CEDAR LAKE AUGMENTATION FEASIBILITY STUDY

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1.0 INTRODUCTION

Kieser & Associates, LLC (K&A), of Kalamazoo, Michigan, was retained by the Cedar Lake Improvement Lake Board (Lake Board) to conduct a feasibility study to evaluate seasonal options to augment summer water levels within Cedar Lake near Oscoda, Michigan. Initial tasks related to automated groundwater and surface water monitoring equipment purchases and installation were authorized by the Lake Board in October of 2009. The Lake Board authorized all other feasibility study tasks on April 20, 2010 for this 14-month study.

The Cedar Lake watershed straddles the southeast corner of Alcona County and the northeast corner of Iosco County. The area draining to Cedar Lake is located in the U.S. Geological Survey Hydrologic Unit Code (HUC) 04070003-0406. This 1,075-acre, high-quality lake is situated approximately 0.5 miles east of the Lake Huron shoreline and one mile north of the City of Oscoda. Cedar Lake is approximately 5.9 miles long, averaging approximately 0.2 miles wide. The lake is shallow, about five feet deep on average with a limited area as deep as fourteen feet. The lake is used for boating, swimming, fishing, hunting, and wildlife viewing. Land uses in the areas immediately surrounding and directly draining to the lake are generally comprised of residential, recreational, transportation, forests, grasslands, and wetlands. These comprise a very small drainage area, only 3,613 acres of land to the immediate northwest drain to Cedar Lake via intermittent streams and groundwater recharge. Because the lake is perched above other surface features, nearly 75% of the surrounding lands to the southwest, south, and east, (including shoreline areas) do not drain to the lake (K&A, 2005). This condition presents a unique influence on both lake water level and water quality.

The lake is primarily groundwater-fed with two intermittent streams, Sherman Creek and a second unnamed creek, known locally as Jones Creek, flowing during late winter months through late spring in the drainage area to the northwest of Cedar Lake. These creeks originate in a large wetlands/cedar swamp complex on the northwest side of Cedar Lake. The lake has two concrete outflow drop-box weir structures at its north end that were constructed in the 1950's to regulate water level at an established legal lake elevation of 608.5 feet (K&A, 2005). Surface outflows from these structures typically occur following snowmelt through May and discharge to Lake Huron through an intermittent stream channel terminating in a wetlands complex north of the lake. A map of these surface water inflow and outflow locations is provided as Figure 1. Water levels in this shallow lake typically continue to drop through the summer months of June-September once spring outflows cease. During dry years with limited summer rainfall, these drops have been recorded as much as 26 inches (K&A, 2005).

2.0 BACKGROUND AND PUPROSE OF THIS STUDY

In July of 2005, K&A completed a Phase I Study for the Alcona-Iosco Cedar Lake Association (AICLA) to provide an initial assessment of the hydrologic conditions influencing Cedar Lake water levels. The Phase I report presented a compilation of available information, field reconnaissance, field data, and a preliminary assessment of estimated gains and losses of lake water as influenced by local and regional conditions. Results of this study demonstrated significant lake level loss in late summer months, and found limited contributing surface water resources to Cedar Lake (K&A, 2005).

As a follow-up to the Phase I efforts, K&A was authorized by the AICLA to complete a Phase II Study to further characterize manageable factors influencing lake levels and preliminarily identify management and/or structural solutions to help maintain lake levels during summer months. The Phase II study revealed that land development and installation of a drainage system on the southeast side of the lake was a major source of water loss from the lake during summer months. In addition, the wetlands complex in the northwest portion of the Cedar Lake watershed was identified as a primary resource of water recharge, both through groundwater and intermittent surface flows (K&A, 2006).

From 2008-2010, a watershed management plan (WMP) was developed by K&A for the Lake Board. This plan represents the framework for watershed needs and solutions by identifying strategies to preserve, protect or restore water quality and natural resources around Cedar Lake. The WMP identified watershed goals developed through stakeholder input and an integrated analysis of the watershed threats and concerns, designated and desired uses in the watershed, and critical areas to protect. The WMP also assisted in the evaluation of augmentation source options (K&A, 2011).

The concept of lake level augmentation for Cedar Lake during the summer months provided a practical opportunity to assist with maintaining biologically/recreationally appropriate lake levels. Based on the observed Phase II relationships between measured lake elevation drop and monthly precipitation during the summer recreational season, some augmentation source options were suggested. Following the Phase II Study, additional groundwater monitoring was completed, and surface water inputs and outputs were further explored. On-going data collection provided K&A with sufficient information to evaluate options to augment summer water levels in Cedar Lake.

This lake augmentation feasibility study is intended to provide an evaluation of water level augmentation options and associated costs to supplement summer water levels in Cedar Lake. A list of each subsequent report section is provided as follows.

Section 3.0	MDEQ Perspectives
Section 4.0	Monitoring and Evaluation
Section 5.0	Augmentation Source Water Options
Section 6.0	Feasibility Evaluation
Section 7.0	Preliminary Engineering and Cost Evaluation
Section 8.0	Summary and Recommendations

3.0 MDEQ PERSPECTIVES

An initial task for this feasibility study included efforts to define the background and purpose of seeking augmentation options for appropriate MDEQ staff, and to solicit feedback prior to conducting primary augmentation feasibility study tasks. Such feedback from local regulatory officials provided important information and insights related to potential constraints, future permit needs and opportunities for environmental/habitat enhancement benefits.

3.1 Meeting with MDEQ

On May 24, 2010, K&A conducted a kick-off meeting at the Gaylord MDEQ field office. K&A prepared meeting materials and topics of discussion related to this project using a holistic and pragmatic approach with lake, watershed and habitat restoration as desired outcomes. This kick-off meeting provided MDEQ with an opportunity to respond to the proposed work scope and approach.

Primary outcomes of the meeting with MDEQ included the following:

- A Phelan Creek partial diversion idea was given some scrutiny due to potential volume reductions in this coldwater stream.
- A King's Corner culvert modification concept received positive responses from MDEQ staff along with a temporary permit suggestion to pilot test this approach.
- Augmentation concepts involving modification of Sherman and Jones Creeks received positive feedback related to potential fisheries spawning habitat improvements and improved wetland resource benefits.
- Permit review associated with an augmentation well that discharges into and benefits a wetland might be less burdensome if natural conveyance through Sherman Creek is used to supplement lake water levels (as opposed to a pipe conveyance).
- MDEQ staff felt that pumping from Lake Huron was the least viable option with respect to permit approval and other potential options.

A detailed written summary of kick-off meeting discussions is provided in Attachment A. Discussion items are revisited in various sections of this report as they pertain to relevant augmentation approaches.

4.0 MONITORING AND EVALUATION

Monitoring and evaluation tasks in this feasibility study involved assessment of data relevant to Cedar Lake water levels that included the following:

- Groundwater elevation data
- Lakewood Shores groundwater elevations
- Lake water levels
- Surface water inflows and outflows
- Local precipitation records
- Water quality analyses
- Hydrogeologic data and aquifer testing

Each of these new monitoring efforts provided relevant information needed to proceed with further evaluation of each potential augmentation source water option for this study.

Furthermore, these data serve as initial building blocks and provide the opportunity for continued, similar record keeping and evaluation for future lake level management decisions. These data are discussed in detail within the following subsections.

4.1 Groundwater Monitoring Data Evaluation

The AICLA has been monitoring groundwater elevations surrounding Cedar Lake with the help of local volunteers since approximately 2004. While the use of volunteers has been helpful in collecting these data, there have also been challenges with this approach. To aid with a more systematic and more comprehensive approach to local groundwater monitoring, the AICLA decided in 2008 that an automated network of data loggers would be a valuable improvement for collecting, managing, maintaining accurate and technically defensible records in the future.

4.1.1 Automated Data Loggers

In 2008, the Lake Association purchased four water level loggers from Heron Instruments. These four level loggers were installed at the Sherman Creek, Jones Creek, King's Corner and Cedar Lake outflow locations to monitor critical surface water elevations. In October of 2009, the Lake Board purchased sixteen additional loggers (of the same make and model) that were installed and maintained by K&A staff during this feasibility study (Dec 2009 through May 2011). These additional sixteen water level loggers were utilized to monitor groundwater elevation data within the entire network of Cedar Lake piezometers (including Lakewood Shores as discussed in the following report section).

Upon each quarterly download of recorded water level data, K&A prepared updates to an improved, automated groundwater database (in lieu of sporadic, manual, volunteer data collection efforts). These hourly water level data were used to monitor relative lake levels at various locations around Cedar Lake as well as estimate flows from contributing surface water sources. Furthermore, these data provided assistance with subsequent evaluation of augmentation options and Lakewood Shores groundwater elevation considerations.

A copy of all water level data records is compiled in electronic format and saved to a compact disc included in Attachment B. Water level data are current up to May 2, 2011 (i.e., the date of the last K&A download).

4.1.2 Lakewood Shores

The Lakewood Shores Property Owner's Association (LSPOA) governs the Lakewood Shores residential area (privately owned parcels located and extending beyond the southeast corner of Cedar Lake, within Iosco County). In past years, the Lakewood Shores residential area has experienced periodic and localized flooding concerns following spring snowmelt and runoff. A network of storm sewers installed and maintained by the Iosco County Drain Commissioner serves the Lakewood Shores drainage area. These were installed to help alleviate these wet conditions associated with historic remnants of a cedar/tamarack swamp. Since these shallow storm sewers have been observed flowing during dry weather, they appear to behave like subsurface tile drains and discharge directly to Lake Huron (K&A, 2006). In more recent years, the Iosco County Drain Commissioner has conducted several improvements to this drainage network providing additional relief from previously reported flooding concerns. As part of this study, K&A work tasks involved monitoring shallow groundwater elevations within Lakewood Shores to observe and document these elevations with respect to Cedar Lake water levels.

In November of 2009, four new groundwater piezometers (shallow groundwater wells) were installed within Lakewood Shores along the southeastern shoreline of Cedar Lake with approval of the LSPOA. Figure 2 depicts a map of these four locations (refer to sites #8-11). As described in the previous section above, Heron water level loggers were also installed at these four locations in Lakewood Shores for groundwater monitoring. These level loggers were utilized to obtain further information with respect to target augmentation water levels in Cedar Lake in an effort to strike a balance between more stable lake levels and potential high groundwater impacts to Lakewood Shores. These data are also included in the electronic water level data records provided in Attachment B. An updated summary table of each Cedar Lake groundwater piezometer monitoring location and construction elevation data is provided in Table 1 (including the four Lakewood Shores monitoring locations installed as part of this study).

Lakewood Shores groundwater elevations are illustrated in Figure 3 with respect to Cedar Lake water levels from April 2010 through September 2010. These data suggest that water levels within the Lakewood Shores area vary by as much as 7 to 8 feet from north to south (with higher elevations observed in the northern Lakewood Shores areas associated with PZ-10s and PZ-11s). The Lakewood Shores groundwater elevations were relatively stable (fluctuating only about 2 feet) and demonstrated consistent responses with respect to increasing and decreasing Cedar Lake level trends within these six months. The Cedar Lake water levels were recorded approximately 2-3 feet higher than those in PZ-10s (the highest Lakewood Shores elevations) and approximately 11 to 12 feet higher than those in PZ-8s (the lowest Lakewood Shores elevations). These data suggest that recent improvements made by the Iosco County Drain Commissioner's Office to the Lakewood Shores drainage system have improved past drainage concerns within this area. Furthermore, the lack of recent flooding complaints despite higher summer lake levels suggest the drainage system and recent improvements are capable of allowing sustained Cedar Lake water levels at or near the lake outflow elevation without causing impacts to the Lakewood Shores area surrounding Cedar Lake.

4.1.3 Surface Water Inflow/Outflow

In 2008, K&A installed three of the original four Heron level loggers adjacent to roadside culverts in Sherman Creek, Jones Creek and King's Corner Road to monitor surface water levels. As intermittent streams, Sherman Creek and Jones Creek serve as primary sources of surface water inputs to Cedar Lake. The ability to track and monitor flows into Cedar Lake from these two streams was a critical part of this feasibility study.

The King's Corner Road culvert was determined to be a source of surface water outflow from the Cedar Lake watershed into the Van Etten Lake watershed via Phelan Creek (K&A, 2006). This was an important discovery during the Phase II Cedar Lake study in 2006, and as a result, the King's Corner Road culvert was also monitored with water level logging equipment during this feasibility study to quantify seasonal flow and volume directed out of the Cedar Lake watershed at this location.

These surface water elevation data were used in combination with field-measured flow data to establish stage-discharge relationships and to monitor seasonal flow and volume through each road culvert location. Figures 4-6 depict each stage-discharge relationship for Sherman Creek, Jones Creek and the King's Corner culverts, respectively. These field-measured elevation and flow data (collected since 2006) reflect strong correlations and were relied upon for use in further evaluation of augmentation options. The Jones Creek and King's Corner culverts were observed to be dry during three site visits (i.e., no flow), and as a result, include fewer data.

A summary of the spring surface water flows at each of these three locations is provided in Table 2. Average spring surface water flows over the past three years (2009-2011) were 2.02 cubic feet per second (cfs) from Sherman Creek, 0.34 cfs from Jones Creek, and 0.26 cfs from the King's Corner culvert (equalized over each period of discharge from 2009-2011). These surface water flows amount to a combined average total of 2.61 cfs. Detailed seasonal flow data plots for these locations are included in Attachment C.

4.1.4 Lake Outflow

K&A installed the fourth original Heron level logger near the Cedar Lake outlet structures in July of 2008 to continuously monitor lake elevation. Lake elevation data measured at this location enabled K&A to calculate lake volume loss during the summer months and outflow volume leaving the lake. A summary graph of Cedar Lake water elevations from 2008 through 2010 is provided in Figure 7 . After the initial installation (July 2008), the lake outflow level logger was removed each fall (typically in Oct/Nov) for the winter months and re-installed after ice-out each spring (typically in April). The historic court-established lake elevation of 608.5 feet is also depicted in Figure 6 (K&A, 2005).

The Cedar Lake water elevation data included in Figure 7 illustrate that during the summer of 2008, water levels were recorded below the outflow structures (i.e., no lake outflow was occurring). In contrast, the 2009 and 2010 water levels were largely recorded at or above the legal lake level (i.e., lake outflow was discharging to the northern wetland and intermittent stream feeding Lake Huron). These field-measured data recorded by the lake outflow level logger were used to generate lake outflow data using a standard engineering weir equation specific to the dimensions of the two outflow drop-box weir structures for the Cedar Lake (as shown below).

West Weir		East Weir	
Avg. Elev. =	608.84 ft	Avg. Elev. =	608.74 ft
Total Length =	12.75 ft	Total Length =	18.92 ft

Using weir equation $Q = c \times L \times h^{3/2}$, where Q = flow (cfs), c = 3.1, L = length of weir (ft), and h = head (or water level) above weir elevation (ft), the two weir equations are simplified as follows:

West Weir :	East Weir:
West Q = $39.525 \times h^{3/2}$	**East Q** = $58.652 \times h^{3/2}$

Average surface water flows were 0.18 cfs from the Cedar Lake outflow structures (equalized over the each period of discharge during 2009 and 2010). A detailed seasonal flow data plot for the lake outflow location is included in Attachment C.

4.1.5 Precipitation

The AICLA has been monitoring daily precipitation with an automated tipping bucket rain gauge since 2004. With the help of local volunteers, the AICLA has been sharing these precipitation monitoring data with K&A. A historic summary (1998-2010) of local precipitation and measured lake elevation drop during the critical summer months of June through September is provided in Figure 8. These precipitation records reveal that during the past 12-year period, the last three years have been above average 'wet' years. The 1998-2010 summer precipitation average was calculated as 12.36 inches. These June through September summer precipitation records for 2008-2010 amounted to 14.88, 15.97, and 16.89 inches, respectively (as depicted in Figure 8). As a result, the corresponding lake level drop during the past three years has not exceeded six inches during these critical summer months.

The K&A 2006 Phase II Cedar Lake Study revealed a correlation between local precipitation and measured lake level drop from June through September for data collected in 2004 and 2005. An update of this relationship is provided in Figure 9. The data included in Figure 9 represent the summer months June through September for the past six years (2004-2010). These data continue to suggest that precipitation is a large factor related to the observed lake level fluctuation in Cedar Lake (R^2 value of 0.77). The average monthly precipitation total during the past six years amounts to 2.76 inches/month.

A frequency distribution of Cedar Lake monthly precipitation is illustrated in Figure 10. These data reflect measured monthly rainfall totals for the summer months June through September for the past six years (2004-2010). The frequency distribution of these precipitation data (Figure 10) suggest that 79% of the time Cedar Lake is receiving 2 inches of rainfall or more per month. Likewise, 42% of the time Cedar Lake is receiving 3 inches of rainfall or more per month.

Furthermore, these precipitation monitoring data suggest that if the Cedar Lake watershed receives local summer precipitation of approximately 2.75 inches each month (recent 6-yr average), the predicted monthly lake level drop would reflect approximately 0.25 feet (or 3 inches) as discerned from Figure 9. The volume required to offset a 1-month lake level drop of three inches in Cedar Lake amounts to approximately 91 million gallons (i.e., 3 million gallons per day (MGD), or 4.6 cfs).

4.1.6 Water Quality Data

Surface water quality data were collected by K&A field staff during two separate field visits to Cedar Lake. An initial set of surface water samples was collected on April 28, 2009 for total phosphorus (TP) and total suspended solids (TSS) during Cedar Lake Watershed Management Plan efforts. Table 3 provides a summary of these analytical data for Sherman Creek, Jones Creek, King's Corner and the Cedar Lake outflow locations. Each of these locations exhibited relatively low concentrations of both TP and TSS. The highest TP concentration was reported as 0.08 milligrams/Liter (mg/L) for the Cedar Lake outflow sample. Though well within the typical range for inland lakes within Michigan, it may rather reflect a localized condition in the wetland rather than an open lake sample compared to previous water quality data collected by the AICLA. The only TSS sample reported above laboratory detection limits was in the King's Corner sample at 4 mg/L (also within an acceptable range). TP samples were submitted to Upstate Freshwater Institute of Syracuse, New York, and TSS samples were submitted to KAR Laboratories, Inc. of Kalamazoo, Michigan for analyses. Copies of these analytical laboratory reports are included in Attachment D.

A second set of surface water quality data was collected by K&A on July 29 and 30, 2010 during feasibility study work tasks. Although not originally planned, these data were collected at select locations to supplement the evaluation of feasible augmentation options. These were specifically related to options for redirecting or enhancing existing surface flows into the lake. A total of 12 select locations were visited and were each monitored for flow, temperature, specific conductivity, dissolved oxygen (DO), pH, and oxidation-reduction potential (ORP or Eh) with hand-held field monitoring equipment. A location map of each sampling location is provided as Figure 11. In addition to field-measured parameters, analytical laboratory samples were collected at five locations for TP, total nitrogen (TN) and TSS. These locations (depicted in Figure 11) included Cedar Lake (near St. George's Point), Phelan Creek-1, Phelan Creek-3, Southern Drain (#1), and the Cedar Lake outflow creek (at Glenn Hollow).

Table 4 provides a summary of all field-measured and analytical laboratory data for the July 29 and 30, 2010 surface water monitoring locations. Temperature values ranged from 10.6 ^{o}C at King's Corner to 24.6 ^{o}C in Cedar Lake, with most measurements averaging around 15 to 18 ^{o}C. Field-measured specific conductivity ranged from 180 to 240 microSiemens/centimeter (uS/cm) at Cedar Lake and Southern Drain (#1), respectively. Dissolved oxygen measurements varied the most and ranged from 2.22 mg/L at King's Corner to 7.54 mg/L at the Southern Drain (#1). Surface water pH values were relatively constant and well within neutral range exhibiting readings from 7.24 to 7.62 standard units. Field-measured ORP values were recorded as low as 80 millivolts (mV) and as high as 159 mV at King's Corner and Phelan Creek-3, respectively. All of the field-measured water quality data were well within typical ranges for surface waters in Michigan.

Surface water samples collected on July 30, 2010 are reported in Table 4. All TP results were reported below the laboratory detection limit of 0.02 mg/L with the exception of the Southern Drain (#1) reported at 0.03 mg/L. Analytical results for TN varied from 0.7 mg/L in Cedar Lake to 1.4 mg/L at Phelan Creek-1 and Southern Drain (#1). Although quite low, the Southern Drain (#1) exhibited the highest TSS result of 4 mg/L. These surface water samples were submitted to KAR Laboratories for analyses. A copy of the analytical laboratory report is provided in Attachment D.

4.2 Hydrogeological and Aquifer Testing

Aquifer testing was conducted in the fall of 2010 to determine site-specific groundwater yield near the existing wetland area adjacent to Sherman Creek and to preliminarily evaluate potential for interference to surrounding resources related to drawdown. These efforts were guided by K&A staff and received local coordination assistance from AICLA and Lake Board representatives.

4.2.1 Installation of Test Well and Observation Wells

As part of the evaluation for feasible augmentation options for Cedar Lake, K&A selected Raymer Company, Inc. (Raymer) of Marne, Michigan to install an augmentation test well and two observations wells on a parcel of land owned by Ms. Joan McDaniels located adjacent to Sherman Creek in October of 2010. Refer to a site location map provided as Figure 12. These efforts received prior written authorization from Ms. McDaniels directed to the Lake Board and AICLA. Under the direction of K&A, a 5-inch diameter PVC observation well was first installed on the property on October 18, 2010 to evaluate site-specific soil conditions and to collect soil samples for selecting the proper screen slot size for the larger augmentation test well. On October 19, 2010, an additional 2-inch diameter PVC observation well was installed. Each observation well was installed using rotary drilling methods and screened between 60 and 70 feet below ground surface (bgl). Upon determination of the proper screen size, a 12-inch diameter PVC augmentation test well was installed and completed to a depth of 70 feet bgl on October 26, 2010. The test well was constructed of a 60-ft long, 12-in diameter PVC casing and a 10-ft long, 12-in diameter stainless steel screen (0.04 slot wire-wrapped). The well screen was gravel-packed from 70 to 50 ft bgl and the remaining annular space of this test well was filled from 50 ft bgl to the ground surface with a bentonite grout slurry. Photographs of well drilling activities are included in Attachment E.

4.2.2 Aquifer Pump Testing

On November 2 and 3, 2010, K&A returned to the McDaniel property to observe Raymer initiate a 24-hour pump test of the 12-inch diameter augmentation test well in accordance with MDEQ aquifer test requirements. The test pumping rate was set at 155 gallons per minute (gpm) or 0.35 cfs. Groundwater drawdown was monitored continuously in the pumping well and the two observation wells using automated water level loggers. The pump test discharge was extended approximately 150 feet into the wetland area west of Cedar Lake Road and north of Sherman Creek. During the course of the pump test, K&A field staff collected in-stream flow measurements from Sherman Creek to monitor potential flow accrual and confirm a surface connection from the adjacent wetland. A graph depicting observed flow response is provided as Figure 13. Measured flow data revealed an increase of approximately 0.37 cfs relative to the initial baseflow reading. This observed increase was nearly equivalent to the pumping rate of 155 gpm (or 0.35 cfs). This increase in flow related to groundwater pumping response would be well below what the creek normally handles during spring runoff (observed peak flows range between 3 to 8 cfs). Sherman Creek and the road culvert have more than enough carrying capacity to handle groundwater pumping flows (from one or from several wells). No observed drawdown impacts were observed in nearby shallow piezometers during the pump testing operations. Following 24-hours of pumping, groundwater elevations were monitored for an additional 24-hour recovery period.

Upon completion of the pump testing and groundwater recovery monitoring, the two observation wells were properly abandoned by sealing each with a bentonite grout slurry from the bottom of the well to the ground surface. With the permission of Ms. McDaniels, the 12-inch diameter test well was properly capped and left in-place for potential future use if the Lake Board chooses to pursue this option further.

A written summary report of the pump test and results was prepared by Williams & Works of Grand Rapids, Michigan on behalf of Raymer and dated November 29, 2010. In short, the pump test results and findings of this report recommend an array of five augmentation wells spaced at least 500 feet apart and set at a pumping rate of 100 gpm in order to operate over a duration of approximately 100 days during the summer months (or 86.4 million gallons). A copy of the pump testing report is provided in Attachment F.

5.0 AUGMENTATION SOURCE WATER OPTIONS

During the summer months of June through September, water elevations in Cedar Lake are dependent upon any limited spring runoff from Sherman and Jones Creeks (depending on how long those flows last) and local precipitation. During dry years (such as 2004 and 2007), with summer precipitation of only 7 to 8 inches, lake levels have been observed dropping as much as 18 to 26 inches (Figure 8). During the past three wet years (2008 to 2010), summer precipitation ranged between 14 and 17 inches and lake levels were much more steady with observed drops of only 4 to 6 inches. These data serve as the basis for identifying source water options to augment Cedar Lake water levels (or minimize losses) during dry years to maintain biologically/recreationally acceptable lake levels.

A total of seven potential source water options were evaluated within this feasibility study to assess opportunities of augmenting Cedar Lake water levels during the summer months of June through September. Refer to Figure 14 for a location map. These seven source water options include:

1. Phelan Creek Partial Diversion
2. King's Corner Culvert Modifications
3. Sherman & Jones Creek Modifications
4. Harvest Wet Weather Lake Outflows
5. Groundwater Augmentation Wells: Discharge to wetland
6. Groundwater Augmentation Wells: Direct piping to lake
7. Lake Huron Pumping to Cedar Lake

An additional option was included in early discussions with MDEQ during the project kick-off meeting which involved the re-circulation of Lakewood Shores subsurface drains (maintained by the Iosco County Drain Commissioner). Due to the complexity of this drainage network, observed low/intermittent flows, and high costs associated with designing a central collection system (or multiple systems) for such a large storm sewer network, this option was excluded from further evaluation.

Below is a summary of each option with a brief concept description and associated potential benefits of implementation.

Source Option	Description	Benefits
Phelan Creek Partial Diversion	Divert a portion of water from nearby Phelan Creek into Cedar Lake, either by direct piping or open-channel flow.	o Portion of water originates in Cedar Lake watershed. o Moderate/high volume of water. o Formerly a county drain. o Precedent for surface water removal.
King's Corner Culvert Modifications	Modify the culvert to increase water level in the wetland west of Cedar Lake Rd. and north of King's Corner Rd to detain more water for Sherman Creek flows.	o Use simple stop board system on a seasonal basis. o Low capital and O&M costs. o Ability to store water in localized wetland area and "divert" to Sherman Creek.
Sherman & Jones Creek Modifications	Increase wetland water levels in the wetland west of Cedar Lake road by constructing step pools (instream rock grade structures) to control the grade of the stream and retain longer surface water discharges into summer months.	o Existing culverts under road could be modified to slow release of spring surface water runoff from wetlands. o Project would enhance spawning habitat during spring/early summer. o Water levels would be less than spring peak flow.

Harvest Wet Weather Lake Outflows	Installing a pump house near the Cedar Lake outflow structures to pump water from the Cedar Lake outlet into the wetland area west of Cedar Lake Rd. for re-circulation.	o Spillway would be modified and current repair issues addressed. o Volume of water re-circulated can be controlled.
Groundwater Augmentation Wells: Discharge to wetland	Pumping groundwater from a semi-confined aquifer to the surface, and discharge to wetland west of Cedar Lake Rd.	o Enhanced habitat and fish spawning areas with more water in wetlands. o Use creeks to convey water instead of piping. o Water levels less than spring peak levels. o More control over water volumes as necessary during dry years.
Groundwater Augmentation Wells: Direct Piping to Lake	Pumping groundwater from a semi-confined aquifer to the surface, and piping directly into Cedar Lake.	o More flexibility in location of wells. o More control of the volume of water as necessary. o Location near golf course or Lakewood Shore is possible.
Lake Huron Pumping to Cedar Lake	Pumping surface water from Lake Huron into Cedar Lake.	o More control of the amount of water as needed. o Precedent has been tested from other water withdrawal permits.

6.0 FEASIBILITY EVALUATION

To evaluate and further assess the feasibility of each potential lake augmentation source water option, K&A utilized the following criteria to identify and summarize both the challenges and benefits unique to each one.

- Constraints of Location and Physical Setting
- Lake Volume Needs, Source Limitations and Seasonal Timing
- Initial Impacts Assessment
- Regulatory Concerns and Permitting

These evaluation criteria and associated findings are summarized in the subsequent sections of this report. These findings were used by K&A to prioritize future Cedar Lake augmentation recommendations.

6.1 Constraints of Location and Physical Setting

The following text summarizes the potential constraints associated with the site-specific location and/or challenges linked to the physical setting of each source water option.

Source Option	Potential Constraints
Phelan Creek Partial Diversion	o Multiple property ownership o Crossing existing underground utilities (relocation may be required) o Acquiring diversion pipe or ditch easements (multiple easements required) o Approximately 1,000 ft distance at closest point to Cedar Lake o Lakewood Shores Golf Course irrigation could reduce amount available for downstream withdrawal (a portion of surface water used prior to 2004) o Van Etten Watershed interests
King's Corner Culvert Modifications	o Alcona County Road Commission R.O.W. and culvert ownership o More water held on adjacent property for longer periods of time
Sherman & Jones Creek Modifications	o Property ownership o Fish passage needs and related design requirements for grade structures o Difficulty of equipment access, clearing grubbing o Property impacts from prolonged high water in wetlands (though water level elevations will be no higher than peak levels observed during Spring melt period)
Harvest Wet Weather Lake Outflows	o Property ownership o Crossing existing underground utilities (relocation may be required) o Acquiring diversion pipe easements (multiple easements required) o Approx. 1,350 ft distance (minimum) o Pumping is required o Potential downstream wetland impacts
Groundwater Augmentation Wells: Discharge to wetland	o Property purchase or easements required o Multiple wells (at least 500-ft spacing) would be needed under driest conditions o R.O.W. overhead power lines o Drilling equipment access, clearing and grubbing
Groundwater Augmentation Wells: Direct Piping to Lake	o Property purchase or easements required` o Acquiring piping easements (multiple easements required) o Approximately 1,350 ft distance (minimum) o Crossing existing underground utilities (relocation may be required) o Multiple wells (at least 500-ft spacing) o R.O.W. overhead power lines o Drilling equipment access, clearing and grubbing
Lake Huron Pumping to Cedar Lake	o Approximately 3,300 ft distance o Pumping required o Acquiring piping easements (multiple easements required) o Crossing existing underground utilities (relocation may be required) o Invasive species control (from Huron to Cedar Lake)

6.2 Lake Volume Needs, Source Limitations and Seasonal Timing

As previously discussed in Section 4.1.5, the average monthly precipitation total during the summer months of June through September over the past six years amounts to 2.75 inches per month. Even if average precipitation occurs, a monthly lake level drop of approximately 0.25 feet (or 3 inches) is likely to continue based upon other external loss influences exerted on Cedar Lake. A 3-inch drop in Cedar Lake water elevation is equivalent to approximately 91 million gallons. Over the duration of one month, this reflects a loss rate of approximately 3 MGD (or 4.6 cfs) and a volume of 364 gallons over a four-month summer duration. Ideally, this loss rate and volume would be targeted for lake augmentation needs. However, since summer precipitation totals will vary from year to year (and may even be cyclical) some years may not require augmentation (if provided via a variable mechanical/pumping option). Refer to Table 5 for a summary of incremental Cedar Lake elevation drop and associated volume.

Below is a summary of source volume/flow limitations and seasonal timing considerations for the various augmentation options.

Source Option	**Available Flow Rate** (cfs)	**Available Volume** (MG) over 120 days	**Seasonal Considerations**
Phelan Creek Partial Diversion	0.6 cfs	46.5 MG	None – diverts one-third portion of Phelan Creek baseflow year-round
King's Corner Culvert Modifications	0.26 cfs	18.9 MG	Limited to amount of precipitation and wet condition of adjacent wetlands. Spring runoff would be routed to Cedar Lake.
Sherman & Jones Creek Modifications	1.9 cfs	150 MG	Continuing to keep more water in the wetland areas (released more slowly) will allow direct precipitation in wetlands to recharge surface flows (in lieu of recharging the wetlands).
Harvest Wet Weather Lake Outflows	0.028 cfs	2.16 MG	Entirely limited to portions of year when lake elevations are above the established lake elevation (primarily April through June)
Groundwater Augmentation Wells: Discharge to wetland	Pumping 1.11 cfs Precip 0.19 cfs Recharge Total 1.3 cfs	86.4 MG 15 MG 101.4 MG	Operate pumps as needed based on precipitation received and spring lake elevations. Keeping the wetland areas wet will allow direct precipitation in wetlands to recharge surface flows (in lieu of recharging the wetlands).
Groundwater Augmentation Wells: Direct Piping to Lake	Pumping 1.11 cfs Precip 0.19 cfs Recharge Total 1.3 cfs	86.4 MG 15 MG 101.4 MG	Operate pumps as needed based on precipitation received and spring lake elevations. Keeping the wetland areas wet will allow direct precipitation in wetlands to recharge surface flows (in lieu of recharging the wetlands).
Lake Huron Pumping to Cedar Lake	4.6 cfs	364 MG	None – potential volume limitations only (based entirely on permitted withdrawal rate)

6.3 Initial Impacts Assessment

This text section provides an assessment of potential impacts on other natural features or nearby habitat associated with each augmentation source water option included in this feasibility study.

Source Option	Potential Impacts
Phelan Creek Partial Diversion	o Potential negative downstream impacts related to reduced surface flows o Cold-water fisheries (via reduced surface flows and potential to increase temperature) o In-stream creek habitat may suffer in dry years from larger withdrawals o Golf course land management and potential for fertilizer runoff redirected into Cedar Lake
King's Corner Culvert Modifications	o Reduced flows downstream within Phelan Creek (primarily during spring runoff) -- However, this was previously part of Cedar Lake watershed drainage area o Increased standing water may cause temperature increase in wetlands connected to Sherman Creek o Increased standing water must not inundate road bed drainage layers
Sherman & Jones Creek Modifications	o Lengthen "wet season" typically associated with spring flows o Fish passage design is critically important
Harvest Wet Weather Lake Outflows	o Reduced flows to downstream wetlands (primarily during spring runoff) – However, this may improve Timberlakes area drainage concerns experienced in the past o Downstream cold-water fisheries may be negatively impacted via reduced surface flows and potential to increase temperature o In-stream creek habitat downstream may suffer in dry years from higher withdrawals
Groundwater Augmentation Wells: Discharge to wetland	o Sherman Creek flow rates must accommodate fisheries (and determine ideal water velocity) during spawning season o Not entirely adequate during below-average dry years o Increased flows in Sherman Creek must not cause new streambank erosion o Potential for evapo-transpiration losses with increased wetland storage
Groundwater Augmentation Wells: Direct Piping to Lake	o Sherman Creek flow rates must accommodate fisheries (and determine ideal water velocity) during spawning season o Not entirely adequate during below-average dry years o Increased flows in Sherman Creek must not cause new streambank erosion
Lake Huron Pumping to Cedar Lake	o No impact on source water removal o Potential to introduce Great Lakes invasive species into Cedar Lake

6.4 Regulatory Concerns and Permitting

The following is a list of potential regulatory concerns and permitting issues related to each source water augmentation option previously identified. This list also includes potential concerns that were discussed in the project kick-off meeting with MDEQ on May 24, 2010 (refer to Attachment A).

Source Option	Regulatory Concerns and Permit Issues
Phelan Creek Partial Diversion	o Designated cold-water stream, removal of flow may negatively impact fishery o MDEQ suggested this option was less favorable than other alternatives
King's Corner Culvert Modifications	o MDEQ suggested a temporary permit should be considered to observe and document the effects of implementing this option o A permit will be needed to modify this culvert structure (whether temporary or permanent) o May require a legal maintenance agreement between the Alcona County Road Commission and the Lake Board and/or AICLA o Notification to adjacent property owners will be required if modifications may cause flooding
Sherman & Jones Creek Modifications	o In-stream grade control structures (such as rock weirs or fish ladders) and/or culvert modifications must be designed to allow for fish passage o A permit will be needed to modify these culvert structures (whether temporary or permanent)
Harvest Wet Weather Lake Outflows	o Property easements and permitting will be required for conveyance pipe installation and approval of the proposed discharge location o Designated downstream coldwater stream, removal of flow may negatively impact fishery
Groundwater Augmentation Wells: Discharge to wetland	o There are no statutes or administrative rules that prohibit lake augmentation wells in Michigan o A water withdrawal permit will be required for operation of a lake augmentation well, including approval of the proposed discharge location in accordance with the Natural Resources and Environmental Protection Act (NREPA) o At the county level, most counties require permits for non-potable high capacity wells (including Alcona County) o Wetland permitting will be required to remove vegetation and construct access roads and/or paths to install and maintain augmentation wells o MDEQ expressed a preference for a 'natural' conveyance, such as the wetlands and naturally adjoining creeks to Cedar Lake o MDEQ may require an extensive testing list to demonstrate the groundwater source is not contaminated
Groundwater Augmentation Wells: Direct Piping to Lake	o Same as previous list… (in addition to the following items) o Permitting will also be required for the conveyance piping o Recreational/aesthetic issues must be addressed with respect to the discharge location o Velocity of the water entering the lake will also need to be evaluated
Lake Huron Pumping to Cedar Lake	o Easements will be required for conveyance pipe installation within county/state right-of-ways o Potential to introduce Great Lakes invasive species into Cedar Lake o More detailed and involved water withdrawal permit process o Recreational/aesthetic issues must be addressed with respect to the discharge location o Velocity of the water entering the lake will also need to be evaluated

6.5 Assessment of Legal Obligations

The section provides a brief summary of potential legal implications associated with lake augmentation. This is not an extensive legal review, nor does it constitute a legal opinion for or against lake augmentation.

A lake's legal level represents a lake's surface water level as compared to sea level. Legal levels have been established on over 300 lakes in Michigan (MDEQ, Inland Lakes and Streams Program, Part 307). A normal level is considered by state law as "the level or levels of the water of an inland lake that provide the most benefit to the public; that best protect the public health, safety, and welfare; that best preserve the natural resources of the state; and that best preserve and protect the value of property around the lake" (Groves, 2011).

There are no statutes or administrative rules that prohibit lake augmentation in Michigan. Establishment procedures to obtain a legal lake level have existed since the enactment of Act 377 of 1921, and the authority of the Drain Commissioner to maintain a legally set level was established in Public Act 39 of 1937, stating:

> "The drain commissioner of the several counties of this state in which the water of any inland lake is situated may, for the protection of the public health and safety and the conservation of the natural resources of this state, and for the best interest of land owners abutting on the lake, provide for the establishment and maintenance of the water of any such lake at a certain height above sea level, and construct and maintain sufficient dams or embankments upon and along the shores of any such lake to keep and maintain the water in such lake at a certain height above sea level, or do anything necessary to provide for the lowering or raising of the water in such lake, depending on the requirement in the particular situation" (State of Michigan, 2010).

Lake boards operate under provisions of Part 309, Inland Lake Improvements, of the Natural Resources and Environmental Protection Act, PA 451 of 1994, as amended (MCL 324.30901 – 324.30929).

Lake boards have the authority to implement a variety of projects. Fundamentally, a lake board could implement any lake project that provides a public benefit. Section 30901(a) of Part 309 defines benefit as follows:

> (a) "Benefit" or "benefits" means advantages resulting from a project to public corporations, the inhabitants of public corporations, the inhabitants of this state, and property within public corporations. Benefit includes benefits that result from elimination of pollution and elimination of flood damage, elimination of water conditions that jeopardize the public health or safety; increase of the value or use of lands and property arising from improving a lake or lakes as a result of the lake project and the improvement or development of a lake for conservation of fish and wildlife and the use, improvement, or development of a lake for fishing, wildlife, boating, swimming, or any other recreational, agricultural, or conservation uses.

Prior to undertaking a significant lake augmentation improvement project, other considerations such as legal easements, permit responsibilities, and potential liability associated with physical structures should be carefully evaluated by experienced legal counsel on behalf of the Lake Board.

7.0 PRELIMINARY ENGINEERING AND COST EVALUATION

Initial planning and cost estimating was conducted by K&A for each potential augmentation source option. These efforts included concept maps and sketches, design and implementation considerations, and estimated implementation costs associated with each option included in this study. In combination with the information summarized in Section 6.0 above, these findings are used by K&A to aid with prioritization of future Cedar Lake augmentation recommendations.

7.1 Engineering Design Considerations and Estimated Implementation Costs

Each potential lake augmentation option previously discussed has a unique set of associated challenges and benefits to be considered. The following provides summary information specific to each augmentation option related to construction implementation cost considerations. A few examples of these considerations include surveying, property acquisitions and easement negotiations, design/engineering plans and permitting, estimated construction material costs, contingency costs, and estimated annual operation and maintenance costs. Example concept maps and sketches for each option are provided in Figures 15 through 20. These maps and figures are intended to accompany the following design consideration and cost summaries.

Phelan Creek Partial Diversion (See Figure 15)

DESCRIPTION	QTY.	UNIT	UNIT COST	EST. TOTAL
Stakeholder coordination	1	lsum	$ 4,000	$ 4,000
Design surveying and legal property surveys	1	lsum	$ 12,000	$ 12,000
Design/engineering	1	lsum	$ 19,270	$ 19,270
Property acquisitions and easement negotiation	0.62	acre	$ 5,000	$ 3,100
Excavation and grading (cut & fill)	1,100	cyd	$ 5	$ 5,500
Stone rip-rap and geotextile at discharge	15	cyd	$ 50	$ 750
Asphalt road removal and repairs	720	sq. ft.	$ 15	$ 10,800
Stream diversion structure	1	ea	$ 3,500	$ 3,500
12" dia. HDPE conveyance pipe	1,200	lft	$ 40	$ 48,000
Topsoil placement (6")	333	cyd	$ 6	$ 1,998
Seeding and erosion controls	1.40	acre	$ 5,000	$ 7,000
Mobilization (4%)	1	lsum	$ 3,706	$ 3,706
Contingency (10%)	1	lsum	$ 9,635	$ 9,635
			Total	**$ 129,435**
			Annual O&M	**$ 3,500**

<u>Notes:</u>

- Implementation costs include considerations for easement negotiations and acquisitions for underground conveyance piping to Cedar Lake
- Annual O&M costs for this option are relatively low

King's Corner Culvert Modifications (See Figure 16)

DESCRIPTION	QTY.	UNIT	UNIT COST	EST. TOTAL
Stakeholder coordination	1	lsum	$ 2,500	$ 2,500
Design/engineering/permitting	1	lsum	$ 2,500	$ 2,500
Headwall and weir construction	1	lsum	$ 12,000	$ 12,000
Mobilization (4%)	1	lsum	$ 480	$ 480
Contingency (10%)	1	lsum	$ 1,248	$ 1,248
			Total	**$ 18,728**
			Annual O&M	**$ 1,500**

Notes:

- Initial capital costs for this option are relatively low, and the project area will be limited to the north side of the culvert at King's Corner Rd.
- Several years may to be needed to observe impacts of these modifications
- Site monitoring and vegetative surveys will be ongoing costs to document the wetland response
- Regular maintenance checks at the King's Corner culvert will be necessary to ensure proper functioning by an approved Lake Board designee

Sherman & Jones Creek Modifications (See Figure 17)

DESCRIPTION	QTY.	UNIT	UNIT COST	EST. TOTAL
Stakeholder coordination	1	lsum	$ 3,000	$ 3,000
Design surveying	1	lsum	$ 4,000	$ 4,000
Design/engineering/wetland permitting	1	lsum	$ 7,488	$ 7,488
Site access/limited clearing & grubbing	1	lsum	$ 3,500	$ 3,500
In-stream grade control structures	5	ea	$ 4,000	$ 20,000
Headwall and weir construction	2	ea	$ 12,000	$ 24,000
Mobilization (4%)	1	lsum	$ 1,920	$ 1,920
Contingency (10%)	1	lsum	$ 4,992	$ 4,992
			Total	**$ 68,900**
			Annual O&M	**$ 5,000**

Notes:

- Several years may to be needed to observe impacts of these modifications
- Site monitoring and vegetative surveys will be ongoing costs to document the wetland response
- Regular inspection/repair at each culvert and instream grade control structures will be necessary to ensure adequate fish passage

Harvest Wet Weather Lake Outflows (See Figure 18)

DESCRIPTION	QTY.	UNIT	UNIT COST	EST. TOTAL
Stakeholder coordination	1	lsum	$ 5,000	$ 5,000
Design surveying and legal property surveys	1	lsum	$ 12,000	$ 12,000
Design/engineering/permitting	1	lsum	$ 20,069	$ 20,069
Property acquisitions and easement negotiation	0.62	acre	$ 5,000	$ 3,100
Pump house structure at lake outflow	1	ea	$ 15,000	$ 15,000
Pumps, electric and controls	1	ea	$ 12,000	$ 12,000
Stone rip-rap and geotextile at discharge	10	cyd	$ 50	$ 500
Excavation and grading (cut & fill)	1,100	cyd	$ 5	$ 5,500
Asphalt road removal and repairs	720	sq. ft.	$ 15	$ 10,800
12" dia. HDPE conveyance pipe	1,350	lft	$ 45	$ 60,750
Topsoil placement (6")	333	cyd	$ 6	$ 1,998
Seeding and erosion controls	1.40	acre	$ 5,000	$ 7,000
Mobilization (4%)	1	lsum	$ 5,146	$ 5,146
Contingency (10%)	1	lsum	$ 13,379	$ 13,379
			Total	**$ 172,242**
			Annual O&M	**$ 15,020**

Notes:

- Annual O&M costs associated with pump operation will vary according to local precipitation amounts and duration of seasonal lake outflow
- O&M costs include an estimated $4/hr[1] for electrical pumping costs over 120 days and $3,500 for parts, repairs, routine maintenance, and winterization

[1] http://deltafarmpress.com/electricity-option-irrigation

Groundwater Augmentation Well: Discharge to wetland (See Figure 19)

DESCRIPTION	QTY.	UNIT	UNIT COST	EST. TOTAL
Stakeholder coordination	1	lsum	$ 5,000	$ 5,000
Design surveying and legal property surveys	1	lsum	$ 12,000	$ 12,000
Design/engineering/permitting	1	lsum	$ 49,151	$ 49,151
Property acquisition	56.00	acre	$ 2,680	$ 150,080
Site access/limited clearing & grubbing	1.50	acre	$ 4,000	$ 6,000
Drilling and pumping well installations	5	ea	$ 19,000	$ 95,000
Pumps, electric and controls	5	ea	$ 5,000	$ 25,000
12" dia. HDPE conveyance pipe	500	lft	$ 40	$ 20,000
Excavation and grading (cut & fill)	1,100	cyd	$ 5	$ 5,500
Stone rip-rap and geotextile at discharge	5	cyd	$ 50	$ 250
Topsoil placement (6")	40	cyd	$ 6	$ 240
Seeding and erosion controls	0.20	acre	$ 5,000	$ 1,000
Mobilization (4%)	1	lsum	$ 12,603	$ 12,603
Contingency (10%)	1	lsum	$ 32,767	$ 32,767
			Total	**$ 414,591**
			Annual O&M	**$ 62,600**

Notes:

- These capital costs include approximately $150,080 for the purchase of the McDaniels' property surrounding Sherman Creek (absent this amount, this option would amount to approximately $259,511).
- Annual O&M costs associated with pump operation will vary according to local precipitation amounts and Sherman Creek wetland response
- O&M costs include an estimated $4/hr for electrical pumping costs from 5 wells over 120 days and $5,000 for parts, repairs, routine maintenance, and winterization

Groundwater Augmentation Well: Direct piping to lake (See Figure 19)

DESCRIPTION	QTY.	UNIT	UNIT COST	EST. TOTAL
Stakeholder coordination	1	lsum	$ 5,000	$ 5,000
Design surveying and legal property surveys	1	lsum	$ 12,000	$ 12,000
Design/engineering/permitting	1	lsum	$ 56,623	$ 56,623
Property acquisition	56.00	acre	$ 2,680	$ 150,080
Easement negotiations and acquisitions	0.62	acre	$ 5,000	$ 3,100
Site access/limited clearing & grubbing	1.50	acre	$ 4,000	$ 6,000
Drilling and pumping well installations	5	ea	$ 19,000	$ 95,000
Pumps, electric and controls	5	ea	$ 5,000	$ 25,000
Asphalt road removal and repairs	720	sq. ft.	$ 15	$ 10,800
12" dia. HDPE conveyance pipe	1,350	lft	$ 40	$ 54,000
Excavation and grading (cut & fill)	1,100	cyd	$ 5	$ 5,500
Stone rip-rap and geotextile at discharge	5	cyd	$ 50	$ 250
Topsoil placement (6")	40	cyd	$ 6	$ 240
Seeding and erosion controls	0.20	acre	$ 5,000	$ 1,000
Mobilization (4%)	1	lsum	$ 14,519	$ 14,519
Contingency (10%)	1	lsum	$ 37,749	$ 37,749
			Total	**$ 476,861**
			Annual O&M	**$ 62,600**

Notes:

- In addition to the previous option, these costs include considerations for easement negotiations and acquisitions for underground conveyance piping to Cedar Lake
- Capital costs include approximately $150,080 for the purchase of the McDaniels' property surrounding Sherman Creek (absent this amount, this option would amount to approximately $321,781)
- Annual O&M costs associated with pump operation will vary according to local precipitation amounts and Cedar Lake volume needs
- O&M costs include an estimated $4/hr for electrical pumping costs from 5 wells over 120 days and $5,000 for parts, repairs, routine maintenance, and winterization

Lake Huron Pumping to Cedar Lake (See Figure 20)

DESCRIPTION	QTY.	UNIT	UNIT COST	EST. TOTAL
Stakeholder coordination	1	lsum	$ 6,000	$ 6,000
Design surveying and legal property surveys	1	lsum	$ 18,000	$ 18,000
Design/engineering/permitting (MDEQ/County/MDOT)	1.00	lsum	$ 84,296	$ 84,296
Property acquisitions and easement negotiation	3.00	acre	$ 5,000	$ 15,000
Pump house structure	1	ea	$ 15,000	$ 15,000
Lift station	1	ea	$ 50,000	$ 50,000
Pumps, electric and controls	3	ea	$ 12,000	$ 36,000
Asphalt road removal and repairs (U.S.-23, MDOT)	750	sq. ft.	$ 25	$ 18,750
Excavation and grading (cut & fill)	5,333	cyd	$ 5	$ 26,665
12" dia. HDPE conveyance pipe	3,300	lft	$ 40	$ 132,000
Stone rip-rap and geotextile at discharge	20	cyd	$ 50	$ 1,000
Topsoil placement (6")	300	cyd	$ 6	$ 1,800
Seeding and erosion controls	2.00	acre	$ 5,000	$ 10,000
Mobilization (4%)	1	lsum	$ 12,969	$ 12,969
Contingency (10%)	1	lsum	$ 33,718	$ 33,718
			Total	**$ 461,198**
			Annual O&M	**$ 41,560**

<u>Notes:</u>

- This option will require substantial permitting and regulatory coordination with MDEQ, Alcona County and MDOT
- A piping distance of approximately 3,300 feet is required and therefore, several property negotiations are likely necessary for conveyance easements
- Given the elevation differences between Lake Huron and Cedar Lake, it is assumed that a lift station may also be necessary
- Annual O&M costs associated with pump operation will vary according to local precipitation amounts and Cedar Lake volume needs
- O&M costs include an estimated $4/hr for electrical pumping costs from 3 pumps over 120 days and $7,000 for parts, repairs, routine maintenance, and winterization

8.0 SUMMARY AND RECOMMENDATIONS

A total of seven potential source water options were evaluated within this feasibility study to assess opportunities of augmenting Cedar Lake water levels during the summer months of June through September. Each option was evaluated against several different criteria to assist with differentiating between the potential benefits and challenges associated with each one. The collective comparison of these potential benefits and challenges can be subjectively summarized as 'project complexity' and is taken into consideration within the overall assessment of implementation feasibility. Below is a summary that compares and contrasts each augmentation source water option with respect to factors such as project complexity, implementation capital costs, annual operation and maintenance (O&M) costs, volume capacity, and capital cost per million gallons delivered (assuming 364 million gallons associated with the estimated seasonal summer precipitation is the amount of water needed to maintain the legal lake level and overcome other external losses).

Source Option	**Project Complexity** (1=low to 5=high)	**Capital Costs** ($)	**Annual O&M Costs** ($)	**Capacity** (MG)	**Unit Cost** ($/MG)
Phelan Creek Partial Diversion	4	$ 129,435	$ 3,500	46.5	$ 2,784
Kings Corner Culvert Modifications	1	$ 18,728	$ 1,500	18.9	$ 991
Sherman/Jones Creeks Modifications	2	$ 68,900	$ 5,000	150	$ 459
Harvest Wet Weather Lake Outflows	5	$ 172,242	$ 15,020	2.16	$ 9,742
Augmentation Wells: Discharge to wetland	3	$ 414,591	$ 62,600	101.4	$ 4,089
Augmentation Wells: Direct pipe to lake	4	$ 476,861	$ 62,600	101.4	$ 4,703
Lake Huron Pumping to Cedar Lake	5	$ 461,198	$ 41,560	364	$ 1,267

Five primary categories are listed above with respect to each source water augmentation implementation option. These five categories are summarized as follows. Bar graph illustrations for each of these categories are provided in Figures 21 through 24.

Project Complexity

This category is subjective and reflects a collective summary of each evaluation criterion based upon best professional judgment. Evaluation criteria included location and physical setting constraints, lake volume needs, source volume limitation, seasonal timing, impacts to environmentally sensitive areas and existing natural resources, potential regulatory concerns and permitting requirements. The overall project complexity for each option was rated on a scale of 1 to 5 (i.e., 1 = low complexity and 5 = high complexity).

Based on the collective information used to score each option, the King's Corner culvert modifications and Sherman/Jones Creek modifications involve the least project implementation complexity, with scoring values of 1 and 2, respectively. The option of augmentation wells with discharge to the existing wetlands was assigned a 3 for project complexity, followed by Phelan Creek diversion and augmentation wells with direct piping to Cedar Lake each receiving higher complexity scores of 4. Two of the seven options received a complexity score of 5 (highest possible score) due to many issues and challenges related to their implementation.

Implementation Capitol Costs

This category is strictly based on necessary capitol costs, which are likely the critical driver for augmentation implementation. Capitol costs for each augmentation source water option include stakeholder coordination, land purchases, legal property surveys and easement negotiations, engineering design and regulatory permitting (local, State and Federal), contractor start-up and mobilization costs, construction/implementation costs, and a 10% contingency.

Strictly based on implementation cost, the King's Corner culvert modifications ($18,728) and Sherman/Jones Creeks modifications ($68,900) require the least costs for implementation. These are followed by the options of Phelan Creek partial diversion ($129,435) and harvesting wet weather lake outflows ($172,242). The option of augmentation wells with direct discharge piping to Cedar Lake was the highest implementation cost option ($476,861). However, both augmentation well options include a cost associated with property purchase of the McDaniels' 56-acre property adjacent to Sherman Creek (~$150,080). Excluding the property purchase cost of $150,080, augmentation wells with discharge to existing wetlands amount to $264,511 and augmentation wells with direct discharge piping to Cedar Lake amount to $326,781. Taking this information into consideration, the highest augmentation option would be Lake Huron pumping to Cedar Lake with an implementation cost of $461,198.

Annual O&M Costs

Annual operation and maintenance costs include considerations related to electrical pumping costs, parts, repairs, routine maintenance, and winterization. The King's Corner culvert modification option has the lowest estimated annual O&M cost of $1,500. The options of Phelan Creek diversion ($3,500) and Sherman/Jones Creek modifications ($5,000) have the next lowest annual O&M costs. Each of these three options exclude mechanical systems involving pumps and electrical costs. The two augmentation well options have the highest estimated annual O&M costs amounting to $62,600 (of which $57,600 is estimated for seasonal 120-day operation of 5 submersible groundwater pumps from June through September).

Capacity

The capacity evaluation category is directly related to the volume of source water available for augmentation purposes (in million gallons, MG). Due to the large volume of source water available from Lake Huron, that pumping option has the highest capacity of source water (assuming 364 million gallons associated with the estimated seasonal summer precipitation and the amount of water needed to maintain the legal lake level). All other options have specific limitations on available source water volume. The harvest wet weather lake outflows option has the least available volume (2.16 MG) due to limitations of lake outflows associated with spring snowmelt and runoff conditions. The King's Corner culvert modifications could yield an additional 18.9 MG to Cedar Lake and was historically part of the original lake drainage area before the culvert was installed. Phelan Creek partial diversion is capable of producing an estimated 46.5 MG seasonally, while the two augmentation well options are capable of producing approximately 101 MG during the summer months. Sherman/Jones Creek modifications require no mechanical systems, provide additional ancillary environmental benefits and produce an estimated 150 MG for lake augmentation purposes.

Unit Costs

The unit cost evaluation category is based on estimated implementation cost per million gallons provided for augmentation ($/MG). This is relative measure of how cost-effective each option can deliver source water based on the money needed for implementation. The most cost-effective option is the Sherman/Jones Creek modifications ($459/MG). The option of King's Corner culvert modifications is the next most cost-effective choice ($991/MG), followed by Lake Huron pumping to Cedar Lake ($1,267/MG). The Phelan Creek partial diversion option amounts to $2,784/MG, and the two augmentation well options with discharge to wetlands and direct piping to Cedar Lake amount to $4,089/MG and $4,703/MG, respectively. The option associated with harvesting wet weather lake outflows is the least cost-effective choice at $79,742/MG, based on the limited seasonal volume of available source water.

Based upon the above evaluation criteria, which summarize the implementation feasibility of each source water option, the following options appear to be least desirable and are not recommended for further consideration of augmentation implementation based on the following reasons.

Harvest wet weather Cedar Lake outflows

- Project complexity rank of 5 (highest value possible) – limited seasonal flows are available, likely negative impacts to downstream coldwater fisheries and existing wetlands, property easements and regulatory permitting are required
- Very limited augmentation volume/capacity available (based on range of volumes needed and relative to other options)
- Very high unit costs associated with dollars spent per million gallons supplied

Lake Huron pumping to Cedar Lake

- Project complexity rank of 5 (highest value possible) – includes over 3,000 feet of piping with pumps and lift stations, potential to introduce invasive species from Lake Huron to Cedar Lake, may require multiple discharge locations (based on exit velocities), property easements and burdensome regulatory permits are required (Alcona County, MDEQ, and MDOT), not looked upon favorably by MDEQ relative to other options available
- High implementation and O&M costs with no ancillary environmental benefits

Phelan Creek partial diversion

- Project complexity rank of 4 (on a scale of 1 to 5) – Designated coldwater stream, removal of flow may negatively impact fishery, includes approximately 1,000 feet of piping (or open channel) for conveyance, several property easements required, Van Etten watershed interests are involved, MDEQ suggested this option was less favorable than other alternatives

Based upon all evaluation criteria, which summarize the implementation feasibility of each source water option including cost-effectiveness, the following options appear to be most desirable and are therefore recommended for further implementation consideration. Prioritization of these recommended Cedar Lake augmentation options is as follows:

1. King's Corner culvert modifications
2. Sherman/Jones Creeks modifications
3. Augmentation Well(s): Discharging to wetland

Each potential augmentation source water option included in this feasibility study was evaluated individually and with respect to anticipated outcomes unique to each strategy. However, as each recommended option is sequentially implemented, an additive and cumulative effect is anticipated with respect to the observed benefits and future needs for additional augmentation related to the next option. As a result, K&A recommends that Cedar Lake water level response and additional augmentation needs/goals be evaluated following implementation of each augmentation effort listed above (as needs/goals change with each successive implementation effort).

K&A suggests that the Lake Board and AICLA consider the following short-term and long-term implementation strategy related to the outcomes of this feasibility study project. These recommendations are prioritized. They are also based on current needs and potential for near-term implementation monies becoming available utilizing a strategic implementation approach associated with the most cost-effective augmentation source water options.

Short-term recommendations include:

- Re-install Sherman Creek piezometer and water level logger following Alcona County Road Commission completion of road/culvert construction activities
- Re-establish stage-discharge relationship at Sherman Creek piezometer and road culvert location
- Protect existing 12-inch augmentation test well on McDaniels' property for potential future use
- Pursue a temporary permit to implement/install King's Corner culvert modifications (MDEQ was supportive of this concept)
- Proceed with implementation of the King's Corner culvert modification option (this may include seeking State implementation grant funds and tax assessments for matching funds assistance)

- Initiate discussion with Joan McDaniels related to feasibility of impelementing Sherman Creek modifications to maximize wetland water retention/storage (via grade control structures, fish ladders and culvert modifications)
- Consideration of McDaniels property purchase (approximately 56 acres) (or solicit it as a donation or conservation easement for tax write-off purposes) surrounding Sherman Creek in order to control potential future impacts that may threaten this existing recharge area (from a watershed management perspective) and to ensure flexibility for other future augmentation options
- Pursue implementation monies for Sherman/Jones Creek modification options (this may include seeking State implementation grant funds and possible tax assessments for matching funds assistance)

Long-term recommendations include:

- Continue to monitor lake levels, groundwater levels and precipitation at each existing monitoring location
- Conduct quarterly downloads of automated water level logger equipment and update electronic database files to maintain current records (building upon the current database for further decision-making purposes)
- Evaluate Cedar Lake's response to King's Corner culvert modifications (once this option is implemented) – This implementation effort will reconnect spring surface flows with Sherman Creek, recharge the wetlands that feed Sherman Creek, and introduce additional surface water runoff to Sherman Creek as the wetlands will be saturated for a longer period of time.
- Evaluate Cedar Lake response to Sherman/Jones Creek modifications (once this option is implemented) – This implementation effort will have cumulative effects on the King's Corner modifications. Spring surface flows will be slowed, keeping the surrounding wetlands saturated for a longer period of time (as opposed to drying out during critical summer months). Direct precipitation (whether average or below average) will have a greater impact on surface water runoff from the wetlands (rather than serving to recharge the wetlands). Based on these anticipated cumulative and ancillary impacts, future augmentation needs/goals will need to be evaluated (i.e., the need or desire for one or more augmentation wells).
- If needed or desired, pursue implementation monies for start-up and use of existing 12-inch augmentation test well located on McDaniels' property (following implementation of King's Corner culvert modifications and Sherman/Jones Creek modifications) to further supplement desired lake elevation goals.
- Build upon existing 12-inch augmentation well, installing additional wells as-needed, based on desired lake elevation goals and available implementation funding.

9.0 REFERENCES

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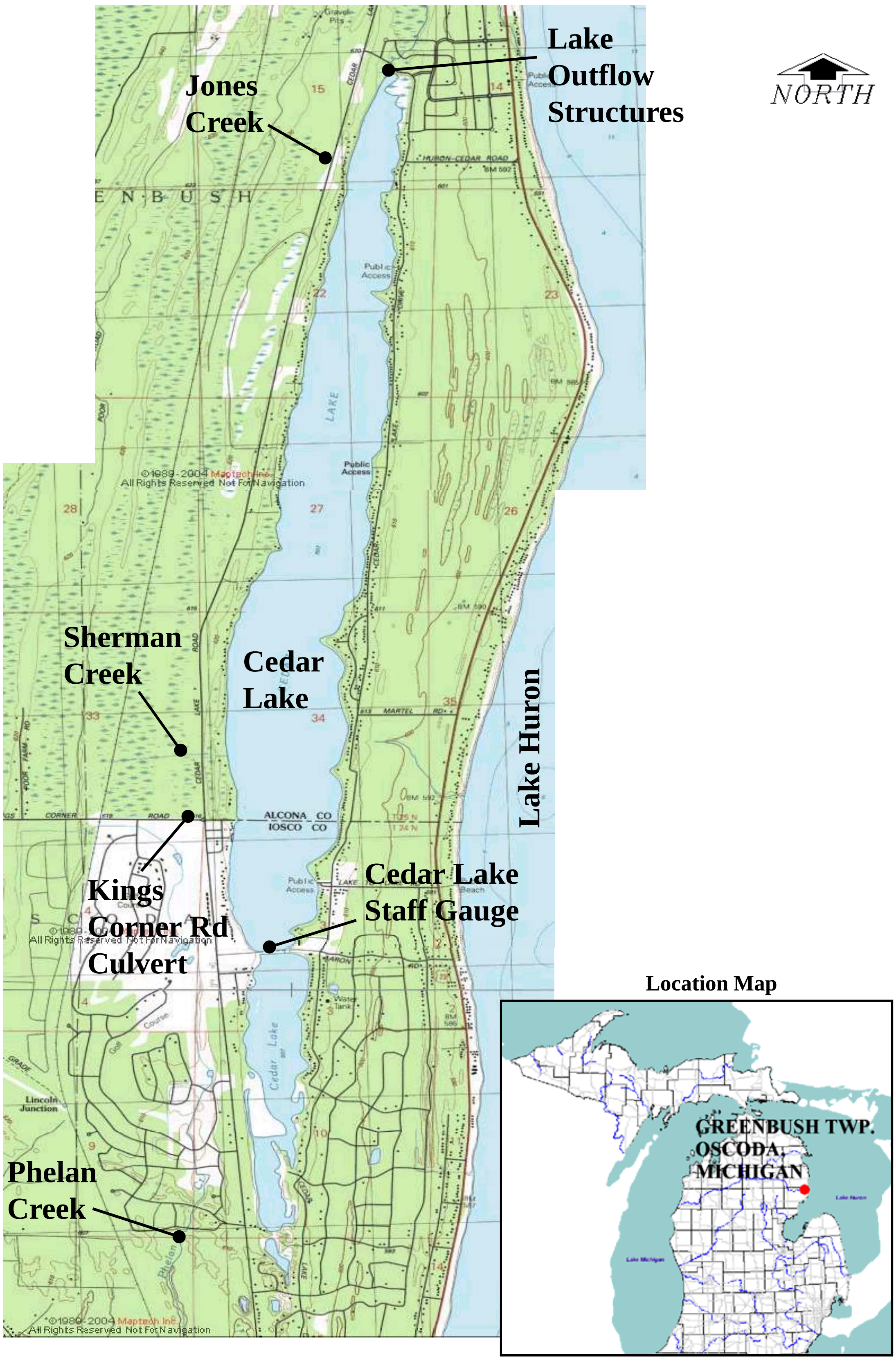

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Map of Cedar Lake and surface water features.

FIGURE 1

Site #1
north of 4484 E. Cedar Lake Dr.

Site #2
3481 W. Cedar Lake Rd.

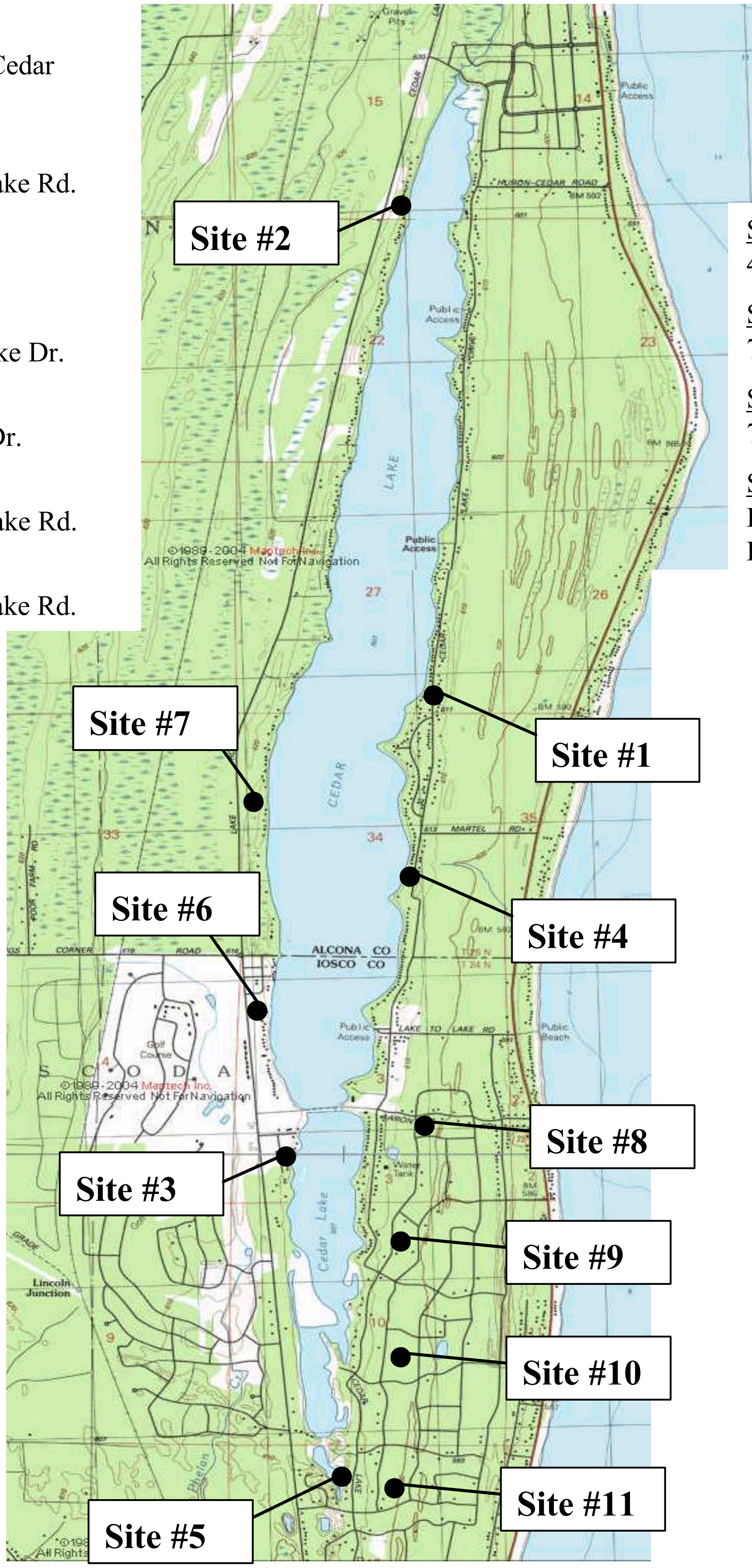
Site #3
7588 Teal

Site #4
4840 E. Cedar Lake Dr.

Site #5
6967 Lakewood Dr.

Site #6
7906 W. Cedar Lake Rd.

Site #7
4795 W. Cedar Lake Rd.



Site #8
4884 Arron Dr.

Site #9
7448 Lakewood Dr.

Site #10
7173 Huntington Dr.

Site #11
Lot north of 6933 Huntington Dr.

Sites 1-3 were original Phase I monitoring locations.

Sites 4-7 were added as part of Phase II monitoring efforts.

Sites 8-11 were added as part of Augmentation Feasibility Study efforts.

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Map of eleven groundwater elevation monitoring sites located around the perimeter of Cedar Lake.

FIGURE 2

Figure 3. Comparison of Groundwater Elevations at Lakewood Shores Piezometers and Cedar Lake Level Water Elevations during 2010 Summer Months.

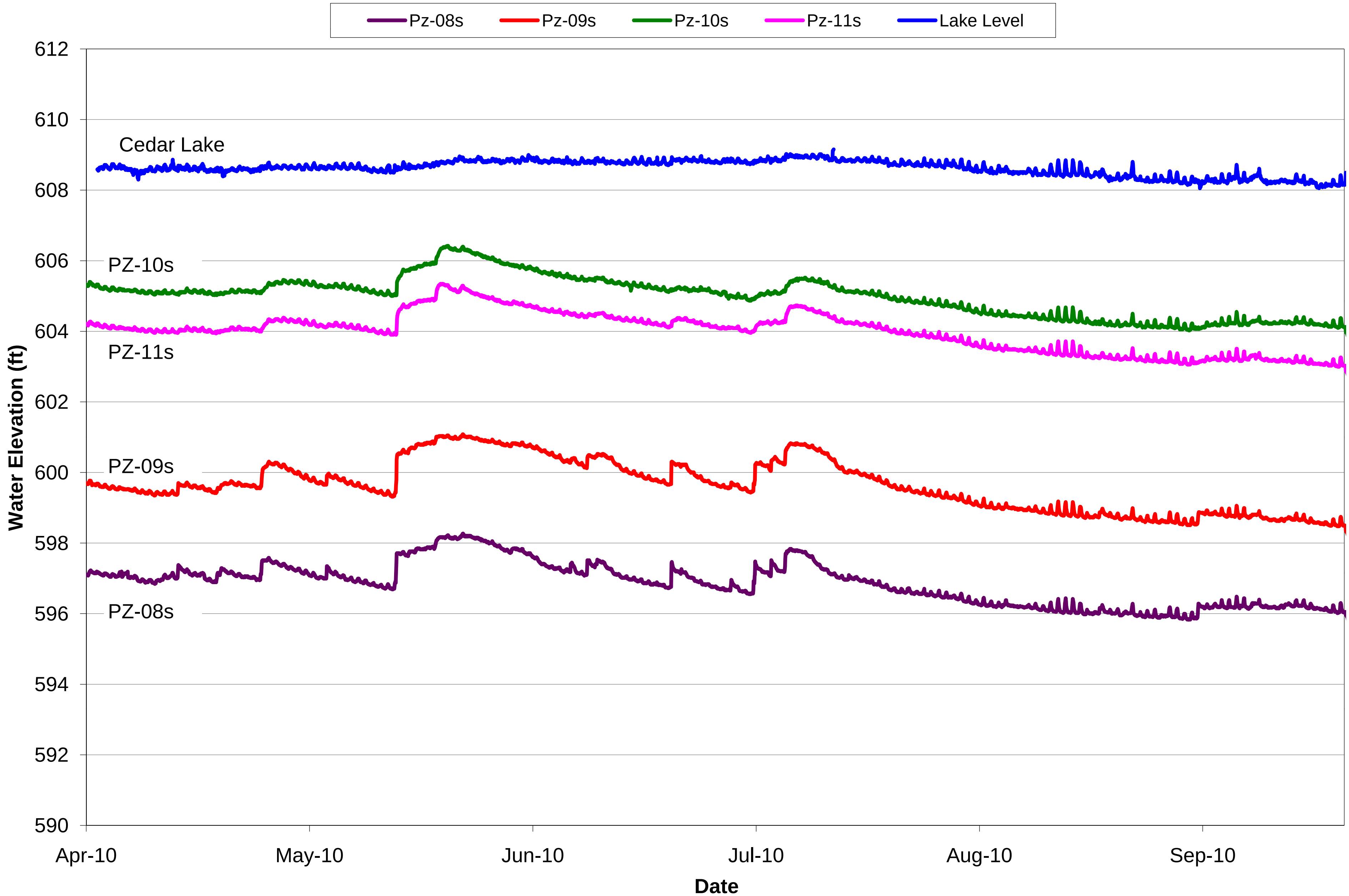

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Figure 4. Observed Stage-Discharge Relationship at Sherman Creek Culvert

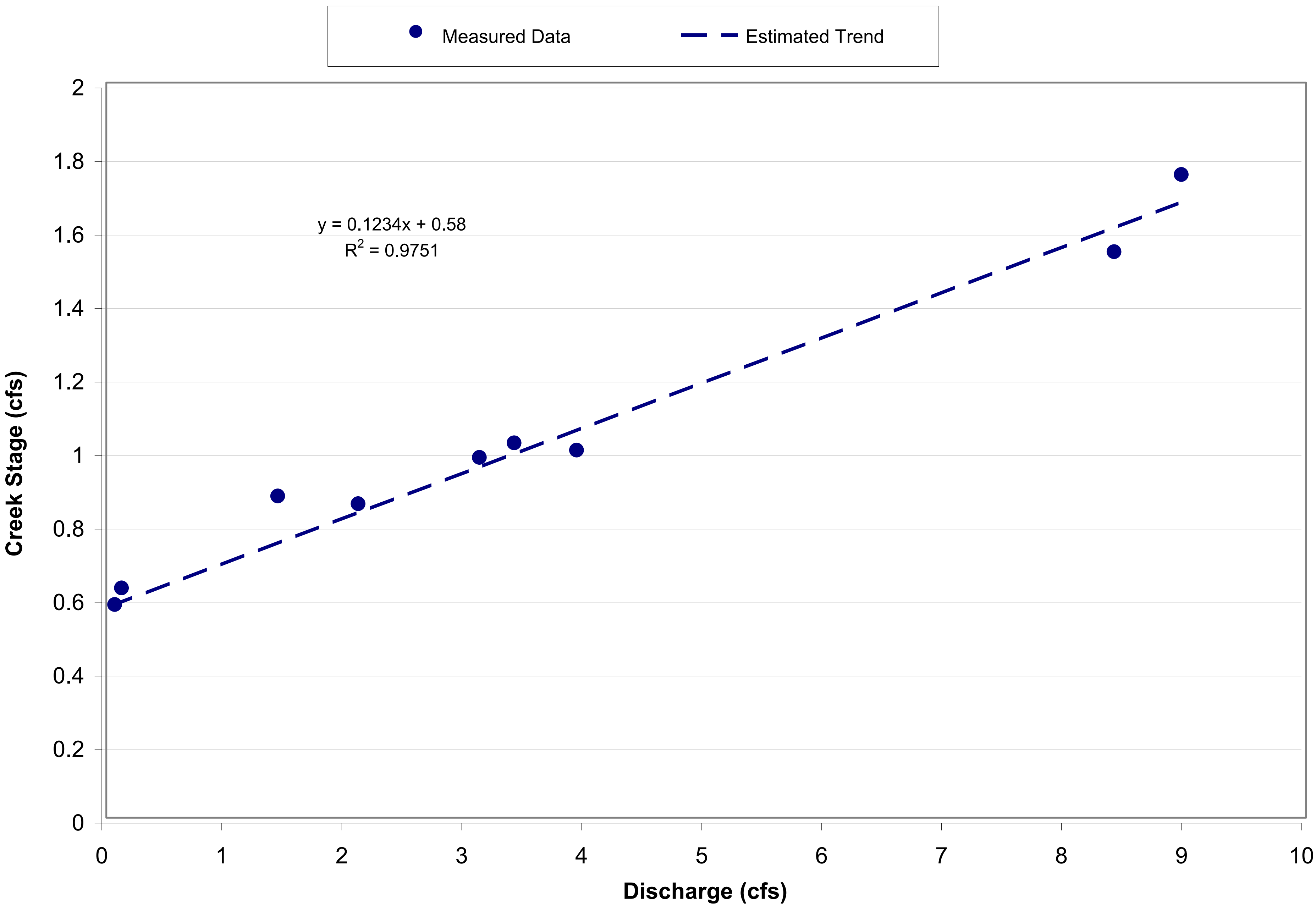

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Figure 5. Observed Stage-Discharge Relationship at Jones Creek Culvert

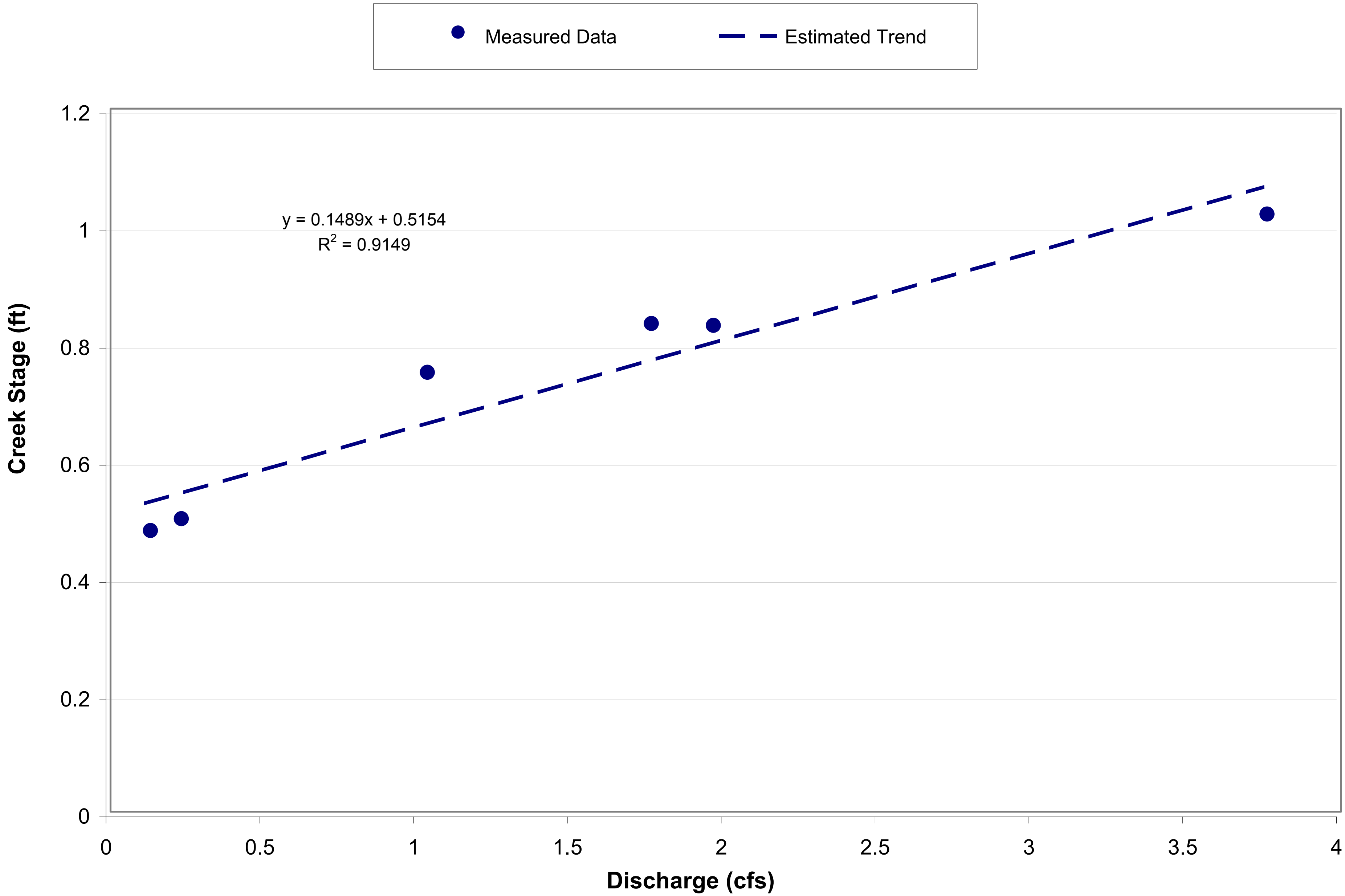

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Figure 6. Observed Stage-Discharge Relationship at King's Corner Road Culvert

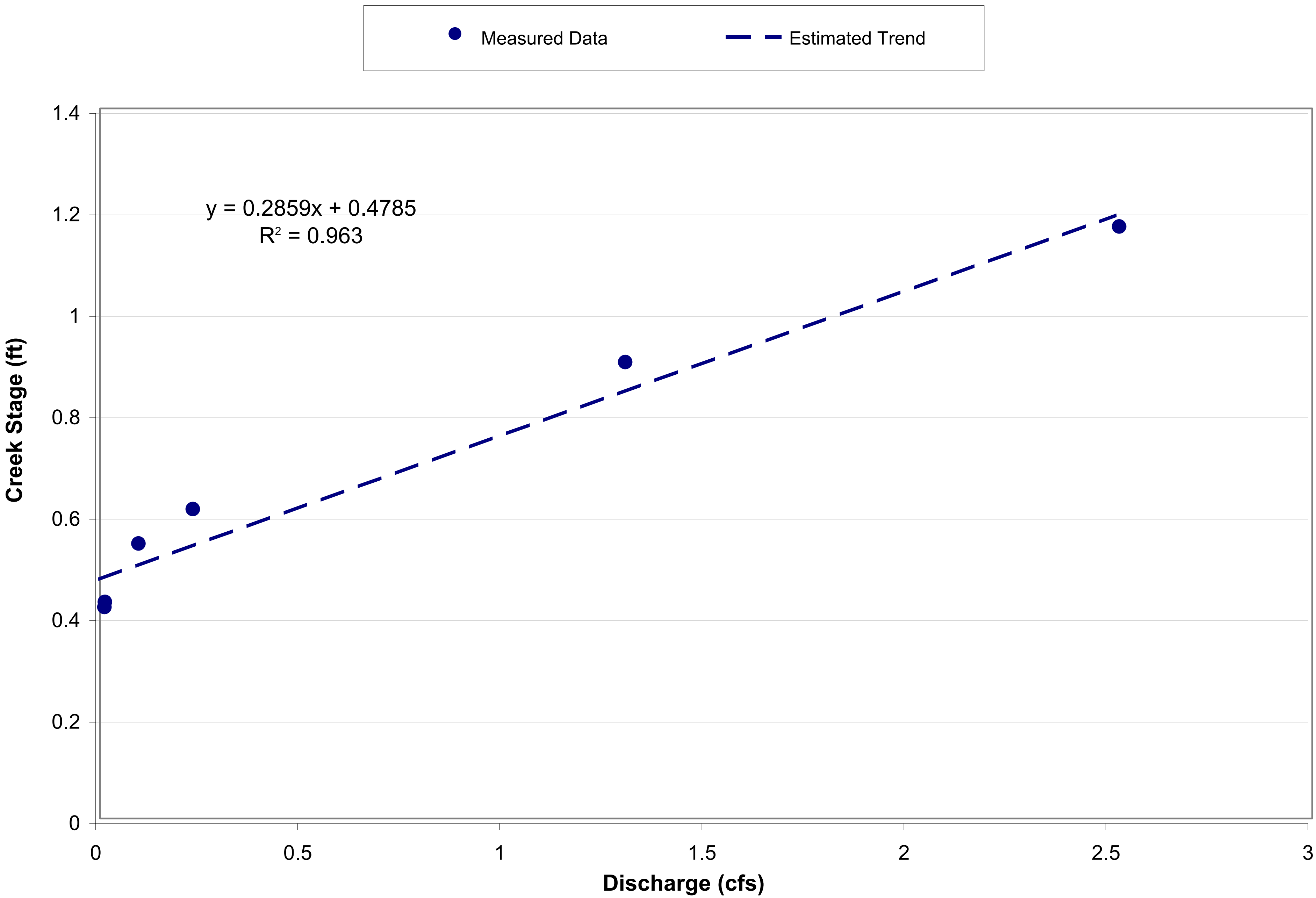

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Figure 7. Cedar Lake Water Elevations
(recorded at the outflow structures located at the north end of Cedar Lake)

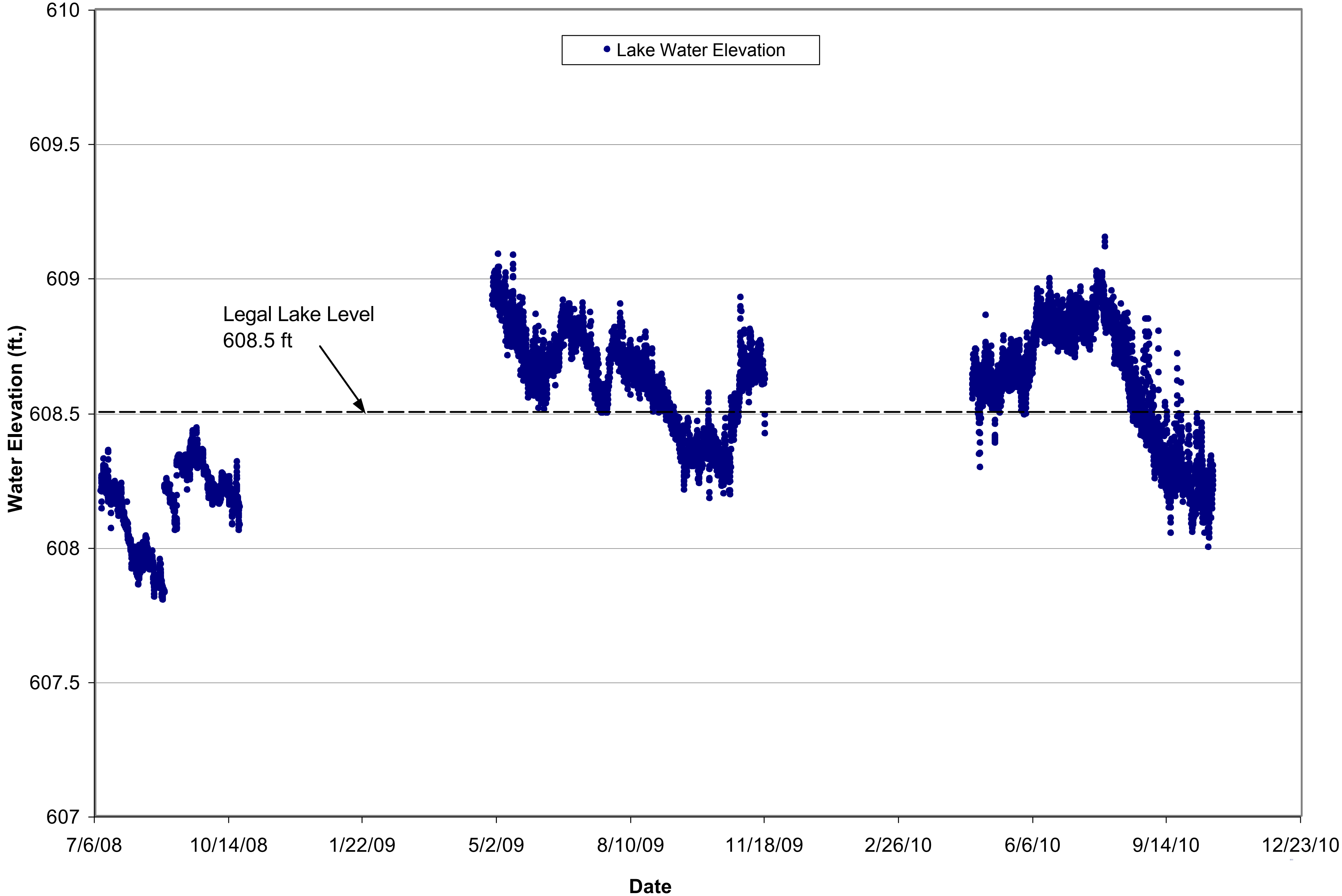

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Figure 8. Summer (Jun - Sept) Precipitation and Lake Level Drop for Cedar Lake
(Precipitation Source: Harrisville, MI, CO-OP Station #203628, Alcona County 1998-2004
Alcona-Iosco Cedar Lake Association (AICLA) Rain Gage 2004-2010)
(Lake Level Source: AICLA Data Loggers)

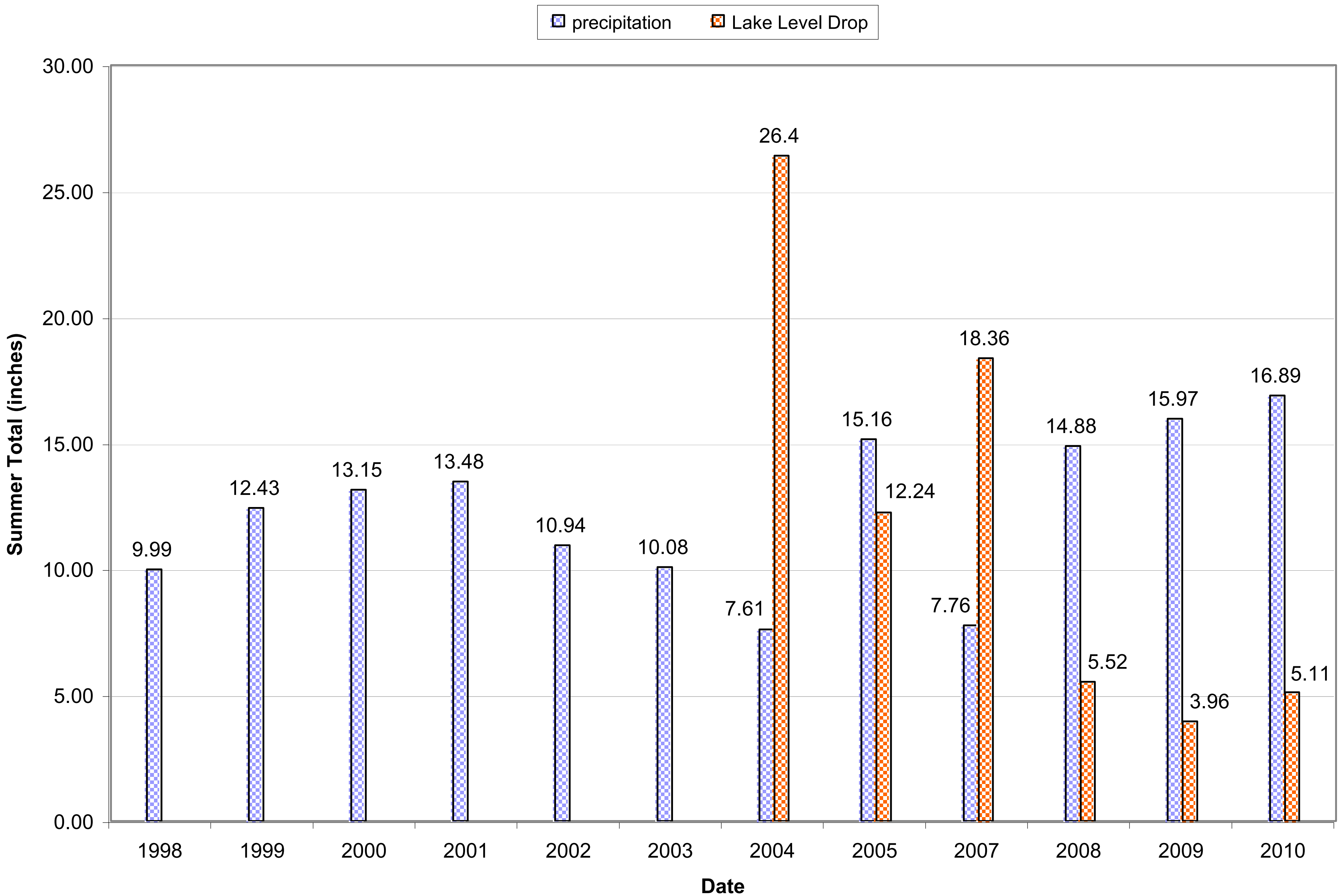

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Figure 9. Cedar Lake Montly Precipitation vs. Monthly Lake Elevation Drop
(June - September Summer Months Only)

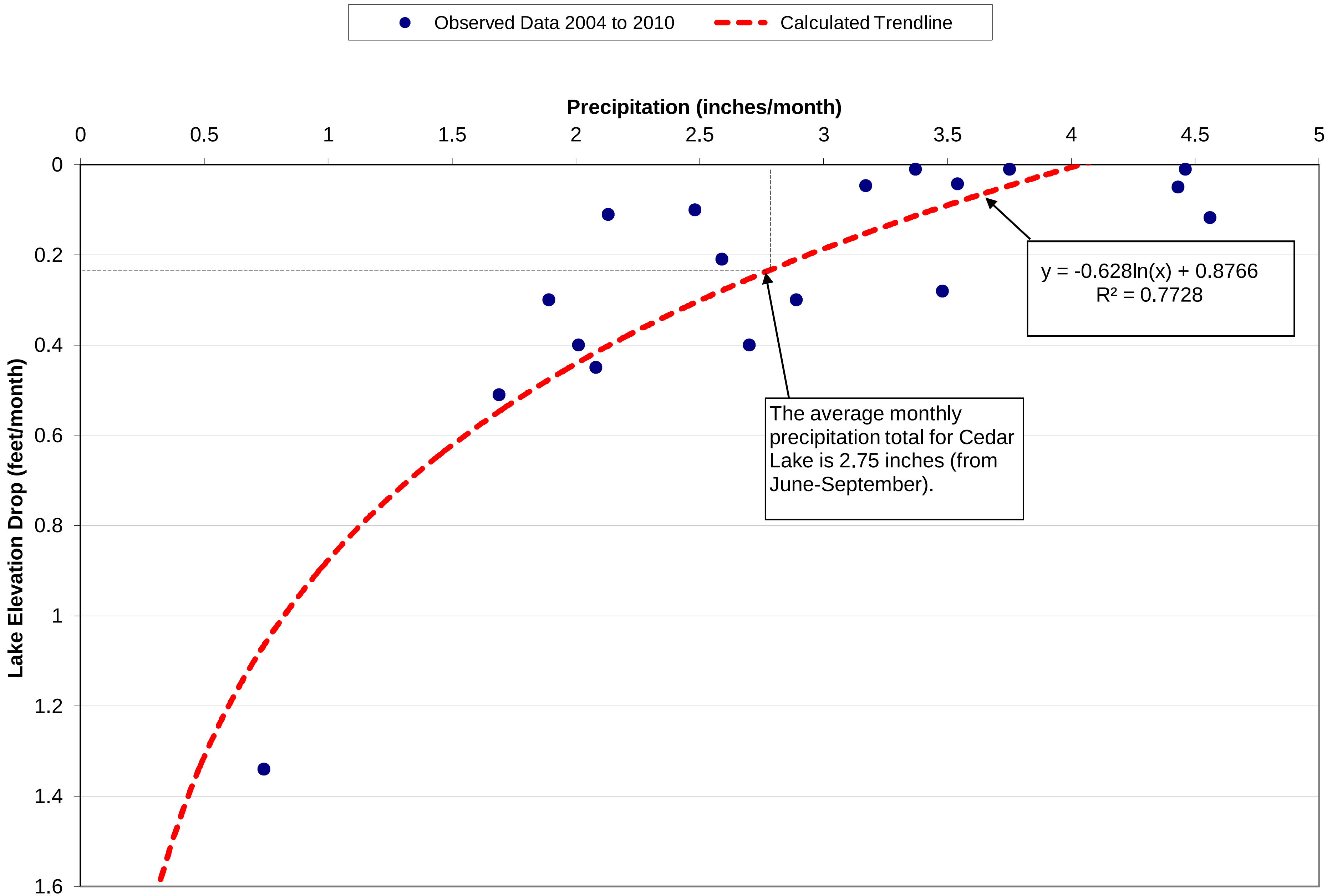

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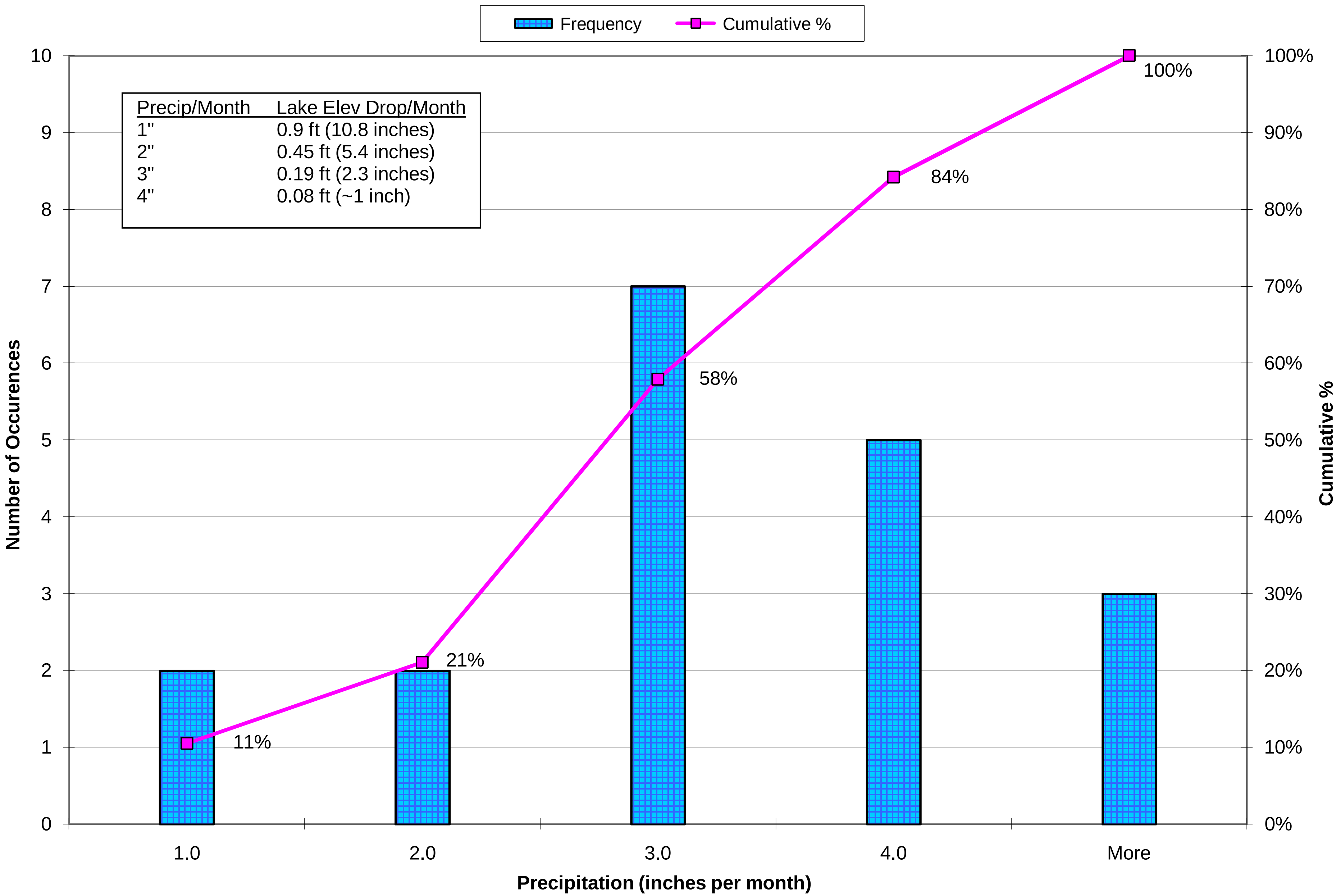
Figure 10. Frequency Distribution of Cedar Lake Monthly Precipitation 2004-2010
(summer months June-September)



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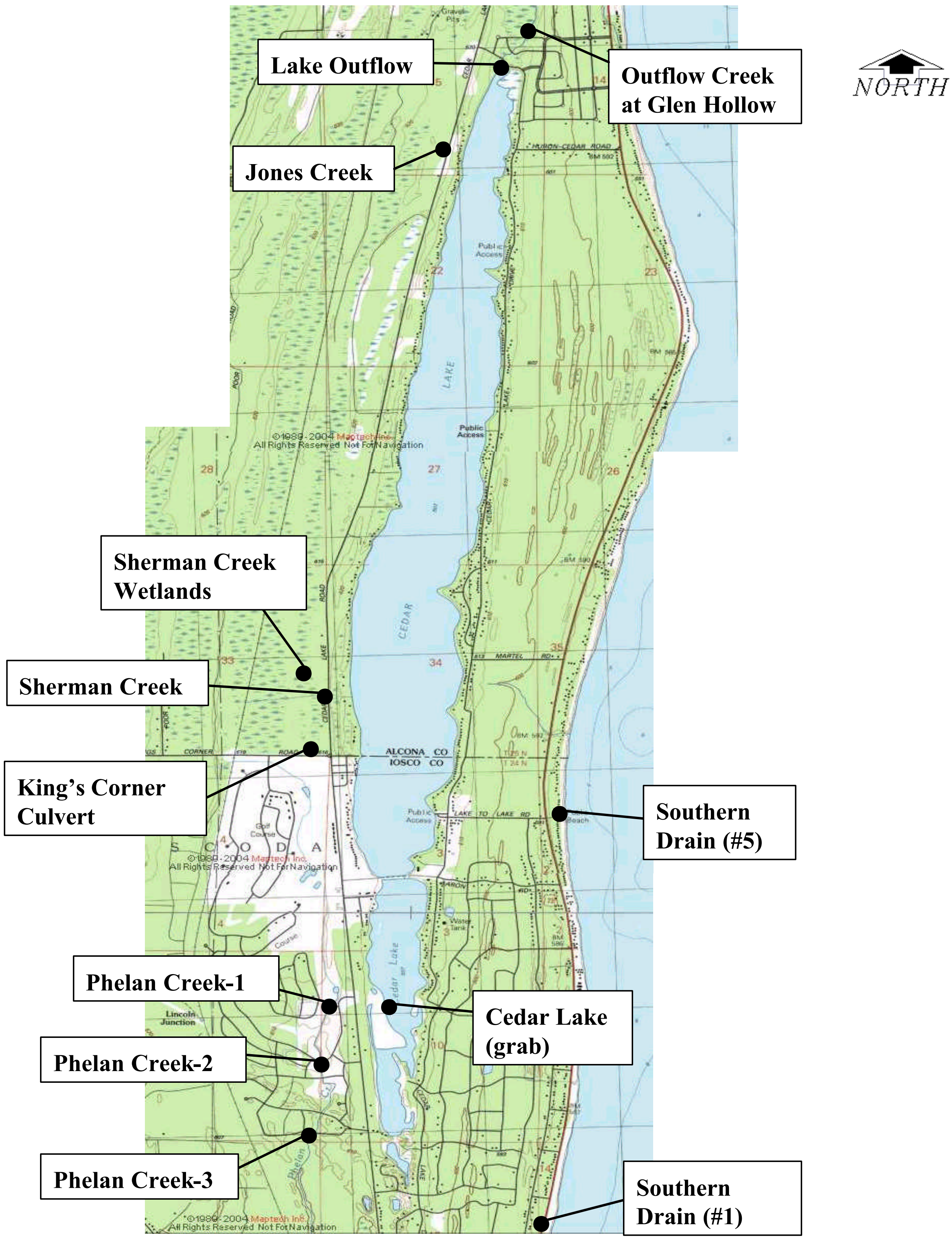

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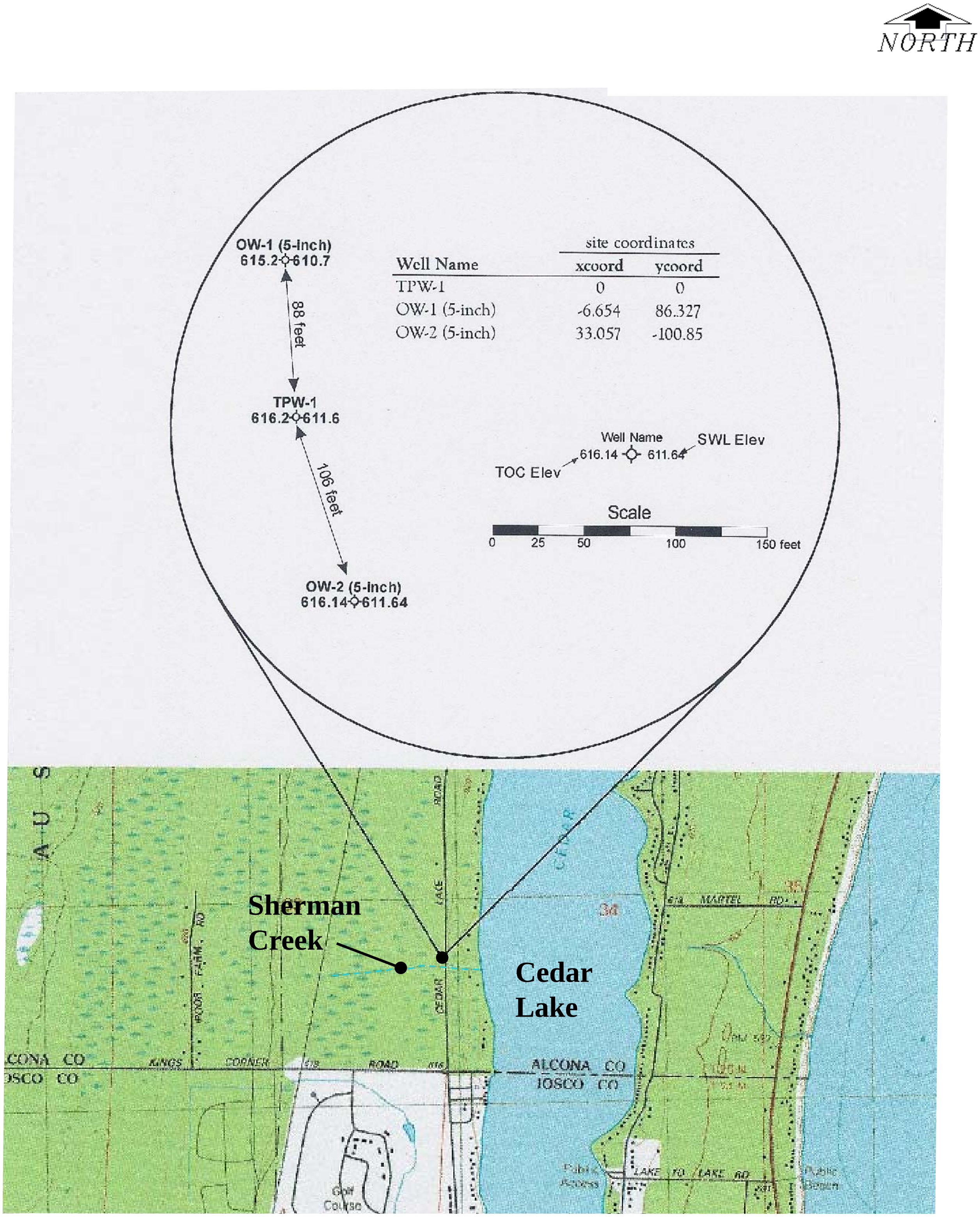
Map of select surface water quality sampling locations from July 29 and 30, 2010.

FIGURE
11



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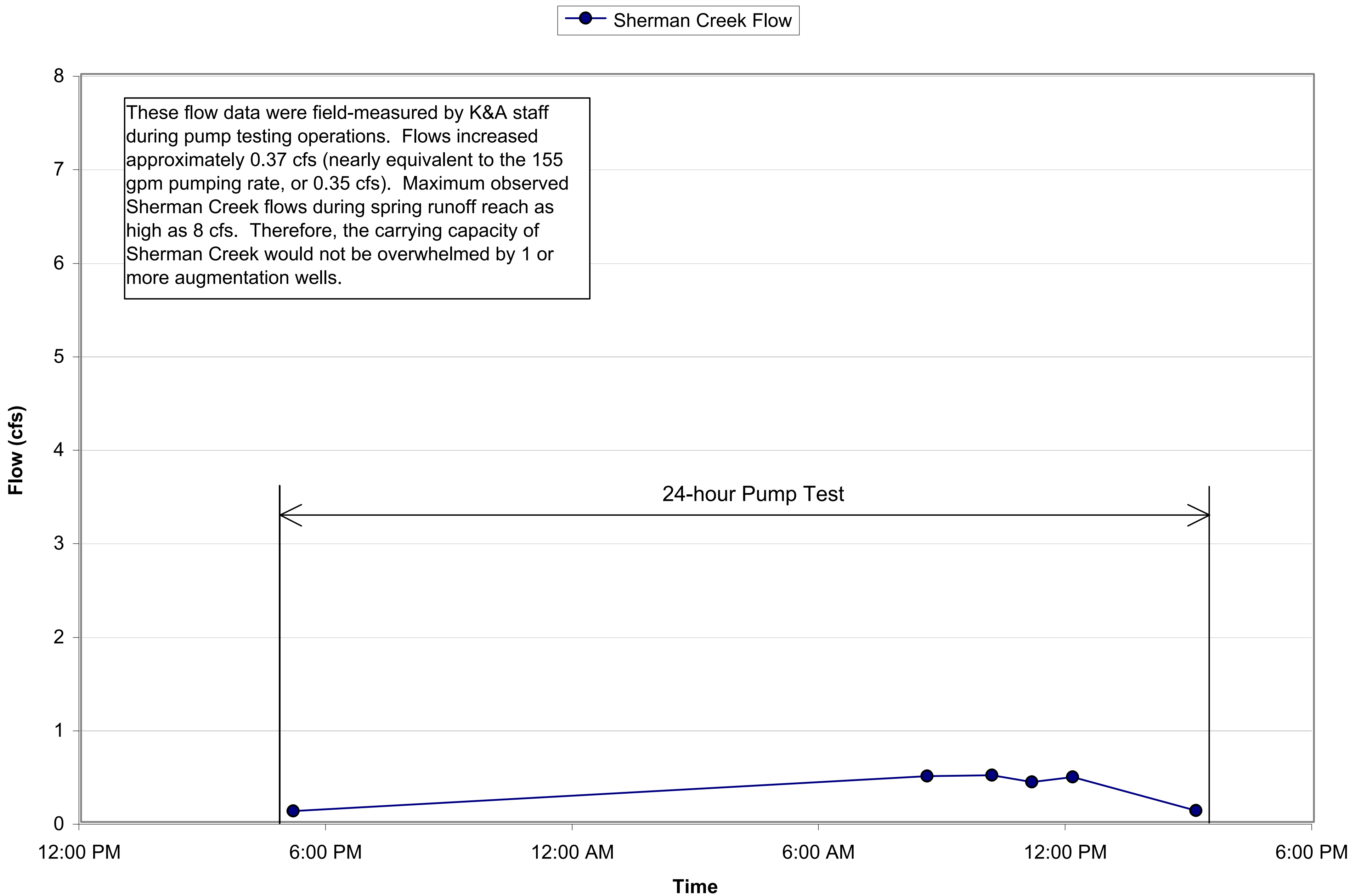
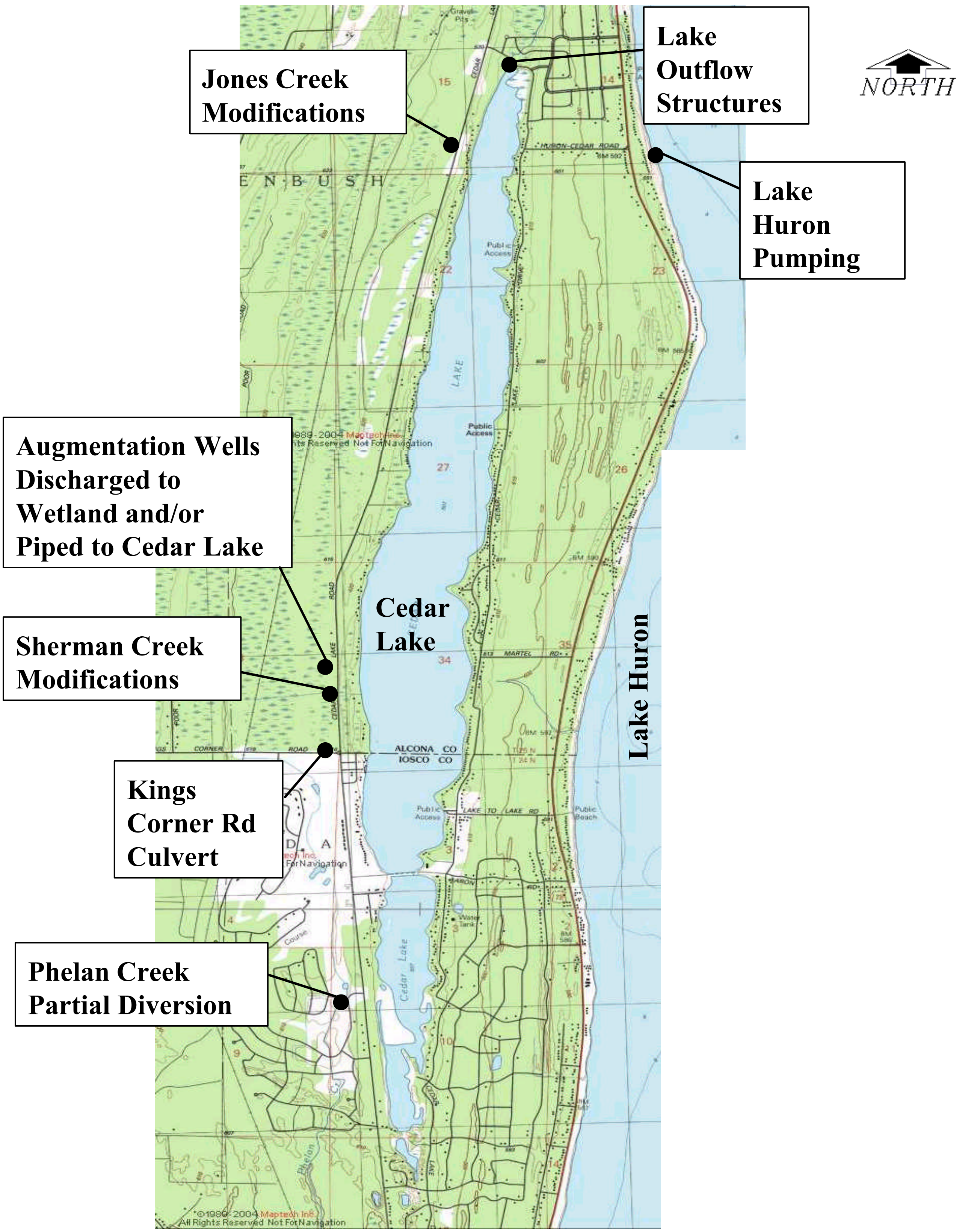
Location map of the augmentation test well site at Cedar Lake (north of Sherman Creek and west of Cedar Lake Road).

FIGURE 12

Figure 13. Observed Flow Impacts within Sherman Creek during 24-hr Pump Test on November 2 and 3, 2010.





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Location map of Cedar Lake and potential augmentation source water options.

FIGURE 14

Figure 15. Phelan Creek Partial Diversion

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Figure 16. King's Corner Culvert Modifications

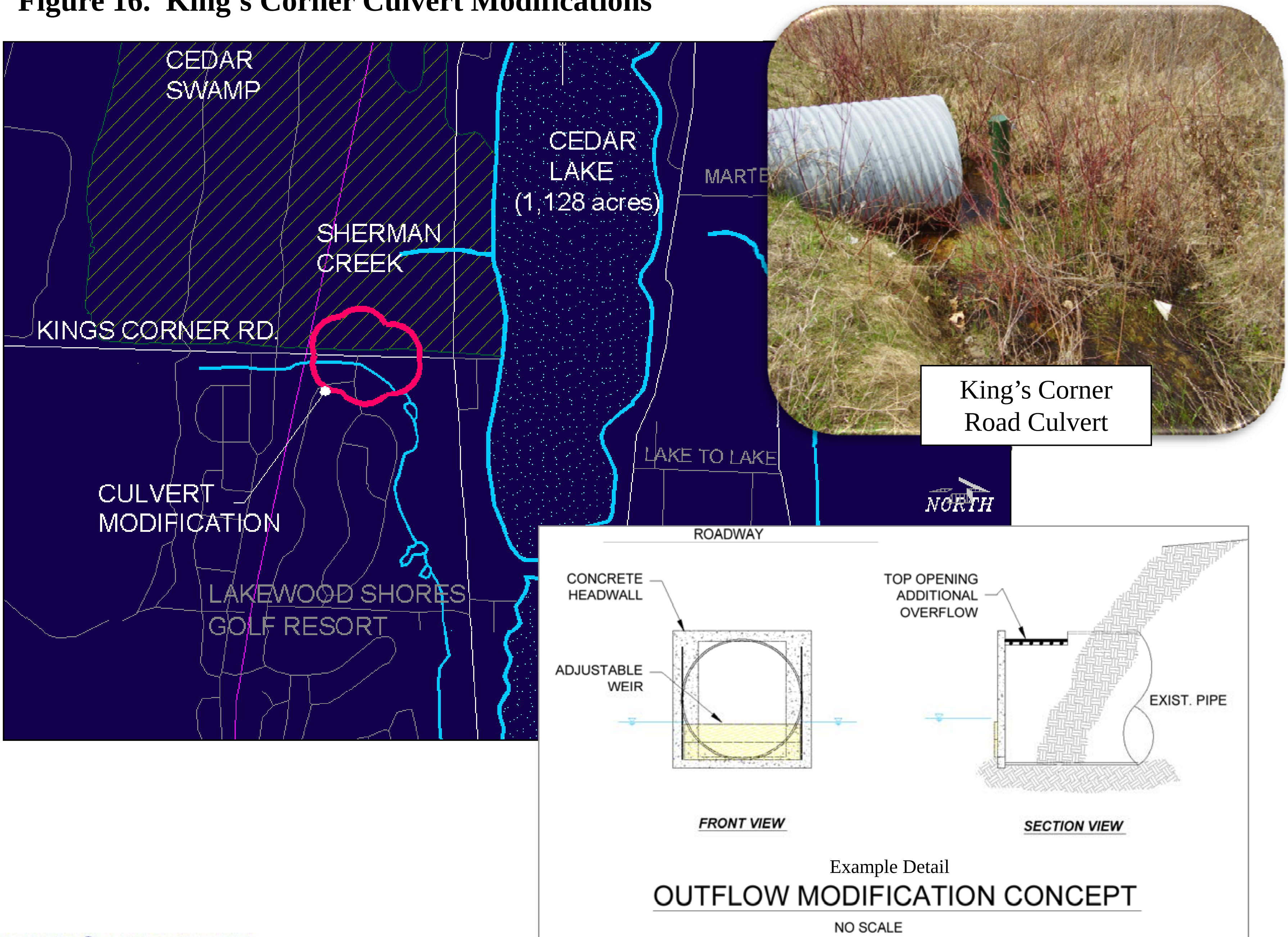

Figure 17. Sherman and Jones Creeks Modifications

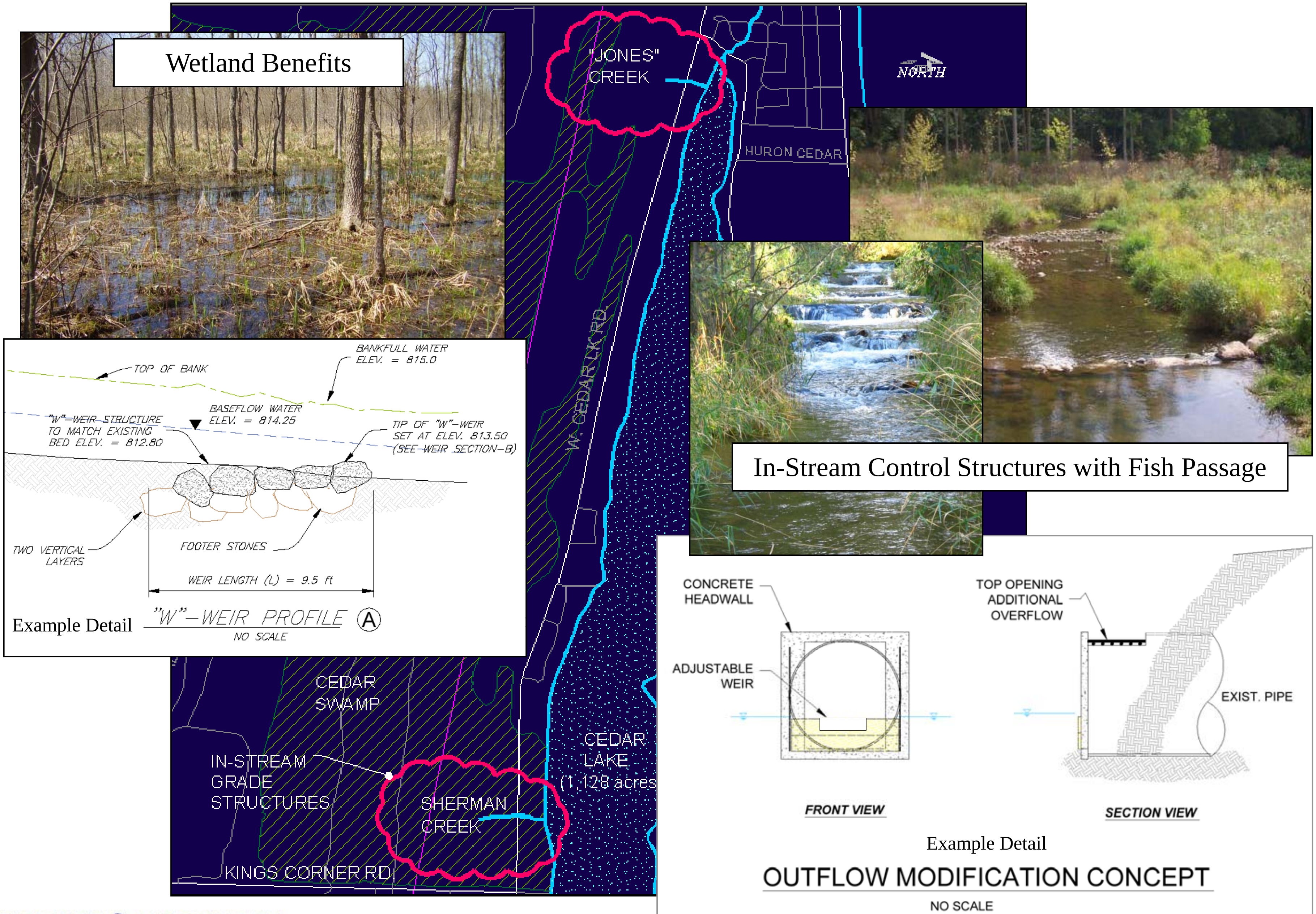

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Figure 18. Harvest Wet Weather Lake Outflows

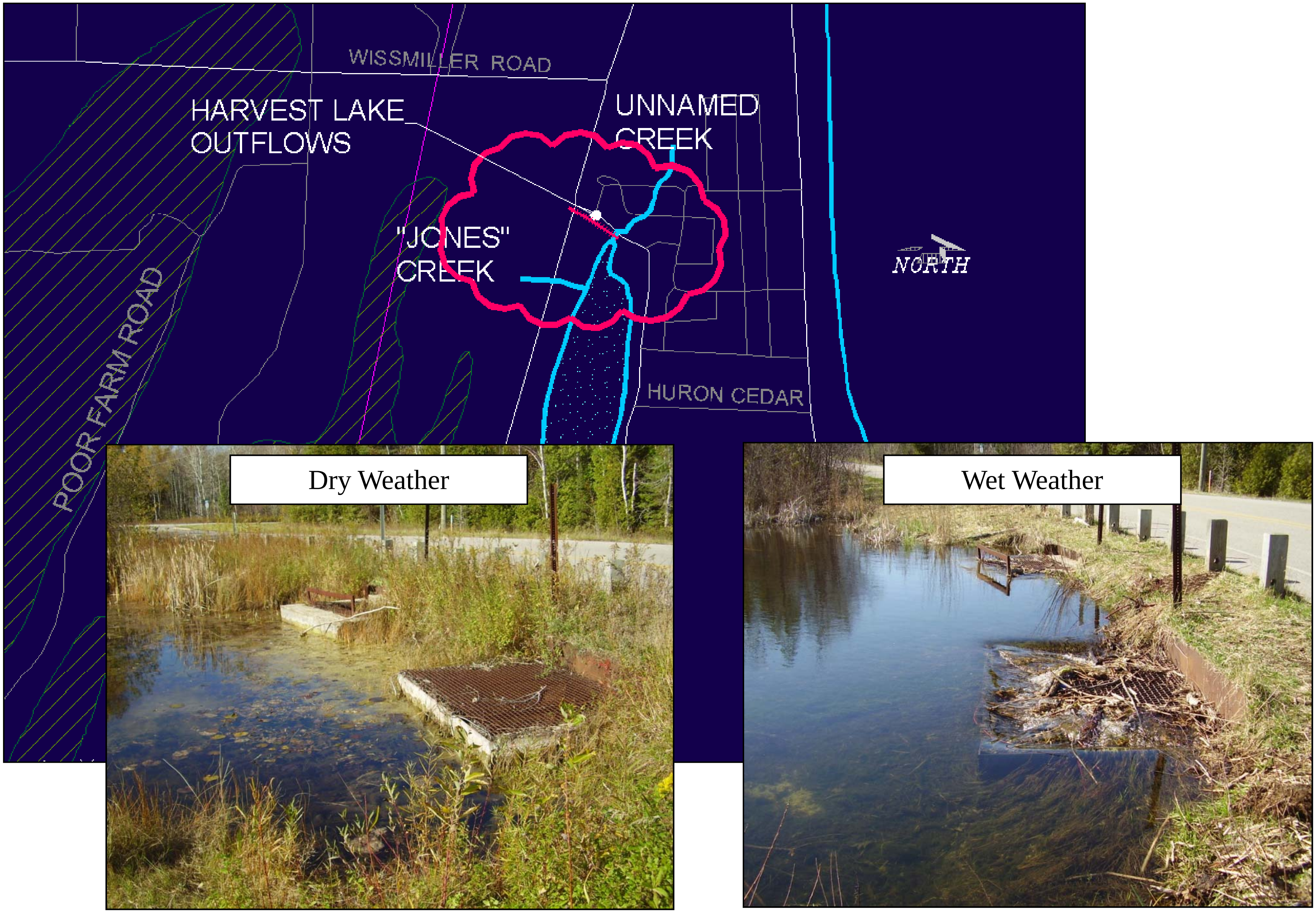

Figure 19. Groundwater Augmentation Wells: Discharge to Wetlands, or Direct Piping to Lake

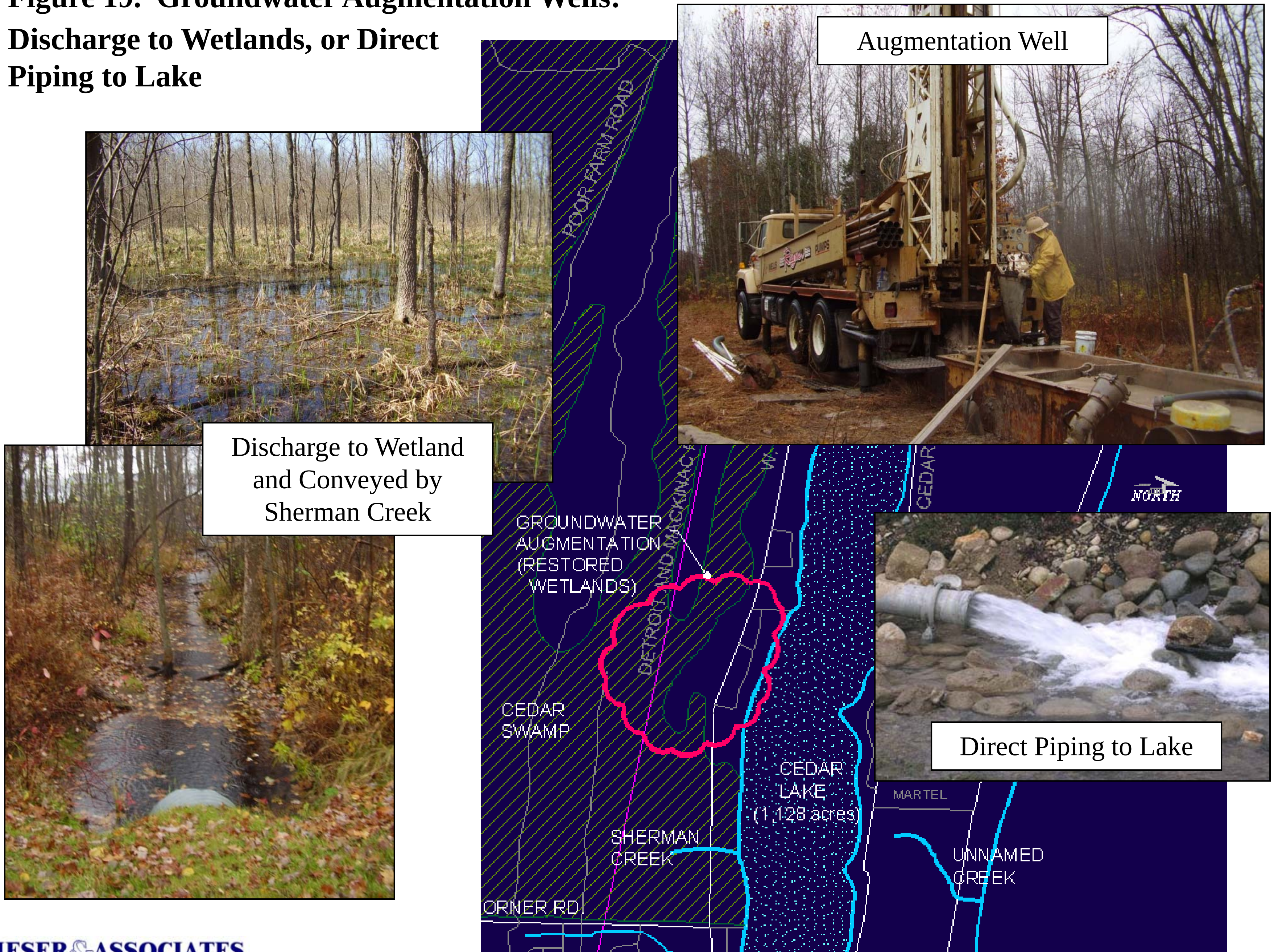

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Figure 20. Lake Huron Pumping to Cedar Lake

Figure 21. Cedar Lake Augmentation Feasibility Study: Summary of Implementation Cost

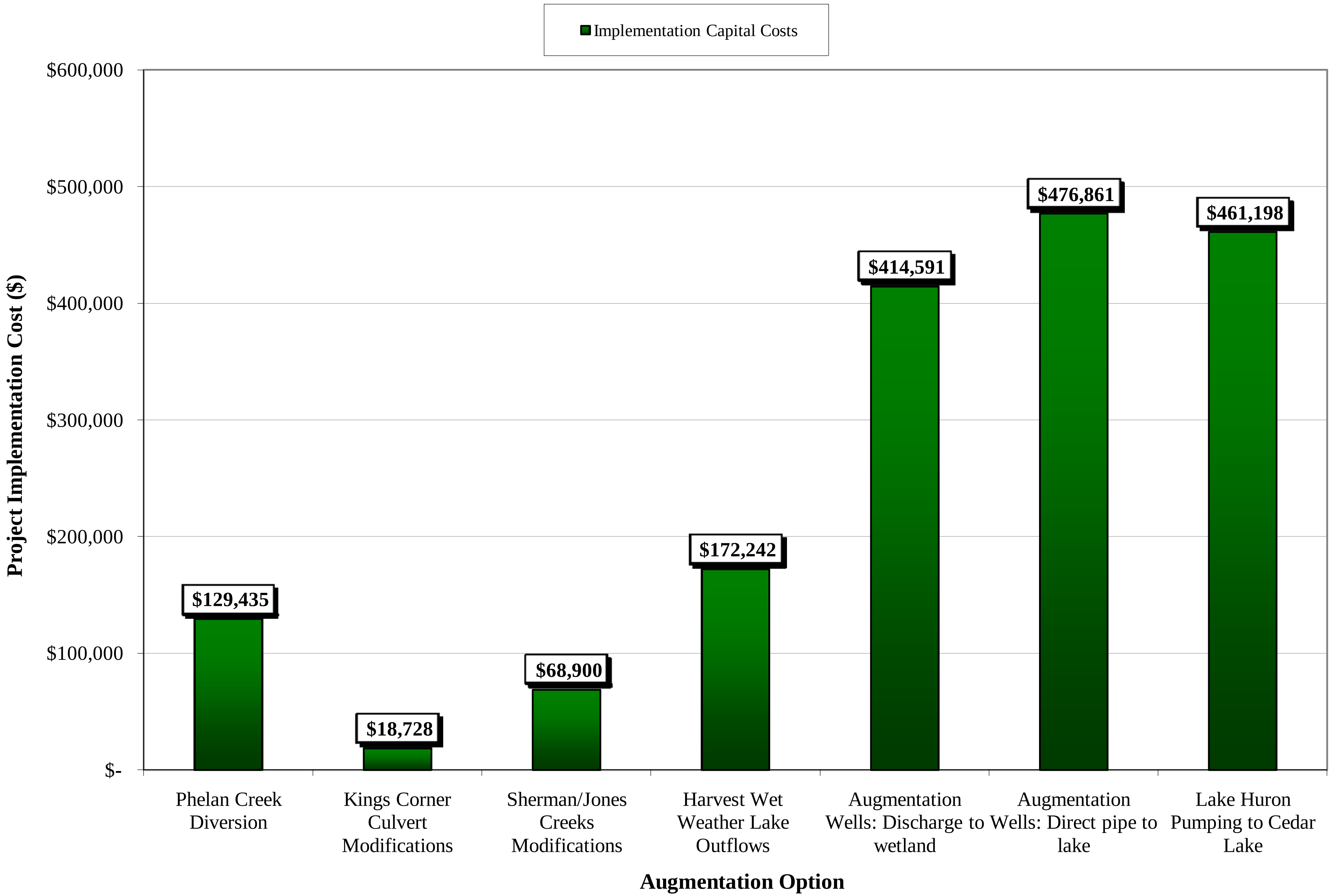

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Figure 22. Cedar Lake Augmentation Feasibility Study: Summary of Annual O&M Costs

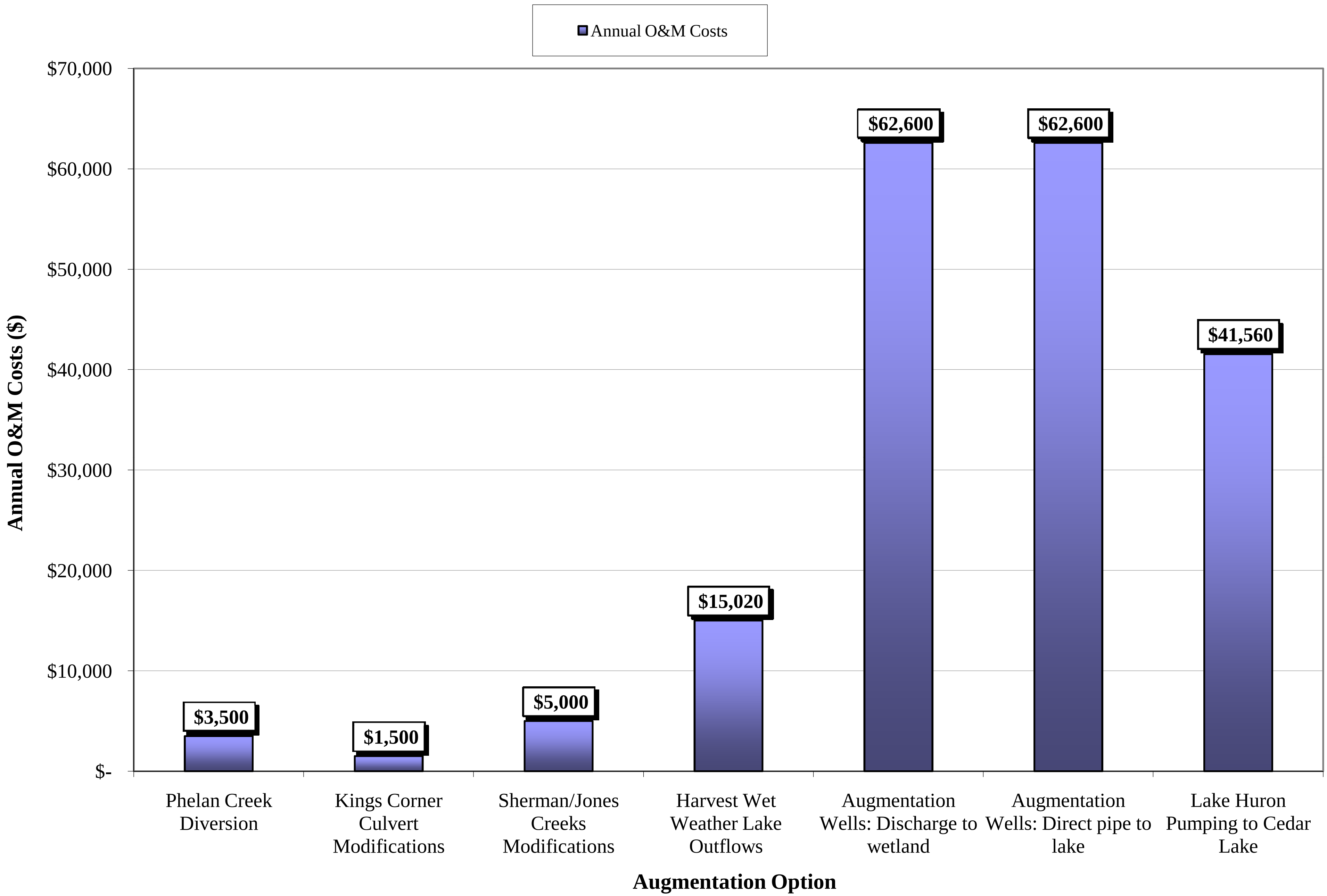

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Figure 23. Cedar Lake Augmentation Feasibility Study: Summary of Augmentation Volume Capacity

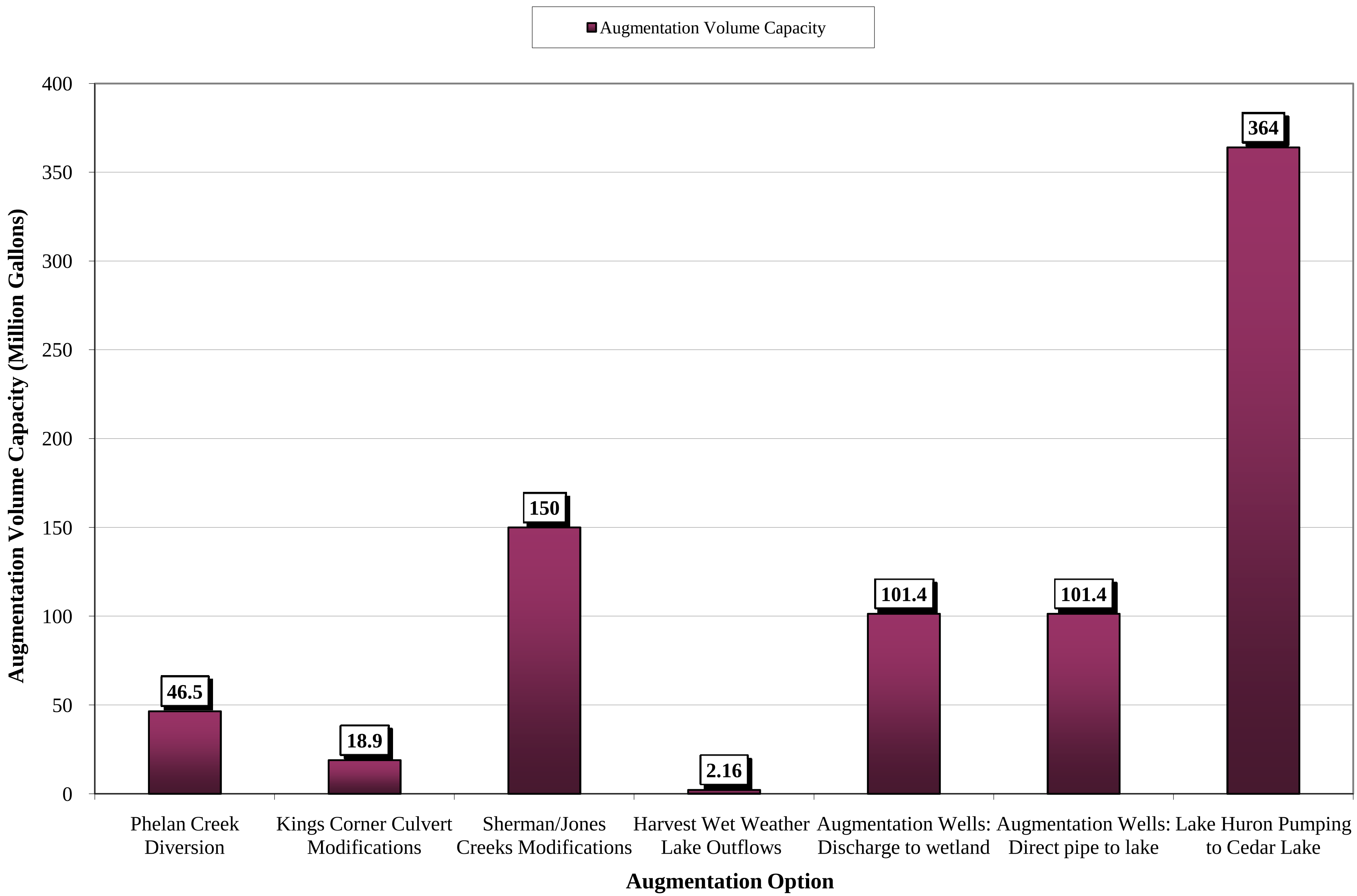

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Figure 24. Cedar Lake Augmentation Feasibility Study: Unit Cost Summary of Augmentation Volume

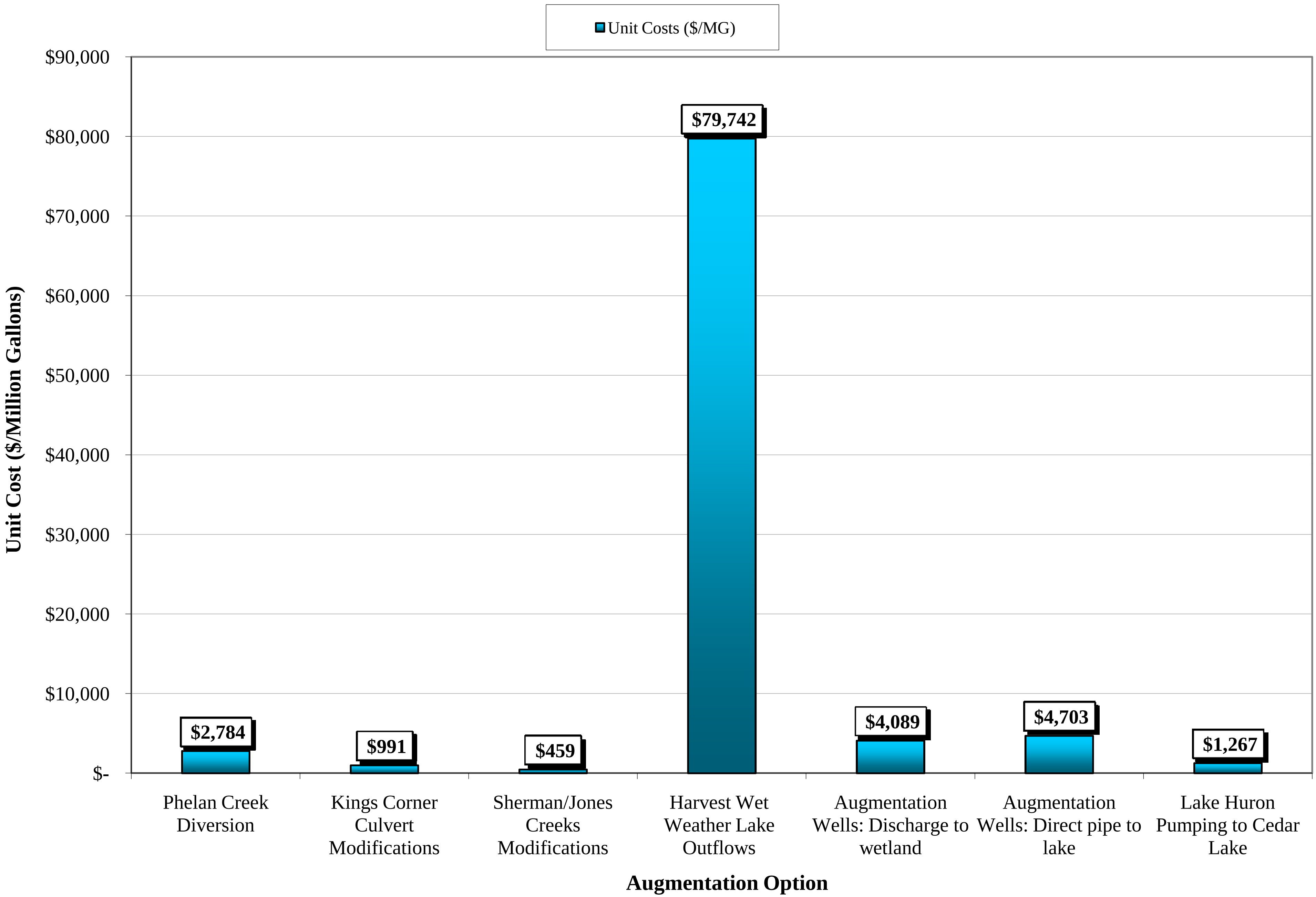

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Table 1. Cedar Lake Piezometer Construction Elevation Summary.

Piezometer ID #	Total Depth (ft)	Ground Elevation (ft)	Top of Casing Elevation (ft)	Screen Length (ft)	Top of Screen Elevation (ft)	Bottom of Screen Elevation (ft)
PZ-1s	7.93	610.83	612.80	2	606.87	604.87
PZ-1s2	10.38	610.38	612.72	3	605.34	602.34
PZ-1d	14.29	612.32	613.82	3	602.53	599.53
PZ-2s	5.47	NM	611.90	2	608.43	606.43
PZ-2d	14.69	NM	612.71	3	601.02	598.02
PZ-3s	5.69	609.77	611.13	3	608.44	605.44
PZ-3s2	9.68	611.52	613.98	3	607.30	604.30
PZ-3d	14.68	610.02	611.53	3	599.85	596.85
PZ-4s	7.63	610.13	611.93	2.5	606.80	604.30
PZ-5s	6.74	609.19	610.88	2.5	606.64	604.14
PZ-6s	7.19	609.86	611.18	2.5	606.49	603.99
PZ-6s2	14.65	615.96	619.03	3	607.38	604.38
PZ-7s	6.26	610.66	611.43	2.5	607.67	605.17
PZ-7s2	9.66	610.50	613.39	3	606.73	603.73
PZ-8s	9.25	597.60	601.12	3	594.87	591.87
PZ-9s	9.67	600.70	604.58	3	597.91	594.91
PZ-10s	10.13	608.30	611.46	3	604.33	601.33
PZ-11s	10.13	607.40	610.72	3	603.59	600.59

Notes:
From a 1954 report, the outlet structures are established at elevation 608.5 feet based on a court order.
Rigg Land Surveying east outlet structure elevation = 608.64 feet. Therefore, Cedar Lake water elev = 608.54 ft. (5-24-05)
Cedar Lake water elev at staff gauge = 608.22 (5-27-05)
Piezometers 1s through 3s2 were installed under Phase I efforts in 2004, surveyed by Rigg Land Surveying of Tawas City, MI.
Piezometers 4s through 7s2 were installed under Phase II efforts in 2005.
Piezometers 8s-11s were installed as initial task of Lake Augmentation Feasibility Study in Nov 2009.
Piezometers 8s-11s were surveyed by Northeast Land Surveys of Oscoda, Michigan in November 2010.
NM = Not measured.

Table 2. Summary of Spring Surface Water Flows Associated with the Cedar Lake Watershed Calculated from Piezometer Data at each Location.

Sherman Creek	Flow (MGD)	Flow (cfs)
2009	1.5	2.32
2010	0.81	1.25
2011	1.61	2.49
Sherman Avg.	**1.31**	**2.02**
Jones Creek		
2009	0.2	0.31
2010	0.25	0.39
2011	0.2	0.31
Jones Avg.	**0.22**	**0.34**
King's Corner		
2009	0.01	0.02
2010	0.09	0.14
2011	0.4	0.62
King's Avg.	**0.17**	**0.26**
Avg. Spring Totals	**1.69**	**2.61**

Table 3. Select Surface Water Sampling Locations visited by K&A on April 28, 2009 (as part of the WMP).

Location	Date	Time	TP (mg/L)	TSS (mg/L)
Sherman Creek	4/28/2009	12:20 PM	0.013	<2
King's Corner	4/28/2009	1:20 PM	0.016	4
Jones Creek	4/28/2009	2:50 PM	0.010	<2
Lake Outflow	4/28/2009	5:00 PM	0.080	<2

Table 4. Select Surface Water Sampling Locations visited by K&A on July 29 and 30, 2010.

Location	Date	Time	Flow cfs	Temperature °C	Spec. Cond. uS/cm	D.O. mg/L	pH S.U.	O.R.P. mV	TP mg/L	TN mg/L	TSS mg/L
Sherman Creek	7/29/2010	7:45 AM	3.6	17.9	220	5.03	7.53	116	--	--	--
Sherman Creek- Wetlands	7/29/2010	8:00 AM	--	18.6	220	4.51	7.24	155	--	--	--
King's Corner	7/29/2010	9:25 AM	0.01	10.6	230	2.22	7.49	80	--	--	--
Jones Creek	7/29/2010	10:00 AM	0.4	18.2	230	5.78	7.62	136	--	--	--
Lake Outflow	7/29/2010	10:30 AM	2.3	23.7	180	3.31	7.24	131	--	--	--
Cedar Lake (grab)	7/30/2010	8:00 AM	--	24.6	180	3.10	--	128	<0.02	0.7	2
Phelan Creek-1	7/30/2010	8:20 AM	1.8	19.1	220	2.40	--	133	<0.02	1.4	<2
Phelan Creek-2	7/30/2010	8:30 AM	1.9	19.0	220	2.60	--	133	--	--	--
Phelan Creek-3	7/30/2010	9:00 AM	2.0	18.5	220	4.06	--	159	<0.02	1.1	<2
Southern Drain (# 1)	7/30/2010	9:45 AM	0.7	14.3	230	7.54	--	164	0.03	1.4	4
Southern Drain (# 5)	7/30/2010	10:00 AM	1.1	14.5	240	5.36	--	170	--	--	--
Outflow Creek at Glenn Hollow	7/30/2010	10:55 AM	2.0	22.6	180	5.66	--	158	<0.02	0.8	<2

Notes:

pH meter malfunction on 7/30/2010.

Sherman Creek, Jones Creek, King's Corner, and Lake Outflow water quality samples were collected on April 28, 2009 and were not repeated during this visit. (Refer to Table 3.)

Table 5. Summary of Incremental Cedar Lake Elevation Drop and Associated Volume.

Lake Elevation Drop		Volume
(inches)	(feet)	(MG)
1	0.08	30.63
2	0.17	61.26
3	0.25	91.88
4	0.33	122.51
5	0.42	153.14
6	0.50	183.77
7	0.58	214.40
8	0.67	245.02
9	0.75	275.65
10	0.83	306.28
11	0.92	336.91
12	1.00	367.53
13	1.08	398.16
14	1.17	428.79
15	1.25	459.42
16	1.33	490.05
17	1.42	520.67
18	1.50	551.30
19	1.58	581.93
20	1.67	612.56
21	1.75	643.19
22	1.83	673.81
23	1.92	704.44
24	2.00	735.07
25	2.08	765.70
26	2.17	796.33

ATTACHMENT A

Kick-off Meeting Summary, May 24, 2011

Cedar Lake Augmentation Kick-Off Meeting
Department of Natural Resources & Environment, Gaylord Field Office
May 24, 2010

Attendees: Scott Rasmussen (DNRE), Greg Goudy (DNRE), Mark Kieser (K&A), Brian Boyer (K&A), Jamie McCarthy (K&A), and Russ Anton (AICLA and Lake Board)

Meeting Minutes: The meeting started with introductions followed by a presentation of Cedar Lake level management background, options, and discussion. The following items and comments were discussed during the meeting.

Jamie McCarthy outlined the meeting objectives and provided information about the augmentation feasibility work scope/tasks that will be completed in 2010 (with results in 2011).

Brian Boyer provided background information on Cedar Lake, including results of the Phase II hydrologic study. He referenced a map at the meeting site to show groundwater and surface water interactions in the watershed to point out sensitive areas and to show the source water areas of Cedar Lake.

The group discussed each of the preliminary source water options for augmenting Cedar Lake levels during dry years. Discussion items for each source water option are included below:

1. Phelan Creek Diversion
    - Since the creek is a cold water/groundwater system, pumping from this source may not affect temperature, but volume might still be a factor; therefore, it makes sense to pump from King's Corner instead

2. King's Corner Road
    - Scott suggested raising the culvert in order to slow the loss of water from Cedar Lake watershed to Van Etten Lake watershed (via Phelan Creek)
    - Greg mentioned the option of using a berm structure to partially block water loss via the culvert, while at the same time allowing the culvert to protect the road bed from flood-related damage
    - Costs were mentioned in terms of reconstruction of the culvert (as opposed to stop boards) and road re-pavement timing with the proposed road construction project
    - Notifying property owners is required if modifications to this culvert will likely cause flooding
    - Scott mentioned that his office has issued a temporary, 5-year permit for blockage of a culvert in Alpena County, which may also be an option for King's Corner culvert

3. Sherman and Jones Creek Modifications
    - For modifications to culverts under West Cedar Lake Road, Russ noted that it may be worth coordinating with the Road Commission as they are going to be doing road construction/re-pavement

4. Harvest Wet Weather Lake Outflows

- Greg asked about what features are below the lake outlet that might be impacted by less flow
- To answer Greg, K&A explained that the lake outflows to a wetland, which experiences high water/flooding of residential areas; after this point the water forms a small coldwater creek before discharge to Lake Huron

5. Groundwater Augmentation Well: Discharge to Wetland
    - Greg commented that it will be easier for DNRE to “deal with” a natural conveyance, such as the wetlands and naturally adjoining creeks to Cedar Lake
    - Greg also mentioned evaporation and evapotranspiration as issues to contend with if releasing water to the wetland rather than using a pipe conveyance

6. Groundwater Augmentation Well: Direct Piping to Lake
    - Direct discharge of water to Cedar Lake will require permitting of structure to convey water
    - Low dissolved oxygen in groundwater may be a potential issue
    - Velocity of water entering the lake at the discharge point will need to be taken into consideration
    - Contaminants and other constituents from groundwater will have to be tested before discharging to Cedar Lake
    - Temperature may be an issue (perhaps in Cedar Lake favor during hot months)
    - Recreational/aesthetic issues must be addressed when dealing with a piped conveyance system (especially at the discharge point)
    - Greg concluded that discharge to the wetland would likely be less onerous than pipe conveyance

7. Lakewood Shores Drainage Recirculation
    - Mark pointed out that the downfall is that the storm sewer is a complicated drainage system with high costs associated with designing a collection system associated with the existing large network of storm sewer piping

8. Lake Huron Pumping to Cedar Lake
    - There are high costs associated with a conveyance pipe, and there is a more involved permitting process
    - There is a risk of invasive species transferring from the Great Lakes to inland Cedar Lake

General Comments:

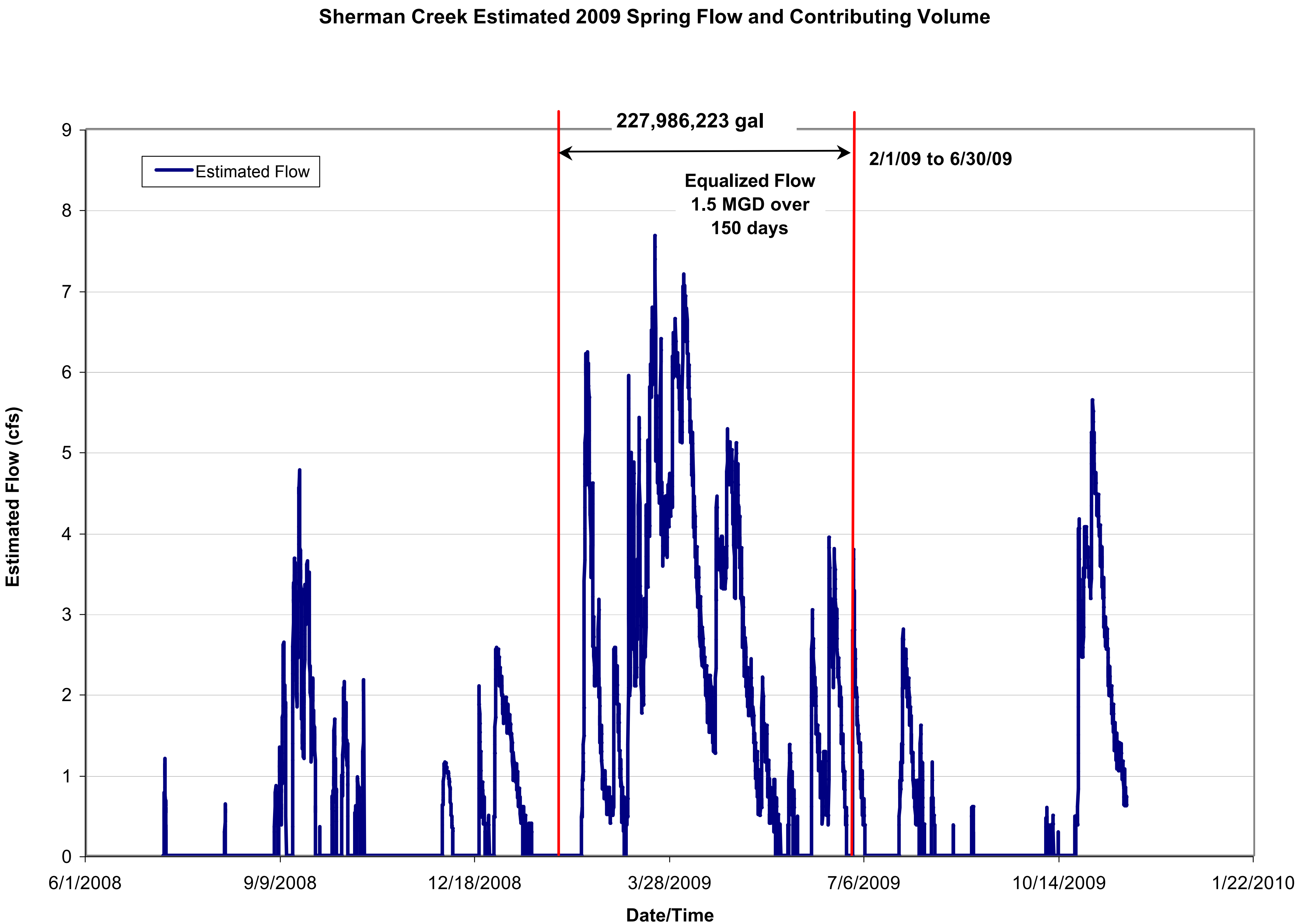
- Scott mentioned maximizing the affects of in-lake springs in Cedar Lake as an additional source of water
- Scott also commented on the fact that authorizations for some of the source water options will involve multiple land owners and maybe problematic in terms of getting all owners to buy into the project
- Greg liked how some of the ideas incorporated several environmental/resource benefits; he was especially interested in blocking off King’s Corner culvert
- Brian noted that a DNRE staff member in Lansing and K&A staff have used the State’s groundwater withdrawal tool and found that withdrawals around Cedar Lake caused no adverse resource impacts
- DNRE staff felt Lake Huron withdrawal was the least viable of the presented source water options and of lowest interest for permitting

ATTACHMENT B

CD of Electronic Water Level Data Records

ATTACHMENT C

Detailed Seasonal Surface Water Flow Plots



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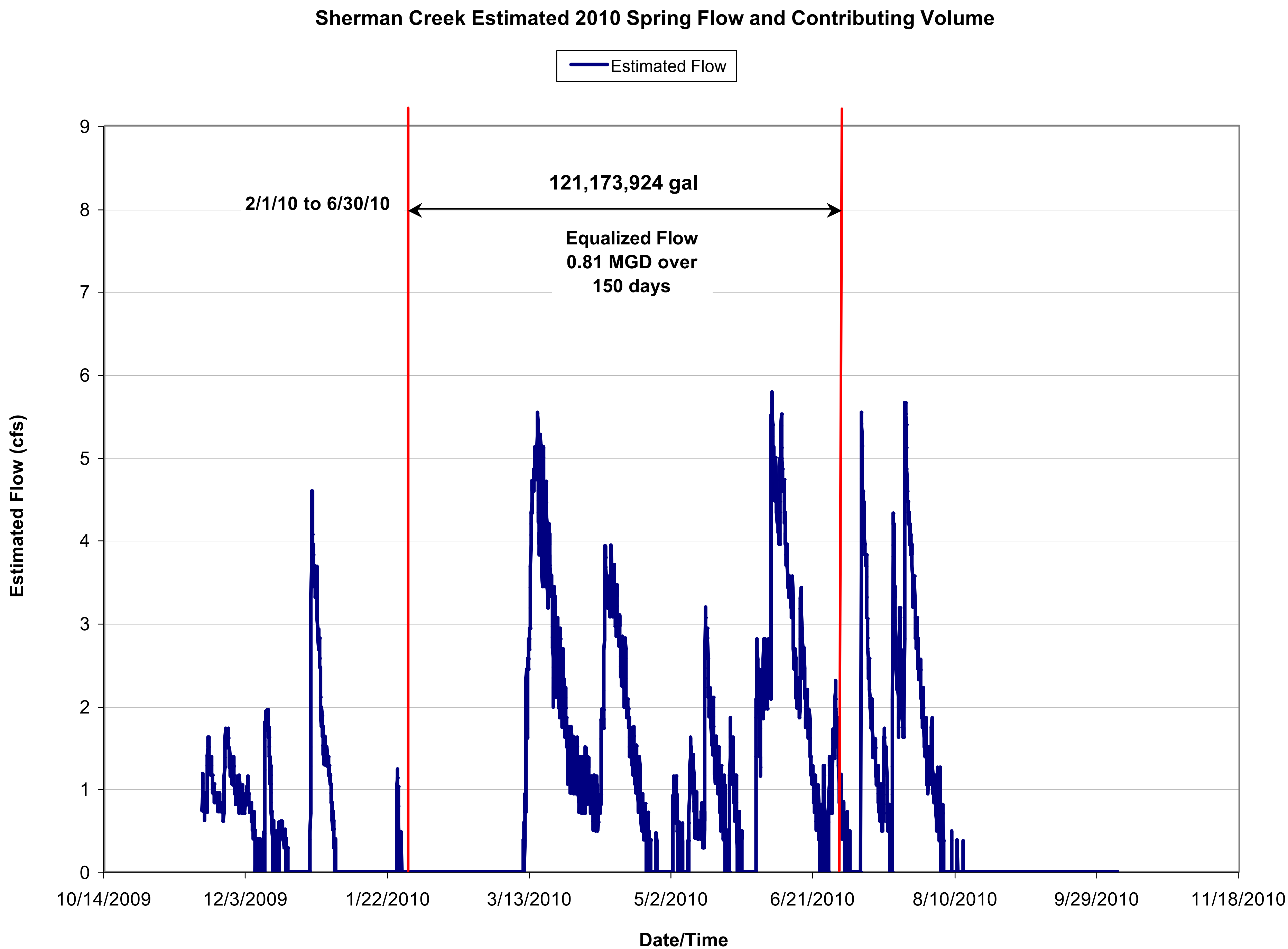

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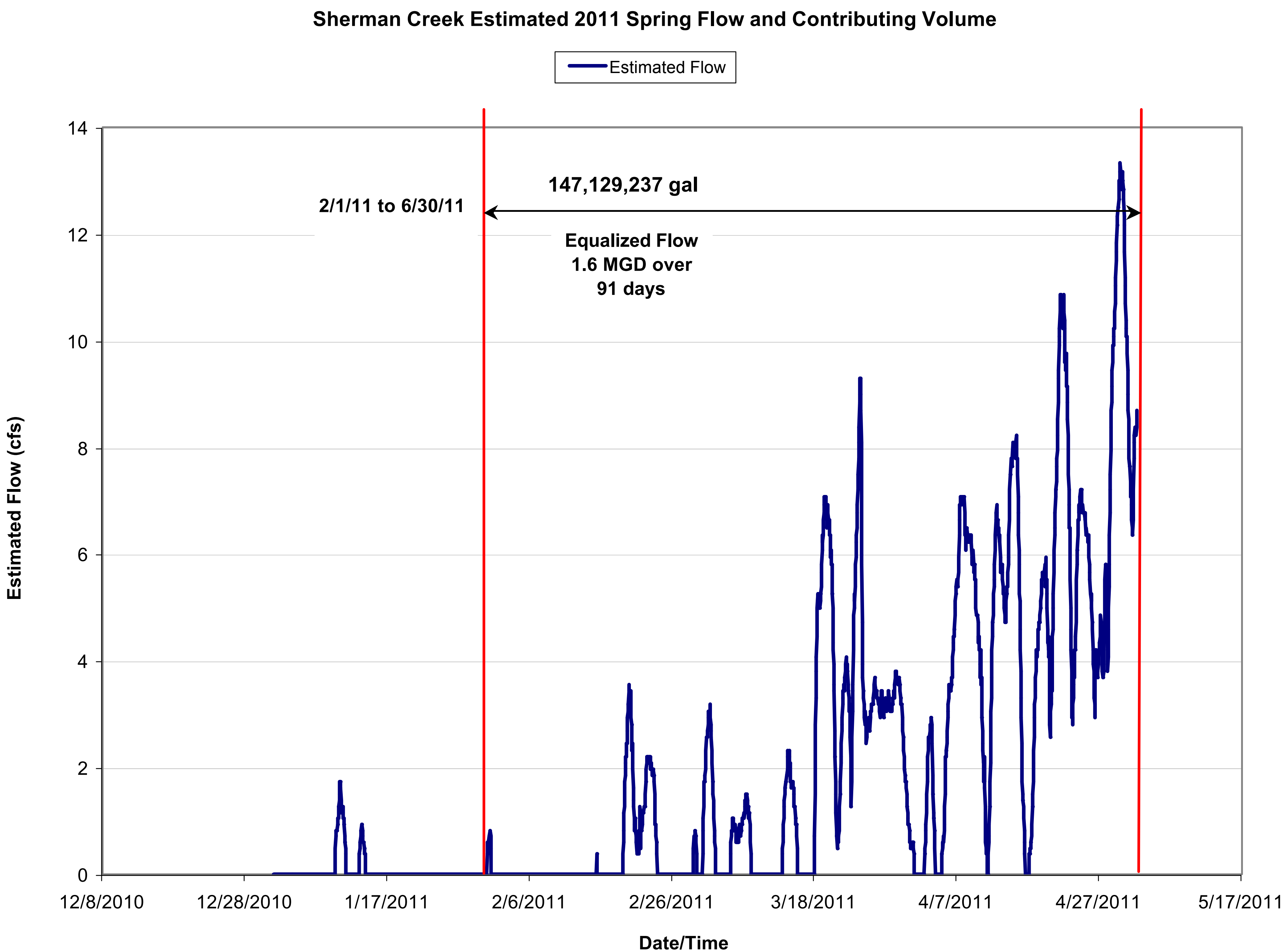
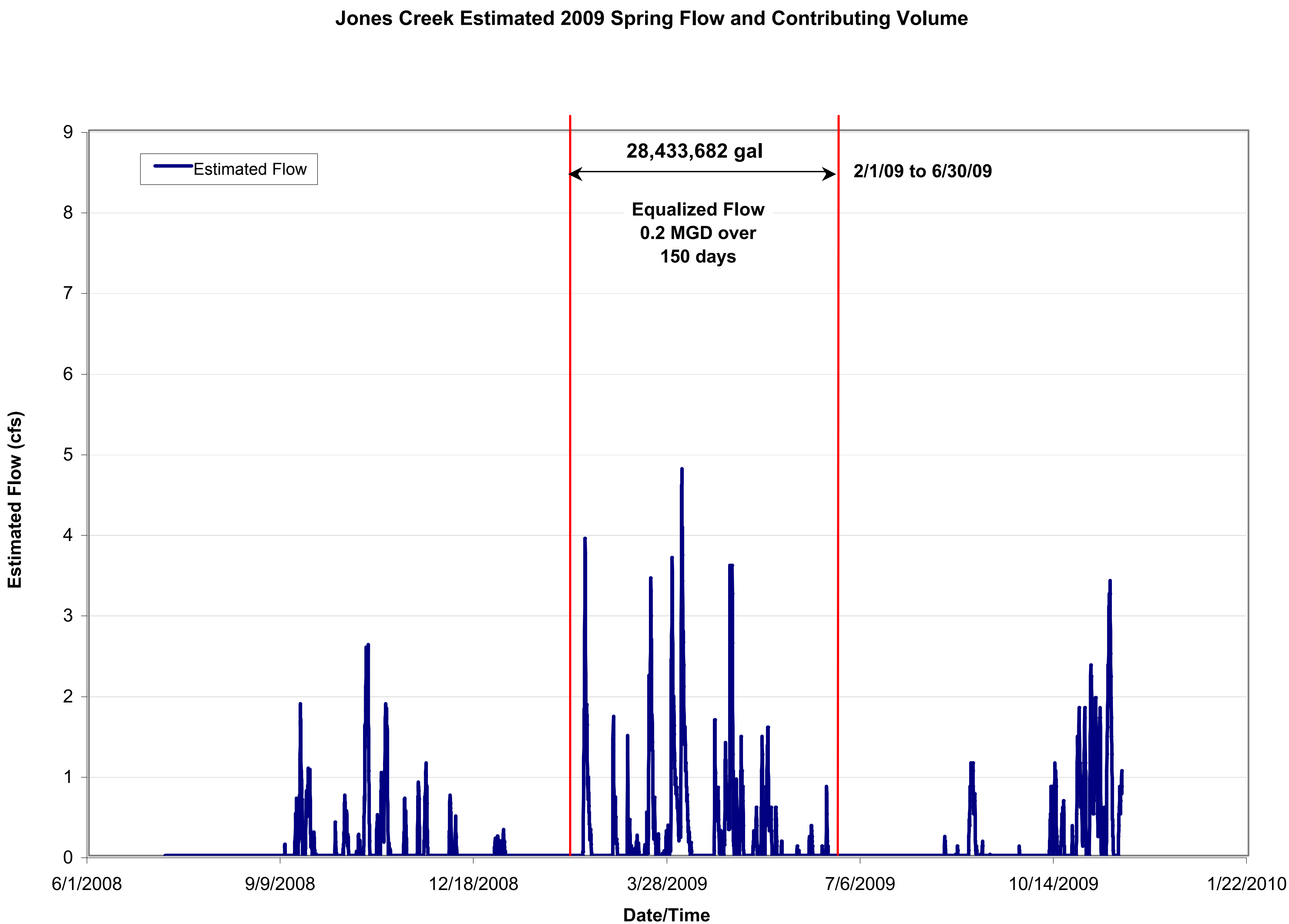
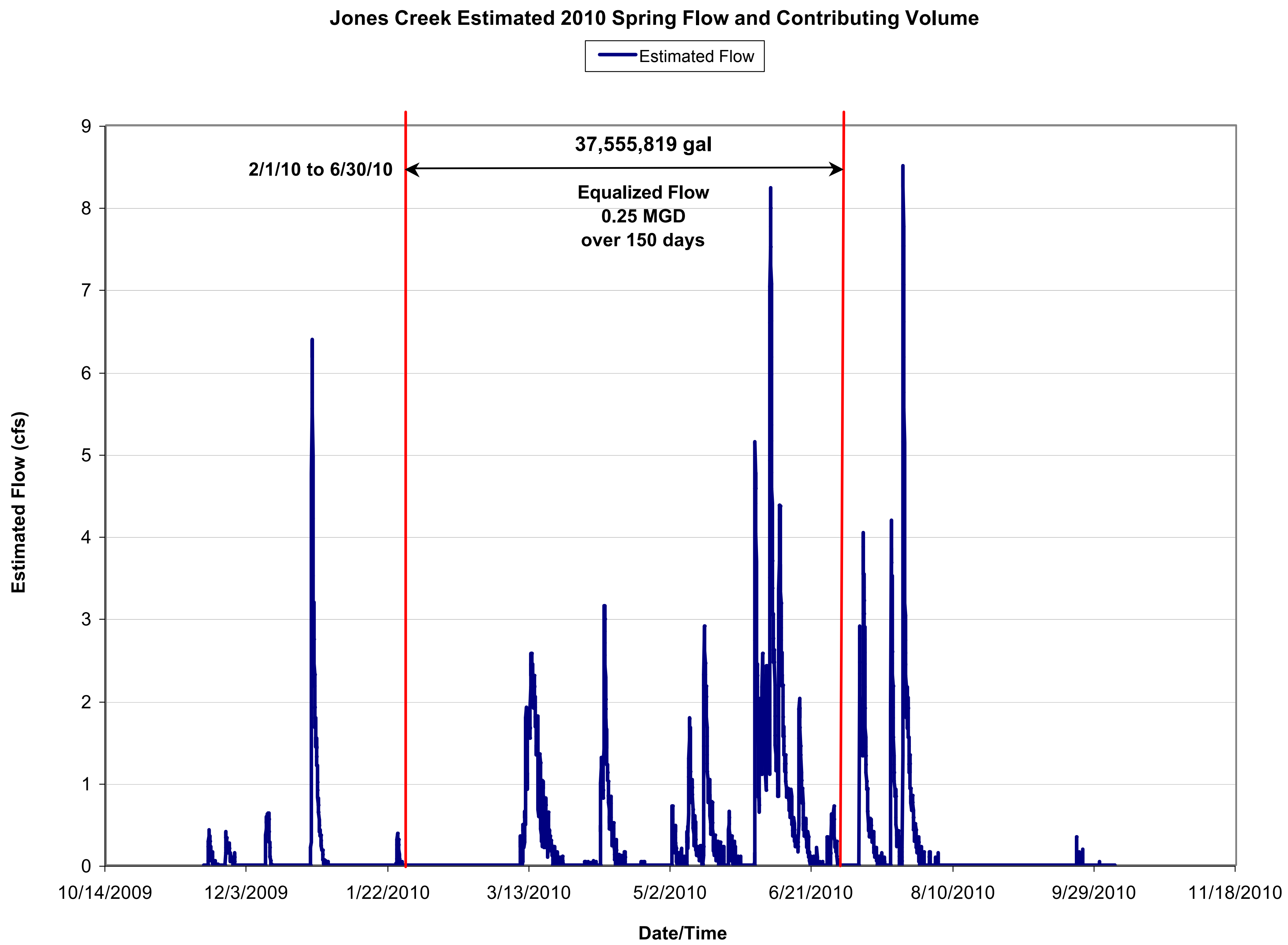


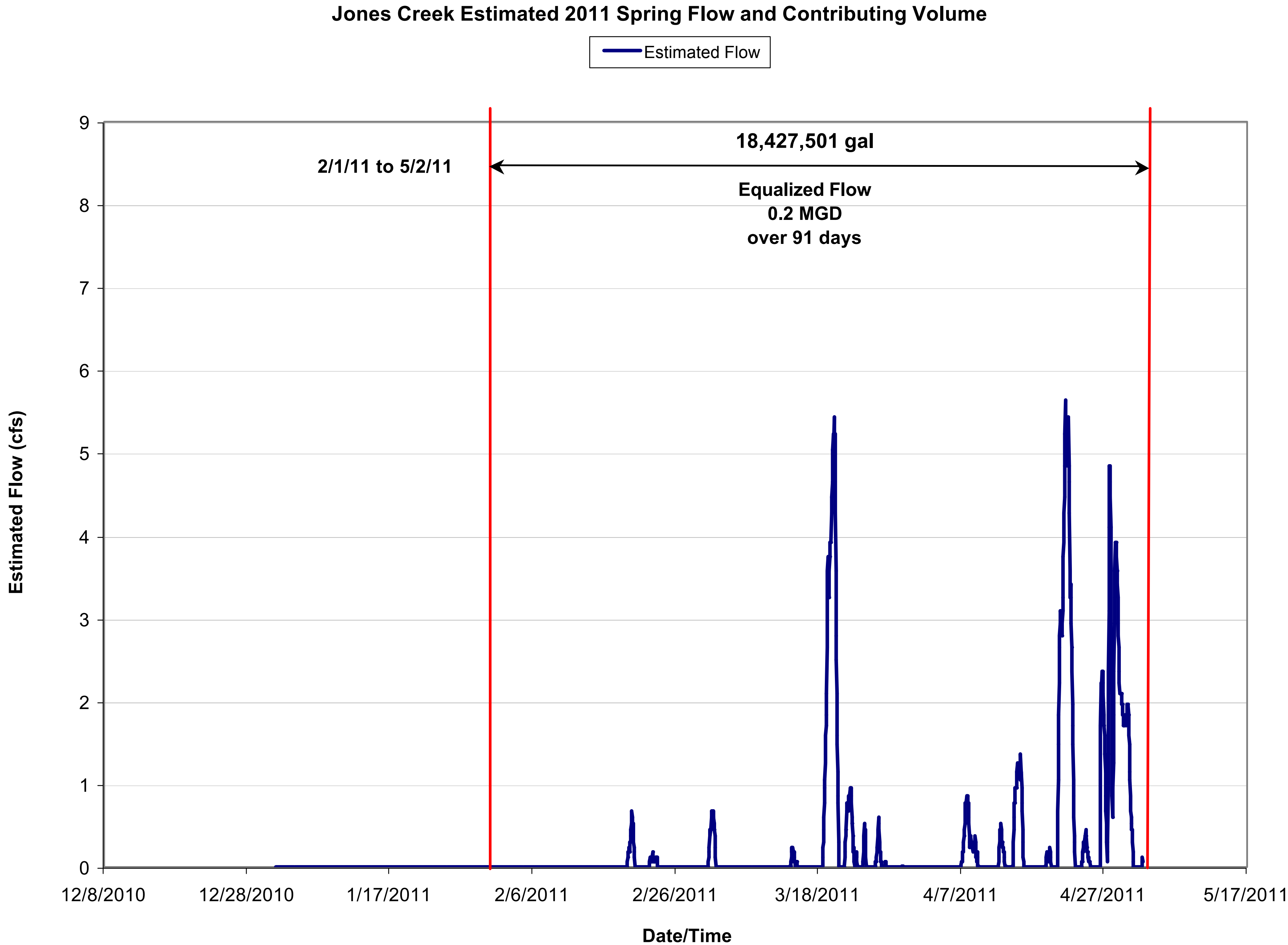
KIESER & ASSOCIATES, LLC



KIESER & ASSOCIATES, LLC

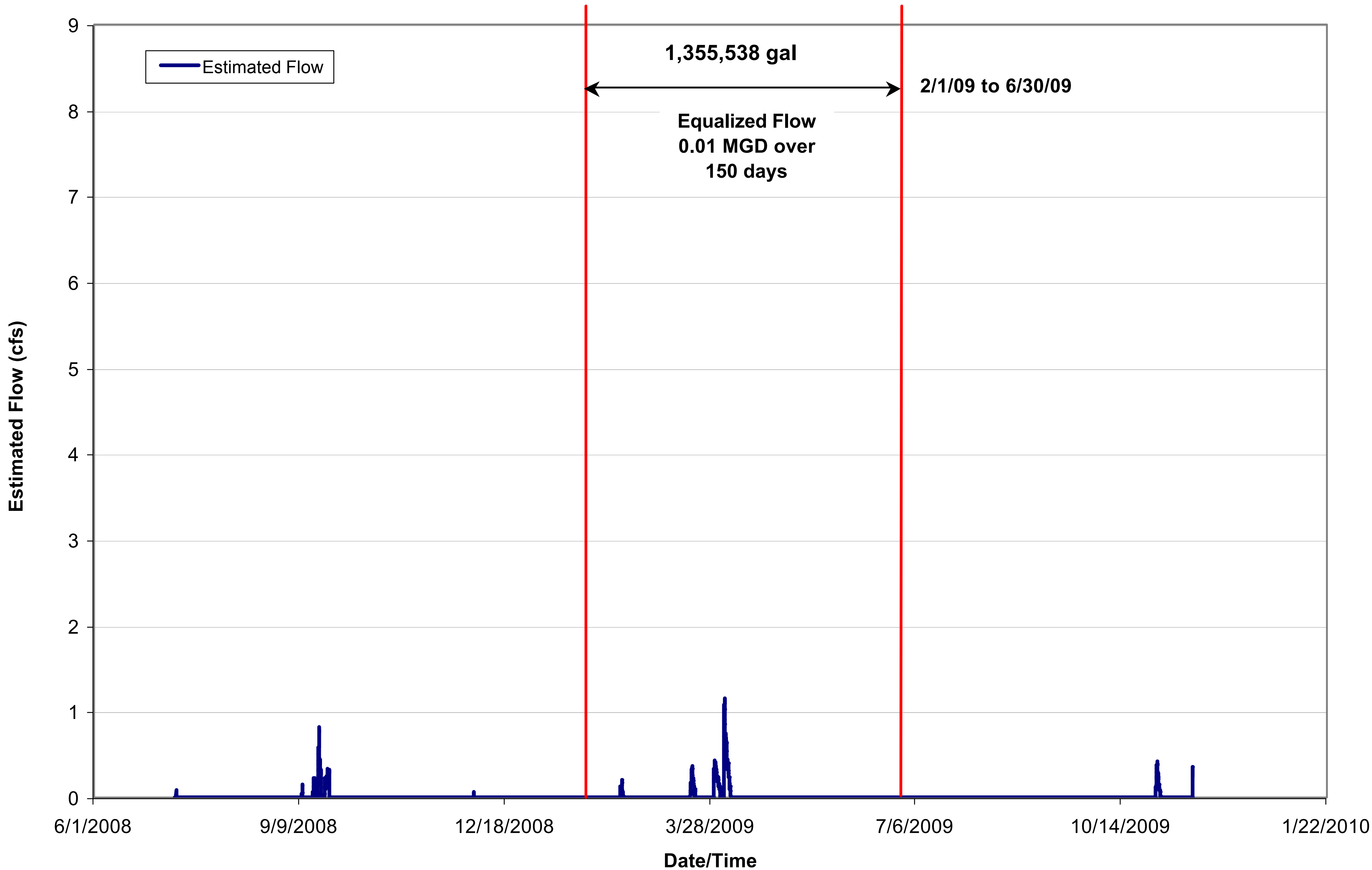


KIESER & ASSOCIATES, LLC

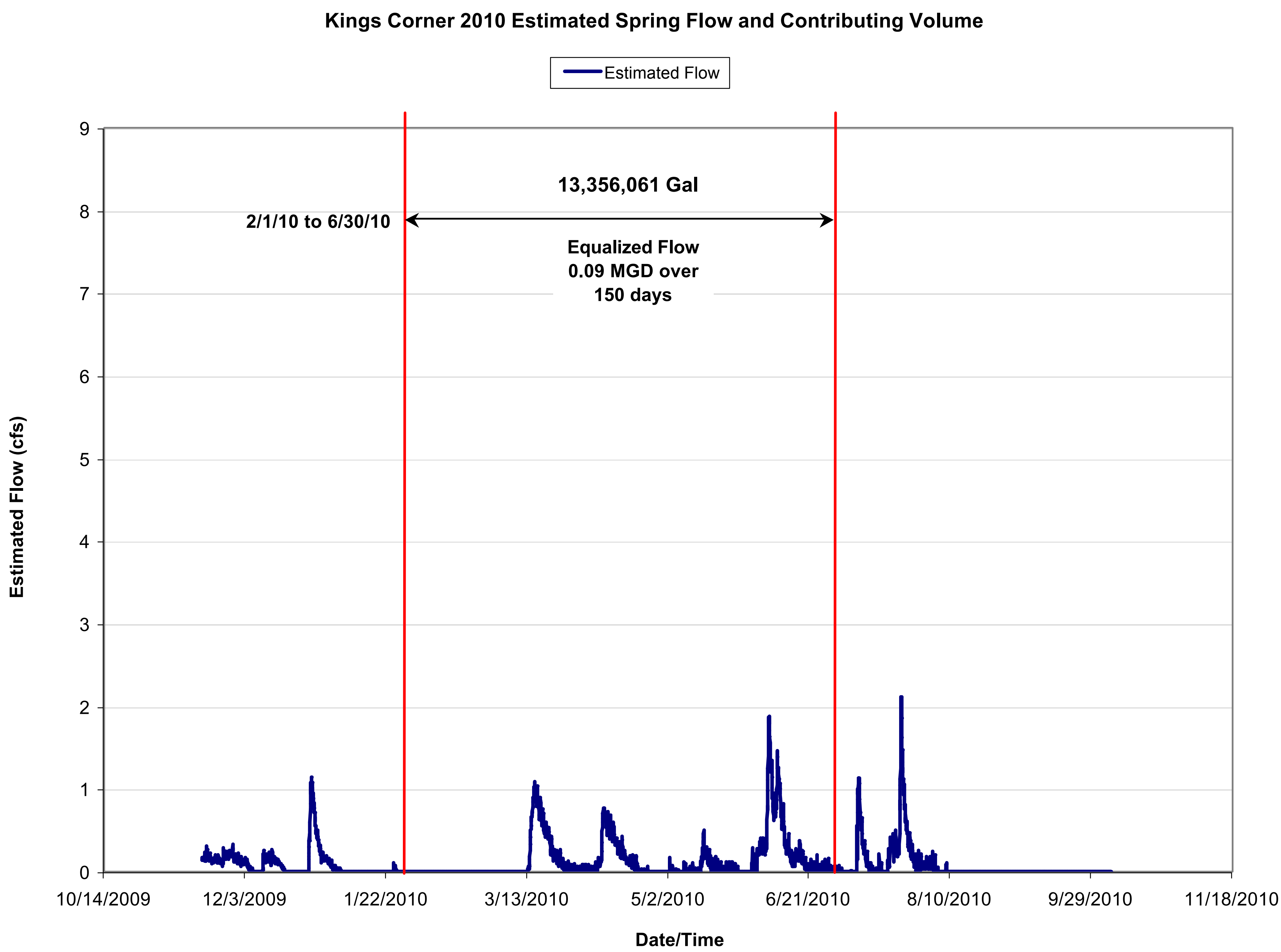


KIESER & ASSOCIATES, LLC

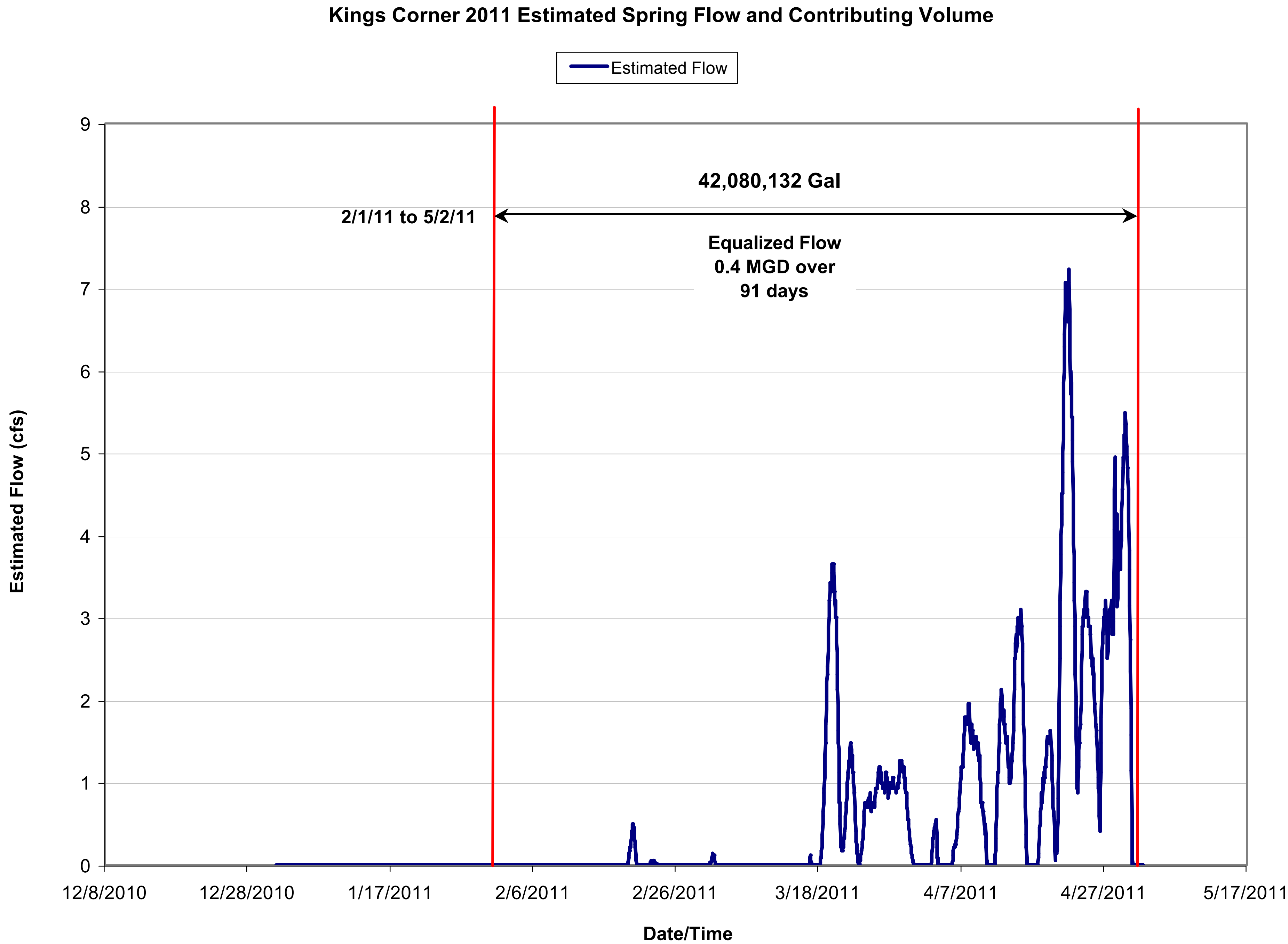
Kings Corner Estimated 2009 Spring Flow and Contributing Volume



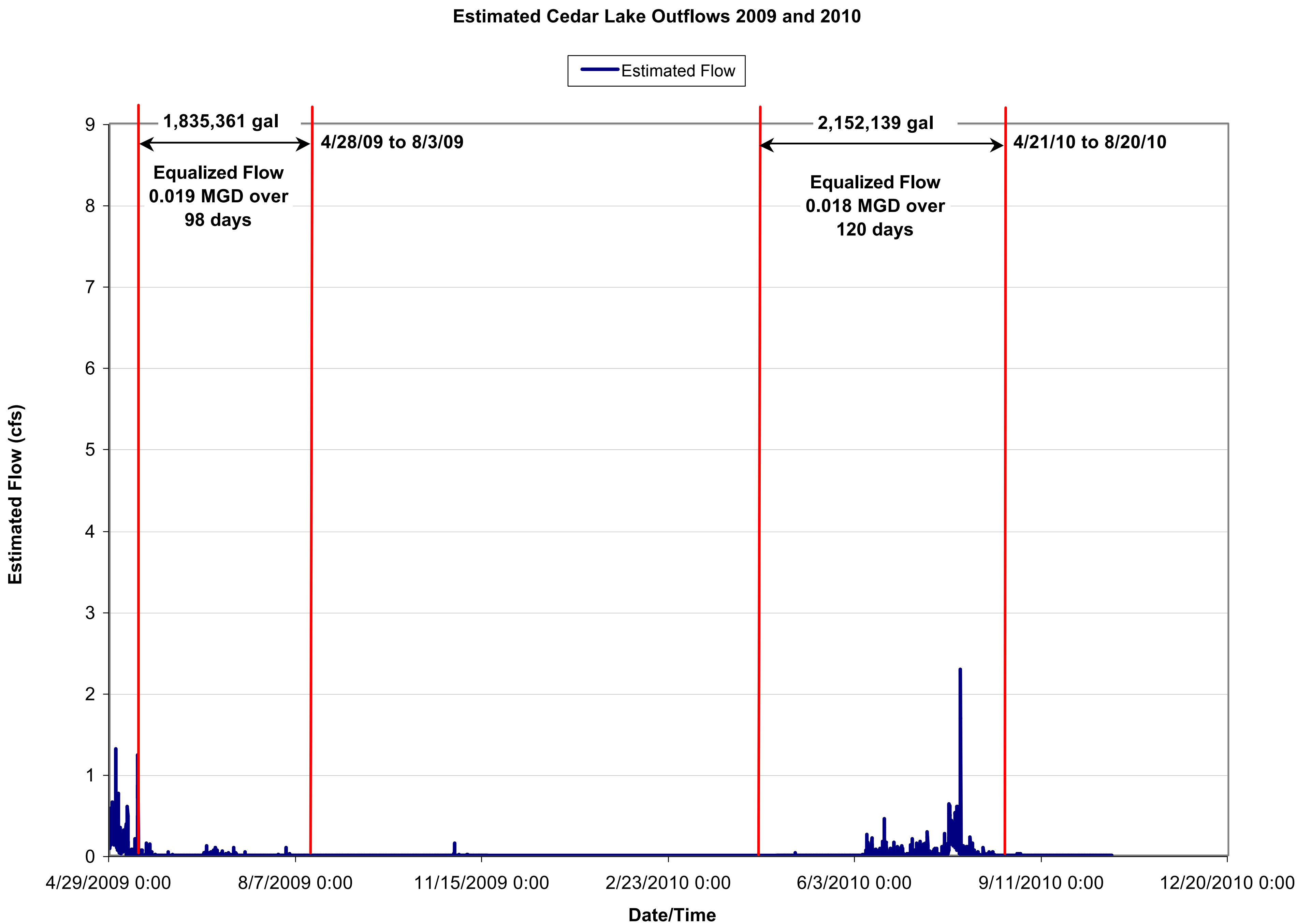
KIESER & ASSOCIATES, LCC



KIESER & ASSOCIATES, LLC



KIESER & ASSOCIATES, LLC



KIESER & ASSOCIATES, LLC

ATTACHMENT D

Surface Water Sampling Analytical Laboratory Reports

KAR *Laboratories, Inc.*

4425 Manchester Road
Kalamazoo, MI 49001
Phone 269 381-9666
Fax 269 381-9698
www.karlabs.com

Kieser & Associates
536 E. Michigan Ave. Suite 300
Kalamazoo, MI 49007

Attn : ***Mr. Brian Boyer***

KAR Project No. :	***091656***
Date Reported :	***05/06/09***
Date Activated :	***04/29/09***
Date Due :	***05/13/09***
Date Validated :	***05/04/09***

Project Description : ***Analysis of four aqueous smaples from Cedar Lake.***

Dear Client,

Your laboratory data is presented to you in this report. Unless otherwise stated under the "Comments" heading, all tests were performed within the maximum allowable holding times, have met or exceeded QC requirements and the result represents the sample as it was received.

If you wish to contact us about this work please mention KAR Project No. 091656. To arrange additional sampling or testing please contact our Client Services Department. If you have any questions regarding quality assurance please call us.

Thank you for the opportunity to serve you. Please do not hesitate to call if we can provide additional assistance.

Respectfully submitted,

David R. Alkema
Laboratory Manager

LABORATORY DETAIL REPORT

KAR Project No. : ***091656***

Client: ***Kieser & Associates*** **Date Reported :** ***05/06/09***

Project Desc. : ***Analysis of four aqueous smaples from Cedar Lake.***

Sample ID : ***"Sherman Creek"***

Sampled By : *BB of Kieser & Associates* **Date Received :** *04/29/09*
Sample Date : *04/28/09* **Sample Type :** *aqueous*
Sample Time : *1220* **KAR Sample No. :** *091656-01*

Test	Result	Units of Measure	Method	Analyzed	Analyst	Comments
Suspended solids, total	<2	mg/L	SM 2540 D	04/30/09	MTW	

Sample ID : ***"King's Corner"***

Sampled By : *BB of Kieser & Associates* **Date Received :** *04/29/09*
Sample Date : *04/28/09* **Sample Type :** *aqueous*
Sample Time : *1320* **KAR Sample No. :** *091656-02*

Test	Result	Units of Measure	Method	Analyzed	Analyst	Comments
Suspended solids, total	4	mg/L	SM 2540 D	04/30/09	MTW	

Sample ID : ***"Jones Creek"***

Sampled By : *BB of Kieser & Associates* **Date Received :** *04/29/09*
Sample Date : *04/28/09* **Sample Type :** *aqueous*
Sample Time : *1450* **KAR Sample No. :** *091656-03*

Test	Result	Units of Measure	Method	Analyzed	Analyst	Comments
Suspended solids, total	<2	mg/L	SM 2540 D	04/30/09	MTW	

Sample ID : ***"North Outflow"***

Sampled By : *BB of Kieser & Associates* **Date Received :** *04/29/09*
Sample Date : *04/28/09* **Sample Type :** *aqueous*
Sample Time : *1700* **KAR Sample No. :** *091656-04*

Test	Result	Units of Measure	Method	Analyzed	Analyst	Comments
Suspended solids, total	<2	mg/L	SM 2540 D	04/30/09	MTW	

SAMPLE CHAIN-OF-CUSTODY DOCUMENT

Project Name: CEDAR LAKE
Project Location: OSCODA, MI
Sampling Date: 4-28-2009
Laboratory Extraction Dates Requested: Yes / No

Project Number:
Sampled By: BBoyer
Lab Delivered To: KAR LABS

Notes/Special Requests:

Required Completion Date: 5/13/2009

Lab ID	Client Sample ID	Sampling Location	Sample Containers (No./Type)	Collection Date	Collection Time	Method composite or grab	Matrix wtr / ww or soil	Requested Analytical Testing: TSS										
	SHERMAN CREEK		1-L plastic	4/28/09	12:20	grab	wtr	X										
	KING'S CORNER		1-L plastic	4/28/09	1:20	grab	wtr	X										
	JONES CREEK		1-L plastic	4/28/09	2:50	grab	wtr	X										
	NORTH OUTFLOW		1-L plastic	4/28/09	5:00	grab	wtr	X										

Laboratory to store remaining sample: **How Long?** **Return?**

	Relinquished By:	Received By:	Date:	Time:	Reason:
1.	[signature]	[signature]	4/29/09	1225	
2.					
3.					

KIESER & ASSOCIATES
ENVIRONMENTAL SCIENCE & ENGINEERING
536 EAST MICHIGAN AVE. / SUITE 300 / KALAMAZOO, MICHIGAN 49007 / ph: (269) 344-7117 / fax: (269) 344-2493

UPSTATE FRESHWATER INSTITUTE
P.O. Box 506
Syracuse, New York 13214

Data Report Number: CHM 9018
Keiser: Cedar Lake
Sampling Date: 4/28/2009

Prepared for:

Brian Boyer, E.I.T.
Environmental Engineering Manager
KIESER & ASSOCIATES, LLC
536 East Michigan Ave. Suite 300
Kalamazoo, MI 49007
(269) 344-7117 (phone)
(269) 344-2493 (fax)
bboyer@kieser-associates.com

Submitted by:

MaryGail Perkins
Laboratory Director
Upstate Freshwater Institute NELAC ID 11462
PO. Box 506
Syracuse, NY 13214
(315) 431-4962 ext.115 (phone)
(315) 431-4969 (fax)
UFILab@upstatefreshwater.org

UFI Lab ID	Client ID	System Name	Sampling Date	Sampling Time	Received Date	Received Time	Comments	TP (µgP/L)	TP flags
2009121001	Sherman Creek	Keiser	4/28/2009	12:20	5/1/2009	12:30	Cedar Lake	13.0	
2009121002	King's Corner	Keiser	4/28/2009	13:20	5/1/2009	12:30	Cedar Lake	16.0	
2009121003	Jones Creek	Keiser	4/28/2009	14:50	5/1/2009	12:30	Cedar Lake	10.4	
2009121004	North Outflow	Keiser	4/28/2009	17:00	5/1/2009	12:30	Cedar Lake	8.0	

Data Flag ID	Meaning of Flag
F2	Sample diluted to run within calibration curve
F3	Sample outside calibration curve
F4	Lower than normal volume of sample analyzed
F5	Sample not digested/prepared properly
F6	Sample not preserved properly
F7	Sample received outside "normal" temperature limits
F8	Sample container inappropriate
F9	Sample container broken/cracked/leaked
F10	analyte
F13	Data associated with failed duplicate
F14	sample received past holding time
F15	sample analyzed past holding time
F16	sample value less then LOQ, *but more than LOD*
F17	Sample was Q6ed (sample should have been rerun but conditions exist that prevent a rerun)
F18	Sample likely/possibly contaminated before arrival
F19	No sample due to lab error
F20	No sample due to field error
F21	Reference outside control limits
F22	Sample value less than LOD
F23	Data associated with failed CCB
F24	Data associated with failed CCV
F25	Data associated with failed LCS
F26	Data associated with failed Matrix Spike
F27	Data associated with failed Reference
F28	Data associated with failed Matrix Spike Duplicate
F29	Data associated with failed Method Blank

Parameter	LOQ[1]	LOD[2]	Method of analysis	Date Calculated
TP	2.8 μgP/L	0.8 μgP/L	SM 18 20 4500 P E	1/14/2009

[1]LOQ= Limit of Quantification

[2]LOD= Limit of Detection

All results meet the requirements of ELAP unless otherwise noted.
This report is not to be reproduced, except in full, without the written approval of Upstate Freshwater Institute (UFI).
The reported results are pertinent to the samples as they were received at the laboratory.
UFI is not responsible for sample handling and storage prior to their receipt.
The attached samples were collected by Keiser according to methods provided by UFI.
NS means no sample was collected and/or received, data flags may provide further information.
Data Flags indicate deviations from SOPs. if further interpretation of results is required, please contact UFI.
UFI Contract Number: 299
ELAP ID 11462

Compiled by: Christopher Hoy

Reviewed by: MaryGail Perkins

Date: 5/28/2009

4425 Manchester Road
Kalamazoo, MI 49001
Phone 269 381-9666
Fax 269 381-9698
www.karlabs.com

Kieser & Associates
536 E. Michigan Ave. Suite 300
Kalamazoo, MI 49007

Attn : ***Mr. Brian Boyer***

KAR Project No. : ***103262***
Date Reported : ***08/20/10***
Date Activated : ***08/11/10***
Date Due : ***08/25/10***
Date Validated : ***08/20/10***

Project Description : ***Analysis of five aqueous samples from Cedar Lake.***

Dear Client,

Your laboratory data is presented to you in this report. Unless otherwise stated under the "Comments" heading, all tests were performed within the maximum allowable holding times, have met or exceeded QC requirements and the result represents the sample as it was received. If a sample was identified as drinking water under the Safe Drinking Water Act, the "Comments" column may also contain federal drinking water information including MCL which is the Maximum Contaminant Level set by USEPA. Values enclosed in brackets ([]) are Secondary MCL's and are non-enforceable guidelines for aesthetic quality.

If you wish to contact us about this work please mention KAR Project No. 103262. To arrange additional sampling or testing please contact our Client Services Department. If you have any questions regarding quality assurance please call us.

Thank you for the opportunity to serve you. Please do not hesitate to call if we can provide additional assistance.

Respectfully submitted,

David R. Alkema
Laboratory Manager

LABORATORY DETAIL REPORT

Client: ***Kieser & Associates***

KAR Project No. : ***103262***

Date Reported: ***08/20/10***

Attest: David R. Alkema
David R. Alkema, Lab Manager

Project Description : ***Analysis of five aqueous samples from Cedar Lake.***

Sample ID : ***"Cedar Lake"***

Sampled By : ***KBB & JAD of Kieser & Associates***

Sample Date : ***07/30/10***

Sample Time : ***0800***

Date Received : ***08/11/10***

Sample Type : ***aqueous***

KAR Sample No. : ***103262-01***

Test	Result	Units of Measure	Method	Analyzed	Analyst	Comments
Nitrogen, total	*0.7*	*mg/L*	*EPA 351.2,353.2*	*08/17/10*	*JHB*	
Phosphorus, total (as P)	*<0.02*	*mg/L*	*SM 4500-P E,B5*	*08/18/10*	*DMC*	
Suspended solids, total	*2*	*mg/L*	*SM 2540 D*	*08/16/10*	*JHB*	*Sample received past holding time; result is approximate.*

LABORATORY DETAIL REPORT

Client: ***Kieser & Associates*** **KAR Project No. :** ***103262***

Date Reported: ***08/20/10***

Attest: David R. Alkema
David R. Alkema, Lab Manager

Project Description : ***Analysis of five aqueous samples from Cedar Lake.***

Sample ID : ***"Phelan Creek"***

Sampled By : ***KBB & JAD of Kieser & Associates*** **Date Received :** ***08/11/10***

Sample Date : ***07/30/10*** **Sample Type :** ***aqueous***

Sample Time : ***0820*** **KAR Sample No. :** ***103262-02***

Test	Result	Units of Measure	Method	Analyzed	Analyst	Comments
Nitrogen, total	*1.4*	*mg/L*	*EPA 351.2,353.2*	*08/17/10*	*JHB*	
Phosphorus, total (as P)	*<0.02*	*mg/L*	*SM 4500-P E,B5*	*08/18/10*	*DMC*	
Suspended solids, total	*<2*	*mg/L*	*SM 2540 D*	*08/16/10*	*JHB*	*Sample received past holding time; result is approximate.*

LABORATORY DETAIL REPORT

Client: ***Kieser & Associates***

KAR Project No. : ***103262***

Date Reported: ***08/20/10***

Attest: David R. Alkema
David R. Alkema, Lab Manager

Project Description : ***Analysis of five aqueous samples from Cedar Lake.***

Sample ID : ***"Phelan #3"***

Sampled By : ***KBB & JAD of Kieser & Associates***

Sample Date : ***07/30/10***

Sample Time : ***0915***

Date Received : ***08/11/10***

Sample Type : ***aqueous***

KAR Sample No. : ***103262-03***

Test	Result	Units of Measure	Method	Analyzed	Analyst	Comments
Nitrogen, total	*1.1*	*mg/L*	*EPA 351.2,353.2*	*08/17/10*	*JHB*	
Phosphorus, total (as P)	*<0.02*	*mg/L*	*SM 4500-P E,B5*	*08/18/10*	*DMC*	
Suspended solids, total	*<2*	*mg/L*	*SM 2540 D*	*08/16/10*	*JHB*	*Sample received past holding time; result is approximate.*

LABORATORY DETAIL REPORT

Client: *Kieser & Associates*

KAR Project No. : *103262*

Date Reported: *08/20/10*

Attest: [signature]
David R. Alkema, Lab Manager

Project Description : ***Analysis of five aqueous samples from Cedar Lake.***

Sample ID : ***"Rentwood"***

Sampled By : ***KBB & JAD of Kieser & Associates***

Sample Date : *07/30/10*

Sample Time : *0945*

Date Received : *08/11/10*

Sample Type : *aqueous*

KAR Sample No. : *103262-04*

Test	Result	Units of Measure	Method	Analyzed	Analyst	Comments
Nitrogen, total	1.4	mg/L	EPA 351.2,353.2	08/17/10	JHB	
Phosphorus, total (as P)	0.03	mg/L	SM 4500-P E,B5	08/18/10	DMC	
Suspended solids, total	4	mg/L	SM 2540 D	08/16/10	JHB	Sample received past holding time; result is approximate.

LABORATORY DETAIL REPORT

Client: *Kieser & Associates*

KAR Project No. : *103262*

Date Reported: *08/20/10*

Attest: David R. Alkema
David R. Alkema, Lab Manager

Project Description : *Analysis of five aqueous samples from Cedar Lake.*

Sample ID : *"Outflow Creek"*
Sampled By : *KBB & JAD of Kieser & Associates*
Sample Date : *07/30/10*
Sample Time : *1055*

Date Received : *08/11/10*
Sample Type : *aqueous*
KAR Sample No. : *103262-05*

Test	Result	Units of Measure	Method	Analyzed	Analyst	Comments
Nitrogen, total	*0.8*	*mg/L*	*EPA 351.2,353.2*	*08/17/10*	*JHB*	
Phosphorus, total (as P)	*<0.02*	*mg/L*	*SM 4500-P E,B5*	*08/18/10*	*DMC*	
Suspended solids, total	*<2*	*mg/L*	*SM 2540 D*	*08/16/10*	*JHB*	*Sample received past holding time; result is approximate.*

SAMPLE CHAIN-OF-CUSTODY DOCUMENT

Project Name: Cedor Lake

Project Location: Alcona / Iosco Co., MI

Sampling Date: 7/30/2010

Laboratory Extraction Dates Requested: Yes / No

Project Number:

Sampled By: KBP, JAD

Lab Delivered To: KAR Laboratories, Inc.

Notes/Special Requests:

Required Completion Date: / /

Lab ID	Client Sample ID	Sampling Location	Sample Containers (No./Type)	Collection Date	Collection Time	Method composite or grab	Matrix wtr / ww or soil	TP	TN	TSS								
	Cedor Lake		1L plastic 250 ml plastic	7/30	8:00 AM	GR	WTR	X	X	X								
	Phelan Creek		↓		8:20 AM	↓	↓	X	X	X								
	Phelan #3		↓		9:15 AM	↓	↓	X	X	X								
	Rentwood		↓		9:45 AM	↓	↓	X	X	X								
	Out Slow Creek		↓		10:55 AM	↓	↓	X	X	X								

Requested Analytical Testing

Laboratory to store remaining sample: How Long? Return?

Relinquished By:	Received By:	Date:	Time:	Reason:
1. Wade [signature]	Hope Staney	8/11/10	@ 9:45a	
2.				
3.				

KIESER & ASSOCIATES
ENVIRONMENTAL SCIENCE & ENGINEERING
536 EAST MICHIGAN AVE. / SUITE 300 / KALAMAZOO, MICHIGAN 49007 / ph: (269) 344-7117 / fax: (269) 344-2493

ATTACHMENT E

Copy of Pump Testing Report

Williams & Works
engineers . planners . surveyors — a tradition of service

November 29, 2010

Mr. Gerry Neubecker, III, President
Raymer Company
1357 Comstock Street
Marne, Michigan 49435

COPY

Reference: **Groundwater Resource Evaluation Cedar lake Wetlands Improvement Project, Alcona County, Michigan**

Dear Mr. Neubecker:

As you are aware, a new test pumping well was recently completed and an aquifer test was performed near Cedar Lake in Greenbush Township, Alcona County. A new system of wetland rehabilitation wells is proposed to provide water for the nearby wetland areas west of Cedar Lake. The purpose of this report, therefore, is to summarize the results of an aquifer test which will provide the basis of design for a proposed array of wells to be used for this purpose. The proposed withdrawal rate for this system (as determined by others) is 500 gpm.

Geologic Background

The surface topography in this area is relatively flat lying between about 600 and 620 feet. Much of the east half of Greenbush Township is marshland and associated with the Cedar Lake Swamp. The regional drainage in this area trends toward the southwest into the Pine River Drainageway and Van Etton Lake (see Figure 1).

Cedar Lake is located at the southeastern edge of Greenbush Township in Alcona County. Although most of southeast Alcona County is drained by the Pine River Basin and its wide network of tributaries, Cedar Lake appears to be somewhat isolated from the Pine River Basin. Compared to the average water level of Lake Huron at 579 feet, the average water level of Cedar Lake is considerably higher at about 607 feet (as taken directly from the USGS map), yet the edge to edge distance between the two water bodies is within ½ mile from each other. Localized mapping of Cedar Lake shows this lake to be within its own relatively small and enclosed watershed.

Groundwater flow in the local area is assumed to flow southward toward Van Etton Lake from the west side of the divide (west of Cedar Lake), or eastward directly toward Lake Huron within the Cedar Lake catchment area (see again Figure 1). A localized map of the local groundwater flow gradient is not possible to depict due to the layout of test wells (shown further below).

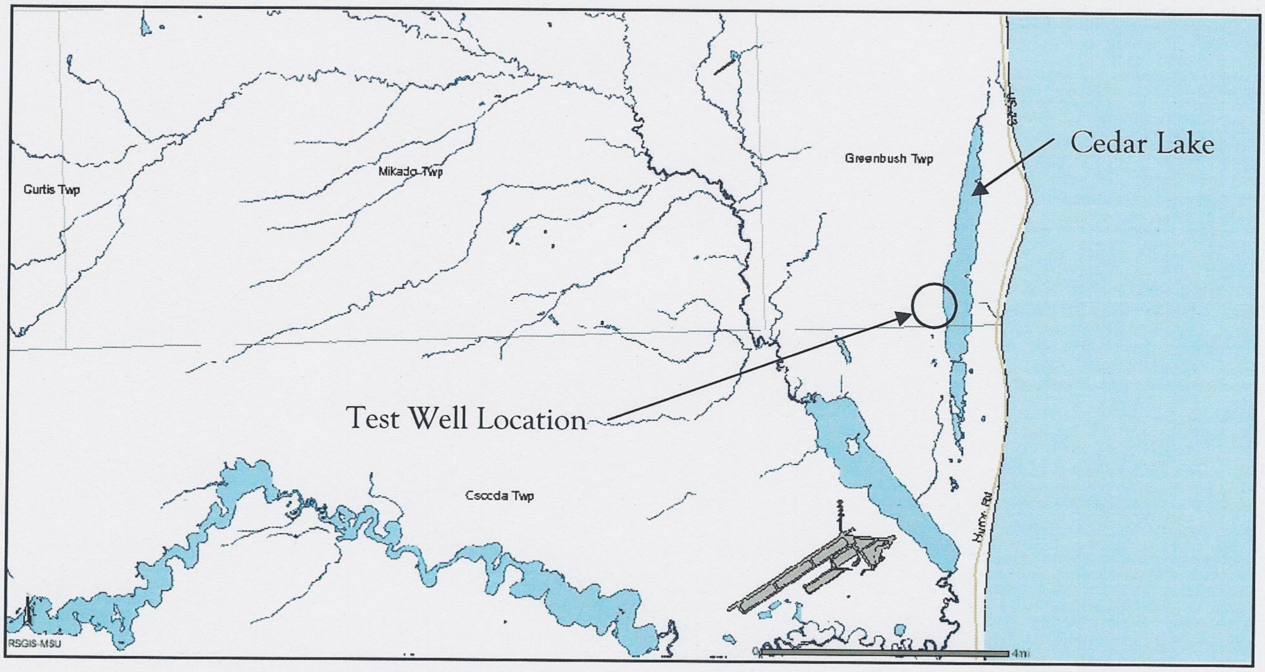


Figure 1. **Location Map of Cedar Lake and the Surrounding Areas of Southeast Alcona County and Northeast Iosco County**

The glacial deposits in this area consist mainly of lacustrine sands and gravels, with dune deposits east of the Lake, and broad fine textured till plains west of the area (see Figure 2).

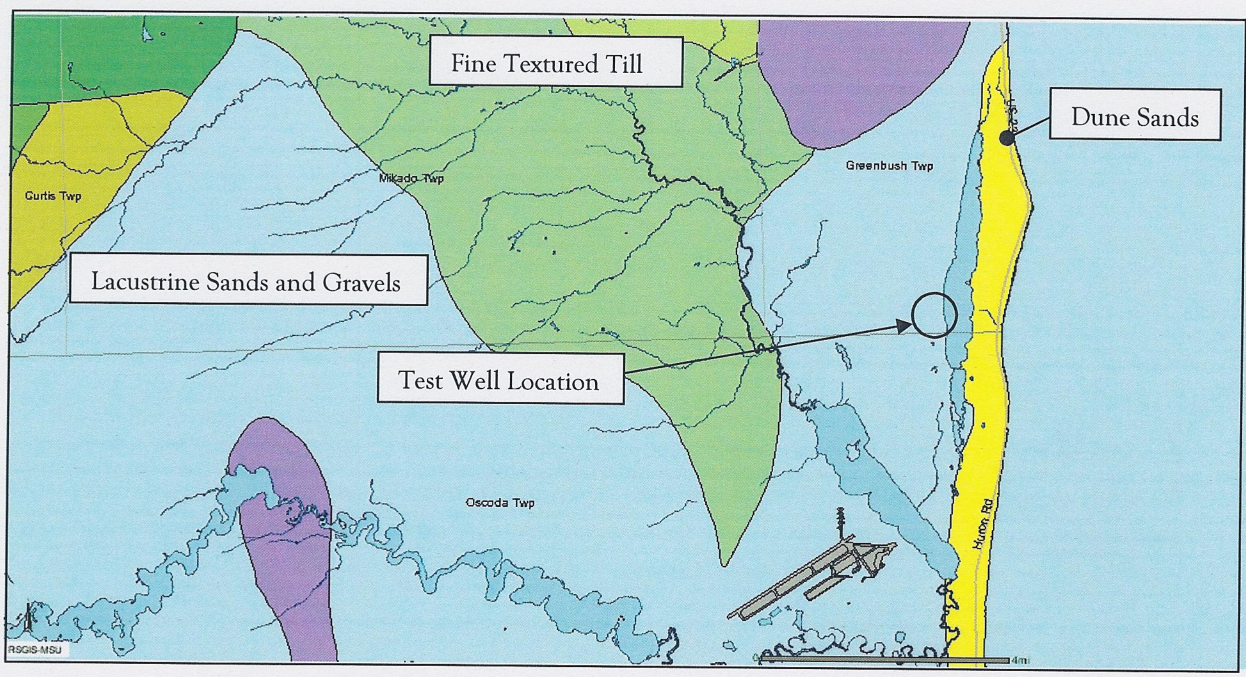


Figure 2. **Glacial Deposits in Southeast Alcona County and Northeast Iosco County**

Test Well and Observation Well Construction

A 12-inch test well and two observation wells were constructed to characterize the hydraulics of the aquifer in this area. A summary of these wells is as follows (well logs are attached to this report for reference);

12-inch Test Well (pumping well) has the following characteristics:

1. Drilled to a depth of 70 feet.
2. 60 feet of 12-inch PVC casing.
3. 10 feet of 12-inch diameter, 0.040 slot SSWW gravel packed screen set at a depth of 70 feet. The screen has a unit entrance capacity of 32.39 gpm/ft (at 0.1 ft/sec entrance velocity), or a total capacity of at least 324 gpm. Therefore, for the purpose of this aquifer test, we should not be concerned with entrance losses contributing to pumping well drawdowns.
4. The annular space filled from 50 feet to the surface with bentonite slurry.

5-inch Observation Well (OW-1) has the following characteristics:

1. Drilled to a depth of 70 feet.
2. 60 feet of 5-inch PVC casing.
3. 10 feet of 4.5-inch diameter, 0.012 slot PVC gravel packed screen set at a depth of 70 feet.
4. The annular space filled from 50 feet to the surface with bentonite slurry.

2-inch Observation Well (OW-2) has the following characteristics:

1. Drilled to a depth of 70 feet.
2. 65 feet of 2-inch PVC casing.
3. 5 feet of 2-inch diameter, 0.010 slot PVC gravel packed screen set at a depth of 70 feet.
4. The annular space filled from 60 feet to the surface with bentonite slurry.

The associated state plane and geographic coordinates, and top of casing elevations for each well are as follows:

Well Name	xcoord	ycoord	latitude	longitude	SWL	TOC elev	SWL elev
TPW-1	19952491.88	439199.59	44.51674	83.34111	4.6	616.20	611.60
OW-1 (5-inch)	19952485.23	439285.92	44.51698	83.34113	4.5	615.20	610.70
OW-2 (5-inch)	19952524.94	439098.74	44.51646	83.34099	4.5	616.14	611.64

A local map of the wellsite is shown below in Figure 3.

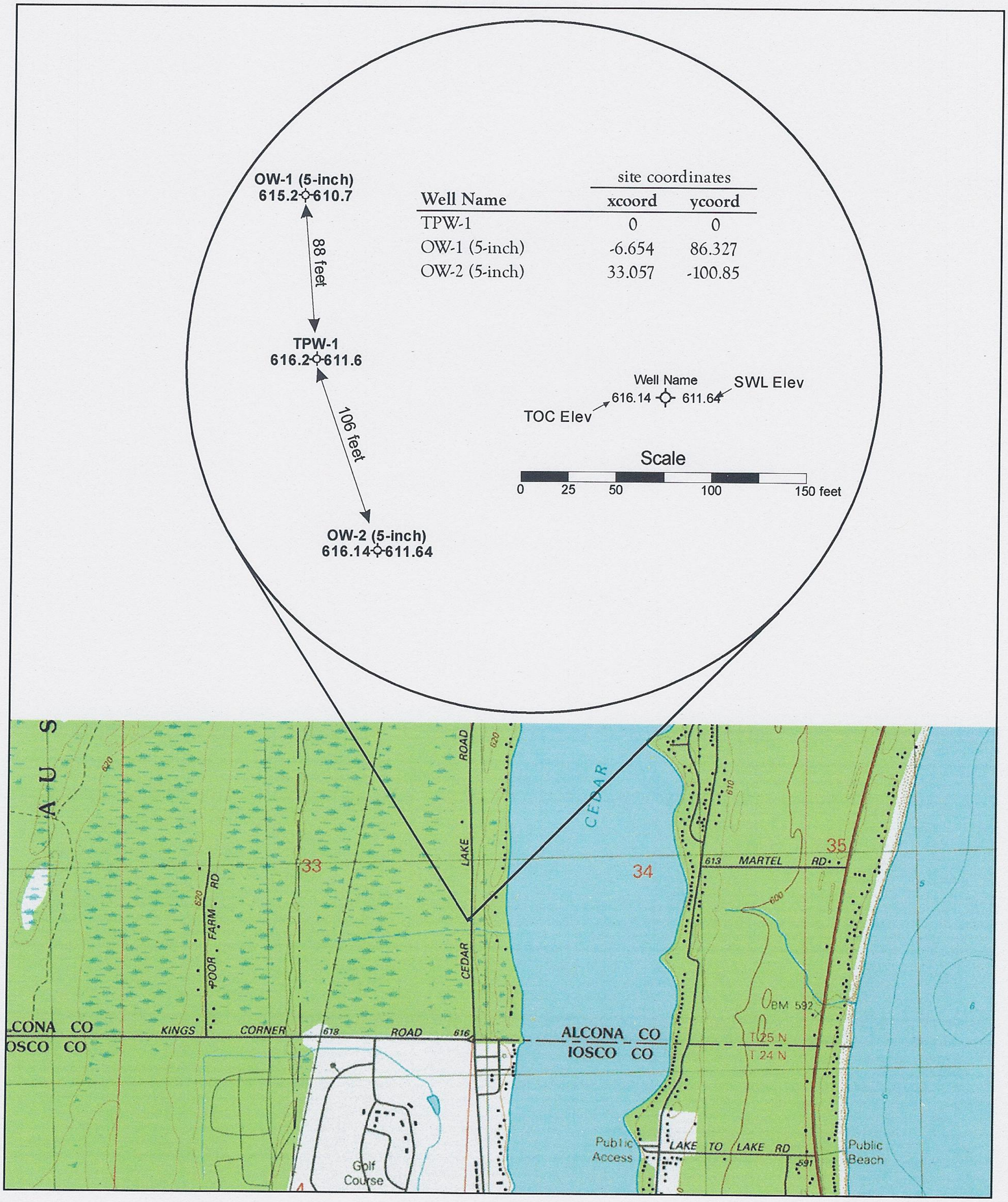


Figure 3. **Local Map of the Test Well Site at Cedar Lake**

Given the arrangement of wells at the site, the local groundwater flow direction based on static water level elevations is difficult to determine. However, based on local drainage in this immediate area, it is likely that the local groundwater flow direction is east-southeast toward Cedar Lake.

The geology in this area consists of sandy soils from the surface to a depth of about 32 feet, which rests on a clayey layer between about 32 and 55 feet. Beneath the intervening clay layer lies a "lower" sandy interval between about 55 and 70 feet. Clayey soils extend at least seven feet below the lower aquifer from 70 to at least 77 feet below grade. The upper sandy interval is saturated and unconfined, and the "lower" aquifer appears to be under semi-confined conditions. The 12-inch test pumping well and both observation wells were installed within the "lower" 15 feet of sandy formation. Static water levels within the lower aquifer are about 3.5 feet below grade in this area.

A localized graphical illustration of the drift package at the wellsite is shown below:

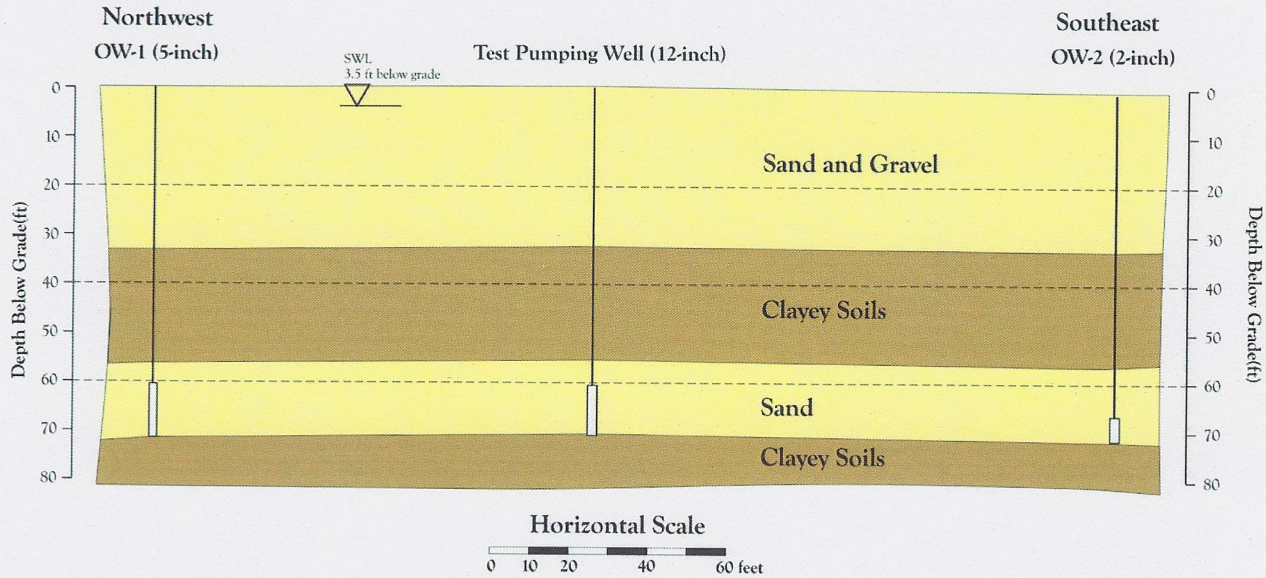


Figure 4. Local Geologic Cross-Section Viewing Northeast

Aquifer Testing

The layout of the aquifer test is shown in Figure 3, above. The aquifer test was performed using the 12-inch PVC well as the pumping well, with a test pumping rate set at 155 gpm (20.7 ft^3/min). The well was pumped for a duration of 24 hours. Drawdowns were monitored in the pumping well and both observation wells using pressure transducers and a data-logging instrument.

Examination of the shape of the semi-log plot in Figure 5 suggests that the aquifer is slightly leaky-confined, or may indicate the presence of a weak recharge-type boundary in the area. In the case of a recharge boundary, either the Lake or the wetland areas or both could provide the conditions for recharge-type boundaries. The plot shows reasonably reversible drawdown and recovery behavior.

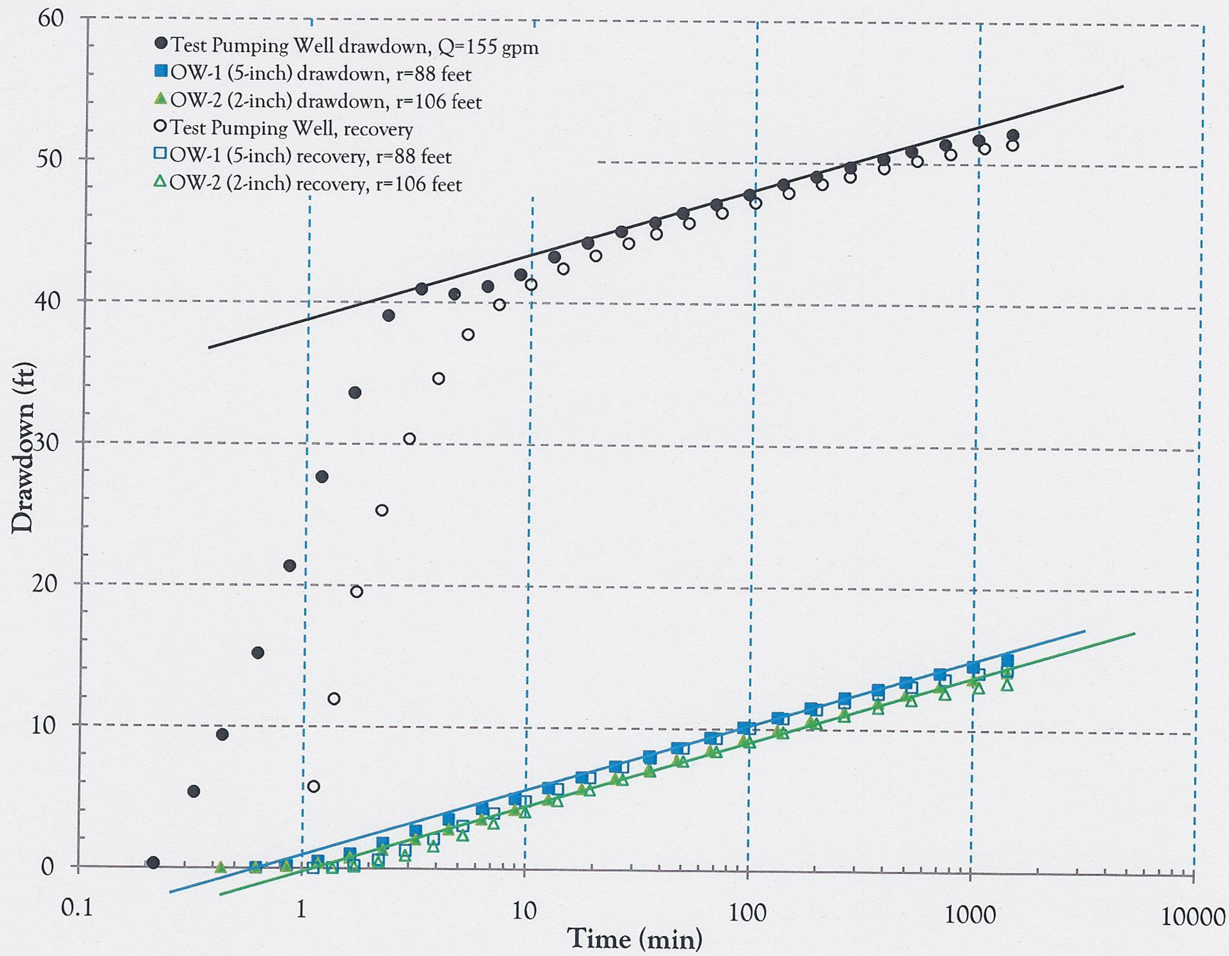


Figure 5 **Semi-Log Plot of Cedar Lake Aquifer Test on the 12-inch Test Pumping Well Showing the Pumping Well and Both Observation Wells, October 2010, Q=155 gpm**

The plot in Figure 6 below shows that the drawdown data from both wells yield similar transmissivity and storage values. In this case, the straight line analysis (after Cooper and Jacob, 1946[1]) was be applied to the early time data before the effects of leakance and (or) boundaries take

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[1] Cooper, H.H., and C.E. Jacob, 1946, A generalized Graphic Method for Evaluating Formation Constants and Summarizing Well-Field History, Transactions of American Geophysical Union, Vol 27, No.4

over. This analysis yields a relatively low transmissivity value of 0.76 ft^2/min, which is plausible given the textural characteristics and saturated thickness of the formation. The calculated storage coefficient (S) from this method is about 0.0002 which is also reasonable for this system. Water levels in the immediate vicinity of the pumping well were very close to the bottom of the confining layer at or near 500 minutes, which may have caused a localized conversion from confined to unconfined conditions. This can explain the late time behavior at the observation wells at or near the same times. Aquifer boundaries could also explain this behavior, as can a weak leaky condition across the confining layer.

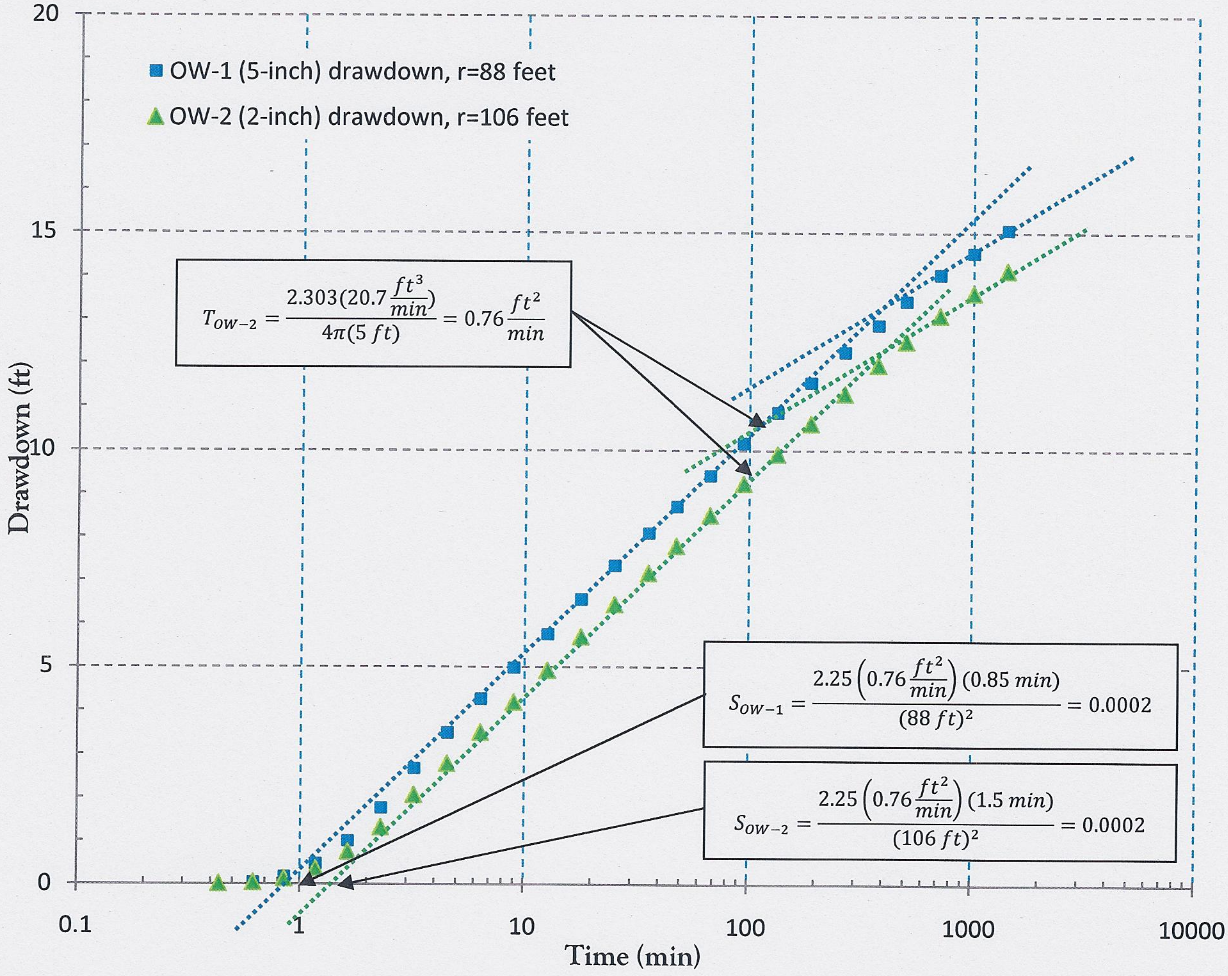

Figure 6 **Semi-Log Plot of Cedar Lake Aquifer Test on the 12-inch Test Pumping Well Showing the Observation Wells, October 2010, Q=155 gpm**

The type curve solution utilized the leaky-confined model after Hantush and Jacob[2]. This analysis assumes that water is instantaneously transmitted across the confining layer from a source aquifer

[2] Hantush, M.S., C.E. Jacob, 1955, Non-steady Radial Flow in an Infinite Leaky Aquifer, Am. Geophys. Union Trans. vol 36, pp 95-100

to the pumped interval, which may or may not be a realistic assumption given that the intervening clayey layer is relatively sand free and dense. However, the presence of an upper saturated aquifer tends to satisfy the model assumption, and the effects of leakance are seen only after long pumping times. Partial penetration effects were not incorporated.

This analysis using the leaky-confined model and ignoring partial penetration is as follows;

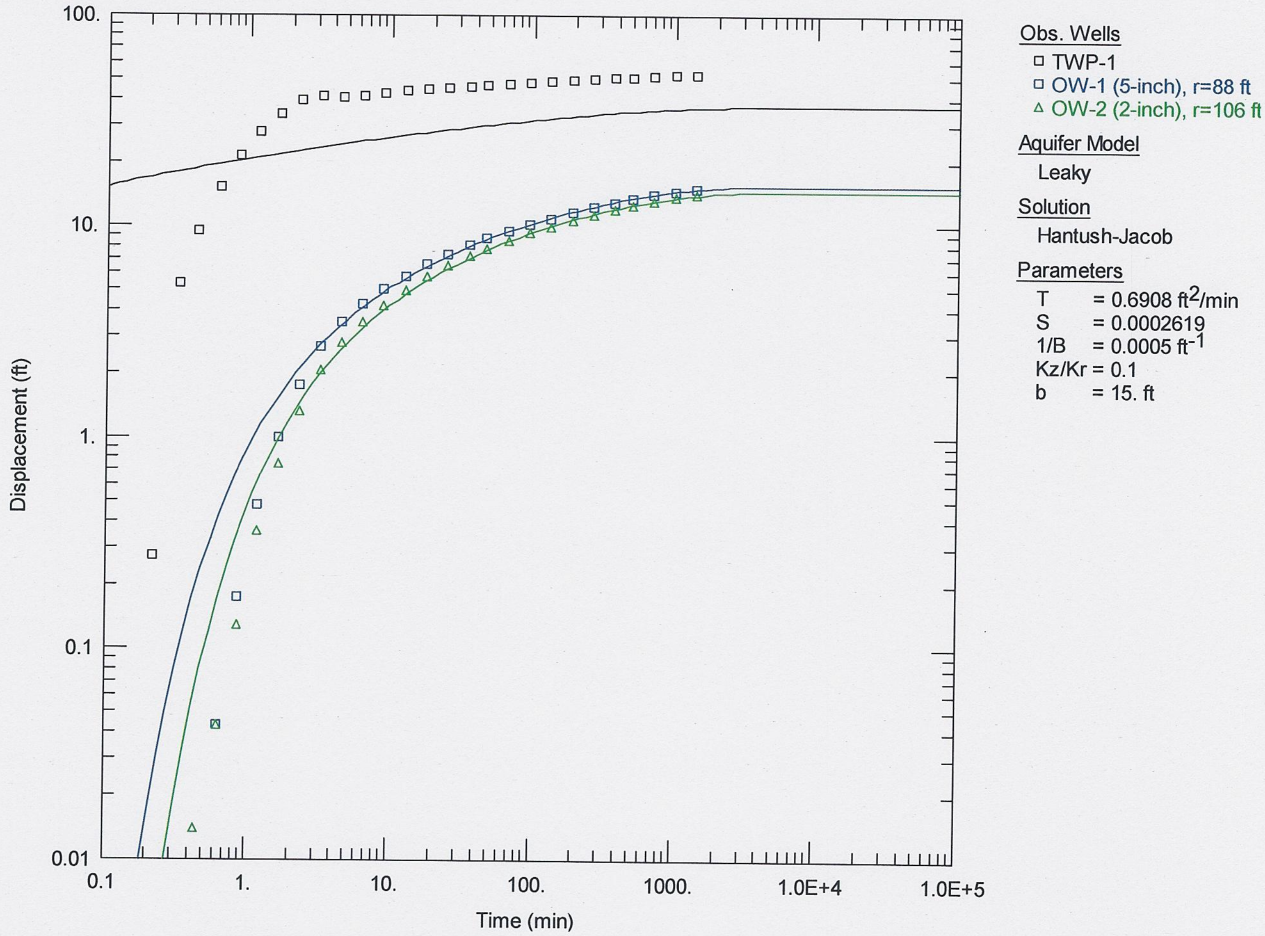

Figure 7 **Leaky-Confined Solution of Cedar Lake Aquifer Test (after Hantush and Jacob, 1955) Q=155 gpm**

The results derived from this solution are reasonably similar to those derived from the straight line analysis, but in this case a small leakance value improves the late time change in drawdown. The resulting horizontal hydraulic conductivity averaged over the entire aquifer thickness (b=15 feet) would be, therefore, about 66 ft/day.

Using this predictor set, the theoretical drawdown after 24 hours at the pumping well is about 36 feet, while the actual drawdown was about 52 feet, representing an apparent well efficiency (or correction factor) of about 69%[3] (which is plausible). The plot of drawdown at the test pumping well is as shown and extrapolated to 100 days. This plot reveals an extrapolated 100 day drawdown of about 57 feet without accounting for leakance.

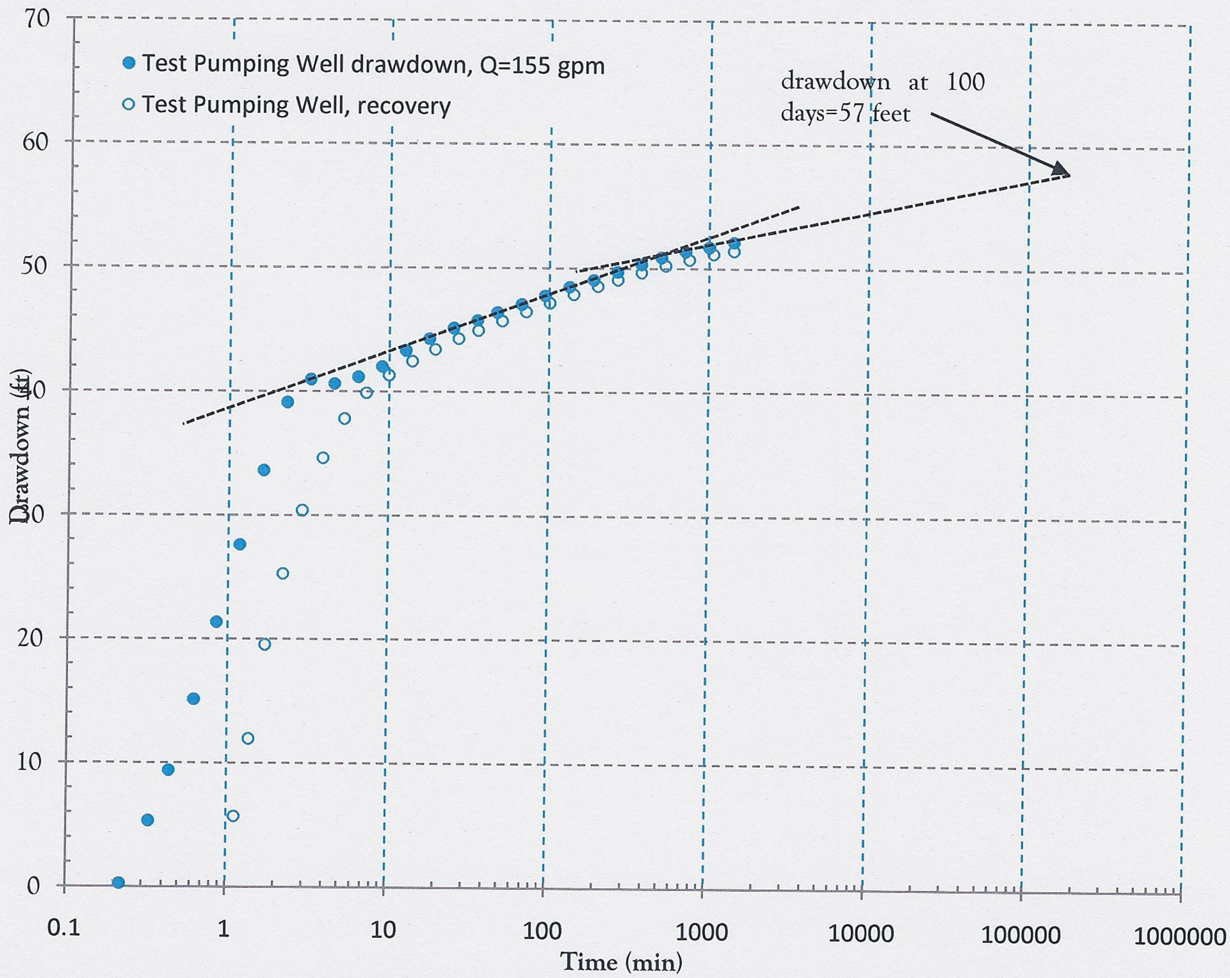

Figure 9 **Test Pumping Well Drawdowns at Cedar Lake (Q=155 gpm) from October, 2010 Aquifer Test**

Using the model predictor set, the pumping water level after 100 days at 155 gpm would be about 37 feet. After adding back the entrance losses, the actual pumping water level will be about 54 feet which is reasonably similar to the extrapolated plot in Figure 9 (the extrapolated curve, however, does not account for leakance). While this pumping rate would be acceptable for a single well, the goal will be to provide 500 gpm from a system of wells which would be run continuously over the summer months. The 100 day pumping period will provide a reasonable approximation to the actual demands that will be placed on this local aquifer.

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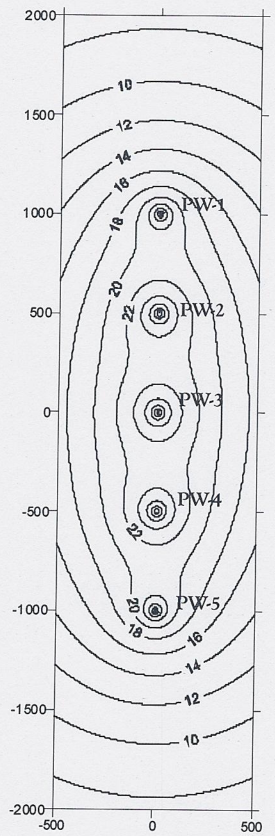
[3] Apparent Well Efficiency=(theoretical dd)/(actual dd)=(36ft)/(52ft)=0.69

In order to simulate the interfering drawdowns resulting from several simultaneously pumping wells, we used the type curve matching software AQTESOLV to provide a regularly gridded drawdown distribution. The software utilizes the principal of superposition by cumulating the individual drawdowns from each well to produce a composite overall drawdown distribution. By trial and error, the production well array spacing and pumping rates were adjusted to ultimately consist of five wells, each well spaced at least 500 feet apart along a line oriented north-south, and each well pumping at a rate of 100 gpm. Wells are assumed to have an apparent well efficiency of 69%, and the maximum allowable drawdown was not allowed to fall below five feet above the top of the screened interval. The predictor set and results of this analysis are as follows:

- transmissivity (T) 0.69 ft^2/min, hydraulic conductivity (K) 66 ft/day
- aquifer storage coefficient (S) 0.00026
- aquifer thickness (b) 15 feet
- leakance (1/B) 0.0005 ft^{-1}
- pumping duration (t) of 100 days
- assumed production well "efficiency" of 69%
- each well (if constructed and developed similarly) will have about 51 feet of available drawdown measured from grade (assuming the top of the screen is set at 60 feet, the SWL is 4 feet, and allow 5 feet above the screened interval).



Well No.	Model DD	Corrected DD
PW-1	29.9	43.3
PW-2	32.3	46.8
PW-3	32.5	47.1
PW-4	32.3	46.8
PW-5	29.9	43.3

Figure 14 **Drawdown Distribution after 100 days with (5) Production Wells, each Pumping 100 gpm. Aquifer Properties: T=0.69 ft^2/min, S=0.0002, b=15 feet, 1/B=0.0005 ft^{-1} (from AQTESOLV output)**

Based upon this analysis, a system of five wells can be placed along a linear array as shown, and each equipped with a pump rated at 100 gpm. If the wells are operated during the summer months, and it is assumed that the duration of operation will be about 100 days. The maximum capacity of about 500 gpm can be achieved when all five wells are operating simultaneously over this time period. At this combined rate and duration, the drawdowns at each well will not exceed five feet above the tops of the well screens.

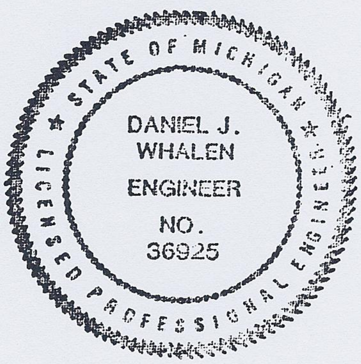
If you have any questions regarding the above discussion or other matters, please do not hesitate to call me.

Sincerely,

Williams & Works, Inc.

Daniel J. Whalen, P.E.

Attachments: Well Construction Logs
Aquifer Test Data



H:\Work\raymer company\cedar lake\cedar lake aquifer test report.docx

ATTACHMENT A – WELL CONSTRUCTION LOGS

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Wellogic

Import ID:

Tax No: | **Permit No:**

County: Alcona | **Township:** Greenbush

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
25N 09E	33	Active		

Well ID: 01000003335

Elevation:

Latitude: 44.5167400000

Longitude: -83.3411100000

Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:
1/2 MILE NORTH OF COUNTY LINE RD., & 75 FT. WEST OF CEDAR LAKE RD.

Well Owner: CEDAR LAKE IMPROVEMENT BOARD

Well Address:
CEDAR LAKE RD.
OSCODA, MI 48750

Owner Address:
1822 W. MILHAM, STE 1C
PORTAGE, MI 49024

Drilling Method: Rotary
Well Depth: 70.00 ft. **Well Use:** Irrigation
Well Type: New **Date Completed:** 10/26/2010

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Solvent welded/glued
Casing Fitting: Centralizer

Diameter: 12.00 in. to 60.00 ft. depth SDR: 21.00

Borehole: 17.50 in. to 78.00 ft. depth

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 3.60 ft. Below Grade (Not Flowing)
Unrestricted Flow Rate: **Yield Test Method:** Air
Well Yield Test:
Pumping Level 70.00 ft. after 8.00 hrs. at 200 GPM

Formation Description	Thickness	Depth to Bottom
Brown Sand & Gravel	32.00	32.00
Gray Clay	23.00	55.00
Gray Sand	15.00	70.00
Gray Clay	8.00	78.00

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 12.00 in. **Blank:**
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
40.00	10.00 ft.	60.00 ft. and 70.00 ft.

Fittings: Coupling

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Bentonite slurry	18.00	None	0.00 ft. to 50.00 ft.

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	250 ft.	East

Drilling Machine Operator Name: C. KAGE
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 2055
Business Name: Raymer Company, Inc.
Business Address: 1357 Comstock Street, Marne, MI, 49435

Water Well Contractor's Certification

This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.

Signature of Registered Contractor **Date**

General Remarks: FURTHER TEST PUMPING INFORMATION TO BE AVAILABLE FROM AQUIFER ANALYSIS REPORT. KIESER & ASSOCIATES, LLC. CONSULTANTS.

Other Remarks:

ATTENTION WELL OWNER: FILE WITH DEED

Contractor 11/8/2010 10:07 AM

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Wellogic

Import ID:

Tax No: | **Permit No:**

County: Alcona | **Township:** Greenbush

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
25N 09E	33	Active		

Well ID: 01000003336

Elevation:

Latitude: 44.5169400000 OW1

Longitude: -83.3411300000

Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:
1/2 MILE NORTH OF COUNTY LINE RD. & 75 FT. WEST OF CEDAR LAKE RD.

Well Owner: CEDAR LAKE IMPROVEMENT BOARD

Well Address:
CEDAR LAKE RD.
OSCODA , MI 48750

Owner Address:
1822 W. MILHAM, STE 1C
PORTAGE, MI 49024

Drilling Method: Rotary
Well Depth: 70.00 ft. **Well Use:** Test well
Well Type: New **Date Completed:** 10/18/2010

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Solvent welded/glued
Casing Fitting: Centralizer

Diameter: 5.00 in. to 60.00 ft. depth SDR: 21.00

Borehole: 8.75 in. to 77.00 ft. depth

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 3.50 ft. Below Grade (Not Flowing)
Unrestricted Flow Rate: **Yield Test Method:** Test pump
Well Yield Test:
Pumping Level 36.25 ft. after 2.00 hrs. at 94 GPM

Formation Description	Thickness	Depth to Bottom
Brown Sand & Gravel	32.00	32.00
Gray Clay	23.00	55.00
Gray Sand	15.00	70.00
Gray Clay	7.00	77.00

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 4.50 in. **Blank:**
Screen Material Type: PVC-slotted

Slot	Length	Set Between
12.00	10.00 ft.	60.00 ft. and 70.00 ft.

Fittings: Coupling

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Bentonite slurry	7.00	None	0.00 ft. to 50.00 ft.

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	250 ft.	East

Drilling Machine Operator Name: C. KAGE
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 2055
Business Name: Raymer Company, Inc.
Business Address: 1357 Comstock Street, Marne, MI, 49435

Water Well Contractor's Certification

This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.

Signature of Registered Contractor **Date**

General Remarks: TEST WELL ALSO USED FOR OBSERVATION PURPOSES FOR AQUIFER ANALYSIS REPORT. KIESER & ASSOCIATES, LLC, CONSULTANTS

Other Remarks:

ATTENTION WELL OWNER: FILE WITH DEED

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Wellogic

Import ID:

Tax No: | **Permit No:**

County: Alcona | **Township:** Greenbush

Town/Range: 25N 09E | **Section:** 33 | **Well Status:** Active | **WSSN:** | **Source ID/Well No:**

Well ID: 01000003337

Elevation:

Latitude: 44.5164600000

OW2

Longitude: -83.3410300000

Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:
1/2 MILE NORTH OF COUNTY LINE RD. & 75 FT. WEST OF CEDAR LAKE RD.

Well Owner: CEDAR LAKE IMPROVEMENT BOARD

Well Address:
CEDAR LAKE RD.
OSCODA, MI 48750

Owner Address:
1822 W. MILHAM, STE. 1C
PORTAGE, MI 49024

Drilling Method: Rotary
Well Depth: 70.00 ft. **Well Use:** Other
Well Type: New **Date Completed:** 10/19/2010

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Solvent welded/glued
Casing Fitting: Centralizer

Diameter: 2.00 in. to 65.00 ft. depth SDR: 21.00

Borehole: 6.25 in. to 77.00 ft. depth

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 3.50 ft. Below Grade (Not Flowing)
Unrestricted Flow Rate: **Yield Test Method:** Air
Well Yield Test:
Pumping Level 20.00 ft. after 2.00 hrs. at 20 GPM

Formation Description	Thickness	Depth to Bottom
Brown Sand & Gravel	32.00	32.00
Gray Clay	23.00	55.00
Gray Sand	15.00	70.00
Gray Clay	7.00	77.00

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 2.00 in. **Blank:**
Screen Material Type: PVC-slotted

Slot	Length	Set Between
10.00	5.00 ft.	65.00 ft. and 70.00 ft.

Fittings: Coupling

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Bentonite slurry	6.00	None	0.00 ft. to 60.00 ft.

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	250 ft.	East

Drilling Machine Operator Name: C. KAGE
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 2055
Business Name: Raymer Company, Inc.
Business Address: 1357 Comstock Street, Marne, MI, 49435

Water Well Contractor's Certification

This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.

Signature of Registered Contractor **Date**

General Remarks: OBSERVATION WELL USED FOR AQUIFER ANALYSIS REPORT. KIESER & ASSOCIATES, LLC, CONSULTANTS.
Other Remarks: Well Use:OBSERVATION

ATTENTION WELL OWNER: FILE WITH DEED

Contractor 11/8/2010 10:53 AM

ATTACHMENT B – AQUIFER TEST DATA

Cedar Lake Aquifer Test
12-inch PVC Test Pumping Well, Q=155 gpm
October, 2010

	drawdown		
	Q=155 gpm	r=88 feet	r=106 feet
Time (min)	Test PW-1	OW-1	OW-2
0.22	0.27		
0.33	5.33		
0.43	9.40		0.01
0.62	15.16	0.04	0.04
0.85	21.34	0.17	0.13
1.18	27.62	0.48	0.36
1.64	33.61	1.00	0.75
2.29	39.06	1.76	1.31
3.22	40.94	2.67	2.06
4.52	40.62	3.48	2.78
6.36	41.14	4.26	3.50
8.97	42.01	4.98	4.19
12.64	43.28	5.76	4.93
17.83	44.26	6.56	5.70
25.17	45.09	7.34	6.45
35.53	45.76	8.09	7.17
47.37	46.39	8.69	7.79
66.88	47.03	9.42	8.50
94.46	47.76	10.17	9.23
133.40	48.47	10.86	9.91
188.41	49.03	11.55	10.61
266.12	49.71	12.25	11.29
375.88	50.32	12.88	11.95
501.23	50.88	13.43	12.50
707.99	51.38	14.04	13.11
1000.05	51.74	14.54	13.62
1419.30	52.15	15.08	14.14

		recovery	
		r=88 feet	r=106 feet
Time (min)	Test PW-1	OW-1	OW-2
1.12	5.73	0.01	
1.36	11.93	0.06	0.01
1.71	19.54	0.22	0.13
2.20	25.28	0.62	0.45
2.89	30.38	1.27	0.92
3.87	34.61	2.09	1.58
5.25	37.75	3.03	2.36
7.20	39.86	3.94	3.21
9.96	41.30	4.82	4.03
13.85	42.43	5.70	4.85
19.36	43.38	6.51	5.63
27.13	44.26	7.29	6.39
36.00	44.93	7.94	7.00
50.64	45.71	8.68	7.72
71.31	46.44	9.37	8.43
100.52	47.17	10.08	9.13
141.77	47.86	10.79	9.81
200.04	48.52	11.44	10.47
266.59	49.07	11.96	10.99
376.35	49.66	12.56	11.59
531.40	50.21	13.10	12.14
750.41	50.70	13.60	12.63
1059.77	51.17	14.07	13.09
1419.77	51.43	14.31	13.35

ATTACHMENT F

Photos of Well Drilling and Pump Testing

Cedar Lake Level Augmentation Feasibility Study

Drilling and Pump Testing Photographs

October 18 to November 3, 2010

Photos taken by: B. Boyer and W. Cleary of Kieser & Associates, LLC

KIESER & ASSOCIATES
ENVIRONMENTAL SCIENCE & ENGINEERING

Cedar Lake Drilling and Pump Testing Photographs

Installation of 5-inch diameter observation well, October 18, 2010.

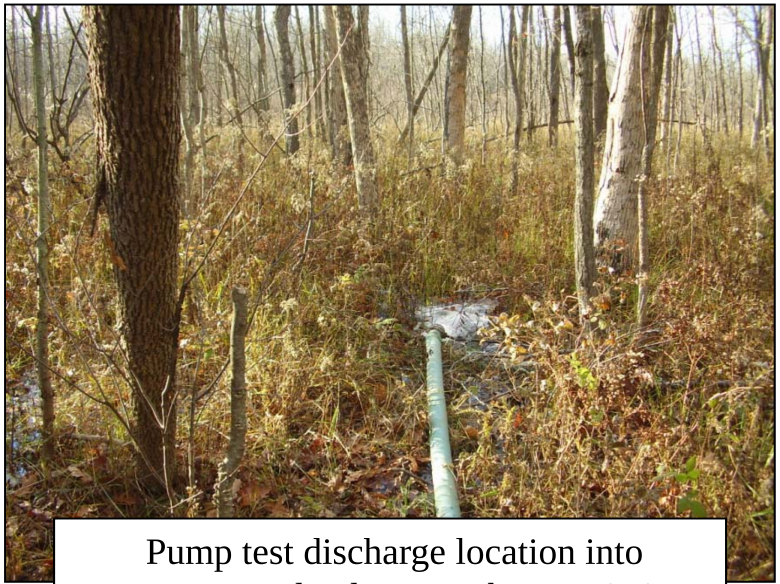
Installation of 5-inch diameter observation well, October 18, 2010.

Installation of 2-inch diameter observation well, October 19, 2010.

Cedar Lake Drilling and Pump Testing Photographs

Installation of 12-inch diameter augmentation test well, October 26, 2010.

Operation of 24-hr pump test at 12-inch diameter well, November 2, 2010.



Pump test discharge location into existing wetland, November 2, 2010.

Sherman Creek discharge into Cedar Lake, November 2, 2010.