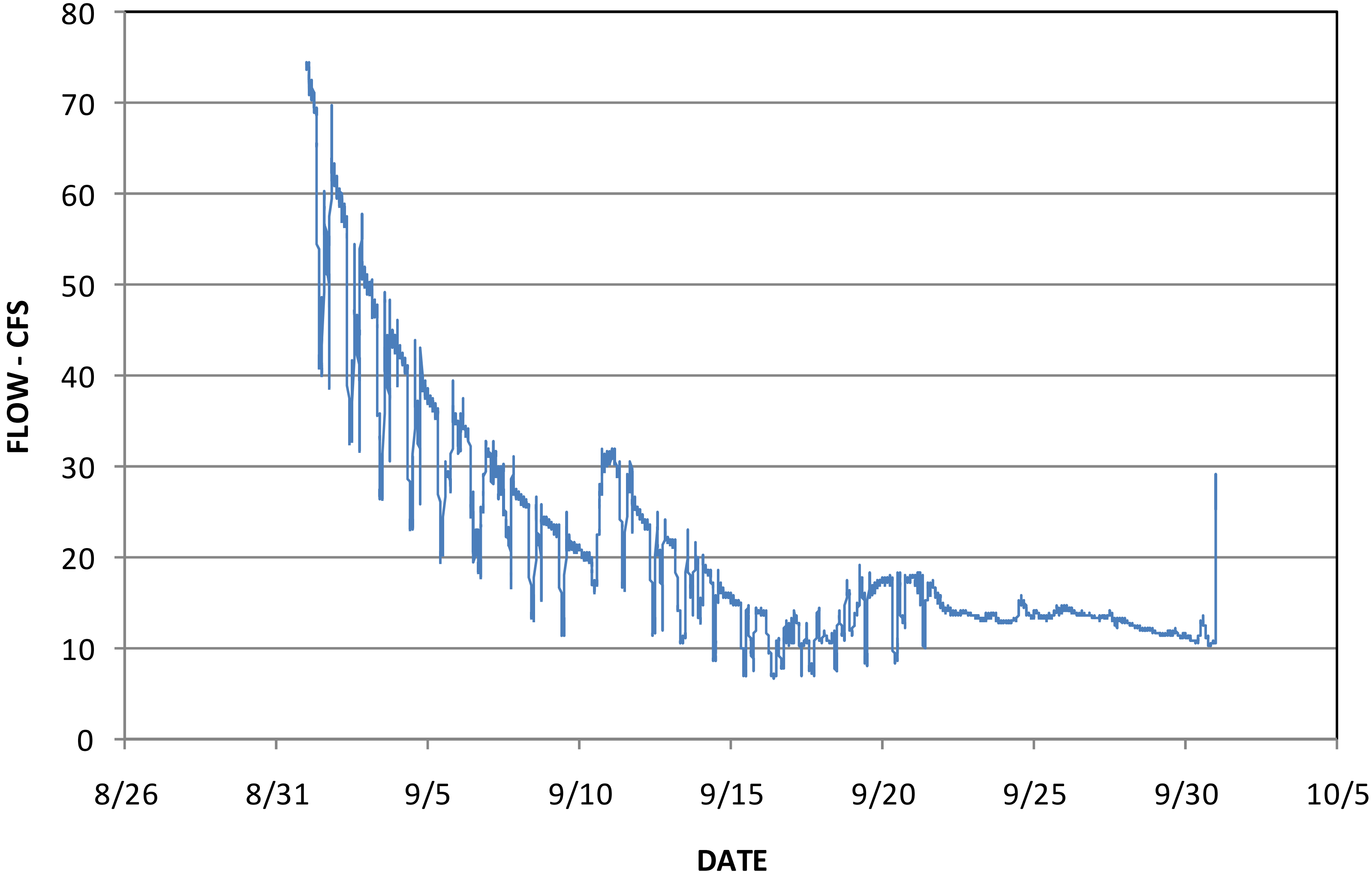
LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
STREAM FLOW - AUGUST 2007

FIGURE
B-7

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 0807



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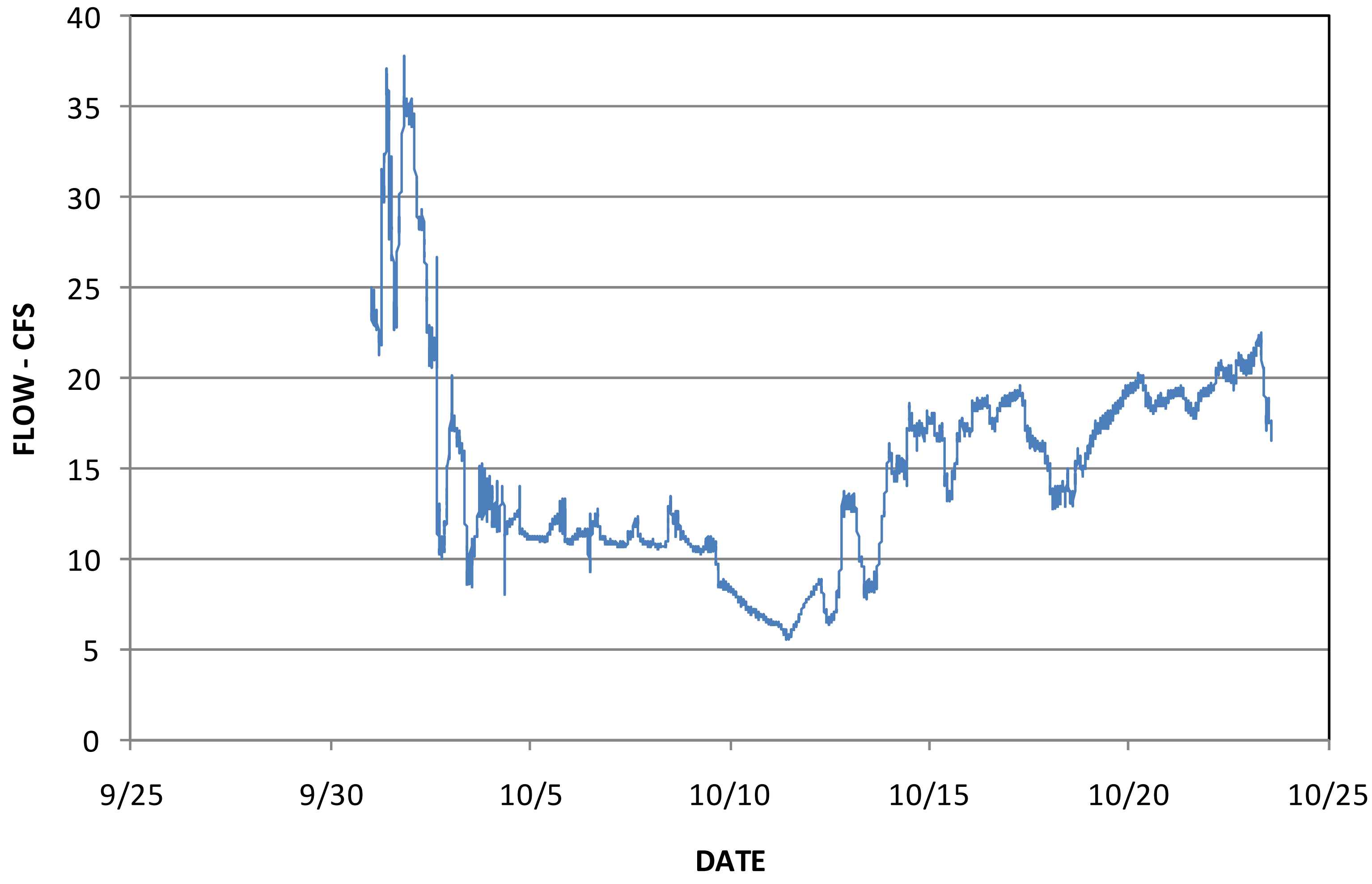
LAKE BEULAH MANAGEMENT DISTRICT LAKE BEULAH, WISCONSIN STREAM FLOW - SEPTEMBER 2007			FIGURE B-8
DRAWN BY	**PROJ. No.**	**DATE**	**FILE**
RN	09-201	4 DEC 10	FLOW 0907



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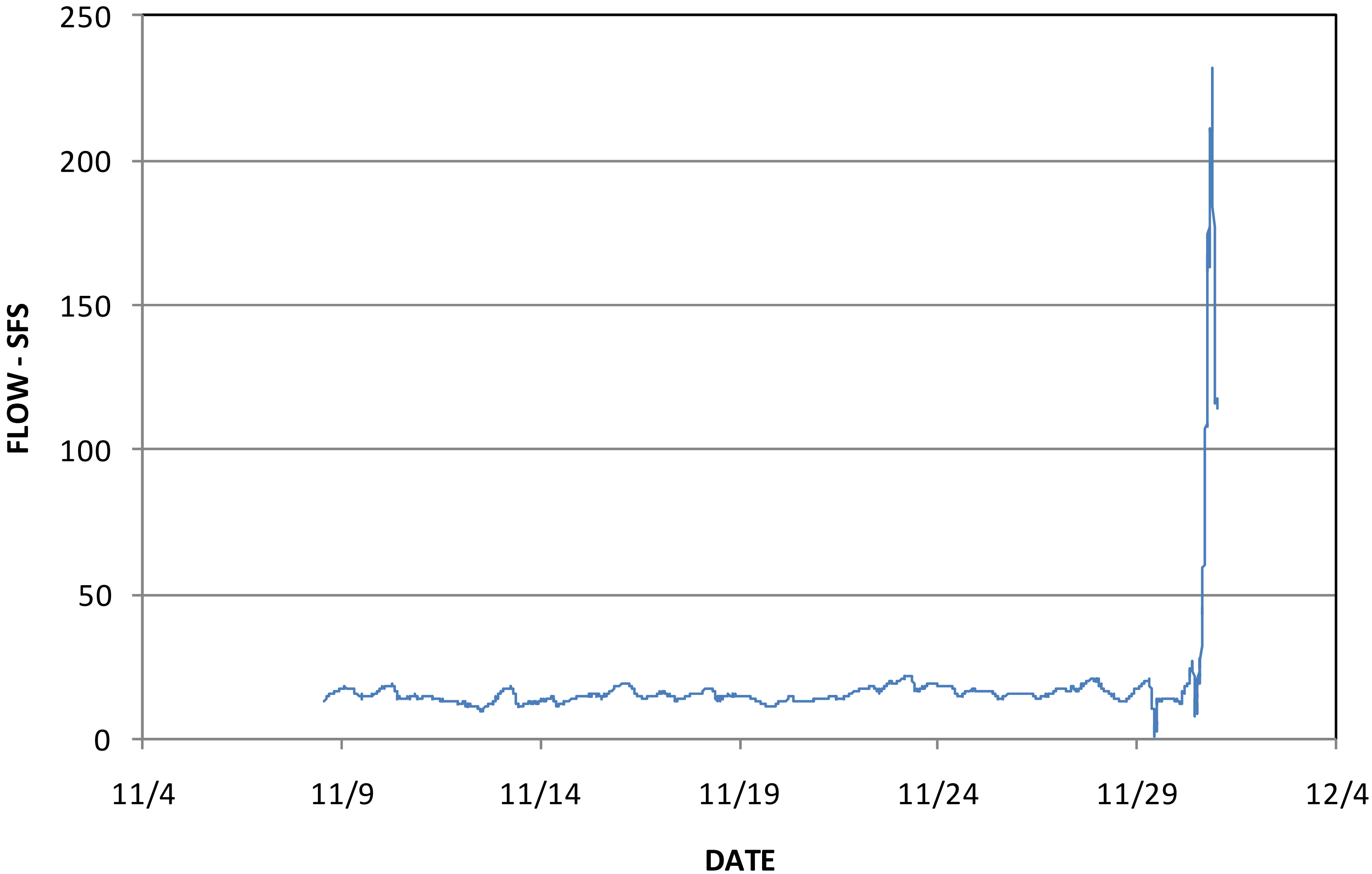
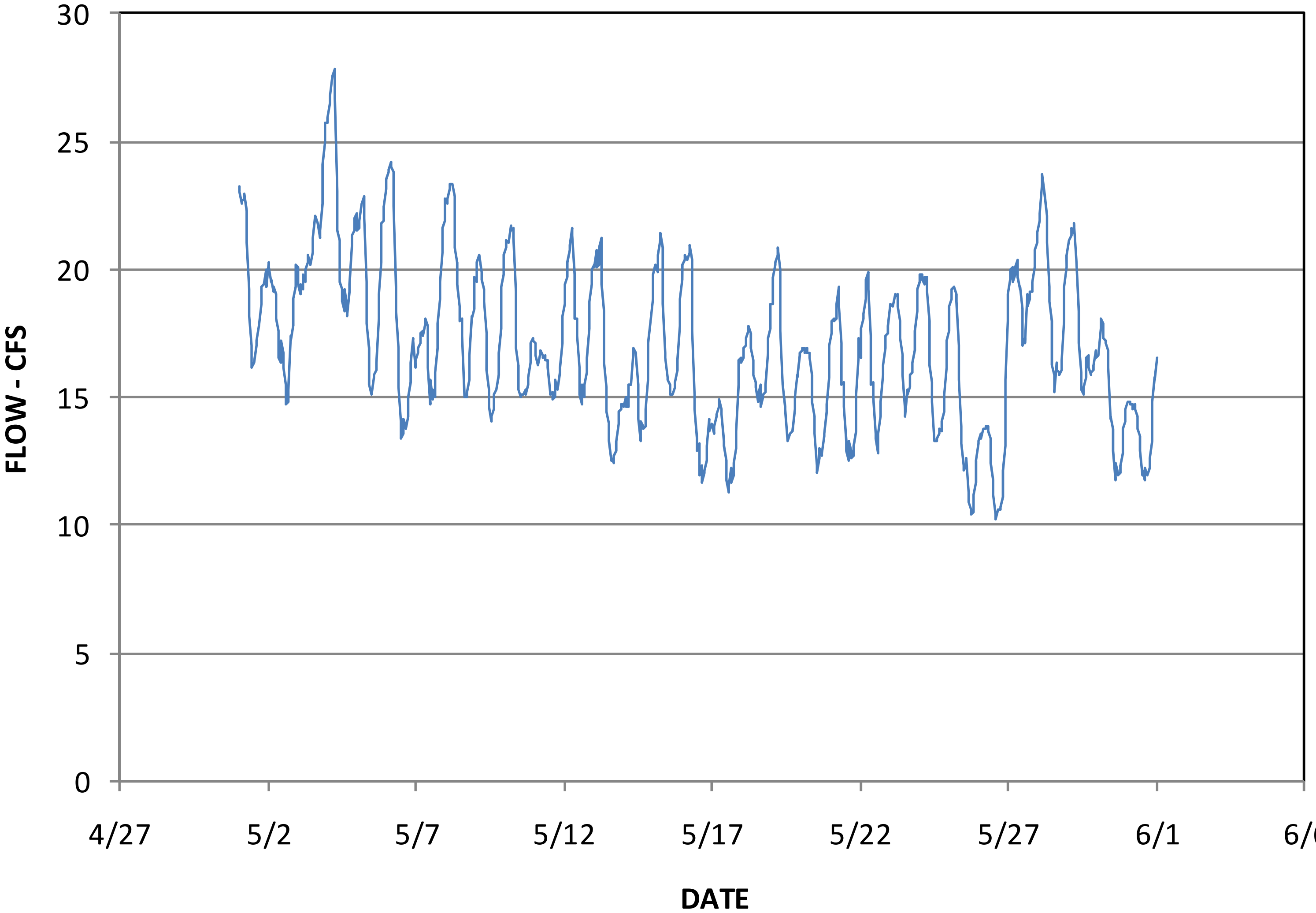
LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
STREAM FLOW - OCTOBER 2007

FIGURE B-9

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 1007



RJN Environmental Services, LLC Surface Water Studies Groundwater Studies Site Investigations 4631 COUNTY ROAD A OREGON, WISCONSIN 53575 (608) 576-3001	LAKE BEULAH MANAGEMENT DISTRICT LAKE BEULAH, WISCONSIN STREAM FLOW - NOVEMBER 2007			FIGURE B-10
	DRAWN BY	**PROJ. No.**	**DATE**	**FILE**
	RN	09-201	4 DEC 10	FLOW 1107



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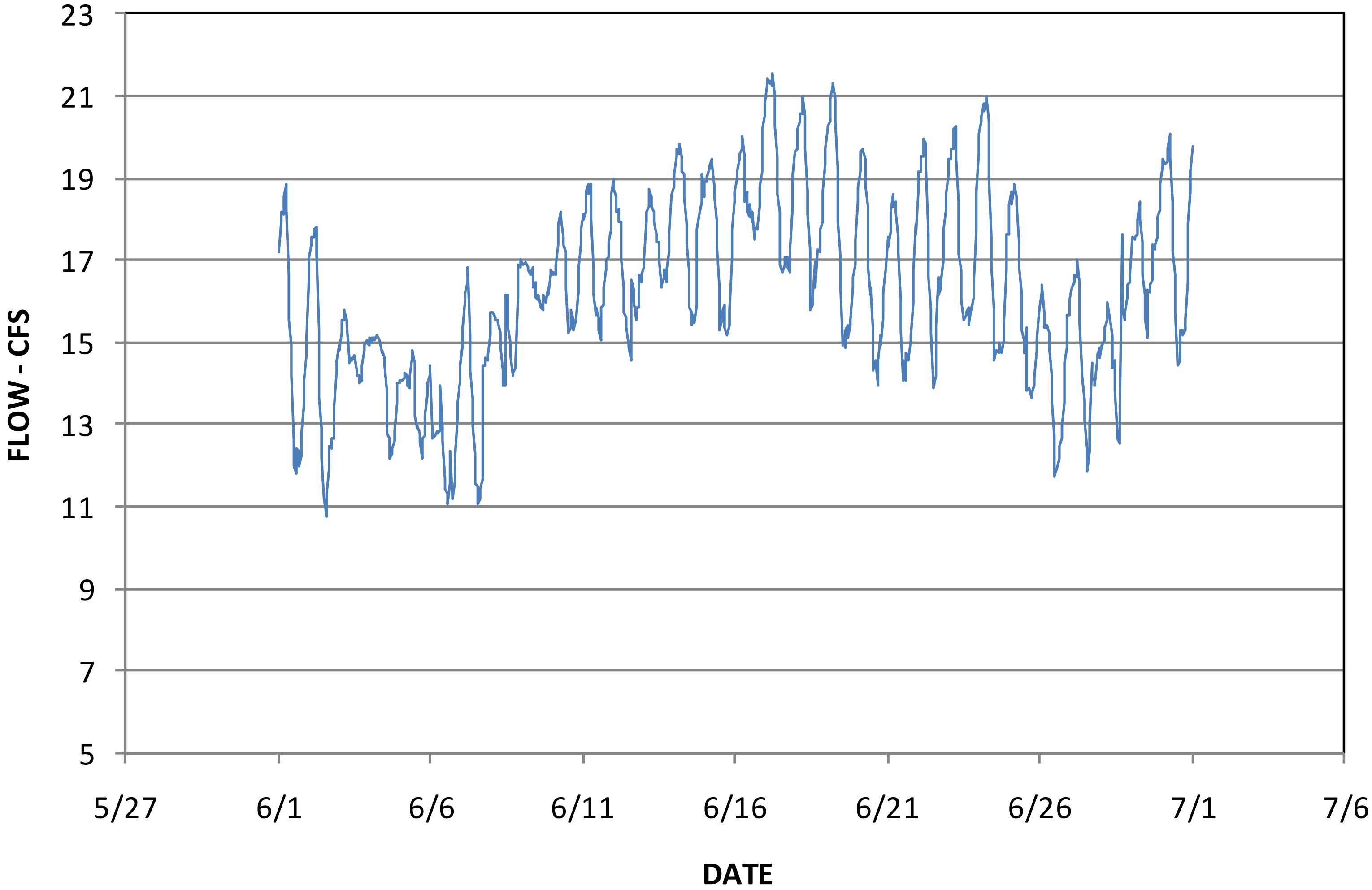
LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
STREAM FLOW - MAY 2008

FIGURE B-11

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 0508



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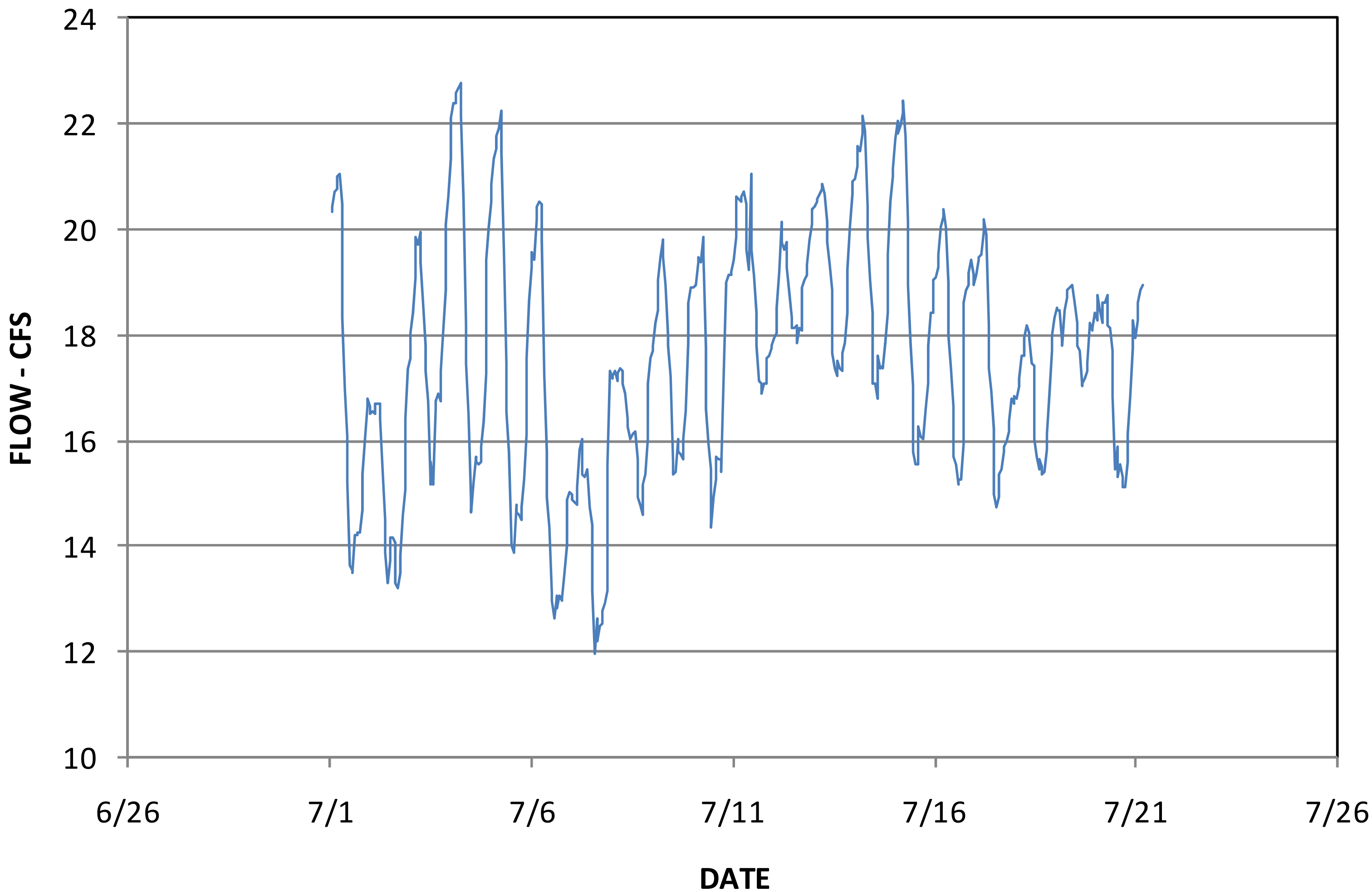
LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
STREAM FLOW - JUNE 2008

FIGURE B-12

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 0608



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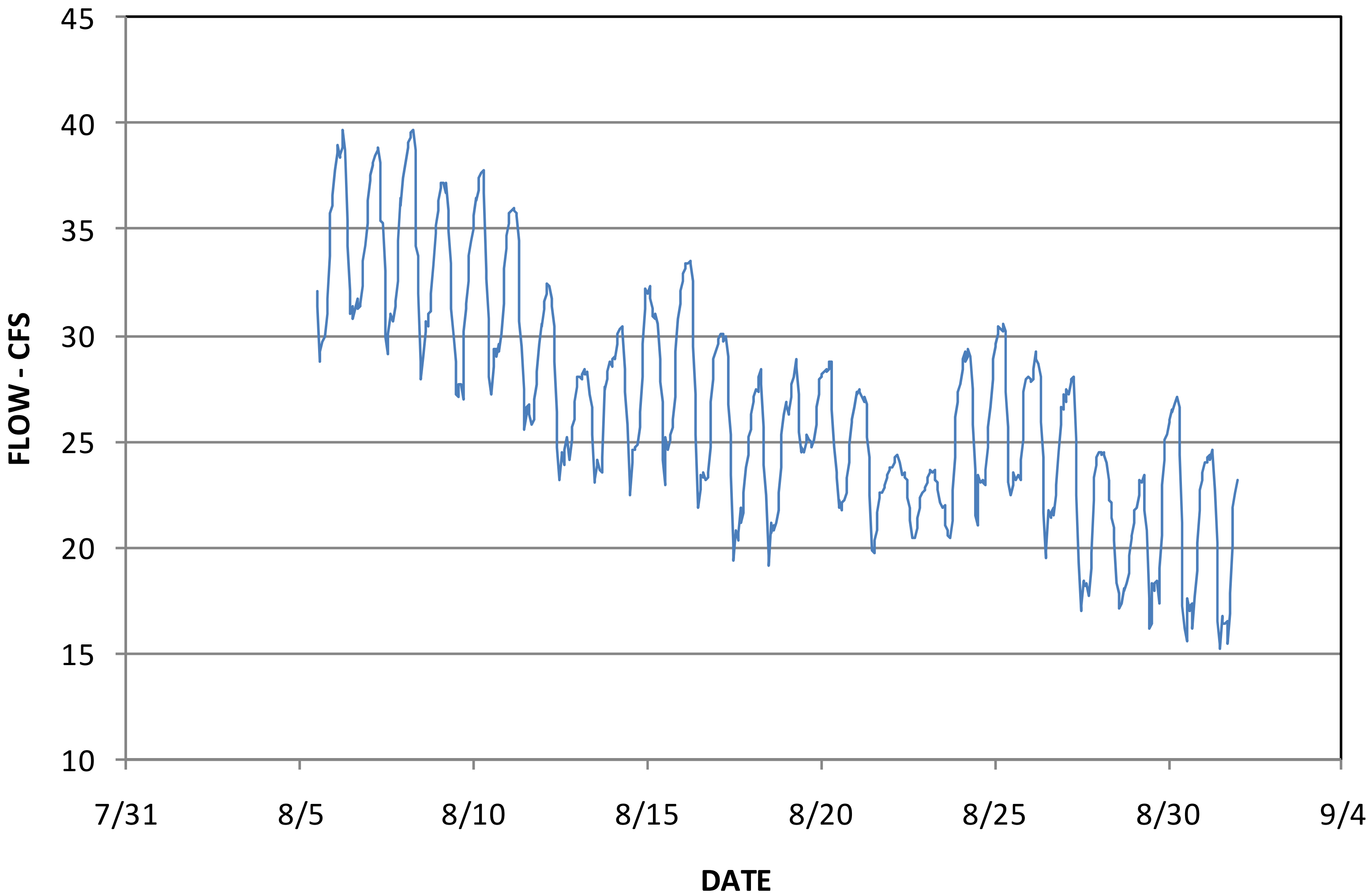
LAKE BEULAH, WISCONSIN
STREAM FLOW - JULY 2008

FIGURE
B-13

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 0708



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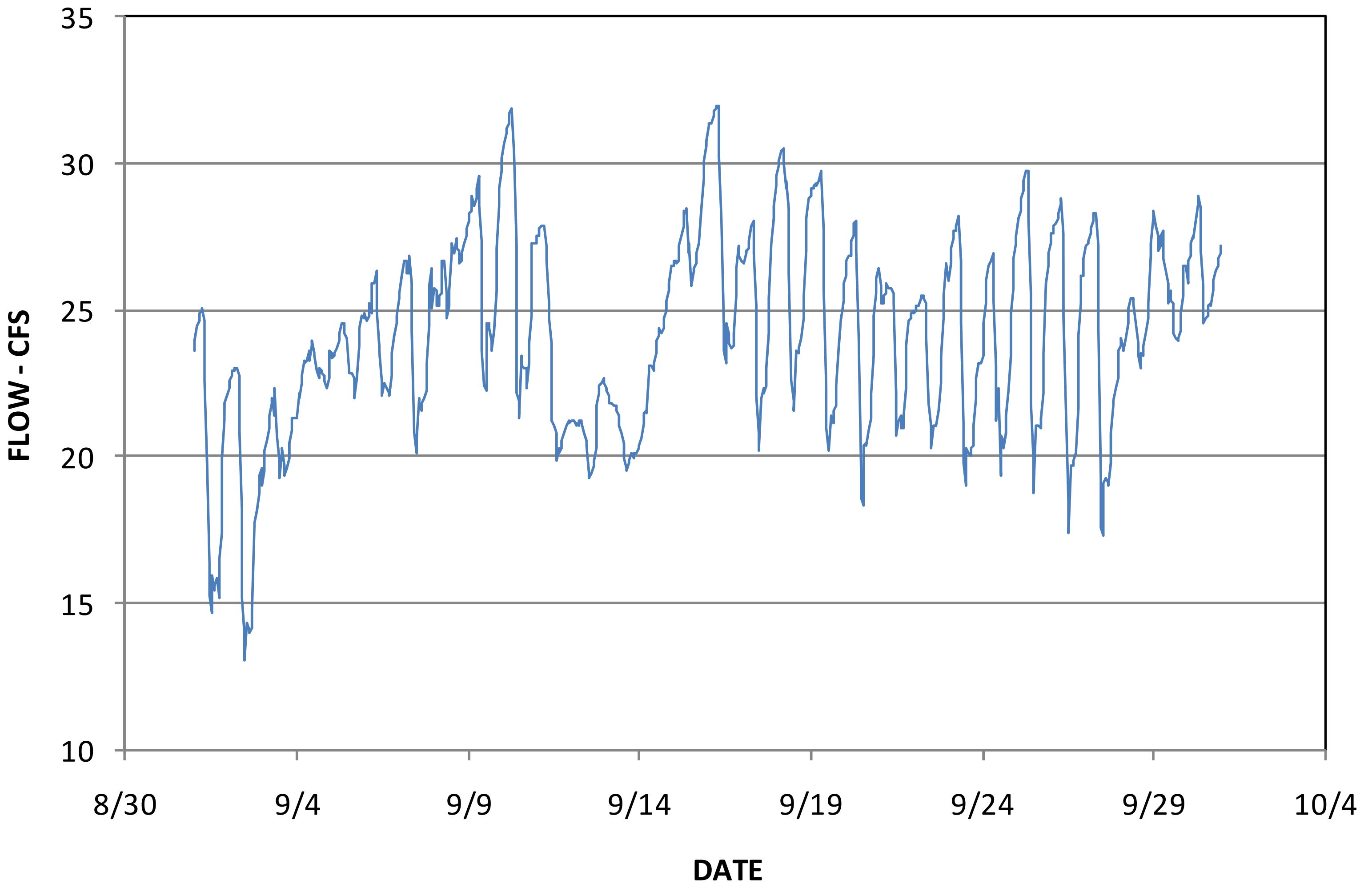
LAKE BEULAH, WISCONSIN
STREAM FLOW - AUGUST 2008

FIGURE B-14

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 0808



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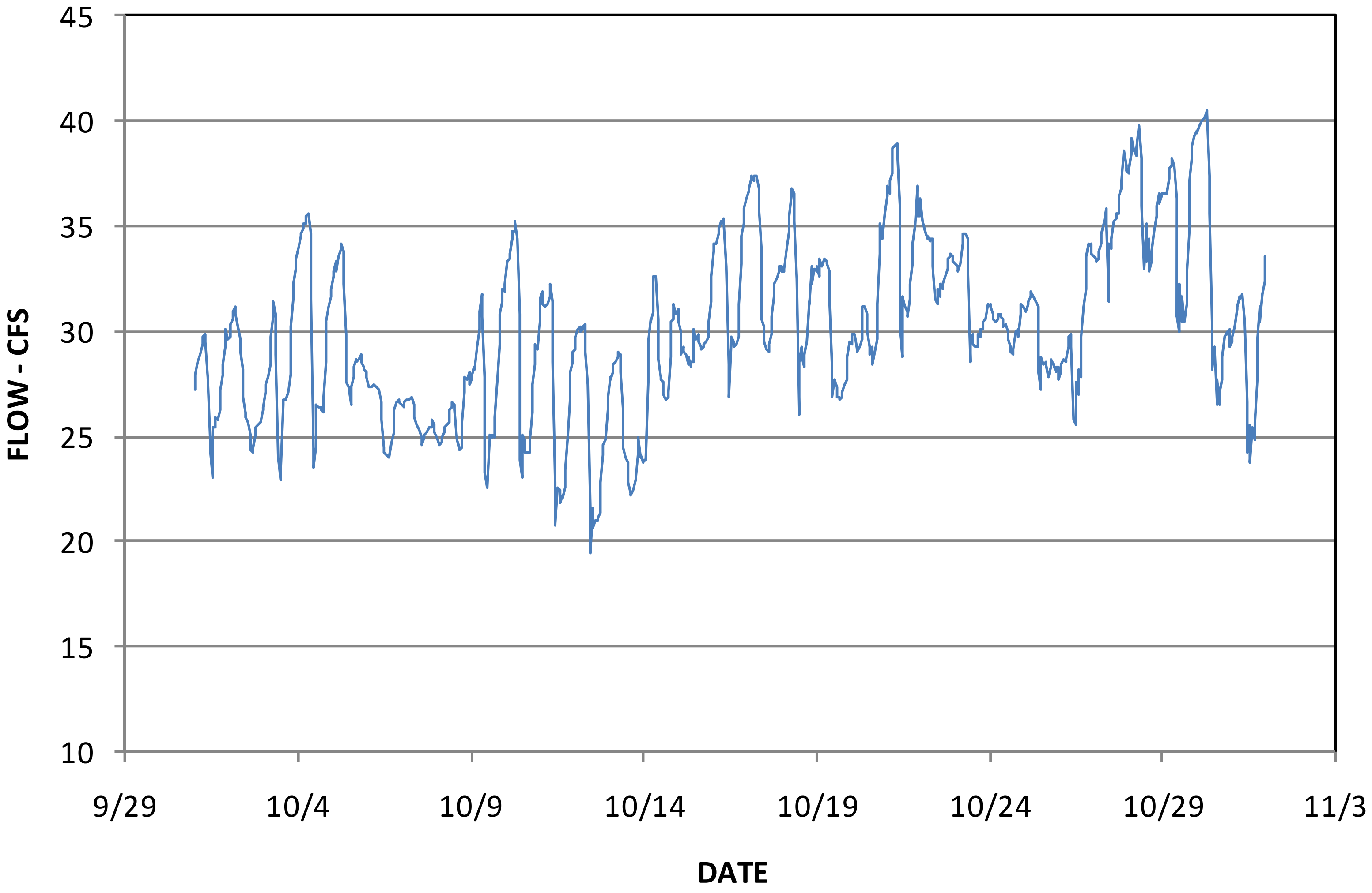
LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
STREAM FLOW - SEPTEMBER 2008

FIGURE
B-15

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 0908



RJN Environmental Services, LLC

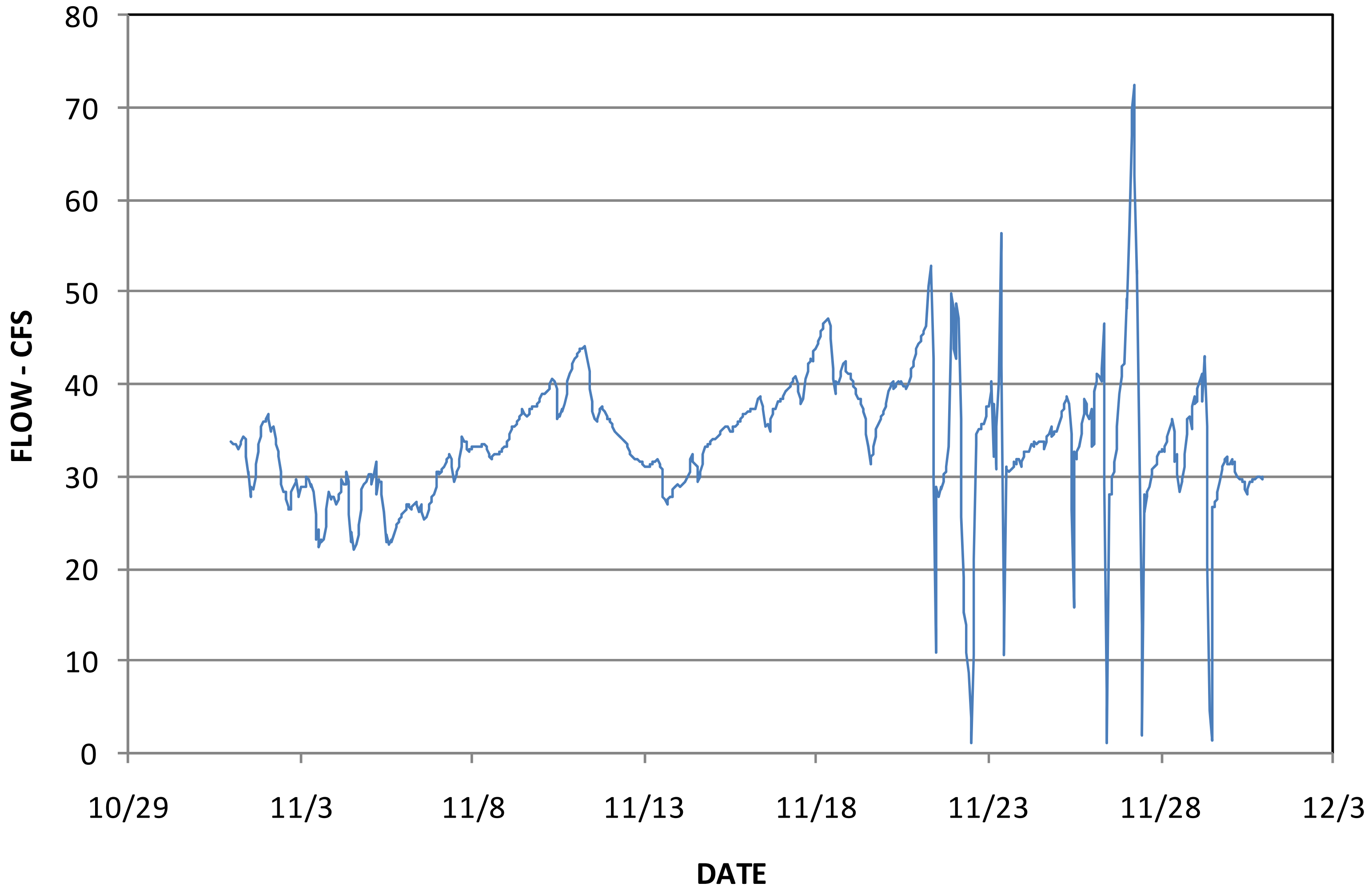
Surface Water Studies
Groundwater Studies
Site Investigations

4631 COUNTY ROAD A OREGON, WISCONSIN 53575 (608) 576-3001

LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
STREAM FLOW - OCTOBER 2008

FIGURE
B-16

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 1008



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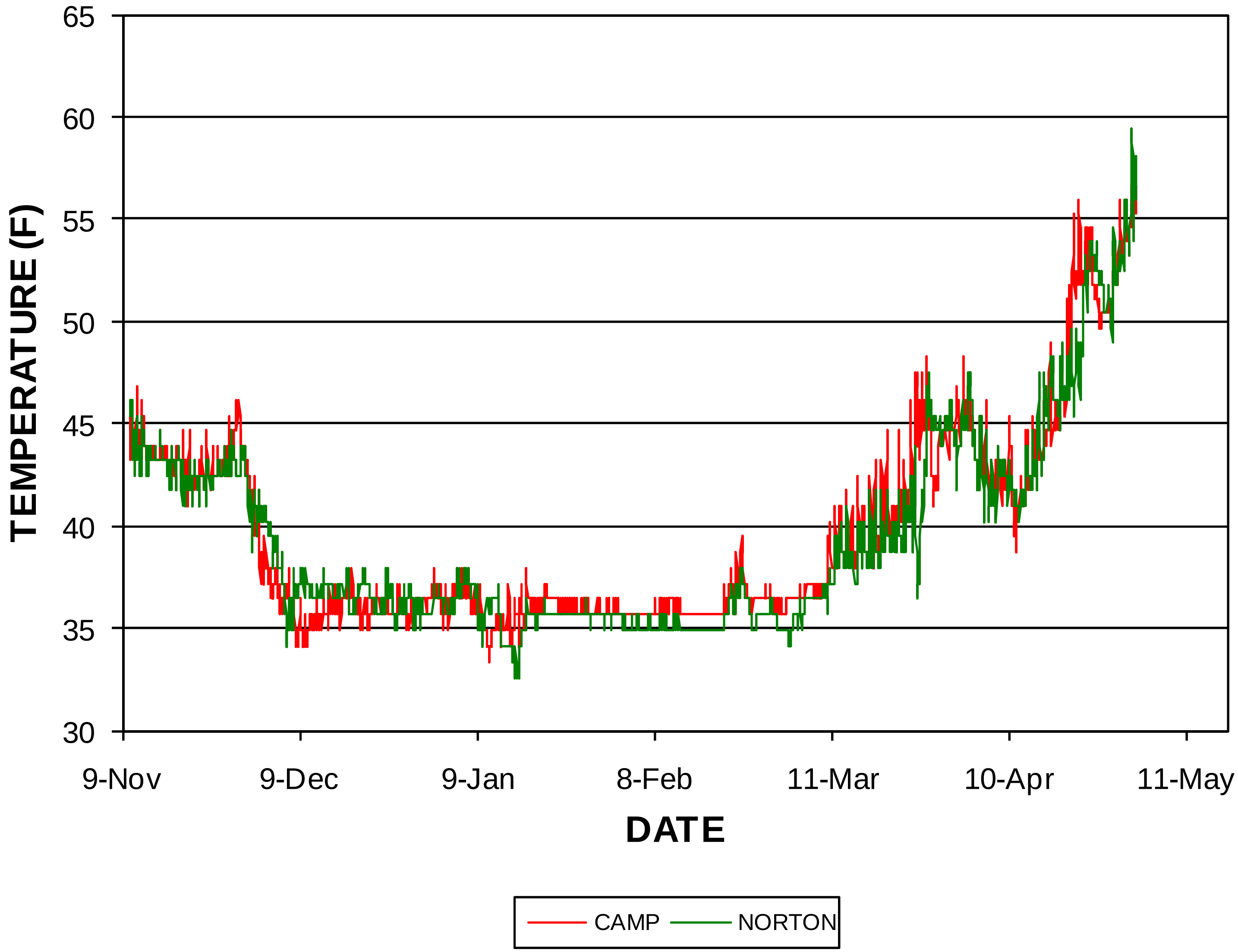
Site Investigations

4631 COUNTY ROAD A OREGON, WISCONSIN 53575 (608) 576-3001

LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
STREAM FLOW - NOVEMBER 2008

FIGURE B-17

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	FLOW 1108



RJN Environmental Services, LLC

Surface Water Studies
Groundwater Studies
Site Investigations

4631 COUNTY ROAD A OREGON, WISCONSIN 53575 (608) 576-3001

LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
LAKE BED TEMPERATURES

FIGURE
B-18

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	4 DEC 10	TEMPERATURES

TABLE B-1
LAKE BEULAH MANAGEMENT DISTRICT
DRIVE POINT WATER LEVELS

DATE	SITE	SITE 1 - DWS		SITE 2 - KOEHLER		SITE 3 - CAMP CA		SITE 4 - BITTER		SITE 5 - NORTON	
	WELL	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP
	ELEVATION	811.71	811.78	811.43	811.39	816.68	816.72	812.61	812.26	812.90	813.14
6/22/2004	DTW	1.47	1.91	1.04	0.93	7.23	7.25	1.84	3.11		2.02
	GWE	810.24	809.87	810.39	810.46	809.45	809.47	810.77	809.15	809.896	811.12
7/1/2004	DTW	1.71	1.77	1.12	1	7.3	5.5	2.91	5.13		1.72
	GWE	810	810.01	810.31	810.39	809.38	811.22	809.7	807.13	809.891	811.42
7/13/2004	DTW	0.9	1.65	1.01	1.02	7.34	7.35	6.5	6.68		2.53
	GWE	810.81	810.13	810.42	810.37	809.34	809.37	806.11	805.58	809.921	810.61
7/15/2004	DTW	1.73	1.67	1.11	1.09	7.47	6.65	1.83	2.42		2.51
	GWE	809.98	810.11	810.32	810.3	809.21	810.07	810.78	809.84	809.898	810.63
7/21/2004	DTW	1.8	1.71	1.25	1.15	7.42	7.45	1.97	5.15		2.62
	GWE	809.91	810.07	810.18	810.24	809.26	809.27	810.64	807.11	809.875	810.52
8/13/2004	DTW	1.78	1.8	1.32	1.1	7.55	7.5	1.77	1.35		2.66
	GWE	809.93	809.98	810.11	810.29	809.13	809.22	810.84	810.91	809.828	810.48
8/18/2004	DTW	1.82	1.84	1.32	1.29	5.52	6.54	2.8	4.25		2.7
	GWE	809.89	809.94	810.11	810.1	811.16	810.18	809.81	808.01	809.935	810.44
8/26/2004	DTW	1.82	1.92	1.4	1.34	7.65	7.61	1.38	2.27		2.74
	GWE	809.89	809.86	810.03	810.05	809.03	809.11	811.23	809.99	809.778	810.4
8/30/2004	DTW	1.17	1.86	1.37	1.25	7.55	7.56	7.26	6.94		2.65
	GWE	810.54	809.92	810.06	810.14	809.13	809.16	805.35	805.32	809.785	810.49
9/14/2004	DTW	1.89	1.43	1.46	1.39	7.65	7.68	1.8	5.3		2.8
	GWE	809.82	810.35	809.97	810	809.03	809.04	810.81	806.96	809.668	810.34
9/27/2004	DTW	2.05	1.75	1.57	1.51	7.66	7.65	7.7	6.88		2.88
	GWE	809.66	810.03	809.86	809.88	809.02	809.07	804.91	805.38	809.611	810.26
10/11/2004	DTW	1.94	2.13	1.57	1.5	7.72	7.76	7.95	7.52	No data	2.88
	GWE	809.77	809.65	809.86	809.89	808.96	808.96	804.66	804.74		810.26
10/25/2004	DTW	2	2.24	1.5	1.44	7.68	7.7	7.46	7.88	No data	2.84
	GWE	809.71	809.54	809.93	809.95	809	809.02	805.15	804.38		810.3
11/3/2004	DTW	2.03	2.2	1.5	1.35	7.65	7.67	7.83	7.42	No data	2.85
	GWE	809.68	809.58	809.93	810.04	809.03	809.05	804.78	804.84		810.29
11/22/2004	DTW	2.03	2.24	1.5	1.43	7.68	7.7	7.9	7.49	No data	2.88
	GWE	809.68	809.54	809.93	809.96	809	809.02	804.71	804.77		810.26
5/5/2005	DTW	2.06	2.13	1.41	1.35	7.62	7.65	6.91	7.23	No data	2.75
	GWE	809.65	809.65	810.02	810.04	809.06	809.07	805.7	805.03		810.39

ELEVATION: Well top elevation (feet, MSL).
DTW: Depth from top of well to water (feet).
GWE: Groundwater elevation (feet, MSL).

TABLE B-1
LAKE BEULAH MANAGEMENT DISTRICT
DRIVE POINT WATER LEVELS

DATE	SITE	SITE 1 - DWS		SITE 2 - KOEHLER		SITE 3 - CAMP CA		SITE 4 - BITTER		SITE 5 - NORTON	
	WELL	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP
	ELEVATION	811.71	811.78	811.43	811.39	816.68	816.72	812.61	812.26	812.90	813.14
5/10/2005	DTW	2.1	2.19	1.4	1.36	7.62	7.65	7.3	7.43	No data	2.99
	GWE	809.61	809.59	810.03	810.03	809.06	809.07	805.31	804.83		810.15
6/12/2005	DTW	2.25	2.25	1.6	1.5	7.75	7.79	7.7	7.3	No data	2.97
	GWE	809.46	809.53	809.83	809.89	808.93	808.93	804.91	804.96		810.17
7/27/2005	DTW	2.42	2.47	1.67	1.57	7.81	7.85	7.96	7.52		3.22
	GWE	809.29	809.31	809.76	809.82	808.87	808.87	804.65	804.74	809.837	809.92
8/2/2005	DTW	2.45	2.52	1.75	1.68	7.89	7.92	8.19	7.73		3.33
	GWE	809.26	809.26	809.68	809.71	808.79	808.8	804.42	804.53	809.724	809.81
8/5/2005	DTW	2.42	2.43	1.76	1.62	7.87	7.87	8.18	7.68		3.32
	GWE	809.29	809.35	809.67	809.77	808.81	808.85	804.43	804.58	809.698	809.82
8/31/2005	DTW	2.52	2.58	1.8	1.72	7.94	7.97	7.92			3.38
	GWE	809.19	809.2	809.63	809.67	808.74	808.75	804.69	812.26	809.757	809.76
9/2/2005	DTW	2.45	2.49	1.79	1.73	7.96	7.92	No data	7.81		3.39
	GWE	809.26	809.29	809.64	809.66	808.72	808.8		804.45	809.72	809.75
9/6/2005	DTW	2.55	2.63	1.8	1.75	8	8	No data	No data		3.4
	GWE	809.16	809.15	809.63	809.64	808.68	808.72			809.681	809.74
9/30/2005	DTW	2.53	2.6	1.66	1.58	7.8	7.83	7.79	No data		3.29
	GWE	809.18	809.18	809.77	809.81	808.88	808.89	804.82		809.847	809.85
10/9/2005	DTW	2.51	2.57	1.73	1.66	7.89	7.92	8.15	No data		3.38
	GWE	809.2	809.21	809.7	809.73	808.79	808.8	804.46		809.757	809.76
10/14/2005	DTW	2.54	2.6	1.77	1.69	7.91	7.95	8.27	7.85		3.4
	GWE	809.17	809.18	809.66	809.7	808.77	808.77	804.34	804.41	809.732	809.74
10/20/2005	DTW	2.55	2.62	1.79	1.71	7.94	7.96	8.31	7.65		3.41
	GWE	809.16	809.16	809.64	809.68	808.74	808.76	804.3	804.61	809.716	809.73
11/4/2005	DTW	2.57	2.6	1.8	1.73	7.94	7.97	No data	No data		3.41
	GWE	809.14	809.18	809.63	809.66	808.74	808.75			809.712	809.73
11/10/2005	DTW	2.55	2.6	1.73	1.65	7.86	7.89	No data	7.73		3.35
	GWE	809.16	809.18	809.7	809.74	808.82	808.83		804.53	809.767	809.79
5/25/2006	DTW	2.05	2.11	1.53	1.19	6.46	7.50	No data	6.91	No data	2.92
	GWE	809.66	809.67	809.9	810.2	810.22	809.22		805.35		810.22
6/1/2006	DTW	2.05	2.10	1.50	1.16	6.46	7.45	No data	6.51	No data	2.93
	GWE	809.66	809.68	809.93	810.23	810.22	809.27		805.75		810.21
6/8/2006	DTW	2.12	2.10	1.34	1.24	7.57	7.57	No data	6.68	No data	3.00
	GWE	809.59	809.68	810.09	810.15	809.11	809.15		805.58		810.14
6/16/2006	DTW	2.32	2.13	1.40	1.32	7.62	7.63	No data	6.82	No data	3.02
	GWE	809.39	809.65	810.03	810.07	809.06	809.09		805.44		810.12
7/31/2006	DTW	2.35	2.30	1.55	1.55	7.80	7.90	7.50	7.20	No data	3.15
	GWE	809.36	809.48	809.88	809.84	808.88	808.82	805.11	805.06		809.99
8/15/2006	DTW	2.21	2.21	1.61	1.51	7.71	7.76	7.75	7.14	2.98	3.16
	GWE	809.5	809.57	809.82	809.88	808.97	808.96	804.86	805.12	809.92	809.98
8/23/2006	DTW	2.31	2.32	No data	1.61	No data	7.85	7.82	6.32	3.12	3.20
	GWE	809.4	809.46		809.78		808.87	804.79	805.94	809.78	809.94

ELEVATION: Well top elevation (feet, MSL).
DTW: Depth from top of well to water (feet).
GWE: Groundwater elevation (feet, MSL).

TABLE B-1
LAKE BEULAH MANAGEMENT DISTRICT
DRIVE POINT WATER LEVELS

DATE	SITE	SITE 1 - DWS		SITE 2 - KOEHLER		SITE 3 - CAMP CA		SITE 4 - BITTER		SITE 5 - NORTON	
	WELL	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP
	ELEVATION	811.71	811.78	811.43	811.39	816.68	816.72	812.61	812.26	812.90	813.14
9/7/2006	DTW	2.20	2.20	1.48	1.40	7.65	7.68	7.64	7.25	2.90	3.02
	GWE	809.51	809.58	809.95	809.99	809.03	809.04	804.97	805.01	810	810.12
9/10/2006	DTW	2.19	2.07	1.50	1.42	7.69	7.70	No data	7.20	2.90	3.05
	GWE	809.52	809.71	809.93	809.97	808.99	809.02		805.06	810	810.09
9/22/2006	DTW	2.18	2.20	1.50	1.40	7.63	7.66	No data	7.18	No data	3.00
	GWE	809.53	809.58	809.93	809.99	809.05	809.06		805.08		810.14
5/10/2007	DTW	1.69	1.72	1.11	1.00	7.31	7.30	No data	6.05	2.45	2.56
	GWE	810.02	810.06	810.32	810.39	809.37	809.42		806.21	810.45	810.58
5/17/2007	DTW	1.67	1.72	1.13	1.00	7.25	7.43	6.31	5.90	2.45	2.56
	GWE	810.04	810.06	810.3	810.39	809.43	809.29	806.3	806.36	810.45	810.58
5/25/2007	DTW	1.72	1.72	1.22	1.06	7.39	7.50	6.29	6.05	2.51	2.61
	GWE	809.99	810.06	810.21	810.33	809.29	809.22	806.32	806.21	810.39	810.53
5/31/2007	DTW	1.75	1.80	1.31	1.10	7.40	7.42	No data	6.25	2.50	2.62
	GWE	809.96	809.98	810.12	810.29	809.28	809.3		806.01	810.4	810.52
6/8/2007	DTW	1.74	1.77	1.30	0.99	7.16	7.26	No data	6.18	2.40	2.53
	GWE	809.97	810.01	810.13	810.4	809.52	809.46		806.08	810.5	810.61
6/15/2007	DTW	1.75	1.79	1.50	1.10	7.39	7.41	6.55	6.16	2.50	2.60
	GWE	809.96	809.99	809.93	810.29	809.29	809.31	806.06	806.1	810.4	810.54
7/9/2007	DTW	1.87	1.91	1.33	1.20	7.48	7.52	7.00	6.00	2.59	2.71
	GWE	809.84	809.87	810.1	810.19	809.2	809.2	805.61	806.26	810.31	810.43
7/26/2007	DTW	1.99	2.10	1.35	1.25	7.58	7.57	7.11	6.62	2.68	2.73
	GWE	809.72	809.68	810.08	810.14	809.1	809.15	805.5	805.64	810.22	810.41
8/4/2007	DTW	1.95	1.99	2.07	2.00	7.46	7.60	No data	6.64	2.52	2.65
	GWE	809.76	809.79	809.36	809.39	809.22	809.12		805.62	810.38	810.49
8/9/2007	DTW	1.91	1.95	1.24	1.14	7.34	7.48	No data	6.61	2.51	2.63
	GWE	809.8	809.83	810.19	810.25	809.34	809.24		805.65	810.39	810.51
8/13/2007	DTW	1.91	1.94	1.25	1.15	7.40	7.48	7.13	6.73	2.57	2.69
	GWE	809.8	809.84	810.18	810.24	809.28	809.24	805.48	805.53	810.33	810.45
9/2/2007	DTW	1.55	1.60	0.94	0.86	7.13	7.16	6.05	5.83	2.21	2.32
	GWE	810.16	810.18	810.49	810.53	809.55	809.56	806.56	806.43	810.69	810.82
9/7/2007	DTW	1.55	1.55	1.75	0.95	7.25	7.25	6.22	5.89	2.20	2.35
	GWE	810.16	810.23	809.68	810.44	809.43	809.47	806.39	806.37	810.7	810.79
9/17/2007	DTW	1.64	1.65	1.15	1.02	7.35	7.33	6.53	5.94	2.07	2.40
	GWE	810.07	810.13	810.28	810.37	809.33	809.39	806.08	806.32	810.83	810.74
9/28/2007	DTW	1.66	1.71	1.20	1.08	7.35	7.38	6.72	6.01	2.33	2.45
	GWE	810.05	810.07	810.23	810.31	809.33	809.34	805.89	806.25	810.57	810.69
10/7/2007	DTW	1.70	1.74	1.20	1.10	7.30	7.39	No data	No data	No data	2.46
	GWE	810.01	810.04	810.23	810.29	809.38	809.33				810.68

ELEVATION: Well top elevation (feet, MSL).
DTW: Depth from top of well to water (feet).
GWE: Groundwater elevation (feet, MSL).

TABLE B-1
LAKE BEULAH MANAGEMENT DISTRICT
DRIVE POINT WATER LEVELS

DATE	SITE	SITE 1 - DWS		SITE 2 - KOEHLER		SITE 3 - CAMP CA		SITE 4 - BITTER		SITE 5 - NORTON	
	WELL	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP
	ELEVATION	811.71	811.78	811.43	811.39	816.68	816.72	812.61	812.26	812.90	813.14
10/11/2007	DTW	1.74	1.72	1.23	1.13	7.35	7.45	6.88	6.56	2.38	2.50
	GWE	809.97	810.06	810.2	810.26	809.33	809.27	805.73	805.7	810.52	810.64
10/18/2007	DTW	1.70	1.72	1.15	1.01	7.27	7.34	6.89	6.64	2.20	2.34
	GWE	810.01	810.06	810.28	810.38	809.41	809.38	805.72	805.62	810.7	810.8
10/23/2007	DTW	1.70	1.72	1.15	1.02	7.27	7.35	6.76	6.44	2.28	2.43
	GWE	810.01	810.06	810.28	810.37	809.41	809.37	805.85	805.82	810.62	810.71
10/29/2007	DTW	1.72	1.75	1.26	1.01	7.36	7.40	6.90	6.35	2.37	2.50
	GWE	809.99	810.03	810.17	810.38	809.32	809.32	805.71	805.91	810.53	810.64
11/15/2007	DTW	1.70	1.74	1.24	1.00	7.34	7.35	6.80	6.30	2.30	2.50
	GWE	810.01	810.04	810.19	810.39	809.34	809.37	805.81	805.96	810.6	810.64
11/23/2007	DTW	1.82	1.85	1.40	1.16	7.43	7.46	7.10	6.95	2.46	2.59
	GWE	809.89	809.93	810.03	810.23	809.25	809.26	805.51	805.31	810.44	810.55
5/1/2008	DTW	1.34	1.36	1.17	0.74	7.02	7.05	5.61	5.28	2.08	2.15
	GWE	810.37	810.42	810.26	810.65				806.98	810.82	810.99
5/9/2008	DTW	1.38	1.40	1.13	0.80	7.08	7.14	5.43	5.35	2.13	2.27
	GWE	810.33	810.38	810.3	810.59				806.91	810.77	810.87
5/17/2008	DTW	1.42	1.45	1.15	0.85	3.78	3.89	5.45	5.31	2.17	2.25
	GWE	810.29	810.33	810.28	810.54				806.95	810.73	810.89
5/24/2008	DTW	1.45	1.47	1.20	0.90	3.80	3.80	5.60	5.50	2.25	2.31
	GWE	810.26	810.31	810.23	810.49				806.76	810.65	810.83
6/4/2008	DTW	1.51	1.53	1.14	0.88	3.80	3.70	5.79	5.70	2.22	2.89
	GWE	810.2	810.25	810.29	810.51				806.56	810.68	810.25
6/14/2008	DTW	1.15	1.35	0.80	0.50	3.30	3.15	4.10	4.25	1.70	1.80
	GWE	810.56	810.43	810.63	810.89				808.01	811.2	811.34
7/7/2008	DTW	1.20	1.25	1.05	0.07	3.65	3.40	5.25	4.85	2.00	2.10
	GWE	810.51	810.53	810.38	811.32				807.41	810.9	811.04
7/16/2008	DTW	1.10	1.19	1.00	0.05	3.50	3.28	4.95	5.05	1.85	1.92
	GWE	810.61	810.59	810.43	811.34				807.21	811.05	811.22
7/25/2008	DTW	1.22	1.22	1.07		3.60	3.45	5.33	5.10	2.00	2.07
	GWE	810.49	810.56	810.36	811.39				807.16	810.9	811.07
7/29/2008	DTW	1.26	1.24	1.08	0.80	3.72	3.49	5.45	5.10	2.10	2.04
	GWE	810.45	810.54	810.35	810.59				807.16	810.8	811.1
8/5/2008	DTW	1.30	1.31	1.20	0.88	3.70	3.57	5.47	5.65	2.04	2.10
	GWE	810.41	810.47	810.23	810.51				806.61	810.86	811.04
8/7/2008	DTW	1.34	1.38	1.12	0.87	3.79	3.63	5.63	5.72	2.15	2.21
	GWE	810.37	810.4	810.31	810.52				806.54	810.75	810.93
8/15/2008	DTW	1.36	1.40	1.16	0.91	3.82	3.66	5.75	5.65	2.20	2.29
	GWE	810.35	810.38	810.27	810.48				806.61	810.7	810.85

ELEVATION: Well top elevation (feet, MSL).
DTW: Depth from top of well to water (feet).
GWE: Groundwater elevation (feet, MSL).

TABLE B-1
LAKE BEULAH MANAGEMENT DISTRICT
DRIVE POINT WATER LEVELS

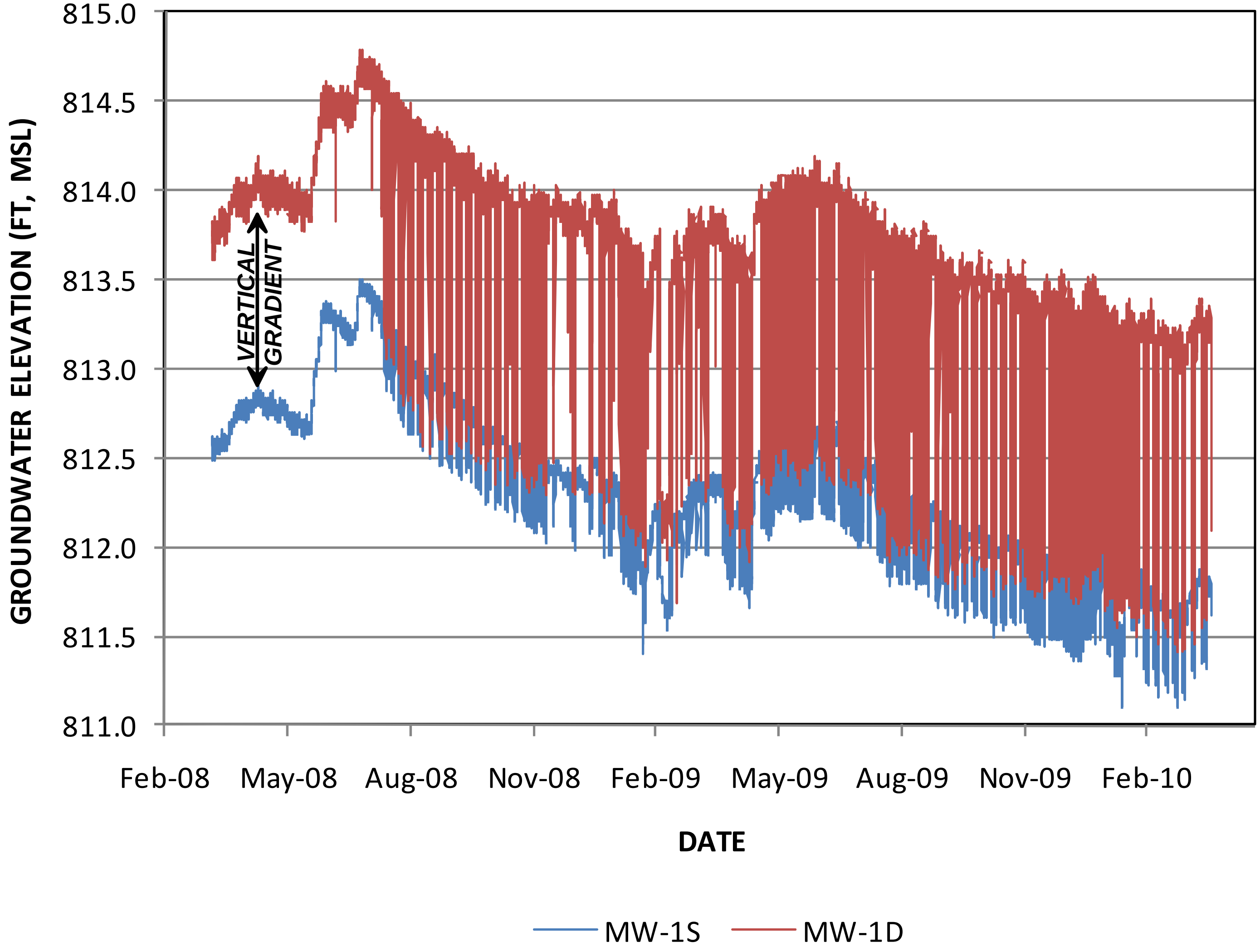
DATE	SITE	SITE 1 - DWS		SITE 2 - KOEHLER		SITE 3 - CAMP CA		SITE 4 - BITTER		SITE 5 - NORTON	
	WELL	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP
	ELEVATION	811.71	811.78	811.43	811.39	816.68	816.72	812.61	812.26	812.90	813.14
8/18/2008	DTW	1.37	1.42	1.20	0.94	3.82	3.65	5.85	6.00	2.22	2.30
	GWE	810.34	810.36	810.23	810.45				806.26	810.68	810.84
9/2/2008	DTW	1.49	1.53	1.38	1.03	3.98	3.73	6.31	6.10	2.34	2.40
	GWE	810.22	810.25	810.05	810.36				806.16	810.56	810.74
9/9/2008	DTW	1.50	1.50	1.35	0.95	3.83	3.70	6.10	6.01	2.25	2.35
	GWE	810.21	810.28	810.08	810.44				806.25	810.65	810.79
10/3/2008	DTW	1.54	1.60	1.29	1.04	3.93	3.78	6.37	6.19	2.38	2.46
	GWE	810.17	810.18	810.14	810.35				806.07	810.52	810.68
10/7/2008	DTW	1.50	1.62	1.35	1.04	3.93	3.78	6.40	6.16	2.35	2.45
	GWE	810.21	810.16	810.08	810.35				806.1	810.55	810.69
10/16/2008	DTW	1.55	1.64	1.27	1.12	3.93	3.84	6.47	6.40	2.41	2.53
	GWE	810.16	810.14	810.16	810.27				805.86	810.49	810.61
10/23/2008	DTW	1.60	1.69	1.37	1.07	3.91	3.81	6.55	6.67	2.43	2.51
	GWE	810.11	810.09	810.06	810.32				805.59	810.47	810.63
10/31/2008	DTW	1.60	1.62	1.40	1.10	3.95	3.85	6.50	6.60	2.50	2.45
	GWE	810.11	810.16	810.03	810.29				805.66	810.4	810.69
11/3/2008	DTW	1.63	1.70	1.36	1.08	3.92	3.82	6.70	6.76	2.43	2.53
	GWE	810.08	810.08	810.07	810.31				805.5	810.47	810.61
11/11/2008	DTW	1.68	1.75	1.42	1.10	3.94	2.85	6.78	6.55	2.50	2.55
	GWE	810.03	810.03	810.01	810.29				805.71	810.4	810.59
11/19/2008	DTW	1.70	1.74	1.37	1.09	3.96	3.83	6.86	6.90	2.51	2.59
	GWE	810.01	810.04	810.06	810.3				805.36	810.39	810.55
5/1/2009	DTW	1.49	1.53	1.09	0.63	3.53	3.38	4.93	5.01	2.38	2.34
	GWE	810.22	810.25	810.34	810.76				807.25	810.52	810.8
5/8/2009	DTW	1.40	1.51	1.19	0.65	3.67	3.52	5.10	5.14	2.45	2.40
	GWE	810.31	810.27	810.24	810.74				807.12	810.45	810.74
5/29/2009	DTW	1.38	1.36	1.18	0.64	3.66	3.39	5.33	5.12	2.44	2.40
	GWE	810.33	810.42	810.25	810.75				807.14	810.46	810.74
6/2/2009	DTW	1.40	1.41	2.40	0.74	3.71	3.35	5.50	5.18	5.00	4.40
	GWE	810.31	810.37	809.03	810.65				807.08	807.9	808.74
6/9/2009	DTW	1.43	1.45	1.14	0.75	3.70	3.51	5.42	5.49	2.45	2.40
	GWE	810.28	810.33	810.29	810.64				806.77	810.45	810.74
6/19/2009	DTW	1.44	1.44	1.15	0.75	3.75	3.58	5.50	5.60	2.45	2.40
	GWE								806.66	810.45	810.74
7/1/2009	DTW			1.30	0.63	3.75	3.61	5.63	5.52	2.52	2.46
	GWE			810.13	810.76				806.74	810.38	810.68
7/8/2009	DTW	1.55	1.60	1.00	1.50	3.90	3.60	5.90	6.00	2.70	2.70
	GWE	810.16	810.18	810.43	809.89				806.26	810.2	810.44
7/15/2009	DTW	1.59	1.61	1.55	1.10	3.85	3.76	6.00	6.30	2.69	2.65
	GWE	810.12	810.17	809.88	810.29				805.96	810.21	810.49
7/23/2009	DTW	1.63	1.67	1.52	1.00	4.00	3.79	6.05	6.15	2.64	2.63
	GWE	810.08	810.11	809.91	810.39				806.11	810.26	810.51
8/17/2009	DTW	1.70	1.73	1.55	1.08	3.90	3.80	6.30	6.28	2.69	2.65
	GWE	810.01	810.05	809.88	810.31				805.98	810.21	810.49

ELEVATION: Well top elevation (feet, MSL).
DTW: Depth from top of well to water (feet).
GWE: Groundwater elevation (feet, MSL).

TABLE B-1
LAKE BEULAH MANAGEMENT DISTRICT
DRIVE POINT WATER LEVELS

DATE	SITE	SITE 1 - DWS		SITE 2 - KOEHLER		SITE 3 - CAMP CA		SITE 4 - BITTER		SITE 5 - NORTON	
	WELL	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP
	ELEVATION	811.71	811.78	811.43	811.39	816.68	816.72	812.61	812.26	812.90	813.14
8/28/2009	DTW	1.71	1.74	1.59	1.01	3.93	3.71	6.39	6.30	2.69	2.65
	GWE	810	810.04	809.84	810.38				805.96	810.21	810.49
9/3/2009	DTW	1.73	1.75	2.79	2.75	3.98	3.72	6.40	6.30	1.60	1.06
	GWE	809.98	810.03	808.64	808.64				805.96	811.3	812.08
9/15/2009	DTW	1.77	1.80	1.68	1.15	4.04	3.91	6.74	6.69	2.85	2.81
	GWE	809.94	809.98	809.75	810.24				805.57	810.05	810.33
9/24/2009	DTW	1.80	1.86	1.60	1.15	3.91	4.11	6.59	6.65	2.82	2.79
	GWE	809.91	809.92	809.83	810.24				805.61	810.08	810.35
9/28/2009	DTW	1.80	1.82	1.60	1.11	4.00	3.91	6.72	6.64	2.75	2.75
	GWE	809.91	809.96	809.83	810.28				805.62	810.15	810.39
10/7/2009	DTW	1.90	1.80	1.55	1.15	4.10	3.90	6.80	6.70	1.85	1.80
	GWE	809.81	809.98	809.88	810.24				805.56	811.05	811.34
10/14/2009	DTW	1.79	1.88	1.80	1.17	3.99	3.89	6.85	6.79	2.85	2.82
	GWE	809.92	809.9	809.63	810.22				805.47	810.05	810.32
10/21/2009	DTW	1.85	1.87	1.76	1.21	3.46	3.91	6.94	6.88	2.86	2.89
	GWE	809.86	809.91	809.67	810.18				805.38	810.04	810.25
10/27/2009	DTW	1.82	1.86	1.57	1.06	3.92	3.80	6.65	6.60	2.80	2.75
	GWE	809.89	809.92	809.86	810.33				805.66	810.1	810.39
11/14/2009	DTW	1.81	1.82	1.74	1.95	4.00	3.84	6.80	6.80	2.88	2.86
	GWE	809.9	809.96	809.69	809.44				805.46	810.02	810.28
11/25/2009	DTW	1.87	1.93	1.88	1.14	4.04	3.90	6.90	6.88	2.86	2.83
	GWE	809.84	809.85	809.55	810.25				805.38	810.04	810.31

ELEVATION: Well top elevation (feet, MSL).
DTW: Depth from top of well to water (feet).
GWE: Groundwater elevation (feet, MSL).



RJN Environmental Services, LLC

Surface Water Studies
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Site Investigations

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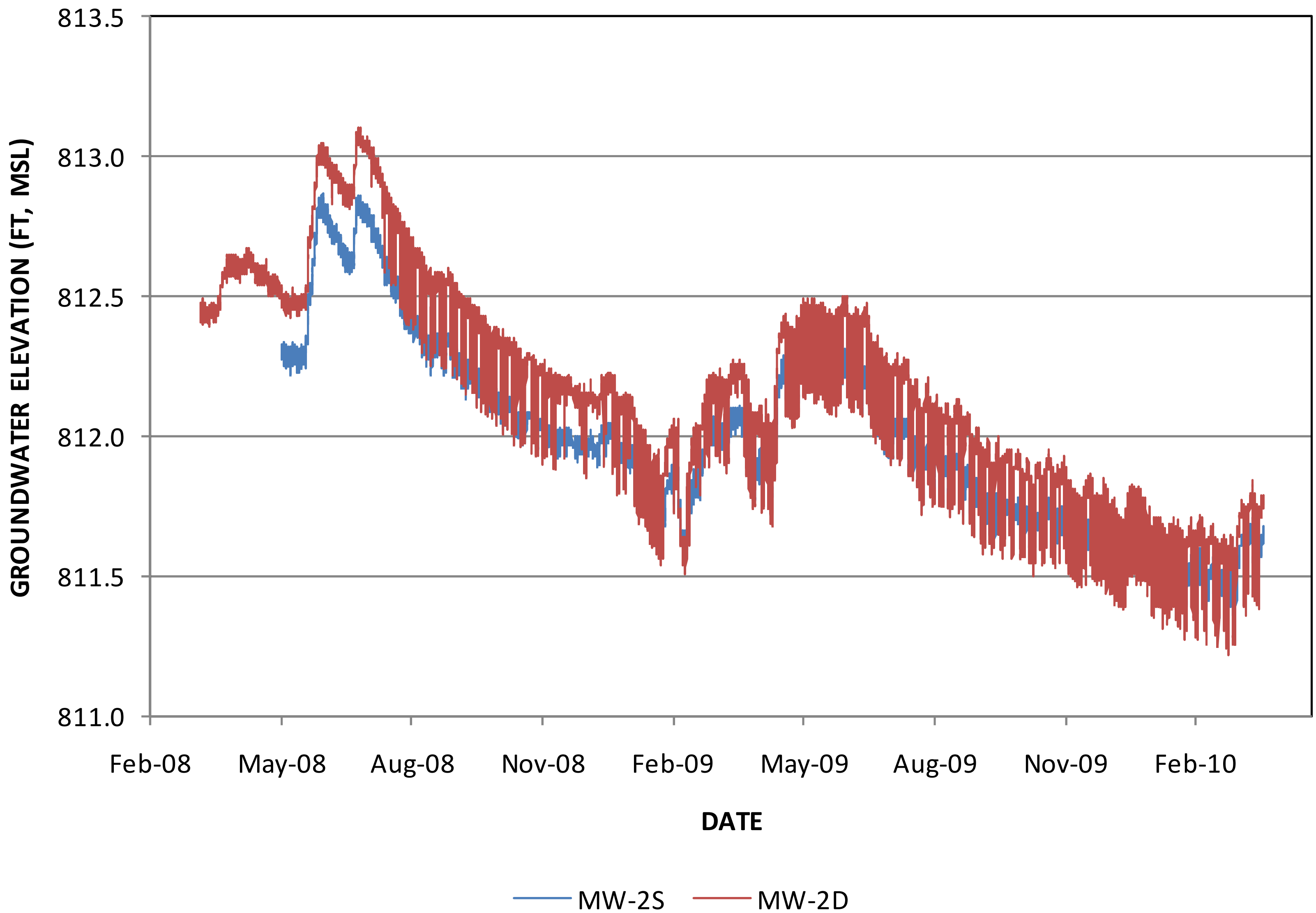
LAKE BEULAH MANAGEMENT DISTRICT
WALWORTH COUNTY, WISCONSIN
GROUNDWATER LEVELS - MW-1 NEST

FIGURE B-19

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-101	14 MAY 10	WELL MW-1



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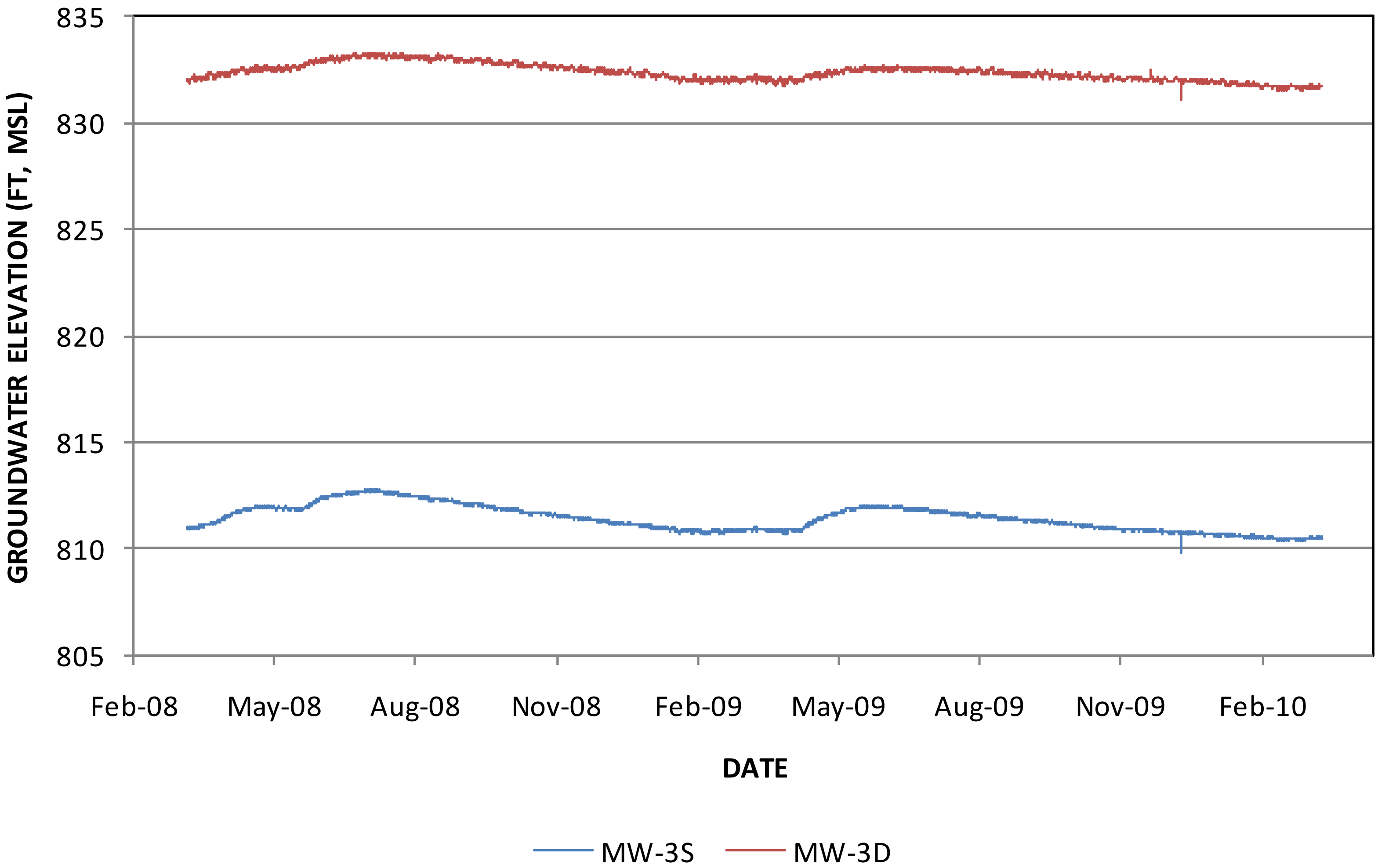
LAKE BEULAH MANAGEMENT DISTRICT
WALWORTH COUNTY, WISCONSIN
GROUNDWATER LEVELS - MW-2 NEST

FIGURE
B-20

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-101	14 MAY 10	WELL MW-2



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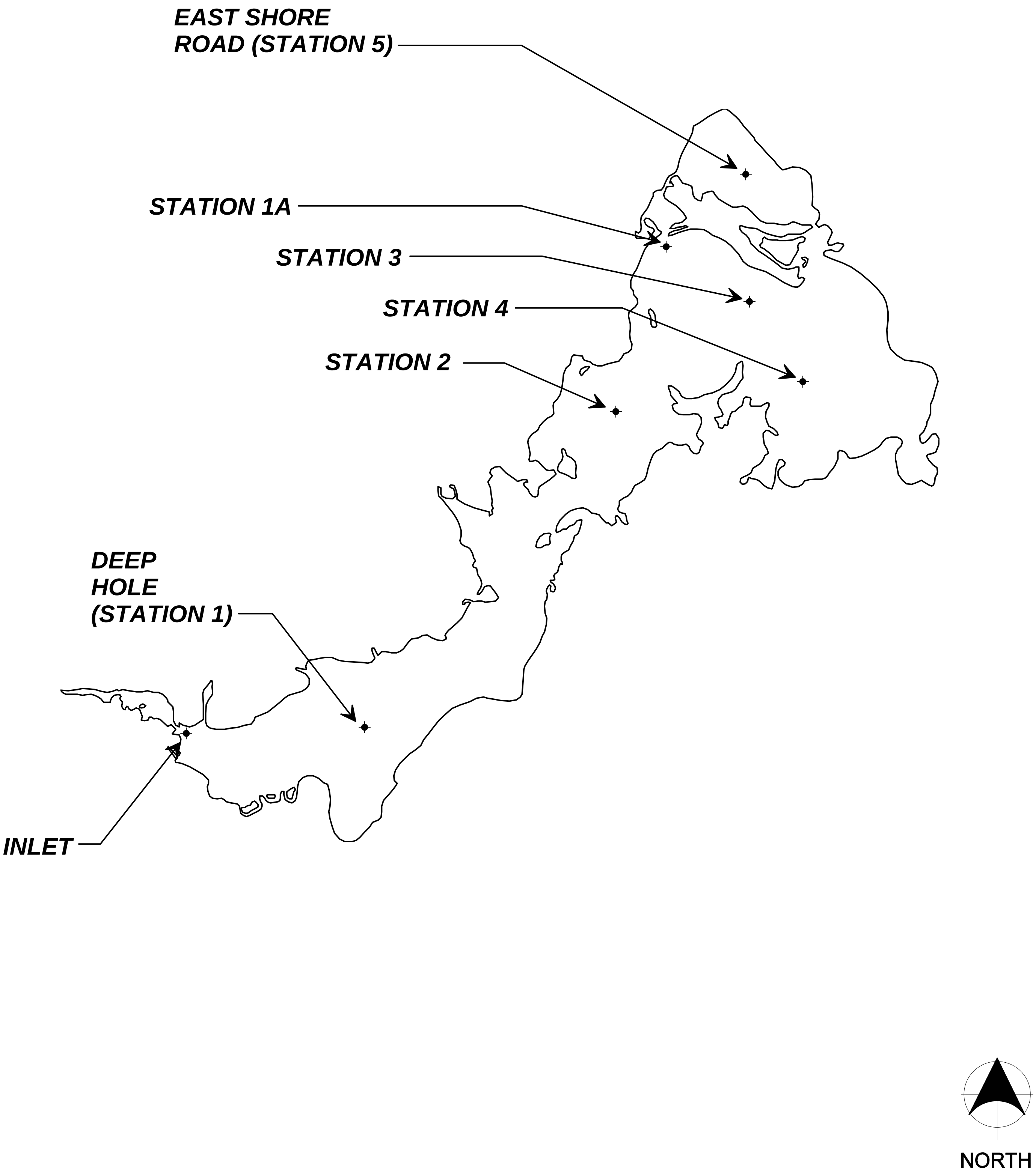
LAKE BEULAH MANAGEMENT DISTRICT
WALWORTH COUNTY, WISCONSIN
GROUNDWATER LEVELS - MW-3 NEST

FIGURE B-21

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-101	14 MAY 10	WELL MW-3

APPENDIX C

USGS WATER QUALITY DATA



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LAKE BEULAH MANAGEMENT DISTRICT
LAKE BEULAH, WISCONSIN
LAKE SAMPLE POINTS

FIGURE 1

DRAWN BY	PROJ. No.	DATE	FILE
RN	09-201	12 MAY 10	SAMP POINTS

424840088241600 Lake Beulah at Deep Hole near East Troy, WI

Water quality data, August 30, 2007

	Date Time	8/30/07 10:32	8/30/07 10:38	8/30/07 10:44	8/30/07 10:47	8/30/07 10:48
00098	Sampling depth m	2	8	14	17	18
00078	Transparency, Secchi m	4.65	--	--	--	--
00300	Dissolved oxygen mg/l	9.4	0.1	0.5	0.1	0.1
00400	pH std units	8.3	7.5	7.4	7.4	7.4
00095	Specific cond at 25C uS/cm @25C	475	553	558	562	574
00010	Temperature, water deg C	23.9	15.8	7	6.3	6.1
00900	Hardness, water mg/l CaCO3	230	260	290	280	280
00915	Calcium, wf mg/l	41	51.6	58.7	57.7	58.3
00925	Magnesium, wf mg/l	31.2	32	33.7	33	32.6
00935	Potassium, wf mg/l	1.4	1.6	1.7	1.7	1.7
00930	Sodium, wf mg/l	8.5	8.6	9.1	8.9	8.8
00417	ANC, wu,fixedEP,lab mg/l CaCO3	193	223	231	235	243
00940	Chloride, wf mg/l	20.4	21.2	21.5	21.5	21.5
00955	Silica, wf mg/l	15.3	10.9	13.2	14.4	17.3
00945	Sulfate, wf mg/l	26.2	28.6	29.2	29	27.1
00625	NH3+orgN, wu mg/l as N	0.42	0.64	0.41	0.69	1.4
00608	Ammonia, wf mg/l as N	0.019	0.259	0.038	0.239	0.817
00631	NO3+NO2, wf mg/l as N	< .019	0.369	0.957	0.6	< .019
00600	Total nitrogen, wu mg/l	--	1	1.4	1.3	--
00671	Orthophosphate, wf mg/l as P	< .002	0.004	0.003	0.003	0.005
00665	Phosphorus, wu mg/l	0.015	0.014	0.014	0.018	0.032
32210	Chlorophyll a, tri,u ug/l	4.05	--	--	--	--
01046	Iron, wf ug/l	<100	<100	<100	<100	<101
01056	Manganese, wf ug/l	< .5	30	50	150	490

424840088241600 **Lake Beulah at Deep Hole near East Troy, WI**

Water quality data, December 3, 2007

	Date Time	12/3/07 10:35
00098	Sampling depth m	0.5
00078	Transparency, Secchi m	5.2
00300	Dissolved oxygen mg/l	14.3
00400	pH std units	8.1
00095	Specific cond at 25C uS/cm @25C	548
00010	Temperature, water deg C	3.4
00900	Hardness, water mg/l CaCO3	280
00915	Calcium, wf mg/l	55.2
00925	Magnesium, wf mg/l	33.6
00935	Potassium, wf mg/l	1.8
00930	Sodium, wf mg/l	9.4
00417	ANC, wu,fixedEP,lab mg/l CaCO3	232
00940	Chloride, wf mg/l	22.1
00955	Silica, wf mg/l	15.7
00945	Sulfate, wf mg/l	28.2
00625	NH3+orgN, wu mg/l as N	0.62
00608	Ammonia, wf mg/l as N	0.189
00631	NO3+NO2, wf mg/l as N	0.285
00600	Total nitrogen, wu mg/l	0.91
00671	Orthophosphate, wf mg/l as P	0.006
00665	Phosphorus, wu mg/l	0.017
32210	Chlorophyll a, tri,u ug/l	1.41
01046	Iron, wf ug/l	<100
01056	Manganese, wf ug/l	< .5

424929088231300 **Lake Beulah, Station 2 near East Troy, WI**

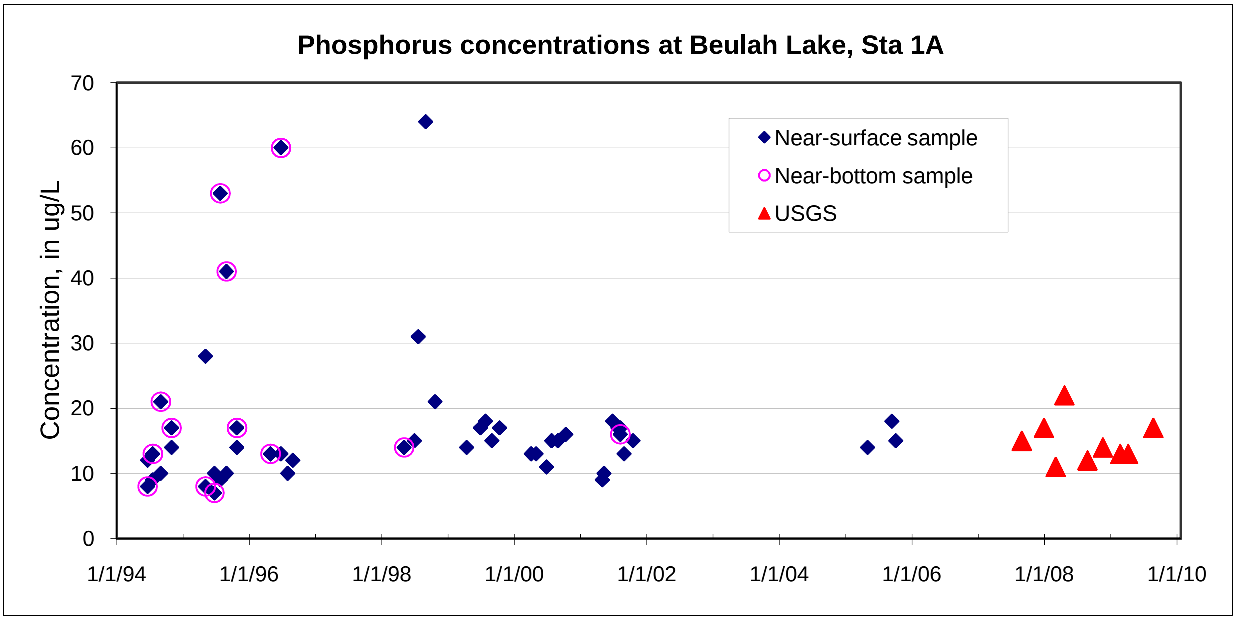
Water quality data, August 30, 2007

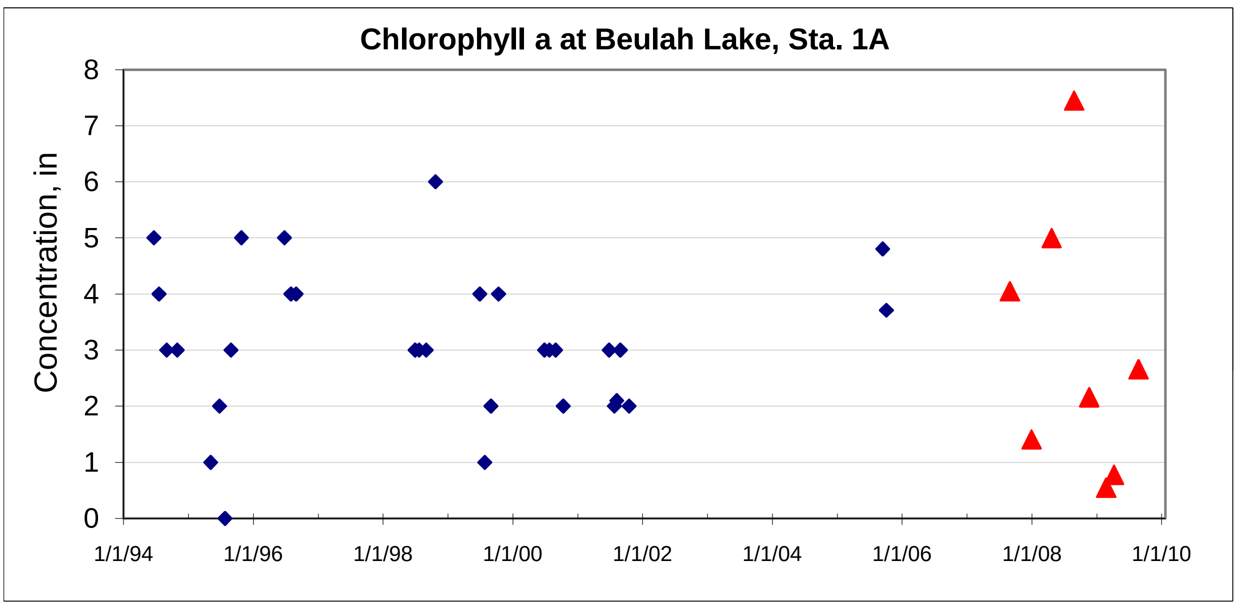
	Date Time	8/30/07 12:52	8/30/07 12:58	8/30/07 13:02	8/30/07 13:04	8/30/07 13:05
00098	Sampling depth m	2	8	12	14	15
00078	Transparency, Secchi m	3.05	--	--	--	--
00300	Dissolved oxygen mg/l	9.7	0.2	1.6	0.1	0.1
00400	pH std units	8.4	7.4	7.4	7.4	7.4
00095	Specific cond at 25C uS/cm @25C	444	493	496	505	509
00010	Temperature, water deg C	24.2	15.6	7.4	6.5	6.3
00900	Hardness, water mg/l CaCO3	220	240	240	240	250
00915	Calcium, wf mg/l	34.4	41.9	43.7	44.7	45.2
00925	Magnesium, wf mg/l	31.7	32.5	31.9	32.2	32.2
00935	Potassium, wf mg/l	1.7	1.8	1.8	1.8	1.8
00930	Sodium, wf mg/l	10.1	10.4	10.1	10.1	10
00417	ANC, wu,fixedEP,lab mg/l CaCO3	171	194	199	202	205
00940	Chloride, wf mg/l	22.9	24.1	23.6	23.9	23.7
00955	Silica, wf mg/l	13	8.15	8.75	11	12.3
00945	Sulfate, wf mg/l	25.3	26.9	26.3	25.7	24.6
00625	NH3+orgN, wu mg/l as N	0.54	0.63	0.67	0.98	1.3
00608	Ammonia, wf mg/l as N	< .015	0.117	0.213	0.429	0.534
00631	NO3+NO2, wf mg/l as N	< .019	< .019	0.133	< .019	< .019
00600	Total nitrogen, wu mg/l	--	--	0.8	--	--
00671	Orthophosphate, wf mg/l as P	0.006	0.006	0.007	0.007	0.006
00665	Phosphorus, wu mg/l	0.013	0.013	0.012	0.022	0.027
32210	Chlorophyll a, tri,u ug/l	4.87	--	--	--	--
01046	Iron, wf ug/l	<100	<100	<100	<100	<101
01056	Manganese, wf ug/l	< .5	20	20	170	250

424934088220400 **Lake Beulah near East Shore Road at East Troy, WI**

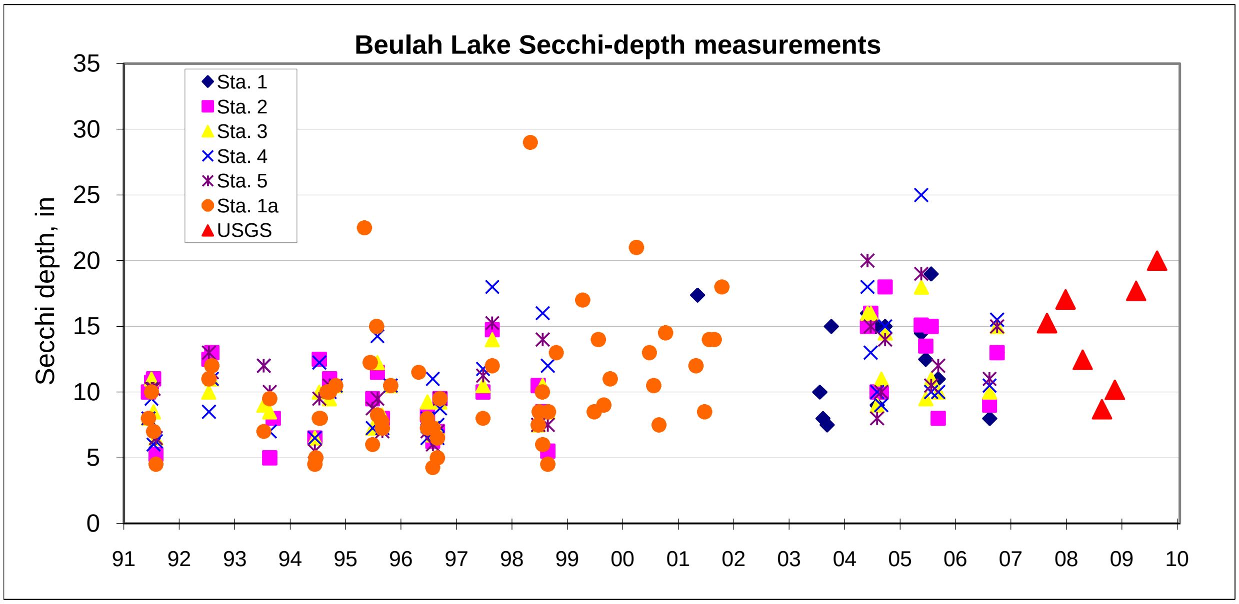
Water quality data, December 3, 2007

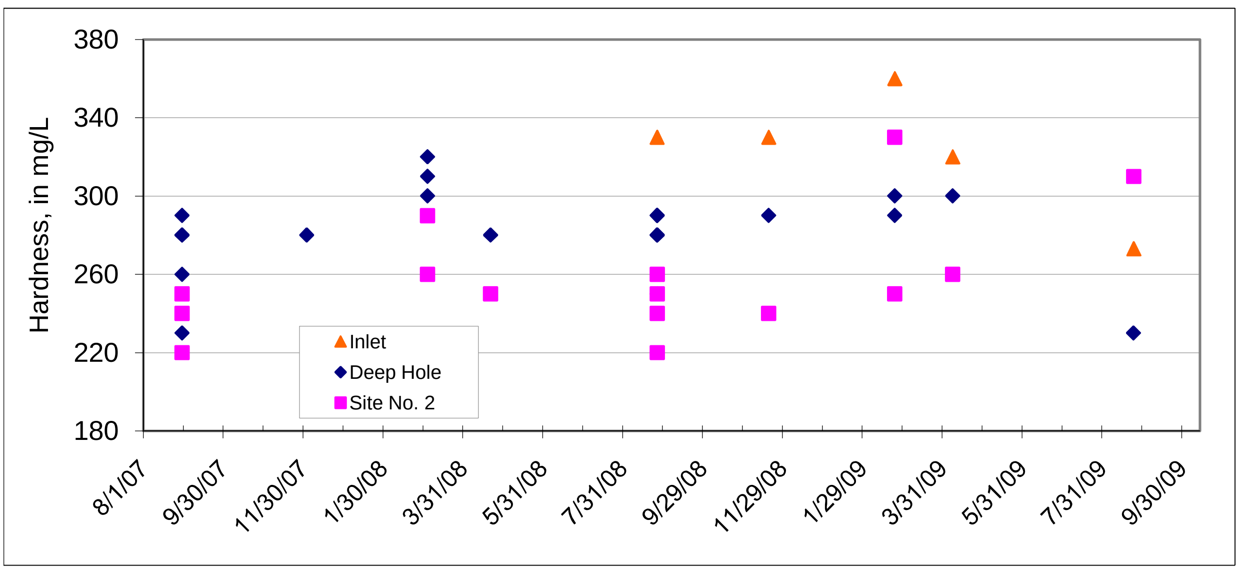
	Date Time	12/3/07 12:20
00098	Sampling depth m	0.5
00078	Transparency, Secchi m	--
00300	Dissolved oxygen mg/l	8.2
00400	pH std units	8.2
00095	Specific cond at 25C uS/cm @25C	514
00010	Temperature, water deg C	0.6
00900	Hardness, water mg/l CaCO3	220
00915	Calcium, wf mg/l	39.2
00925	Magnesium, wf mg/l	30.8
00935	Potassium, wf mg/l	1.8
00930	Sodium, wf mg/l	13.2
00417	ANC, wu,fixedEP,lab mg/l CaCO3	192
00940	Chloride, wf mg/l	31.6
00955	Silica, wf mg/l	15.2
00945	Sulfate, wf mg/l	25.9
00625	NH3+orgN, wu mg/l as N	0.79
00608	Ammonia, wf mg/l as N	0.277
00631	NO3+NO2, wf mg/l as N	0.039
00600	Total nitrogen, wu mg/l	0.83
00671	Orthophosphate, wf mg/l as P	0.005
00665	Phosphorus, wu mg/l	0.017
32210	Chlorophyll a, tri,u ug/l	0.98
01046	Iron, wf ug/l	<101
01056	Manganese, wf ug/l	M



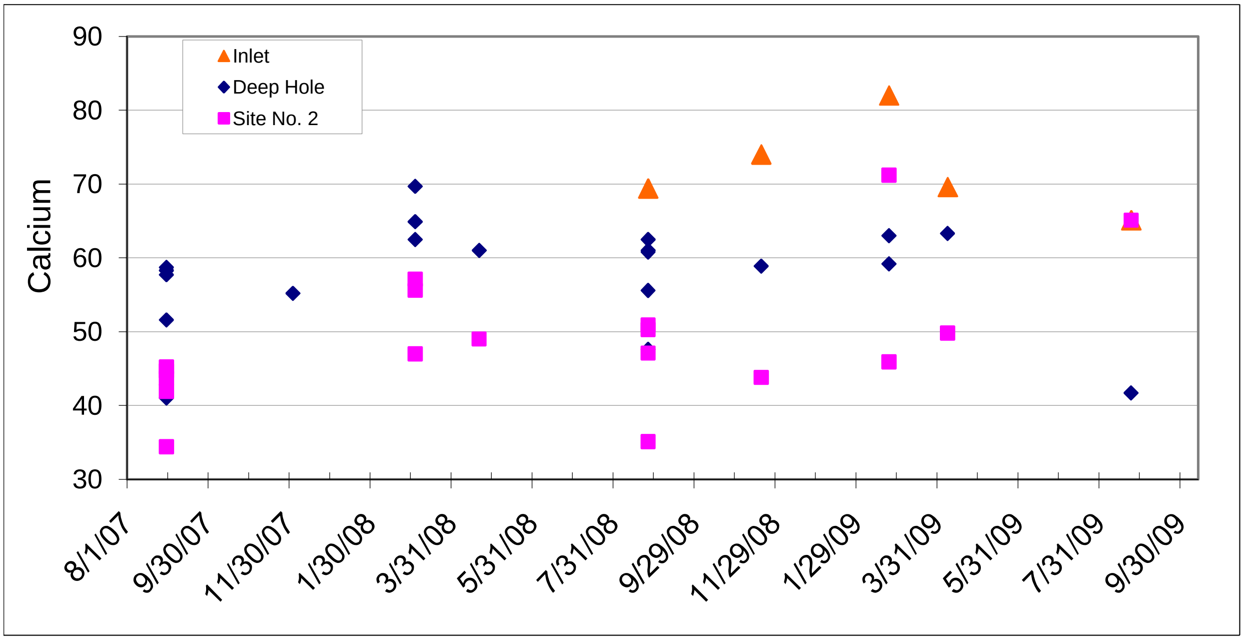


Note: USGS data are from Deep Hole location.





Notes: USGS data from top graph are from Deep Hole location. Second graph contains all USGS data.



Calcium
90
80
70
60
50
40
30
Inlet
Deep Hole
Site No. 2
8/1/07
9/30/07
11/30/07
1/30/08
3/31/08
5/31/08
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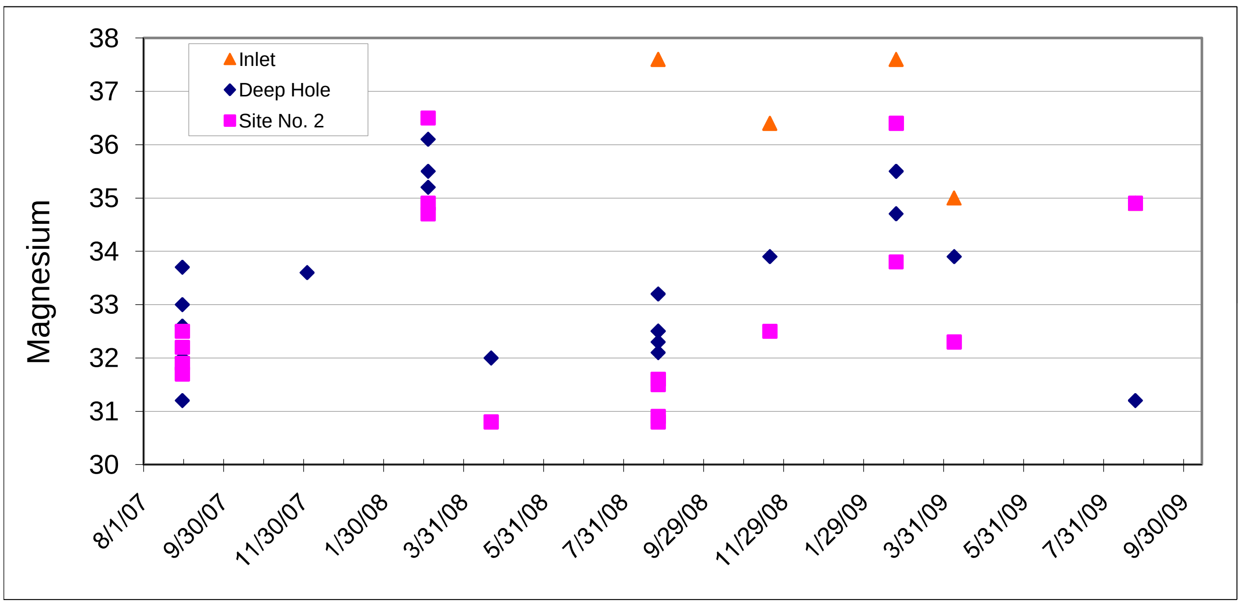
7/31/09
9/30/09



Magnesium
38
37
36
35
34
33
32
31
30
Inlet
Deep Hole
Site No. 2
8/1/07
9/30/07
11/30/07
1/30/08
3/31/08
5/31/08
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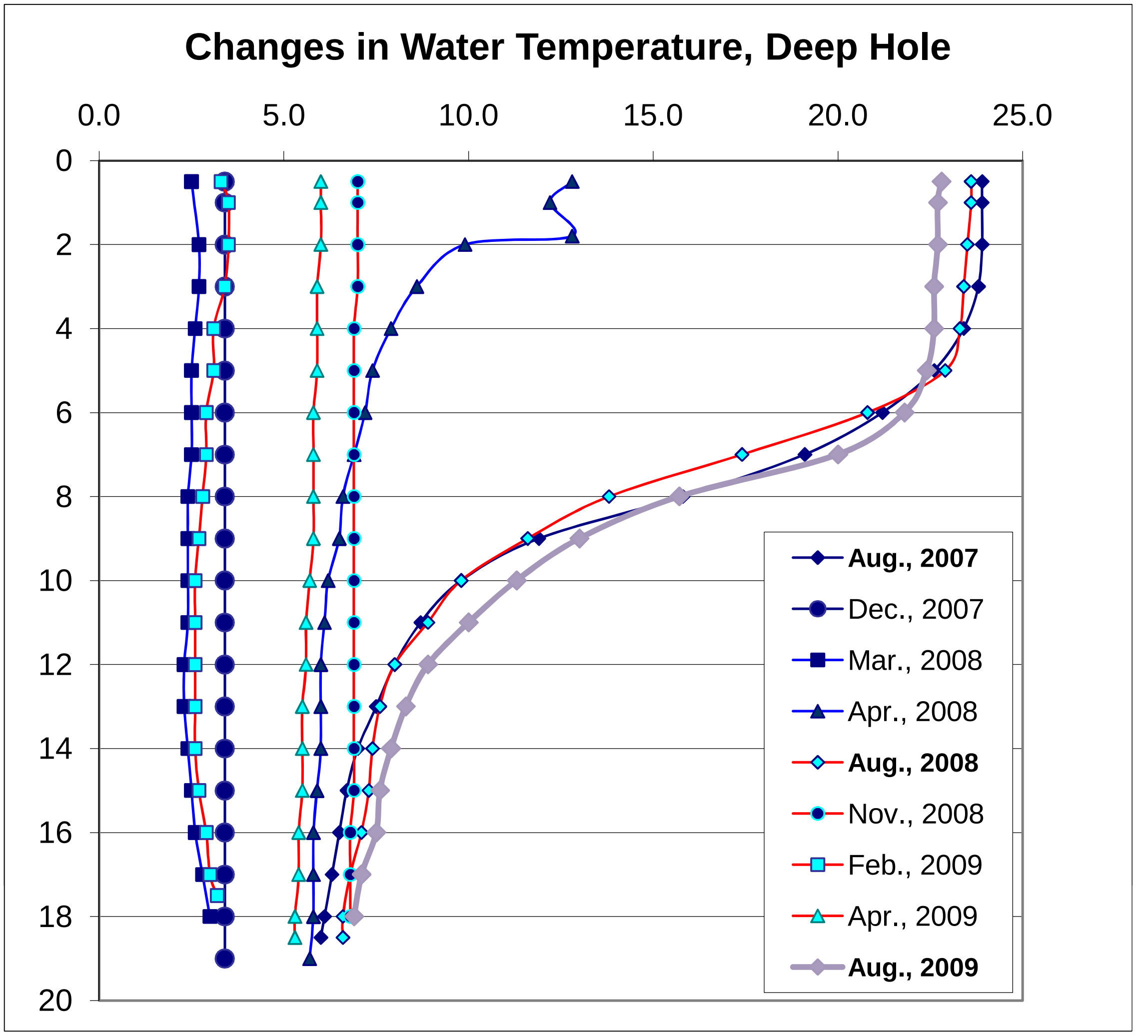
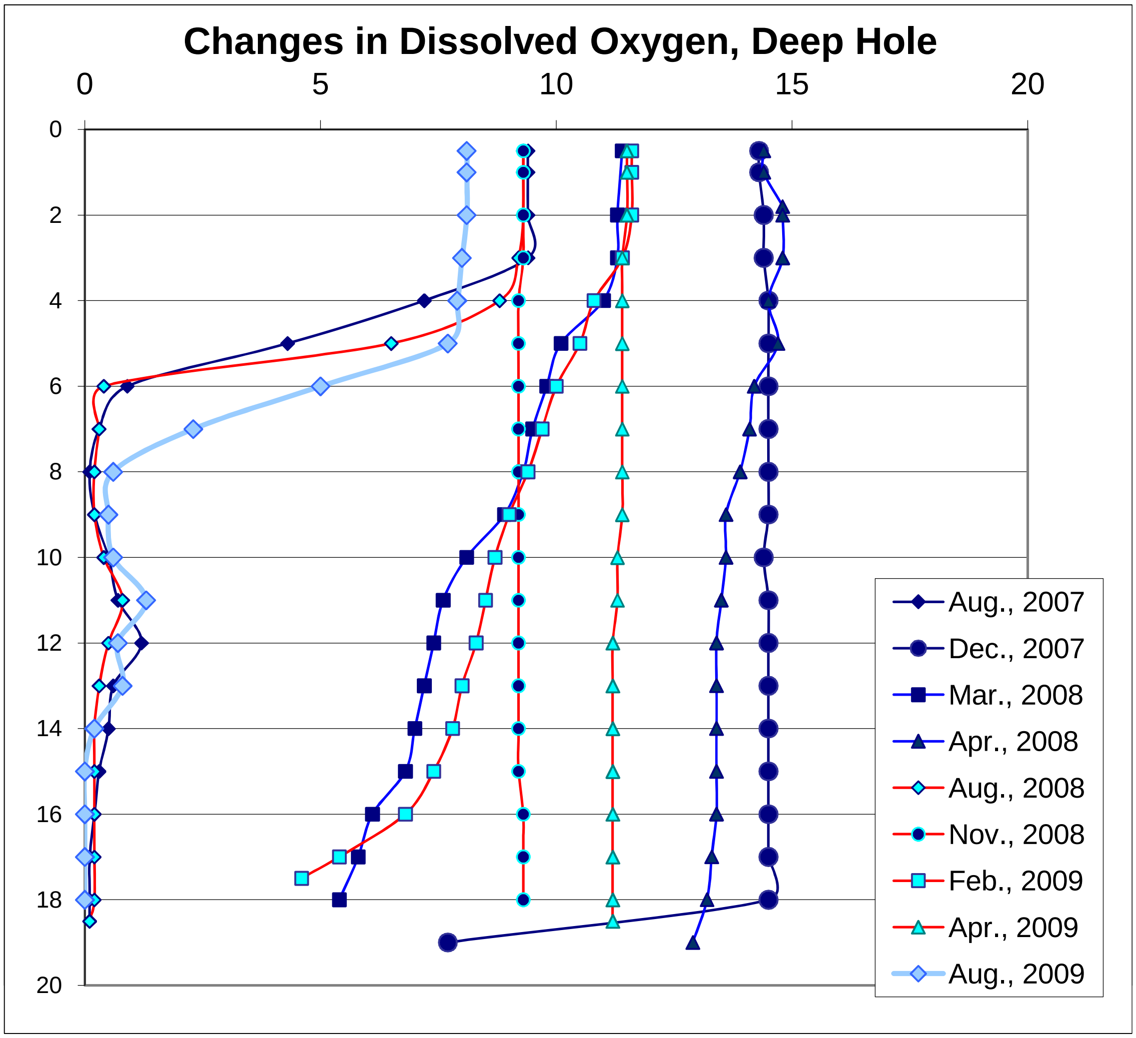
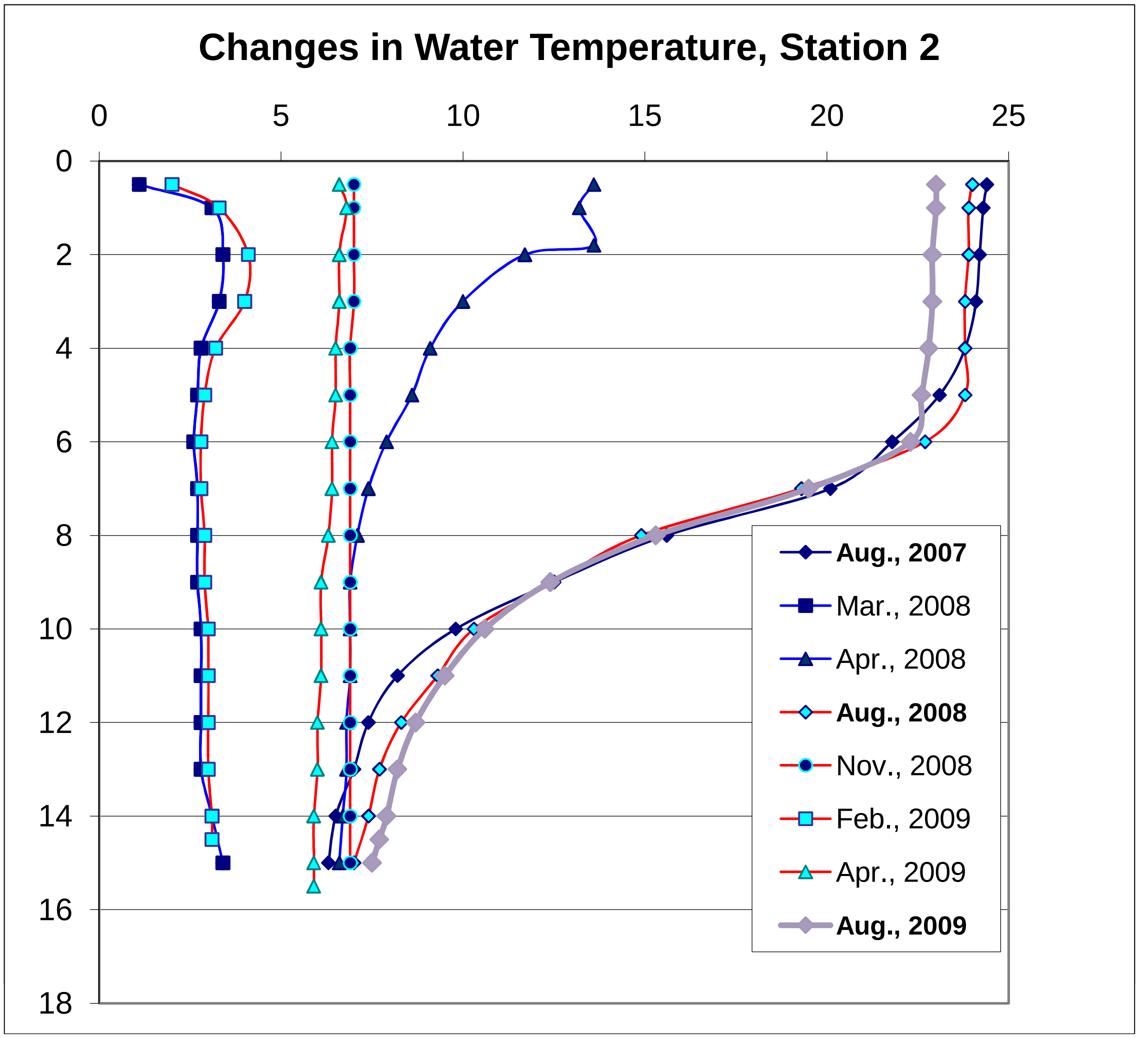
7/31/09
9/30/09

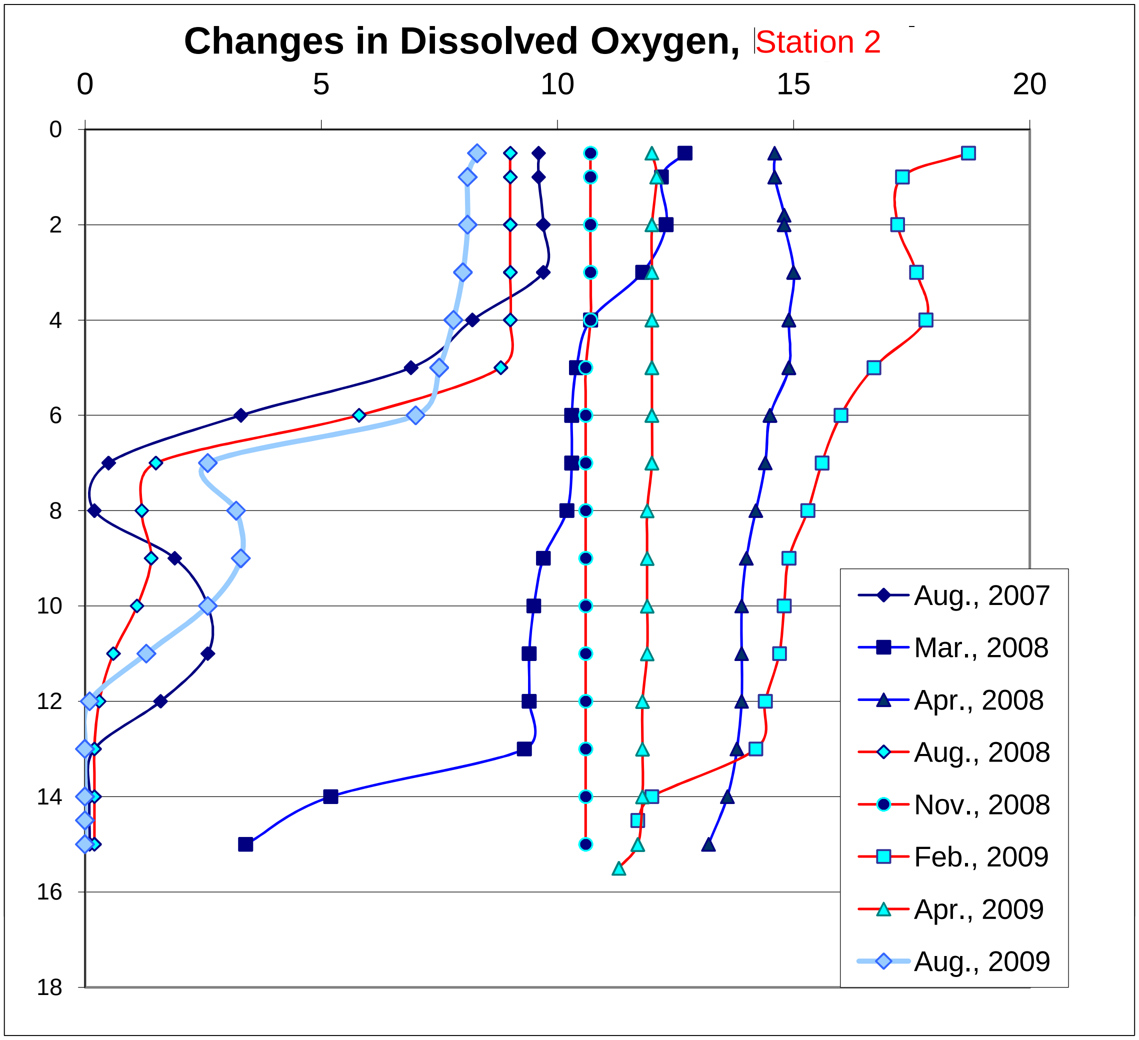


Changes in Water Temperature, Deep Hole
0.0
5.0
10.0
15.0
20.0
25.0
0
2
4
6
8
10
12
14
16
18
20
Aug., 2007
Dec., 2007
Mar., 2008
Apr., 2008
Aug., 2008
Nov., 2008
Feb., 2009
Apr., 2009
Aug., 2009

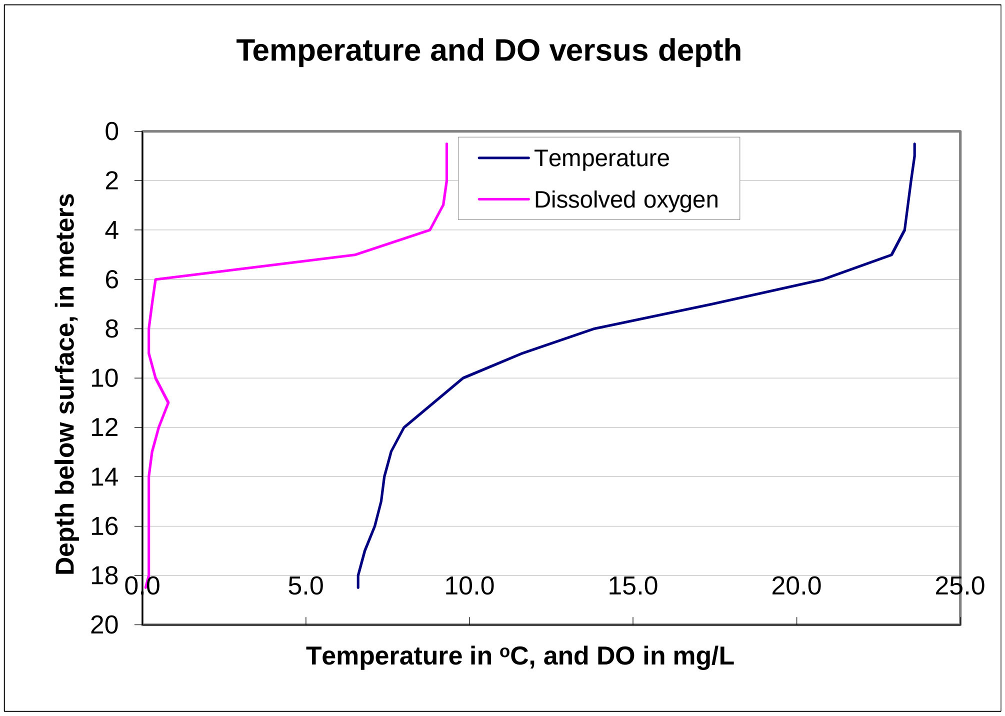


Changes in Dissolved Oxygen, Deep Hole
0
5
10
15
20
0
2
4
6
8
10
12
14
16
18
20
Aug., 2007
Dec., 2007
Mar., 2008
Apr., 2008
Aug., 2008
Nov., 2008
Feb., 2009
Apr., 2009
Aug., 2009

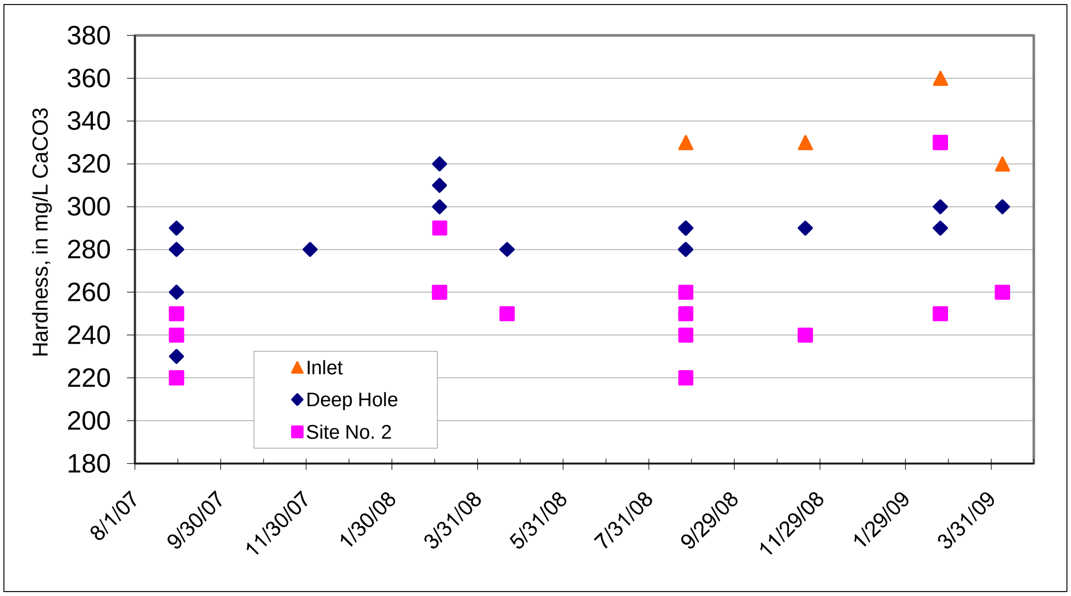

Changes in Water Temperature, Station 2
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16
18
Aug., 2007
Mar., 2008
Apr., 2008
Aug., 2008
Nov., 2008
Feb., 2009
Apr., 2009
Aug., 2009



Changes in Dissolved Oxygen, Station 2
0
5
10
15
20
0
2
4
6
8
10
12
14
16
18
Aug., 2007
Mar., 2008
Apr., 2008
Aug., 2008
Nov., 2008
Feb., 2009
Apr., 2009
Aug., 2009



Note: USGS Deep Hole data, August 2008.



380
360
340
320
300
280
260
240
220
200
180
Hardness, in mg/L CaCO3
Inlet
Deep Hole
Site No. 2
8/1/07
9/30/07
11/30/07
1/30/08
3/31/08
5/31/08
7/31/08
9/29/08
11/29/08
1/29/09
3/31/09