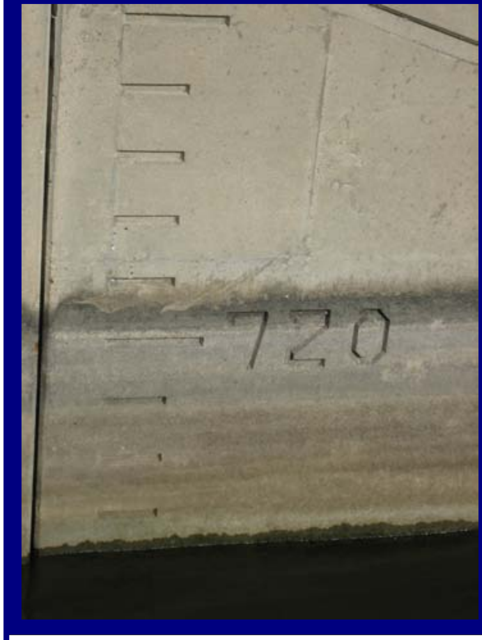
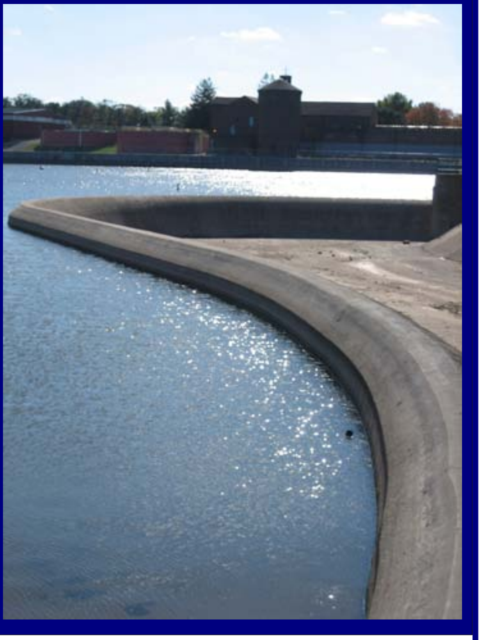
Interim Water Supply Plan

Prepared For:

City of Bloomington, Illinois
January, 2010





Prepared By:

Wittman Hydro Planning Associates

a division of Layne Christensen Company

Interim Water Supply Plan

prepared for
Bloomington, Illinois

January 6, 2010

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK

Contents

List of Figures

List of Tables

Executive Summary

The water supply challenges of the City of Bloomington, Illinois (City) are typical of many communities. The Water Department must address both short-term issues related to surface-water quality deterioration and interim-term needs for additional sources of supply. The City is working to alleviate two areas of concern: high nitrate levels in Lake Bloomington, and finding new sources of water to support population growth in the City. The primary objective of this project is to design an interim water supply plan that takes into consideration available supplies, water quality, management, and infrastructure options.

Background

The City relies on Evergreen Lake and Lake Bloomington for their community drinking water supply. The raw water from these two lakes is treated at the Lake Bloomington Water Treatment Plant and delivered to customers in Bloomington, Towanda, Hudson, and Bloomington Township.

The City has had significant problems through the years with nitrates. Historically, nitrate levels in Lake Bloomington have exceeded the EPA health standard of $10 mg/l$ almost every spring for as long as records have been kept. The majority of the watershed area for both Evergreen Lake and Lake Bloomington is used for agriculture. The two reservoirs also lose a fraction of their volume every year to siltation. As storage slowly shrinks and water quality challenges treatment plant operators to comply with regulatory limits, the City continues to develop and grow.

The 1988 and 2005 droughts illustrated that surface water reservoirs in this part of the State are vulnerable. Public water-supply systems that rely on surface water as their sole source of supply need to have sufficient storage to meet their average needs over an extended period of time in order to withstand prolonged drought. To ensure an adequate water supply for the future the City needs to identify new sources of water.

McLean County proposes to integrate water suppliers into a regional water supply system at some point in the future. The City has recognized the interim need to incrementally increase supply,

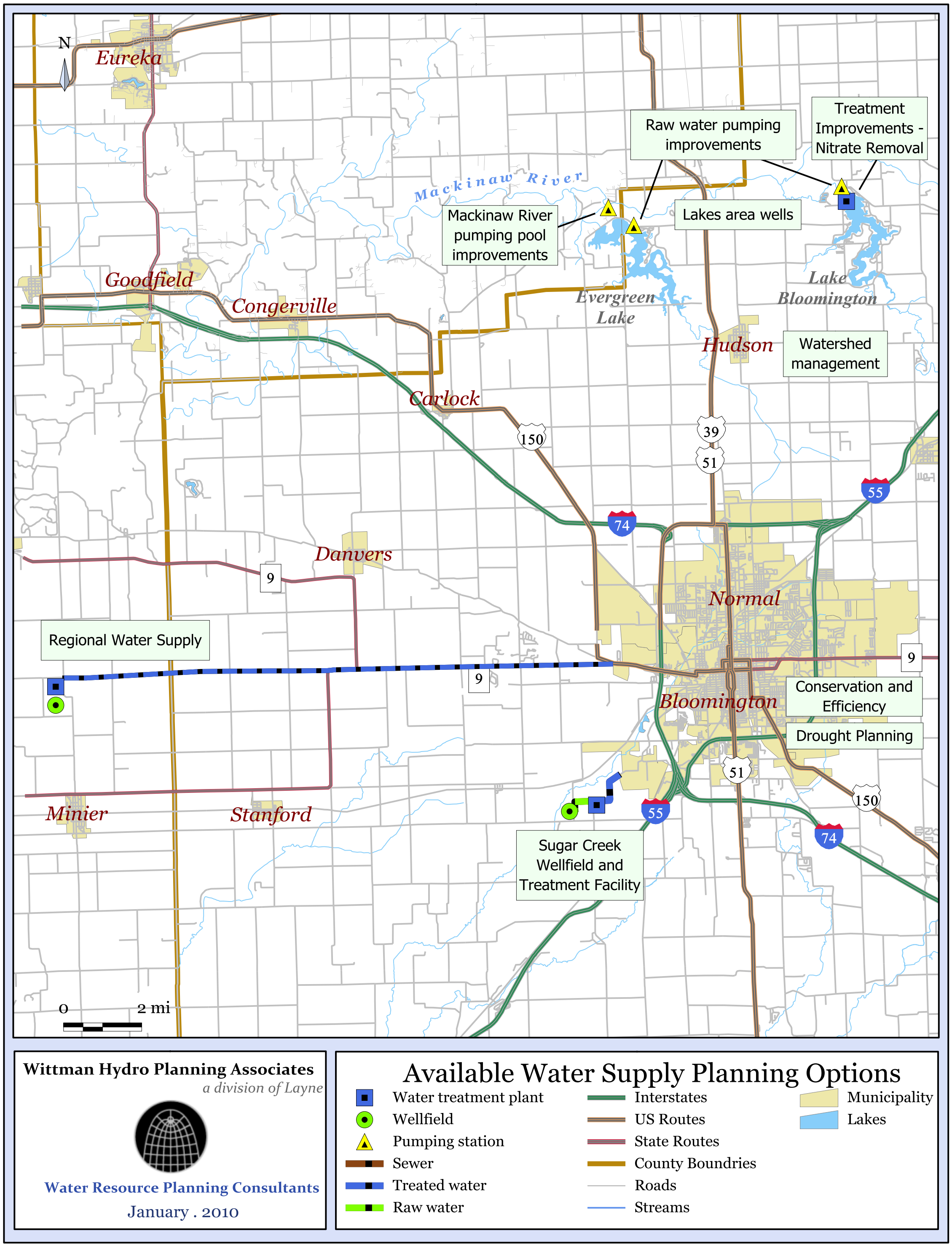


Figure 1: Water supply planning options

improve capabilities to manage nitrates, and begin the process of managing demand so that the utility is able to provide sustainable and safe drinking water. An integrated approach to managing both supply and demand is the most efficient and cost-effective manner of addressing water supply issues in the long-term.

Study purpose

The objective of the study is to determine the most sustainable and cost effective way to meet the current and future water supply needs of the City's utility customers. Work to investigate and evaluate multiple water supply, treatment and management options has produced a range of potential components, shown in Figure 1. Wittman Hydro Planning Associates (WHPA) drilled deep and shallow exploratory wells in local aquifers, collected data on water use and current demands, conducted aquifer tests to determine the yield of local groundwater systems, modeled current yield for the two water supply reservoirs, developed a proposed drought/conservation ordinance, and initiated the first steps of a water utility conservation plan. This data was used to consider the different options to optimize water quality and increase water quantity.

Recommended program of improvements

The evaluation of alternatives identified the group of infrastructure and management measures that will achieve the water supply objectives of the City. Phased implementation of these measures is recommended, based on prioritization to select those measures for early implementation that reduce the risk of severe capacity limitations or regulatory non-compliance. Phased implementation also provides an opportunity for management measures such as conservation and water loss reduction to achieve results. Successful demand management efforts have the potential to limit the growth in demand for water, thereby changing demand projections and the timing of needed infrastructure. Demand management will not eliminate the need for the recommended investments in interim water supply infrastructure, but it does have the potential to reduce costs by delaying the investments in later years. The recommended program of infrastructure and management measures is shown in Figure 2.

Water conservation

It is recommended that the City develop and implement a comprehensive water conservation plan. An effective conservation plan has multiple benefits. It will reduce the risks of severe capacity restrictions or regulatory non-compliance that could result from high nitrate concentrations in Lake

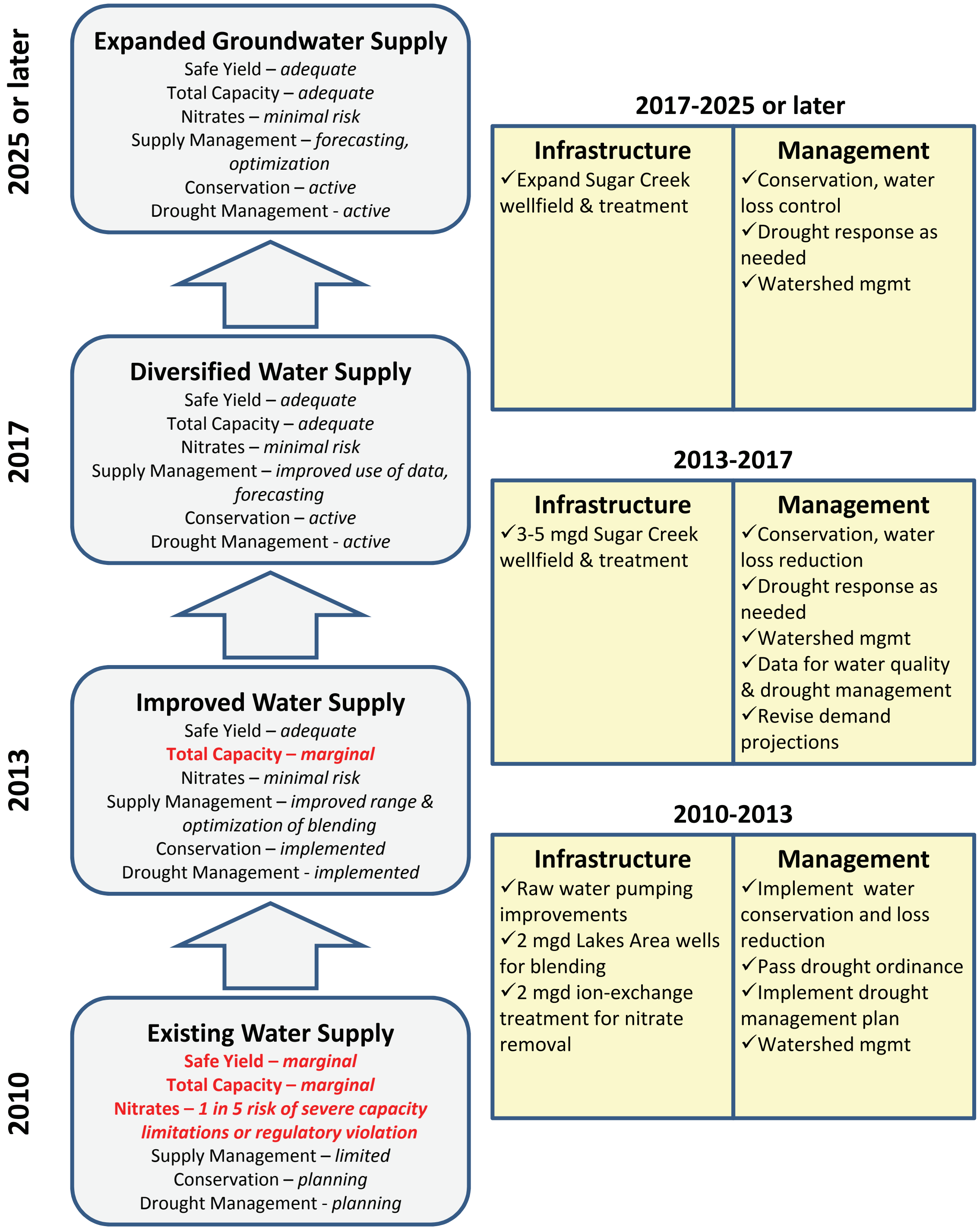


Figure 2: Recommended program of improvements

Bloomington and Evergreen Lake. By improving water use efficiency, the community will be better prepared for drought conditions and less likely to suffer negative economic impacts as a result. Improved water use efficiency will also reduce the demand for additional capacity, allowing investments in later years of the plan to be deferred or scaled back in capacity.

The water conservation plan should aggressively target water loss reduction by continuing the City's current meter replacement efforts and expanding efforts to reduce leakage in the distribution system to the lowest economical level. Conservation efforts to improve water use efficiency by customers will result in long-term reductions in cost to the City and it's rate-paying customers. Additional information is included in Appendix D.

Drought planning

It is recommended that the City approve a drought ordinance and implement a drought management program. The safe yield of the supplies currently available to the City are marginal in capacity. In the event of a severe drought, supplies could be reduced to an extent that has a negative economic impact on the community. Production of high-quality water is more challenging for treatment plant operators when reservoirs are depleted. Planning for drought management is critical to ensure that the City is prepared to recognize drought conditions and to proactively implement measures to conserve supplies before they are depleted. Additional information is included in Appendix E.

Watershed management

It is recommended that the City continue current watershed management efforts and seek opportunities to obtain funding to expand upon them. Agricultural activities in the watersheds of both reservoirs result in sedimentation and runoff of fertilizers and pesticides into the reservoirs. The projected safe yield of the reservoirs continuously declines due to sedimentation. The current combined safe yield of $14.8\,mgd$ is projected to decline to $14.1\,mgd$ by 2020 and $13.5\,mgd$ by 2030 (3). Runoff of fertilizers into the reservoirs results in increased concentrations of nitrates. Improvements have been recommended to manage nitrates in the source water, but the operating costs of these facilities is directly related to the concentrations of nitrates in the raw water. Over the long-term, watershed management efforts will reduce the operating cost of treatment for nitrate removal, and will preserve the safe yield of the reservoirs.

Raw water pumping improvements

Pumping and nitrate monitoring improvements are recommended for the Lake Bloomington and Evergreen Lake raw water pumping stations. The current practice of blending supplies from the reservoirs is and will remain the least-cost means of managing nitrates. Improving the flexibility of pumping operations and providing treatment plant operators with continuous monitoring of nitrate concentrations in both reservoirs will provide them with the tools needed to optimize blending. Additional details are provided in Chapter 5.

Wells for blending

The construction of wells in the area between the lakes is recommended as an immediate measure to reduce the risk of severe capacity restrictions or regulatory non-compliance that could result from high nitrate concentrations in Lake Bloomington and Evergreen Lake. It is estimated that a $2\,mgd$ groundwater supply available for blending with raw water from Evergreen Lake will reduce this risk from 1 in 5 to 1 in 10 in the year 2013. In conjunction with proposed ion-exchange (IX) treatment for nitrate removal, the risk will be reduced to minimal levels. The low-nitrate water from wells will reduce the operating cost of IX treatment. Additional information and specific recommendations are included in Appendix C.

Treatment for nitrate removal

The construction of ion-exchange treatment facilities is recommended to further reduce the risk of severe capacity restrictions or regulatory non-compliance that could result from high nitrate concentrations in Lake Bloomington and Evergreen Lake. Based on historical nitrate events it is estimated that, in conjunction with the wells for blending, $6\,mgd$ of IX treatment capacity will reduce this risk to minimal levels and $2\,mgd$ will provide adequate capacity to manage nitrate events in 50% of years. It is proposed that the facilities be constructed with $2\,mgd$ of permanent capacity and provisions for connecting an additional $2\,or\,4\,mgd$ of rented temporary capacity when needed. In the planning and design phase for this project, it is recommended that the mix of permanent to temporary capacity be reviewed to select the most cost effective configuration. Additional details are provided in Chapter 5.

Sugar Creek wells and treatment

The construction of a groundwater supply and treatment facility near Sugar Creek is recommended to provide needed total capacity, additional safe yield, and to diversify the City's water supply. The initial required capacity will be $3\,to\,5\,mgd$, depending on actual growth in population and water demand and the effectiveness of conservation and water loss reduction programs. Alternative transmission main routes have been proposed, one direct to minimize costs, and the other slightly longer to provide the potential for water sales to communities to the west in the near-term and for connection to the proposed regional water supply in the long-term. Additional details are provided in Appendix C and Chapter 5.

Chapter 1

Introduction

The City of Bloomington's Water Department (City) must address both short-term issues related to surface-water quality deterioration and interim-term needs for additional sources of supply. The City is working to alleviate two areas of concern: high nitrate levels in Lake Bloomington, and finding new sources of water to support population growth in the City. The primary objective of this project is to design an interim water supply plan that takes into consideration available supplies, water quality, conservation, and management options.

1.1 Background

The City of Bloomington, Illinois relies on Evergreen Lake and Lake Bloomington for their community drinking water supply. Together these two reservoirs have an estimated capacity of $22,900acre-feet$. The raw water from these two lakes are treated at the Lake Bloomington Water Treatment Plant and then delivered to customers in Bloomington, Towanda, Hudson, and Bloomington Township. Together, at an average water use of $11.5\,million\,gallons\,per\,day\,(mgd)$, these two lakes could theoretically supply the City's customers with 1-2 years of drinking water.

The City has had significant problems through the years with nitrates. Historically, nitrate levels in Lake Bloomington have exceeded the EPA health standard of $10\,mg/l$ almost every spring for as long as records have been kept. The majority of the watershed area for both Evergreen Lake and Lake Bloomington is used for agriculture. Runoff and erosion from the agricultural catchments must be monitored and managed to protect drinking water quality and avoid accelerated siltation in the reservoirs. Evergreen Lake typically has lower levels of nitrates and by pumping water from Evergreen Lake when nitrate concentrations in Lake Bloomington exceed the EPA limit, the City has kept nitrate levels under the maximum contaminant level since 1992. However, this solution has limits and the water supply is vulnerable during periods of drought. The two reservoirs also lose a fraction of their volume every year to siltation. As storage slowly shrinks and water quality inches up to a regulatory limit, the City continues to develop and grow. To ensure an adequate water supply for the future the City also needs to identify new sources of water.

Over the past several decades the City of Bloomington has been consistently working to maintain water quality in the reservoirs and ensure a sufficient water supply for the community. In 1991, the spillway of Evergreen Lake was raised five (5) feet to increase capacity and reduce drought risk. The Mackinaw River pumping pool was built to allow selective withdrawals from the Mackinaw River when lake levels drop too low. The City has installed aeration equipment in both lakes to improve water quality, and is currently working on bank stabilization of Evergreen Lake and tributaries feeding both lakes to minimize sediment loading. The City is continuously working with local and state agencies to improve water quality through better watershed management.

However, the 1988 and 2005 droughts illustrated that surface water reservoirs in this part of the State are vulnerable. Public water-supply systems that rely on surface water as their sole source of supply need to have storage far beyond their average needs in order to be resilient to prolonged drought.

In addition to drought, the City of Bloomington continues to grow. A larger community means increased average and peak demands.The agricultural land use and soil characteristics in Central Illinois give reservoirs a limited life span. While demands are increaseing, storage is slowly decreaseing. Calculations and measurements confirm that both Lake Bloomington and Evergreen Lake have high sedimentation rates. While watershed management is wokring to reduce sediment erosion rates and raising the Evergreen Lake spillway has increased supply, a more integrated assessment of options needs to be conducted.

If drought and growth coincide, the Bloomington water supply will likely be stressed and water-quality problems may become more prevalent. The City has recognized the need to incrementally increase supply and begin the process of managing demand so that the utility is able to provide sustainable and safe drinking water. Although managing both supply and demand is complex, the City has embarked on addressing both sides of the issue and recommendations are described to build each into water supply planning.

1.2 Study purpose

This study is designed to determine the most effective way to meet anticipated future drinking water demands. Wittman Hydro Planning Associates (WHPA) drilled deep and shallow exploratory wells in local aquifers, collected data on water use and current demands, conducted aquifer tests to determine the yield of local groundwater systems, modeled current yield for the two water supply reservoirs, developed a proposed drought/conservation ordinance, and initiated the first steps of a water utility conservation plan. This data was used to consider the different options to optimize water quality and quantity.

1.3 Organization

The study breaks naturally into three different components: surface water yields; groundwater yields; and management options for water quality and quantity. Each of these components required different approaches and integration of the results into a practical water supply plan.

The amount of water that can be reliably provided by Lake Bloomington, Evergreen Lake, and the Mackinaw River pumping pool depends upon the volume of the lakes, local streamflow, climate, drinking water demand, and operational rules governing withdrawals. We analyzed previous studies and data and applied a water balance-model to determine the safe yield of the City of Bloomington's water supply. This model provides results that represent the worst-case scenario based upon historical drought records (Chapter 3 and Appendix A).

WHPA explored the local aquifers around and between the lakes and several areas to the south of the City (Figure 1.1). WHPA first evaluated the potential for groundwater availability through review of existing reports and well logs. In the lakes area, WHPA confined exploration to drilling test holes only on public property. These borings showed that there was a thin aquifer at depth and exploration of the lakes area was discontinued. In the south after the data review was complete, test borings around Downs and an aquifer test was completed on a golf course supply well on the southwest side of town. Neither area looked promising. Test borings near Sugar Creek showed a high permeability sand and gravel aquifer that was more than $50\,ft$ thick. An aquifer test was done that showed good results and a likely source of $3-5\,mgd$ supply. Using this new data, WHPA developed a transient MODFLOW groundwater model and predicted wellfield yields and developed several conceptual wellfield designs (Chapter 5 and Appendix C).

To evaluate different infrastructue and management options for increasing water quality and quantity, WHPA modeled the performance of current and proposed approaches to managing nitrates and estimated relative risks of exceeding capacity during periods of elevated nitrates (Section 4, Section 6, and Appendix B). We also developed a Conservation Plan (Section 5.6) and Drought Response Plan (Section 5.7).

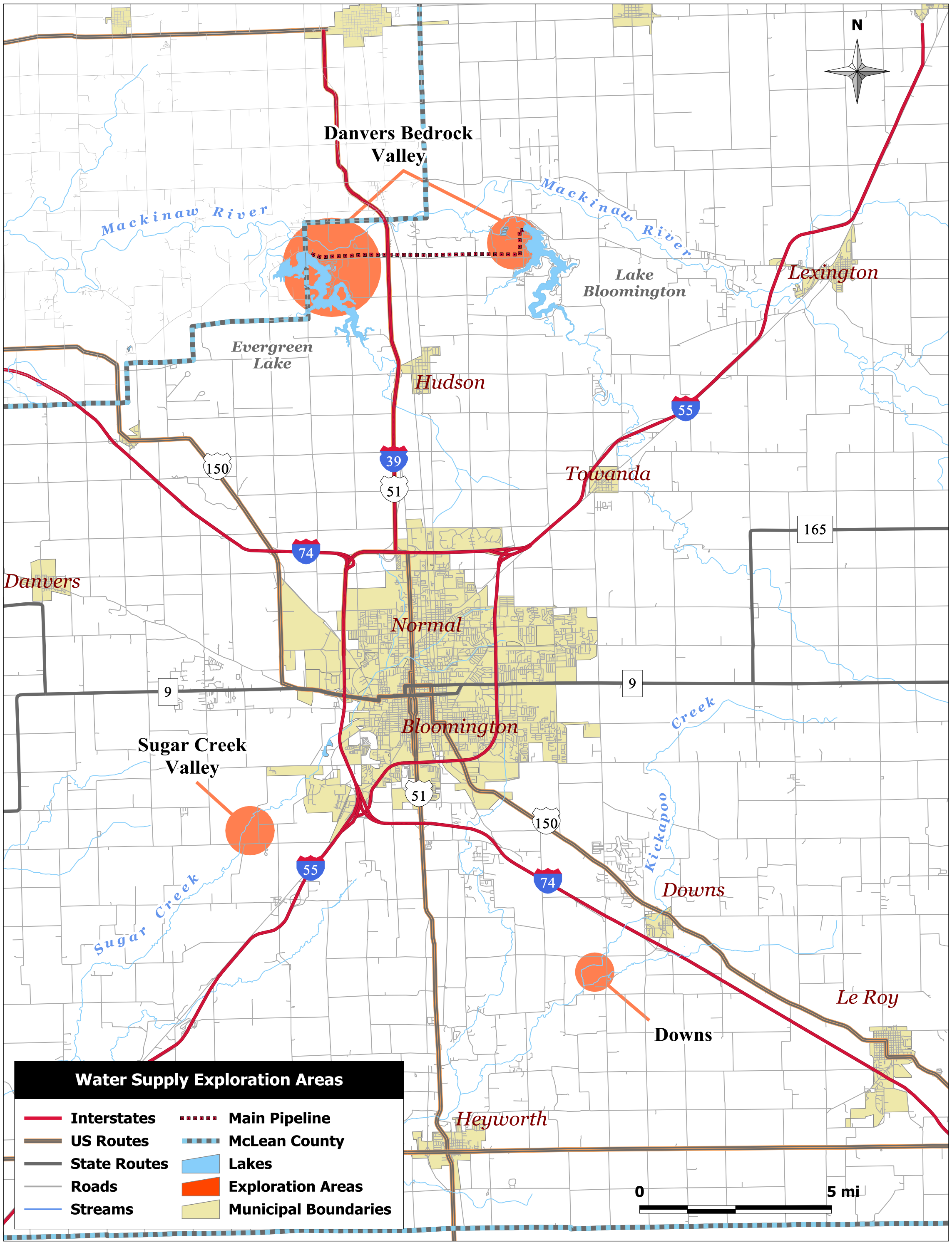


Figure 1.1: Groundwater availability study areas explored for the City of Bloomington's Water Department.

Chapter 2

Demands

To conservatively plan for needed water supply and infrastructure, the current water demands (including trends) of a utility must be understood. Historical demands are first analyzed and modeled so that future demands can be projected. Projected demands are then used as criteria to evaluate the adequacy of the supply and evaluate water supply alternatives. The City of Bloomington (City) must consider many factors as they plan for the future of their water supply. Demand projections are central to answering some of these questions.

1. Does the City have adequate supplies to maintain reliable water service during extended periods of drought?
2. Does the City have adequate supply and treatment capacity to meet projected maximum day demands?
3. Can the supply and treatment infrastructure meet projected demands when stressed by elevated levels of nitrates?

Demand projections are used in different ways to answer these questions when evaluating the performance of current systems and proposed alternatives.

2.1 Historical demands

High service pumping data from 1980 to 2008 were reviewed to track water use. The average day pumping increased from $7.7\ to\ 12.1 mgd$ over these 29 years (Figure 2.1). Maximum day pumping ranged from $10.4\ to\ 21.6 mgd$ and varied due to both weather and the overall increase in demands. Within these 29 years, you can see year-to-year fluctuations in demand, which are due mostly to the normal variation in the weather of the Midwest. The drought of 1988-1989 is apparent in both the average and maximum day demands. The increase in historical demands are driven by population growth and economic factors [Dzielgielewski et al., 2005].

2.2 Projected demands

We used a simple and common approach to projecting demands that was generally conservative while make use of the historical trends to estimate future demands. This method of demand projections is appropriate when detailed billing, demographic, and economic development data are not currently available. Projections made using this method can not take into account recent changes in water use efficiency by different customer classes; population growth or economic and social changes that differ from past trends; or improvements in the water utility's efficiency of supplying

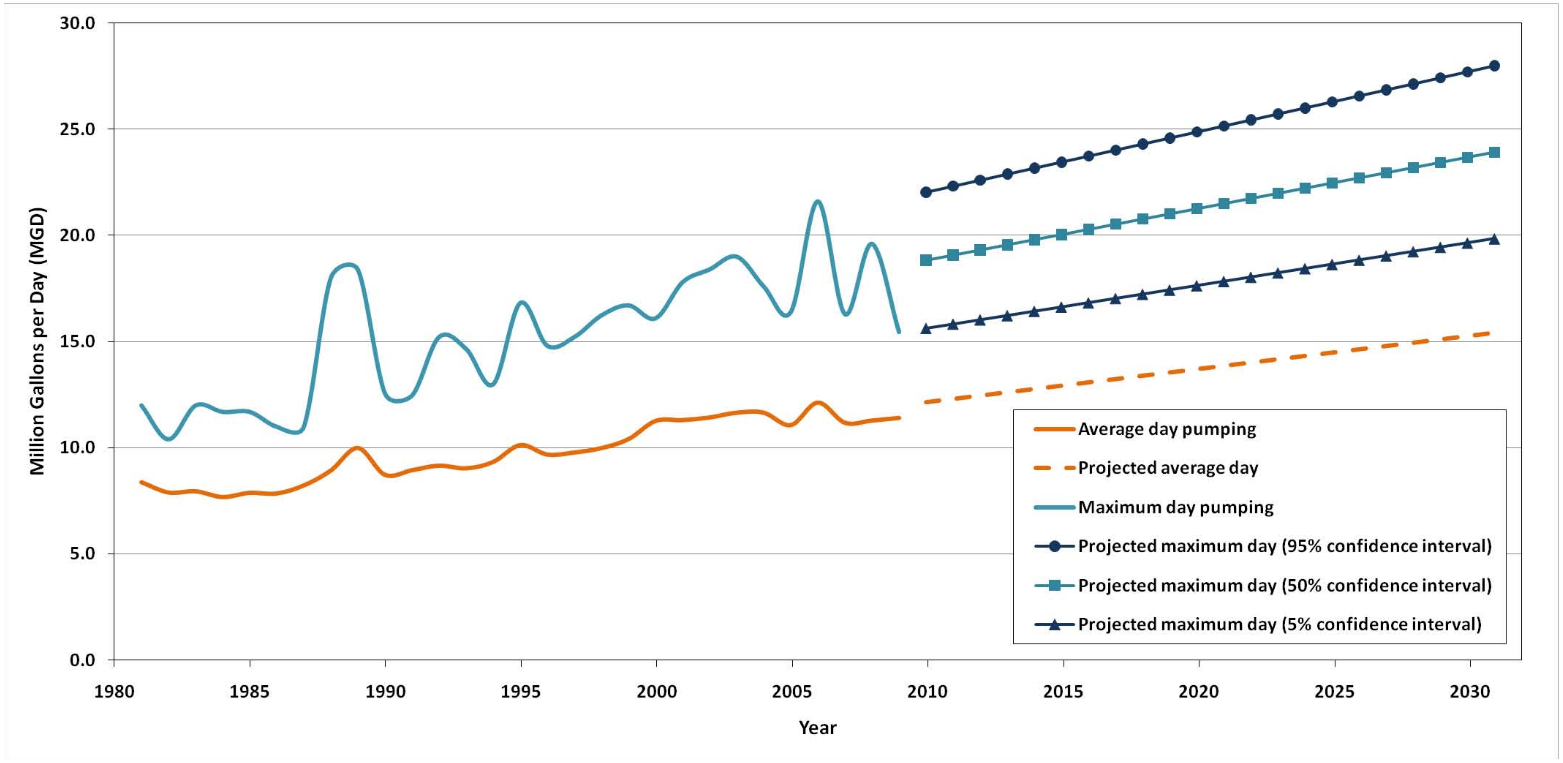


Figure 2.1: Historical and projected average-day and maximum-day demands.

water. This approach to demand projections provides an estimate of what infrastructure will be required in the future. The actual demands are expected to be lower or higher than the projected demands because of the combined effects of climate and economic growth. Additionally, the water utility may implement demand management efforts that promote efficiency and result in water use that is lower than projected.

2.2.1 Projected average-day demands

Historical annual average-day demands were linearly regressed against time, producing a trendline that approximates the steady increase in average demands over time. The equation of this line was then used to project future average-day demands for each year from 2010 to 2030. This method of projecting future average demands assumes that the incremental annual growth in the historical average demand data will continue in the future. The regression equation derived for Bloomington's average-day demands is:

$$y = (0.000427 * x) - 5.023 \tag{2.1}$$

Where:

$y = average - day\ demands, in\ mgd$; and

$x = time, in Julian\ days\ and\ here\ was\ set\ to\ 12/31\ of\ each\ year$

We found that there was a $0.156\ mgd$ increase in average-day demands per year in the historical data set. Average day demands increase to a total of$13.8\ mgd$ in 2020 and $15.4\ mgd$ in 2030 (Figure 2.1).

2.2.2 Projected maximum-day demands

In contrast to average demands, maximum demands show significant variability from year to year and can not be accurately projected with simple regression. Maximum-day demands are largely dependent on temperature and the amount and timing of precipitation. For any community, the ratio of maximum demand to average demand tends to fall within a community-specific range, which allows the use of historical data to predict the range of possible future maximum demands. The range of ratios reflects the make up of the community's customer base: a consistent base of industrial use tends to result in lower ratios, while significant single-family residential use tends to result in higher ratios. Within the range of ratios for a particular community, cool and wet years will typically fall at the low end of the range, and hot and dry years toward the upper end.

To project maximum-day demands for Bloomington we first calculated the historical ratios of maximum-day demands to average-day demands for each year from 1980-2008. Since maximum-day demands are largely dependent on weather, a range of maximum-day demands were calculated. The range of maximum-day demands was calculated statistically by assuming constant growth and bounding that projection by determining the 5 and 95 percent confidence intervals for the maximum-day to average-day ratios. There is a 90 percent likelihood that for any given year the projected maximum-day demands will fall within this range. The projected 5 and 95 percent confidence intervals for the maximum-day to average-day ratios were calculated by the following equation:

$$CI = x \pm (Z * \sigma) \tag{2.2}$$

Where:

CI = 5 or 95 percent confidence interval; the $+$ is used when calculating the 95 percent CI and $-$ is used when calculating the 5 percent confidence interval;

x = the mean of the historical maximum-day to average-day demand ratio;

Z = the standard normal (Z) random variable for the 0.95 probability; and

σ= the standard deviation of the historical data set.

To estimate the projected maximum-day demands at these confidence intervals the maximum-day to average-day ratios at each confidence interval were then multiplied by the projected average-day demands. The 50 percent confidence interval was calculated as the mean of the historical maximum-day to average-day demand ratio. As shown in Figure 2.1, 90 percent of the maximum-day demands will fall between the 5 and 95 percent confidence interval lines. This model predicts that by 2030 there is a 90 percent likelihood that the maximum-day demands will fall between 20 *and* 28 *mgd* if the historical trends in average demands continue into the future.

2.3 Using demands to evaluate alternatives

The main purpose of projecting demands is to evaluate alternative water supply options. Each option that was explored during this study was assessed to determine if in conditions of drought and maximum demand, water-quality standards can be reliably met even during periods of poor source water quality. The projected average-day demands are used when evaluating whether the current and potential supplies can meet demands during drought conditions. Alternatives for total supply and treatment capacity are evaluated using the 95 percent maximum-day demands. Additional criteria were considered in developing recommendations, but meeting demands was the essential, first criteria. Options for meeting demands during high-nitrate events are evaluated against both average and 50% maximum day demands. The evaluation of the performance of water supply alternatives with respect to demands is described in Chapters 5 and 6.

Chapter 3

Safe Yield

Water is currently supplied to the City's water treatment plant from Lake Bloomington, Evergreen Lake, and under certain circumstances the Mackinaw River. For planning purposes, the safe yield of water supplies must be adequate to meet demands during a period of extended drought. The safe yield of the water supply was determined by modeling conditions experienced during the extreme drought of record which occurred from 1939 to 1941. A cost-effective, holistic approach to drought planning includes preparation on the supply and demand sides of the system. With an integrated approach to managing supply and demand during periods of extended drought, projected average demands are used as the standard criteria for minimum adequacy of safe yield of supplies. Implicit in this criteria is the understanding that drought planning include ordinances and other legal preparations to facilitate the implementation of demand-side measures to control excessive and wasteful water use during periods of scarcity.

3.1 Safe yield of existing supplies

Modeling determined that the safe yields of Lake Bloomington and Evergreen Lake in the year 2008 were 5.2 *mgd* and 8.6 *mgd*, respectively, based on the 1939-41 drought. Safe yields for the year 2028 are projected to be 4.9 *mgd* and 7.8 *mgd*, respectively. The decline in yield over time is caused by sedimentation and the gradual reduction of storage volume in the reservoirs. The Mackinaw River pumping pool, which is used to replenish Evergreen Lake under limited conditions, effectively increases the safe yield of Evergreen Lake. The pumping pool is not available 100% of the time. If water levels in the Mackinaw River are too low, insufficient water enters the pumping pool to allow uninterrupted operation of the pumps. Based on conservations with utility personnel, it was estimated that the average capacity of the pumping pool is 25% of what it would be if pumping could continue uninterrupted anytime lake levels were low enough to permit its usage [Rick Twait, personal communication]. Based on modeling with data from the 1963-64 drought, this contribution to theoretical yield was estimated to be 1.2 *mgd* in 2008 and is projected to be 1.1 *mgd* in 2028. Data for the Mackinaw River are not available for the period including the 1939-41 drought. We assumed that the contribution of the Mackinaw River pumping pool to the safe yield of Lake Evergreen under 1939-41 drought conditions would be equal to 80% of that modeled using 1963-64 drought conditions. With this contribution, the adjusted safe yield for Lake Evergreen was 9.6 *mgd* in 2008 and 8.7 *mgd* in 2028. Safe yields for 2008 and 2028 are summarized in Table 3.1, and are discussed in greater detail in Appendix A. Figure 3.1 shows the projected average and maximum demands of the system and the modeled safe yield of the current water supply. To maintain adequate safe yield, additional supplies must be developed. The Figure 3.1 shows that the projected safe yield of existing supplies will be exceeded by average demands soon after 2020.

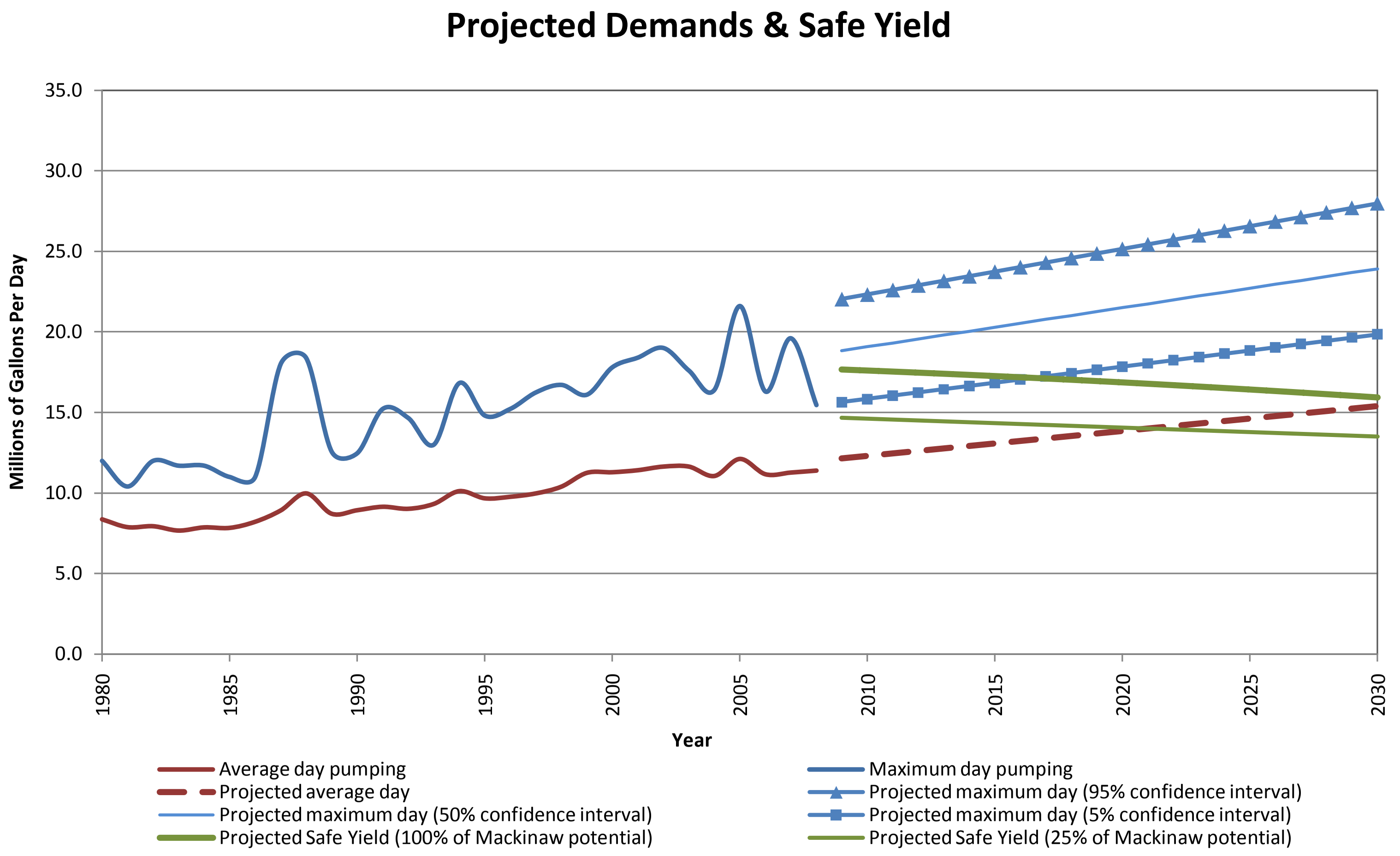


Figure 3.1: Projected demands and safe yield.

Table 3.1: Safe yields.

Year	Lake Bloomington *mgd*	Lake Evergreen *mgd*	Lake Evergreen with Mackinaw Pumping Pool *mgd*	Total *mgd*
2008	5.2	8.6	9.6	14.8
2028	4.9	7.8	8.7	13.6

mgd=million gallons per day

3.2 Options that increase safe yield

Of the water-supply planning options that have been investigated to increase total supply and treatment capacity or to manage elevated nitrate concentrations, several would result in an increase in the safe yield of water supply available to the City during periods of extended drought. Other management strategies are oriented toward improving the efficiency of use, which will eventually reduce growth in average demands, and as a result reduce the required safe yield in the planning horizon. We considered a range of potential supplies that would also increase the safe yield of the water supply, including:

- Wells in the Danvers Valley between Lake Bloomington and Lake Evergreen, with a capacity of $1-2 mgd$.
- Improvements to the Mackinaw River pumping pool and permit modifications to allow greater utilization
- A wellfield and treatment facility near Sugar Creek, southwest of the City, with a capacity of $3-5 mgd$.

The analysis of alternatives in Chapter 6 evaluates all options, including the addition of new supplementary sources of supply.

Chapter 4

Nitrates

The quality of water in the streams that flow into Lake Bloomington and Evergreen Lake is highly dependent on the activities on the land in their drainage basins. The watersheds of these reservoirs cover large areas of agricultural land. Fertilizers applied to cropland enters the streams and reservoirs in runoff. Nitrates from the fertilizer present a serious challenge to the water treatment plant operators. The level of nitrates in drinking water is regulated by the USEPA to a maximum contaminant level (MCL) of $10\,mg/l$. Nitrate levels in both reservoirs have exceeded this level in the past. To date, nitrate levels in the water supply have been managed by blending the supplies from both reservoirs to maintain levels below the regulatory limit.

Nutrients create other treatment challenges as well. Algal blooms, which are fed by nutrients in runoff, can create difficult taste and odor problems. There have been instances when elevated nitrates and taste and odor issues were present in different reservoirs, limiting the flexibility of treatment plant operators to blend supplies.a

Because nitrates present the most critical water quality issue and have a defined regulatory limit, they are used in this study as the basis for evaluating the water quality performance among alternatives.

4.1 Analysis of historical data

The City of Bloomington Water Department has a significant amount of historical water quality data from both reservoirs, the Mackinaw River and the streams that flow into the reservoirs. In general, nitrate levels fluctuate seasonally, but they are dependent on many factors. It is not possible to use historical data to predict with certainty the levels of nitrates that will be encountered by water treatment plant operators at any given time. It is possible, however, to assess the relative general performance of different configurations of supply and treatment under a range of conditions that historical data indicate are likely. Based on that assessment, alternatives may be compared, costs and risks considered, and a configuration selected that provides water treatment plant operators with the necessary tools to reliably produce an adequate quantity and quality of water under varying conditions.

For the Water Supply Plan, historical nitrate data was used in the following ways:

- Analysis of average monthly nitrate levels in both reservoirs
    - The relationship of average monthly nitrate levels in Lake Bloomington to Evergreen Lake was used to develop a practical model to evaluate general performance of different supply and treatment alternatives
    - The frequency of monthly average nitrate levels in Lake Bloomington was analyzed to determine reasonable criteria for assessing the general performance of supply and treatment alternatives

- Analysis of historical nitrate events in which levels in Lake Bloomington exceeded the regulatory limit of $10 mg/l$
  - The speed of onset of events was analyzed for the purpose of determining the time available for the implementation of actions to address high nitrates.
  - The duration of events was analyzed for purposes of estimating equipment utilization and operating costs

The analysis of nitrate data is discussed in greater detail in Appendix A.

4.1.1 Nitrate data record

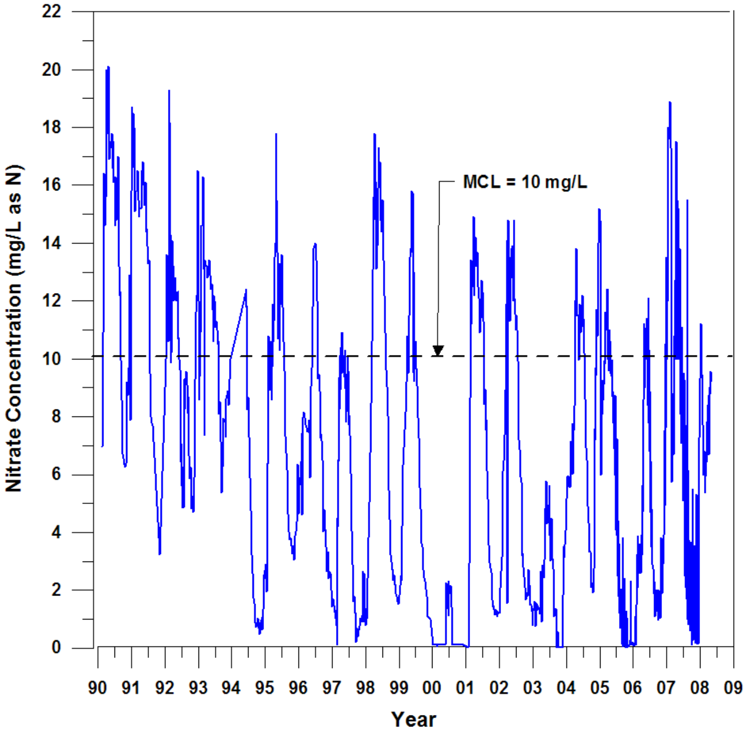
As shown in Figure 4.1, nitrate concentrations in Lake Bloomington and Evergreen Lake fluctuate seasonally. Nitrate concentrations in Lake Bloomington have exceeded the MCL frequently the past several years. Nitrate levels in Evergreen Lake have also exceeded the MCL, though less frequently. The concentrations of nitrate in Evergreen Lake are generally lower than those in Lake Bloomington, which allows water treatment operators to manage nitrate levels by blending the two supplies. Though historical nitrate levels in Evergreen Lake have been lower most of the time, there have been exceptions. While the general relationship between the two reservoirs is fairly consistent, the nitrate concentrations in both lakes reflect the activities in each watershed. This means that quality of water in one can not be reliably used to accurately predict the other.

The data available for the analysis included the following:

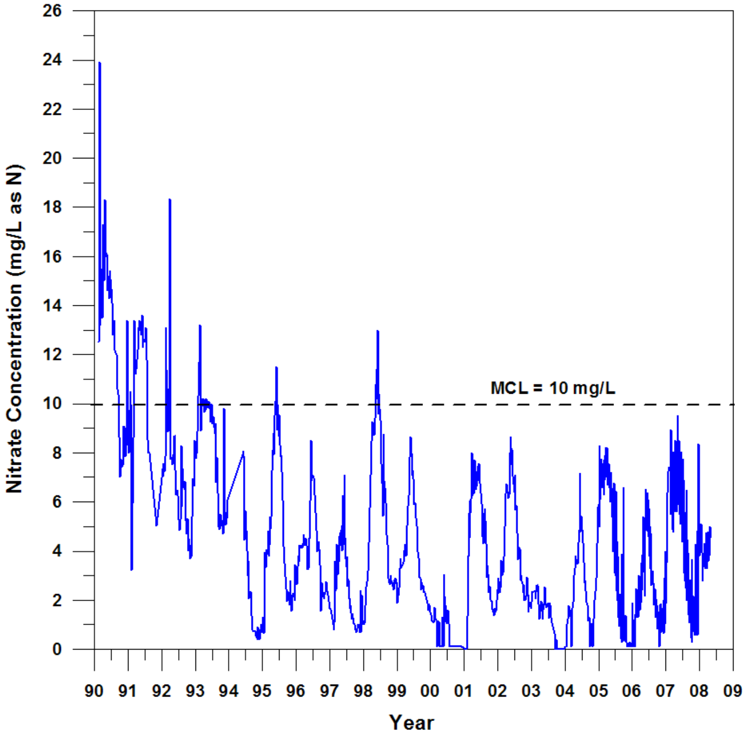
- Nitrate concentrations in Lake Bloomington and Evergreen Lake from 1983 to 2009, consisting typically of several values per month.
- Nitrate concentrations in the Mackinaw River pumping pool, consisting of sporadic data collected during utilization of the pumping pool
- Nitrate concentrations in finished water from 1983 to 2009, consisting of data for most days.

4.1.2 Analysis of historical monthly average nitrate concentrations

Historical nitrate data was analyzed to establish criteria and determine performance of supply and treatment alternatives. Monthly average nitrate concentrations were calculated for Lake Bloomington and Evergreen Lake for all months with available data. The relationship of the monthly average nitrate concentrations for both lakes was analyzed, and a frequency distribution was developed for the ratio of average monthly nitrates in Evergreen Lake to average monthly nitrates in



a. Lake Bloomington



b. Evergreen Lake

Figure 4.1: Historical nitrate levels in Lake Bloomington and Evergreen Lake.

Lake Bloomington. The frequencies with which historical average monthly nitrate concentrations in Lake Bloomington exceeded a range of levels were calculated.

The results of our analysis showed:

- The mean ratio of monthly average nitrate concentrations in Evergreen Lake to those in Lake Bloomington is 0.762, with a standard deviation of 0.300
- The mean ratio was used to develop a mass-balance model to evaluate and compare the idealized performance of different supply and treatment alternatives. This was done for a range of monthly average nitrate concentrations in Lake Bloomington.
- The performance of selected supply and treatment alternatives were then evaluated under a wider range of possible conditions by means of sensitivity analysis to the nitrate ratio
- Frequency curves indicating the percentage of months in which average monthly nitrate levels are exceeded defined the relative risk and performance of different supply and treatment alternatives. Separate curves were developed for all months, and for the peak months (4.4).

4.1.3 Analysis of historical elevated-nitrate events

The previous section described variation in average monthly nitrate concentrations. This allows us to better anticipate regular seasonal changes through the year. It is not uncommon, however for nitrate concentrations to spike rapidly in a few days. Since 1990, there have been 18 events in which nitrate concentrations in Lake Bloomington exceeded the MCL of $10 mg/l$ for some period of time. A typical event for the year 2001 is shown in Figure 4.2.

Differences between these events provide insight into the range of durations and timing of elevated nitrates. The duration of events and average nitrate levels during events provide the basis for estimating operating costs of different approaches to providing safe drinking water. The “shapes” of events vary considerably in terms of the slope or speed of onset, duration, and maximum nitrate levels. Graphs of all of the elevated-nitrate events are presented and discussed in Appendix A.

The speed of onset of nitrate events determines the amount of time that water treatment plant operators have to react to increasing nitrate levels. Recommended supply and treatment alternatives are thus structured to ensure that nitrate management strategies are operationally practical. For each event, the date was identified in which nitrate concentrations in Lake Bloomington exceeded the MCL of 10 mg/l. During the period in which nitrate concentrations were increasing, the dates on which concentrations reached $4 mg/l$, $6 mg/l$ and $10 mg/l$ were also identified. For each event, the number of days between these thresholds and the date on which nitrate concentrations exceeded

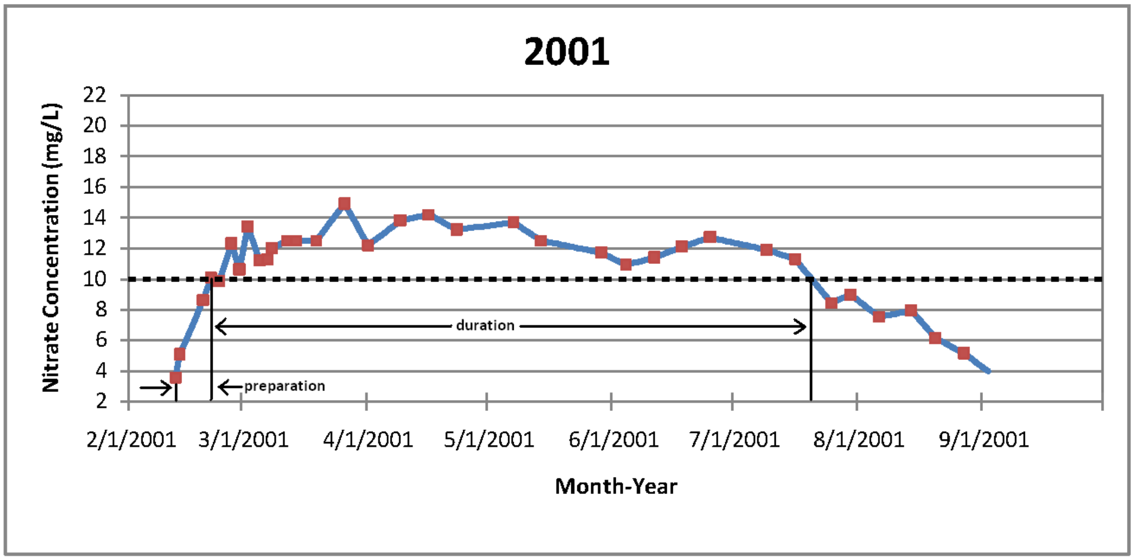


Figure 4.2: Typical elevated nitrate concentration event, Lake Bloomington 2001

$10mg/l$ were calculated. Figure 4.3 shows that the length of time for nitrate concentrations to increase from each threshold to the MCL of 10 mg/l varies significantly. Most frequently, nitrate concentrations take 1-2 weeks to increase from 8 to $10mg/l$, 1-2 weeks to increase from 6 to $10mg/l$, and 3-4 weeks to increase from 4 to $10mg/l$. While some historical nitrate events have afforded water treatment plant operators time to prepare, the data indicates that circumstances can change and decisions need to be made quickly. Recommendations for supply and treatment infrastructure are designed to implement nitrate management strategies quickly to comply with federal and state water quality regulations.

4.2 Use of nitrate data for evaluating alternatives

The purpose of planning is to inform decision-making by determining the infrastructure components the utility must have to provide reliable, safe water to its customers. It relies on historical

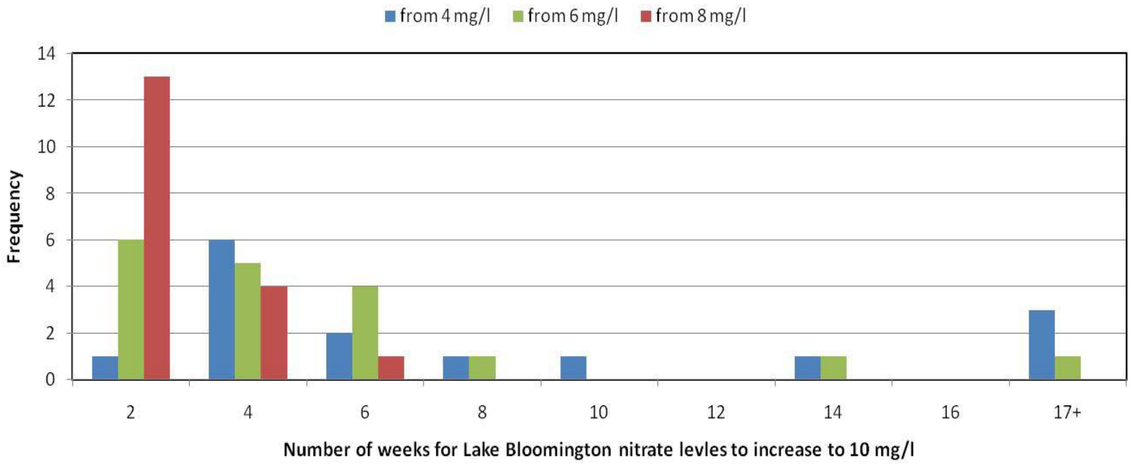


Figure 4.3: Frequency of the number of weeks for nitrate concentrations in Lake Bloomington to increase from multiple threshold nitrate concentrations to the MCL of $10\,mg/l$. *Note: 70% of the nitrate events occurred less than one month after surpassing* $4\,mg/l$ *nitrate concentration.*

data, and does not anticipate all possible scenarios that may be encountered by treatment plant operators. Planning can however, anticipate the range of conditions that will be encountered in all but extreme circumstances. The evaluation of supply and treatment alternatives will identify the improvements needed to provide water treatment plant operators with the tools that they need to manage the production of safe drinking water under a range of conditions.

Two models were developed to evaluate the nitrate-management performance of different supply and treatment alternatives. Both models are based on a mass balance of nitrates, and are used to determine the nitrate concentration level in waters blended from different sources and treatment processes. At lower concentrations of nitrates the source and treatment capacity is constant and equal to the rated capacity of those facilities. When nitrate concentrations in the source water reach levels that would otherwise result in finished water nitrate concentrations greater than the target, the capacity is reduced to maintain the target nitrate concentration.

Two points are critical for the evaluation of nitrate-management performance. First, the nitrate concentration at which capacity is reduced to average demand is determined. This point is critical throughout the year. Managing demands to this level would likely require significant mandatory water use restrictions, particularly during periods of higher demands. In Figure 4.4, the curve shows the percentage of all months in which a range of average monthly nitrate concentrations in Lake Bloomington are exceeded.

Second, the nitrate concentration at which capacity is reduced to maximum demand (50%) is determined. This point is critical only during periods of high demands; in seasons with lower demands

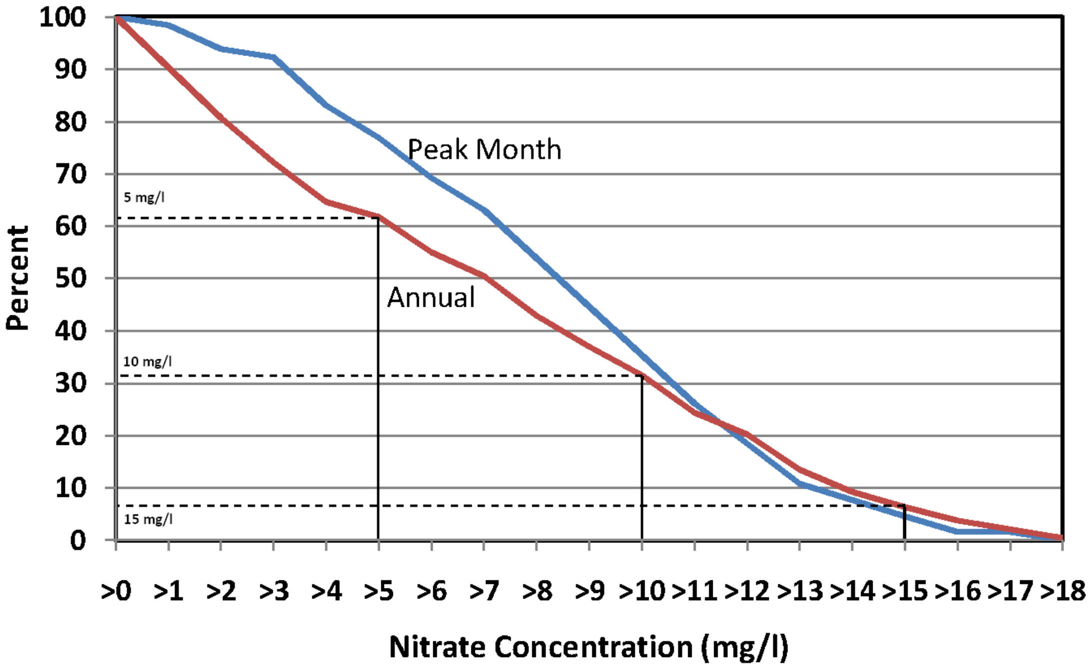


Figure 4.4: Percent of all and peak (June, July, August) months in which average nitrate concentrations in Lake Bloomington were exceeded.

the reduction of supply and treatment capacity to this level would be less critical. Managing demands to this level through voluntary or mandatory temporary water use reductions would be practical. Figure 4.4 shows the percentage of peak demand months (June, July and August) in which different average monthly nitrate concentrations in Lake Bloomington are exceeded.

All supply and treatment alternatives are evaluated in the same manner, which allows different combinations of supply and treatment infrastructure to be compared in terms of the relative risk of exceeding capacity and evaluated against utility criteria for acceptable levels of risk.

4.3 Nitrate management options

One approach to managing elevated nitrate events (assuming that watershed best practices are in place) is to find a source of low-nitrate water to add to the raw water delivered to the treatment plant. This might be a deep groundwater source that could support the use of marginally high nitrates in the two reservoirs. Another approach would be to directly use a new (hopefully low nitrate) groundwater supply to reduce demands on Lake Bloomington and Evergreen Lake, providing more room to balance the mix from the two reservoirs. In addition to the capacity directly added by the new groundwater supply, the flexibility that it provides effectively adds capacity at the main plant as well. Finally, ion-exchange treatment can be used to remove nitrates during periods when additional groundwater supplies alone are insufficient.

In subsequent sections of this report we outline how a combination of these approaches could be used to extend and expand Bloomington's treatment capacity. Each could play a role in moving the utility toward a reliable, long-term water supply.

Chapter 5

Water Supply Planning Options

This project identified supply, treatment, conservation, and drought preparedness and local ordinances that could together provide options for the Utility. Our local groundwater investigations focused on either adding low nitrate water at the treatment plant or providing an alternate groundwater supply. Our analysis of surface waters independently evaluated the reservoir yields and specifically considered the sue and value of using the Mackinaw Pumping Pool. Treatment options included small ($2\,mgd$) ion exchange (IX) systems to reduce nitrate loads in raw water. Conservation planning, at a very general level, was done to help the City see what it needs to do to manage water use and reduce water loss. An ordinance is proposed that would give the utility the regulatory support need to manage demands during prolonged shortages.

The purpose of the planning process is to identify the path or paths that will step from the present to a future in which these objectives are met in a way that minimizes long-term costs and acceptably manages risk along the way. An option for addressing one objective may provide no benefit with respect to a second, while other options may address multiple objectives. A wide range of options are identified early in the planning process in order to ensure that the most effective long-term strategy is identified.

The many options investigated for the present study provide solutions to the City's water supply challenges in different ways and to different degrees. The general options are identified in Figure 5.1. They address improvements to ensure adequate safe yield in periods of drought, adequate total capacity to meet maximum demands, and the capability to treat and deliver adequate supplies when raw water quality is poor. Water use efficiency, drought planning and watershed management efforts are presented as means of mitigating the demands and stresses on the system. The evaluation of these options individually and in various combinations provides insight into their relative advantages and disadvantages. A brief description of each water-supply planning option follows. Alternatives made up of combinations of these options are described and evaluated in Section 6.

5.1 Danvers Bedrock Valley wells

The use of water supplies with low nitrate concentrations to blend with higher-nitrate sources is an effective means of managing nitrates, and currently utilized by the City. Historically, the nitrate concentrations in Evergreen Lake have been low enough to allow blending with higher-nitrate water from Lake Bloomington to maintain nitrate concentrations below the MCL. If nitrate concentrations are above the MCL in both reservoirs simultaneously, this approach will not be effective.

Groundwater investigations determined that wells could be developed in the lakes area capable of supplying up to $2mgd$ of low-nitrate water in either of two locations. The first is in the Danvers bedrock valley midway between the two lakes, along the route of the existing transmission main. The second is near Evergreen Lake on property owned by the City. Groundwater from either or

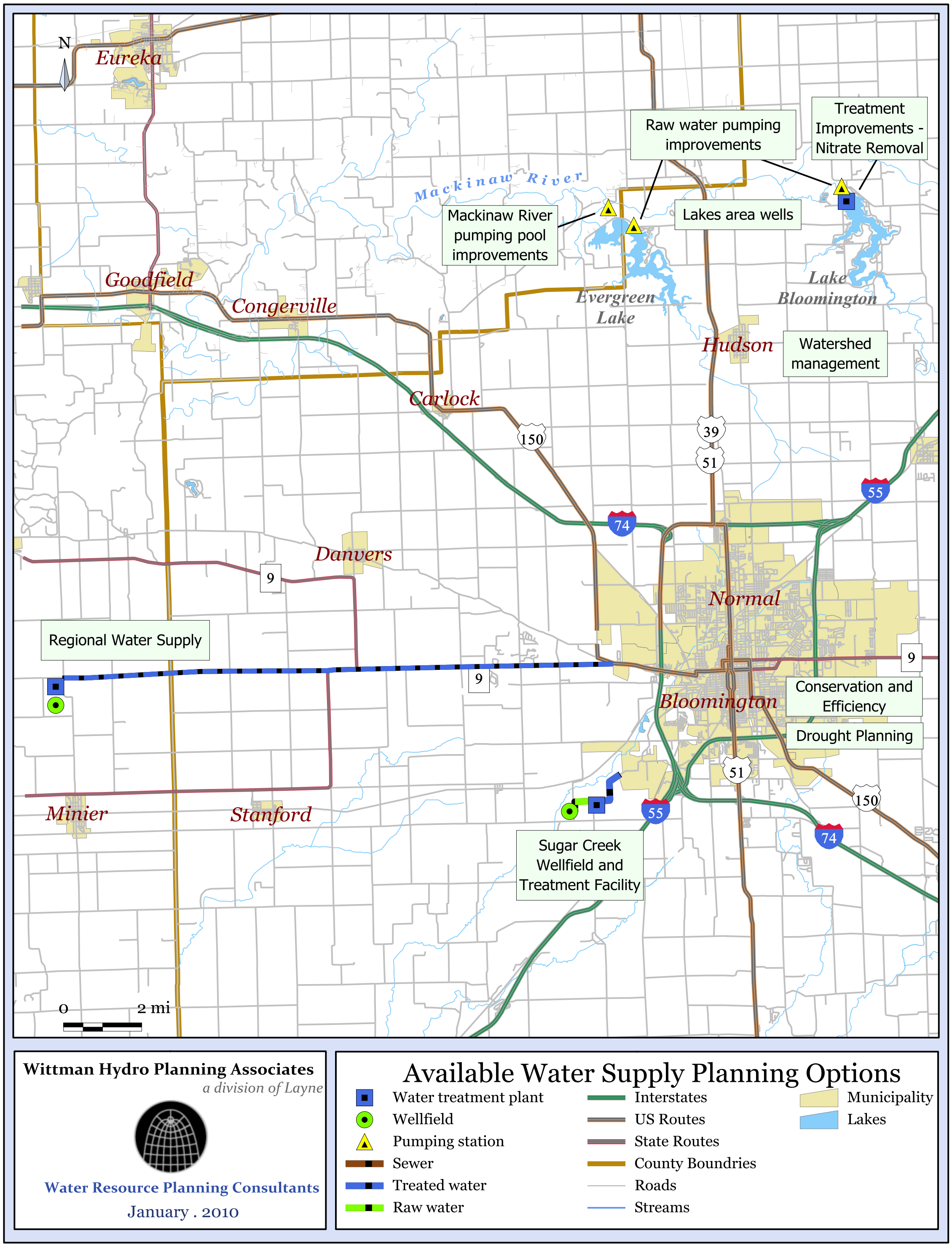


Figure 5.1: Water supply planning options

Table 5.1: Danvers Valley wells - advantages and disadvantages.

Advantages	**Disadvantages**
• Increases the total supply of the system • Increases the safe yield of supply • Cost of operation is comparatively low • When used in conjunction with treatment for nitrate removal, reduces the cost of treatment	• Does not increase the total treatment capacity of the system • Groundwater availability is limited • Acquisition of land required

both location would be pumped directly into the raw water transmission main from Evergreen Lake providing dilution of nitrates in that supply before it reaches the treatment facility. The concept for this option is shown in Figure 5.2.

The capacity of wells in the Danvers Valley is limited to $1\,to\,2\,mgd$ at each location by the relatively thin aquifer and the slow recharge rates into the aquifer. Because this aquifer is not likely to be able to supply more than $2\,mgd$ when the reservoirs have high nitrate concentrations, the effectiveness of nitrate management with this quantity of groundwater for blending is limited. If blending is used in conjunction with treatment to reduce nitrates, this option will help to reduce the loading on nitrate removal treatment processes. Blending wells substitute low-nitrate supplies for high-nitrate supplies, and do not increase total supply capacity. Table 5.1 presents some of the advantages and disadvantages of this water supply option.

5.2 Treatment for nitrate removal

Removal of nitrates by means of ion-exchange (IX) or another treatment process is an effective means of reliably managing finished water nitrates. Removal of nitrates by IX is highly efficient, with typical removal of 90% to 95% of nitrates. Consequently, it is possible to achieve water quality goals by treating only a portion of the filter effluent with IX and re-blending to achieve levels within acceptable limits. Figure 5.3 shows a schematic representation of the existing treatment plant process, plus proposed nitrate removal treatment for a portion of the filter effluent. A portion of the filtered water is diverted to permanent and temporary IX treatment units, and the IX treatment effluent is re-blended with the remaining filter effluent before it enters the clear well. The capacity of IX treatment depends on both the nitrate concentration in the filter effluent and the de-

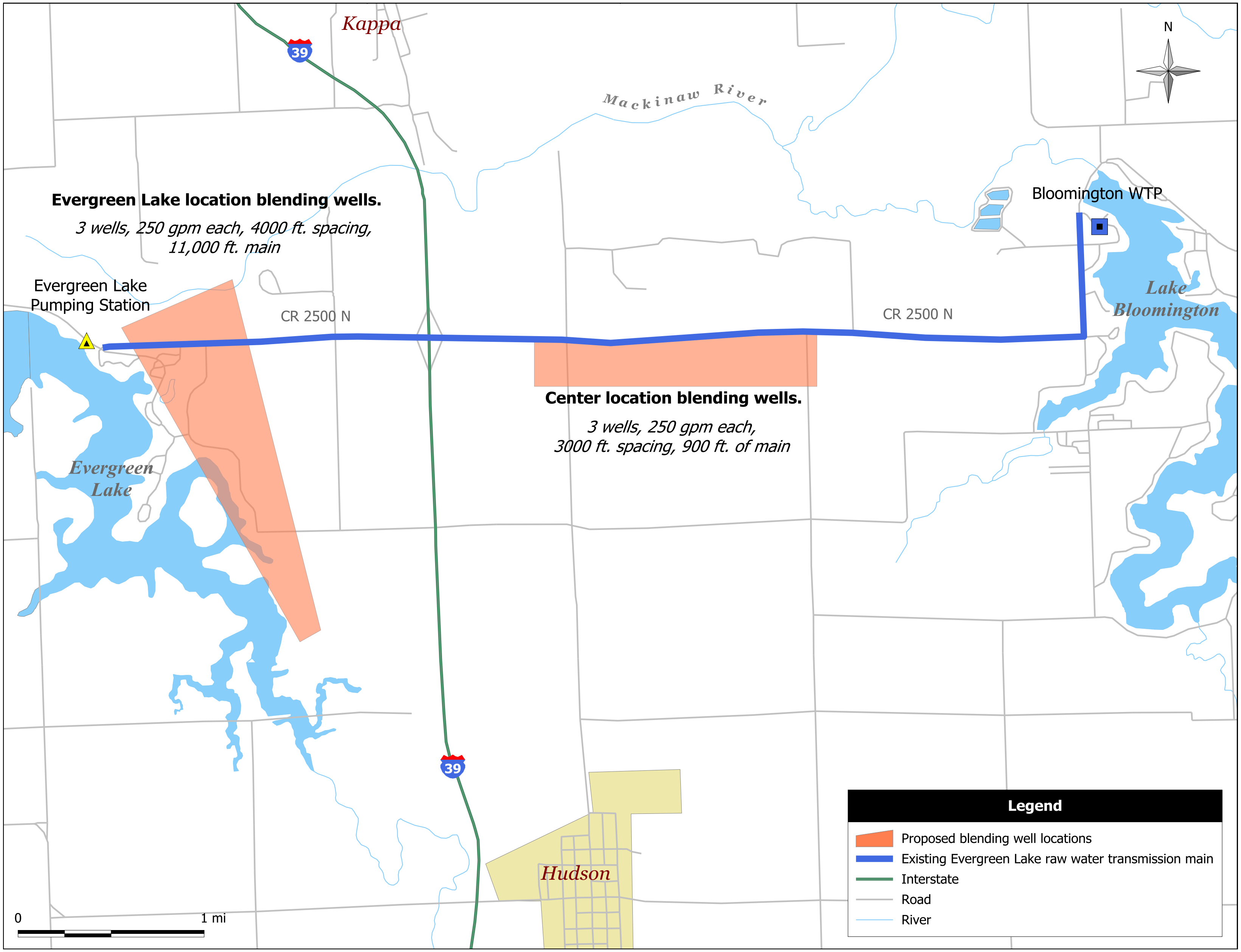


Figure 5.2: Danvers Valley wells for blending.

Table 5.2: Ion exchange treatment system design and operating parameters.

Type of System	**Low Waste Ion Exchange**
Flow (mgd)	4.0
Nitrate concentration (mg/l)	15.0
Size and quantity of vessels	Six 84” diameter vessels
Number of regenerations per day	9
Salt usage per day (lbs)	11,300
Wastewater per day (gallons)	17,000
Wastewater (% of treated flow)	0.57%

mand for water in the system. At higher nitrate concentrations, more IX capacity is required to maintain acceptable finished water quality without limiting overall plant capacity. The City has considered IX treatment for nitrate removal in recent years, but no equipment has been installed [Consoer Townsend Envirodyne Engineers Inc, 2007].

The IX treatment process relies on the use of specially formulated resin media to remove nitrates from the water as it passes through treatment vessels. The resin media must be regenerated periodically with a brine solution, in a manner similar to that of a home water softener. The wastewater produced during the regeneration process contains high levels of nitrates, sodium, and chlorides. The frequency of regeneration and the volume of wastewater produced varies by IX system manufacturer, with some systems designed specifically to minimize the volume of wastewater produced. Disposal of wastewater is a major consideration in the evaluation of the feasibility and cost of any nitrate removal processes. Figure 5.4 shows a conceptual IX process as it could be implemented at the existing water treatment facility. Piping modifications connect the filter effluent line to a set of variable speed pumps which deliver a portion of the flow to the IX treatment units. The pumps control the flow rate to the IX treatment process and raise the pressure to overcome head losses through the resin media. The treated low-nitrate effluent is then returned to mix with the non-IX treated filter effluent prior to entering the clearwell. Salt storage tanks and brine saturator tanks are required for the periodic regeneration of the resin media. Bulk salt is delivered by truck to the treatment plant. For the wastewater produced by regeneration, a tank is required for equalization and storage prior to disposal. Several options exist for disposal, including the use of tanker trucks to deliver wastewater to the Bloomington Normal Water Reclamation District’s Treatment Plant, pumping via force main to the City’s wastewater collection system, or permitted injection into a well completed in a deep formation near the treatment plant. Basic operating parameters for a minimal-wastewater IX system are presented in Table 5.2.

The design capacity of IX treatment increases if either nitrates or demands increase. Different con-

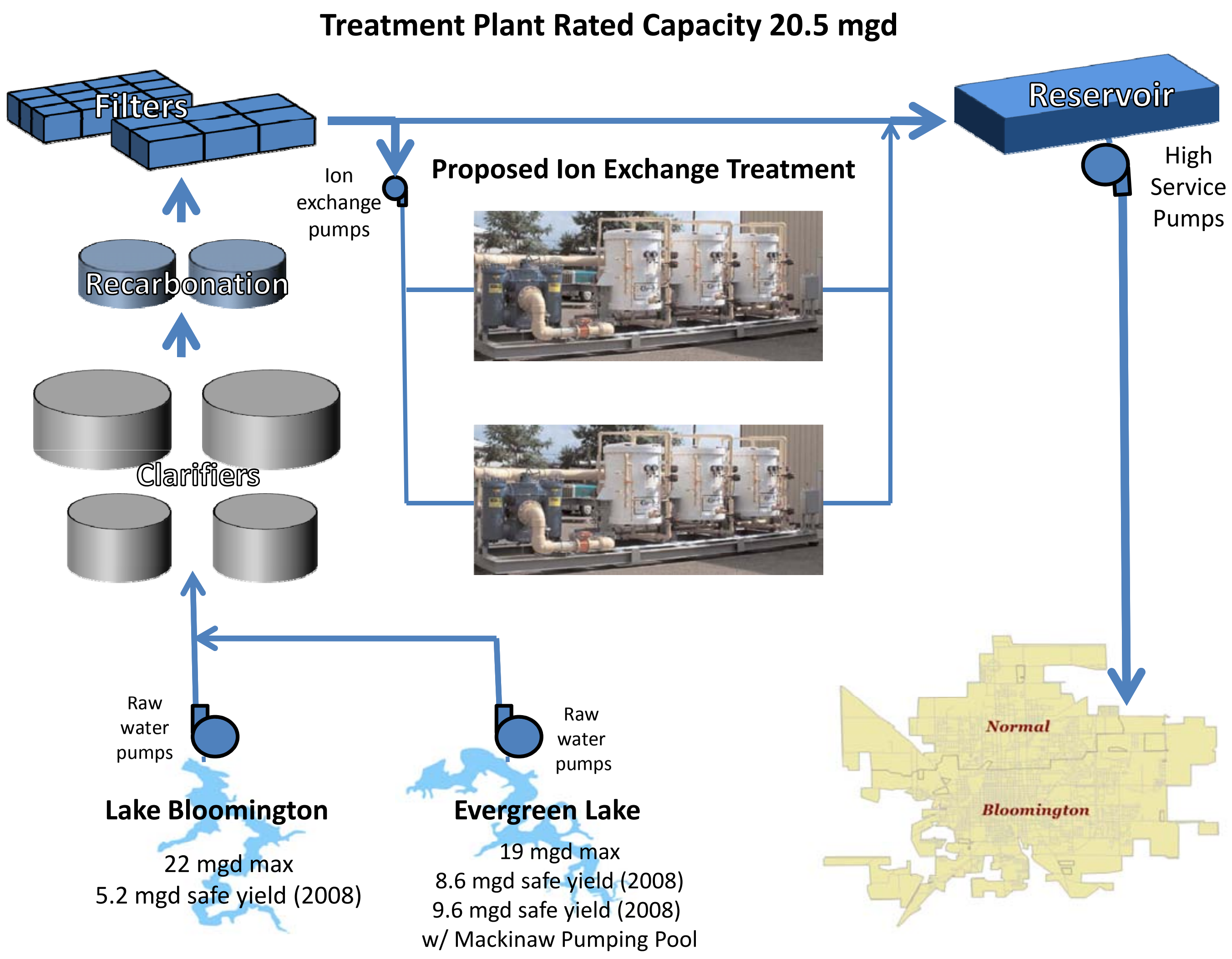


Figure 5.3: Water treatment process.

Table 5.3: Treatment for nitrate removal - advantages and disadvantages.

Advantages	Disadvantages
• Allows greater utilization of existing sources with increased nitrate concentrations • May be configured to allow capacity to be temporarily increased only when needed • Future expansion of permanent capacity straightforward	• High cost of operation for rental of temporary equipment when needed • Wastewater disposal • Does not increase the total supply and treatment capacity of the system • Does not increase safe yield of supply

figurations of permanent and temporary infrastructure may be needed in an effort to minimize the cost of nitrate removal. A base amount of infrastructure is required for any IX system, including piping modifications, salt storage, and wastewater collection. A combination of permanent IX treatment infrastructure, along with the required piping would be necessary to connect temporary treatment units that would be required to manage extraordinary nitrate events. A balance of permanent and less-frequently needed temporary capacity could be the mix needed to reduce costs and maintain flexibility. Table 5.3 presents some of the advantages and disadvantages of this water supply option.

5.3 Raw water pumping improvements

Blending water from the two reservoirs is the first and least cost strategy for managing nitrates. The raw water pumping stations at Lake Bloomington and Evergreen Lake are limited by their ability to pump at a wide range of flow rates. This inhibits the ability of operators to blend water from the two lakes, particularly at lower flow rates. The flexibility to adjust pump rates reduces the risk of exceeding capacity of treatment for nitrate removal as well as reducing the operating cost of treatment. Nitrate concentrations in raw water are currently determined by periodic sampling by operations staff. When nitrate concentrations approach the regulatory limit, sampling frequency increases. Operations staff currently use this information to determine blending rates.

Improving this infrastructure would require the installation of an additional 5 *mgd* pump with variable frequency drive at each raw water pump station to provide the capability to pump at lower rates

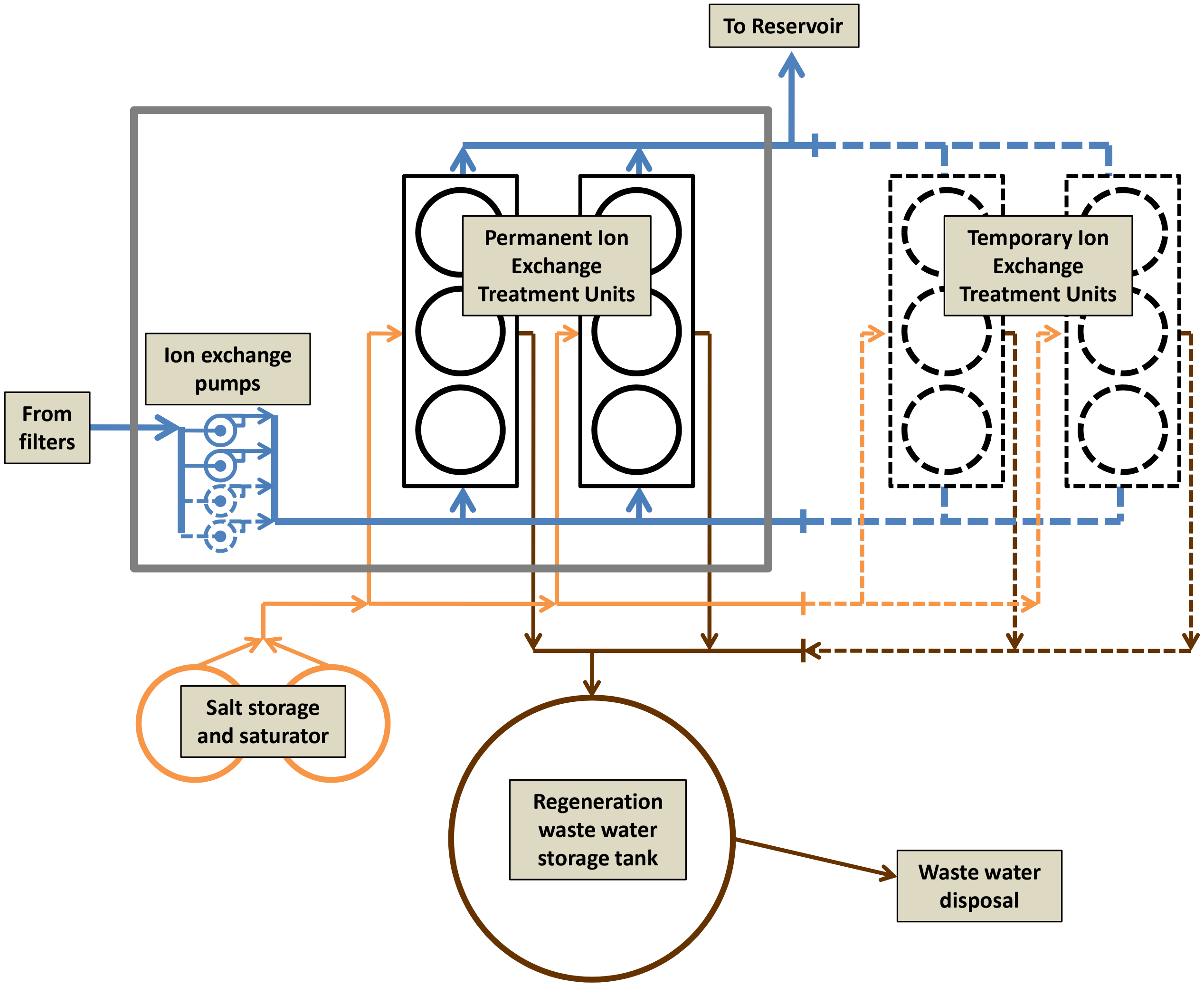


Figure 5.4: Conceptual process schematic - ion exchange treatment for nitrate removal.

Table 5.4: Raw water pumping and control improvements - advantages and disadvantages.

Advantages	Disadvantages
• Enables the optimization of blending as the first and least cost nitrate management option. • Reduces the operating cost of IX treatment for nitrate removal • Provides better data to plant operators for monitoring of nitrate levels and anticipation of required treatment.	• Does not add additional safe yield or total capacity

than possible with existing pumps. Optimization would be enhanced by increasing the flexibility and range of pumping rates from each raw water pump station. The installation of continuous nitrate monitoring equipment at each pump station would improve the data stream used by treatment plant operators to optimize the blending of water sources. The increased level of monitoring will improve the ability of operators to follow trends and make informed preparations to begin IX treatment or arrange for the delivery of additional temporary IX treatment equipment (Table 5.4).

5.4 Sugar Creek wellfield and treatment facility

Groundwater is available in aquifers along Sugar Creek, southwest of the existing service area. A new wellfield and treatment facility developed in this area has the potential to add $3-5\,mgd$ of supply and treatment capacity to the system. The new supply would reduce demand on the existing supply and treatment facilities. It adds both safe yield and total capacity to the system. Reducing demands on the existing plant reduces the risk that the supply and treatment capacity at the existing facility will be exceeded during high-nitrate events. It also results in some reduction of the utilization and operating cost of IX treatment that is required for nitrate removal at the existing facility.

A significant initial investment is required to establish a new wellfield and treatment facility. Figure 5.5 shows the conceptual layout of the supply, treatment and distribution facilities required for a $3\,mgd$ supply. A $3\,mgd$ groundwater supply would consist of 4 vertical wells constructed in a single wellfield. A lime softening and filtration facility would be constructed with an initial treatment capacity of 3 mgd, and designed for future expansion. Approximately $11,500\,ft$ of water main would be required to deliver raw water to the treatment facility and treated water to the point of connection with the distribution system.

Figure 5.6 shows an alternative layout for a 3 mgd supply which connects to a larger diameter main in the existing distribution system for improved system hydraulics. Approximately $20,500\,ft$ of water main would be required for this route. This route would facilitate possible bulk water sales to nearby communities to the west, and it provides a potential point of connection for a future regional water system, as proposed by McLean County Regional Planning Commission *[McLean County Regional Planning Commission, 2009]*.

A 5 mgd groundwater supply would consist of either 6 vertical wells constructed in two wellfields or a single Ranney collector well. A collector well may have inherent advantages in terms of ultimate capacity and ability to produce in drought conditions. A lime softening and filtration facility would be constructed with an initial treatment capacity of 5 mgd, and designed for future expansion. The conceptual layouts of 5 mgd supply and treatment facilities are shown in Figures 5.7 and 5.8. Table 5.5 presents some of the advantages and disadvantages of this water supply option.

5.5 Mackinaw River pumping pool

The Mackinaw River pumping pool, shown in Figure 5.9 was constructed after the 1988-89 drought for the purpose of augmenting the supply available from Evergreen Lake. The supply does not increase the total capacity of raw water supply to the treatment plant, but it does increase the effective safe yield of Evergreen Lake. The contribution to safe yield is described in greater detail in Chapter 3 and Appendix A.

Pumping is allowed under limited conditions specified in the permit issued by the Army Corps of Engineers, which is described in Appendix A. Pumping is not permitted unless there is a combined water levels deficit in Lake Bloomington and Evergreen Lake of $8\,ft$ or more below normal pool. Pumping must cease when the combined water level deficit is reduced to $4\,ft$. Minimum stream flows in the Mackinaw River must be maintained during different seasons, which limits the availability of water. The pumps are capable of delivering 20 mgd of water to Evergreen Lake if sufficient water is available in the pumping pool. In practice, pumping must cease periodically to allow water levels in the pumping pool to recover. Pumps are not restarted until operators visually inspect the level of water in the pool to ensure that pumps will not be damaged when restarted. It is estimated that pumping occurs on average 25% of the time that it would otherwise be permitted by deficits in lake water levels.

Improvements to the Mackinaw River pumping pool would increase the contribution to the safe

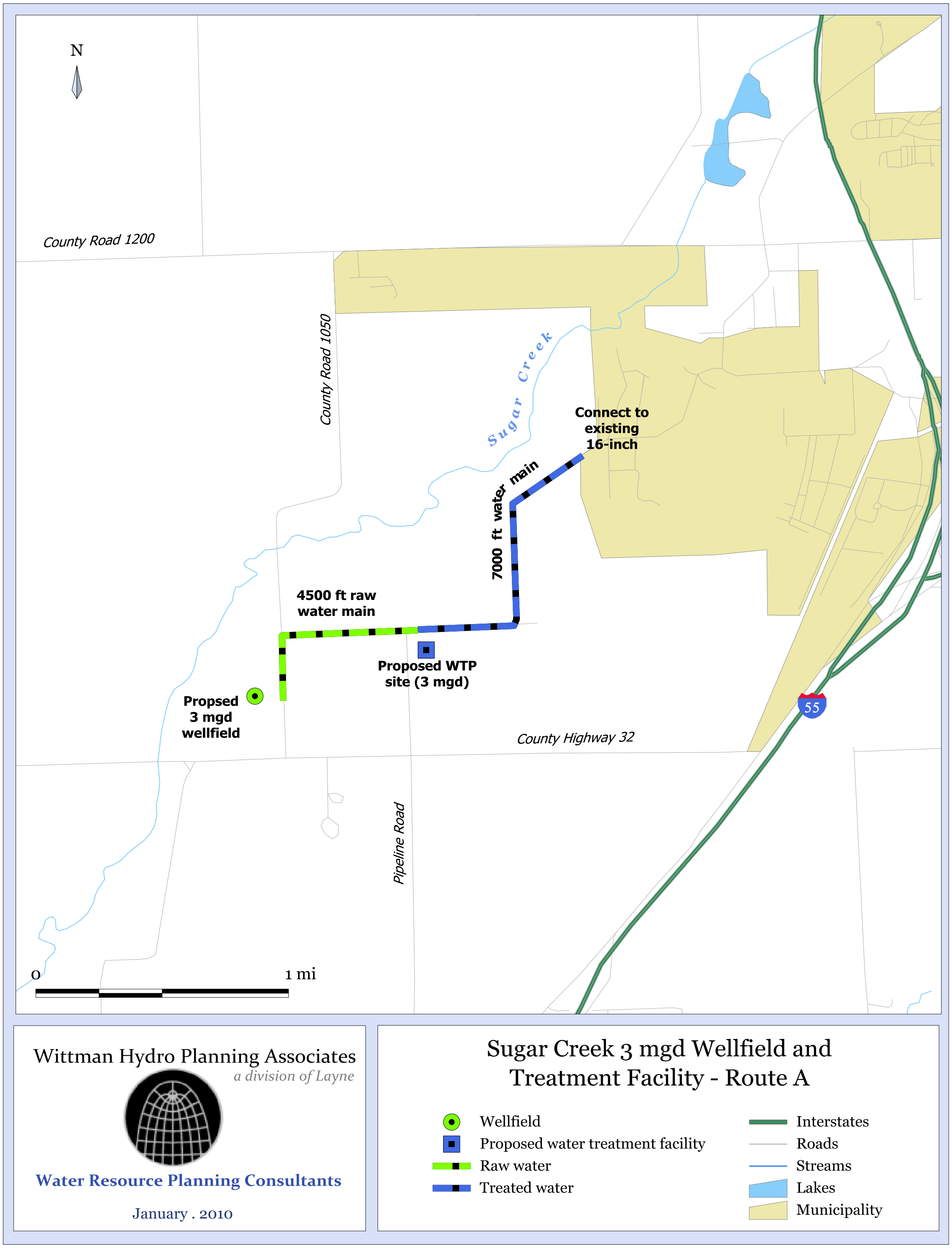


Figure 5.5: Sugar Creek 3 mgd wellfield and treatment - layout A.

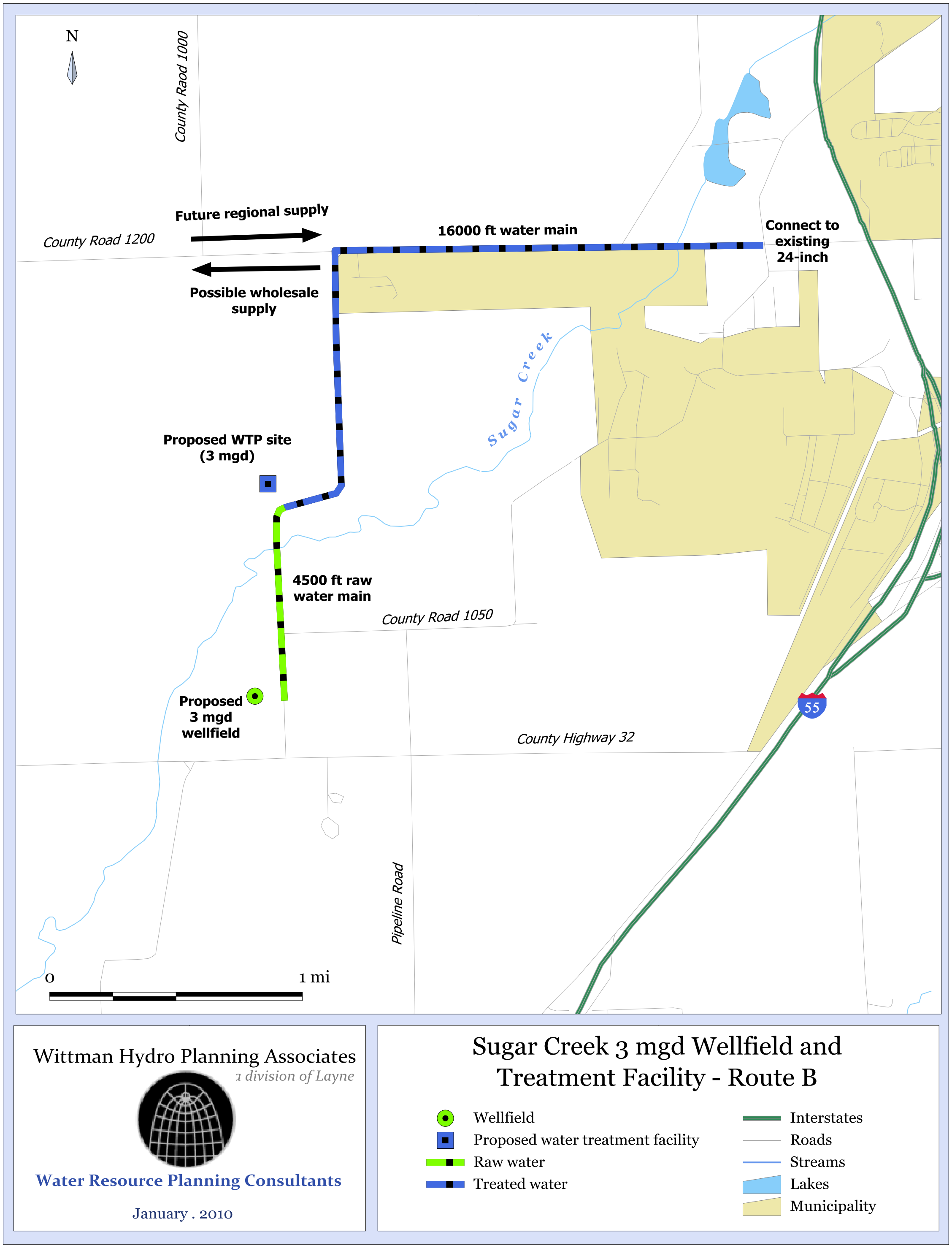


Figure 5.6: Sugar Creek 3 mgd wellfield and treatment - layout B.

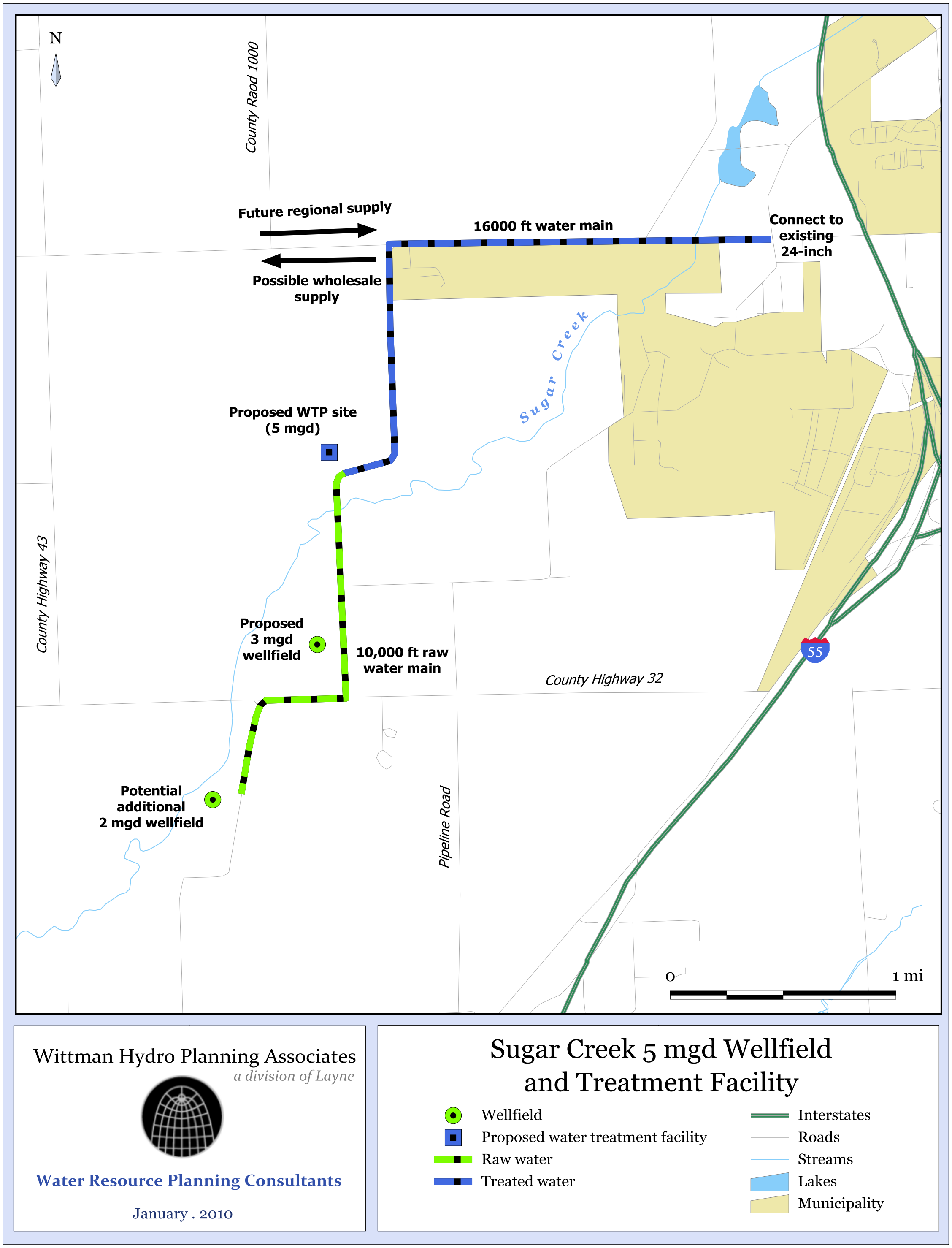


Figure 5.7: Sugar Creek 5 mgd wellfield and treatment facility

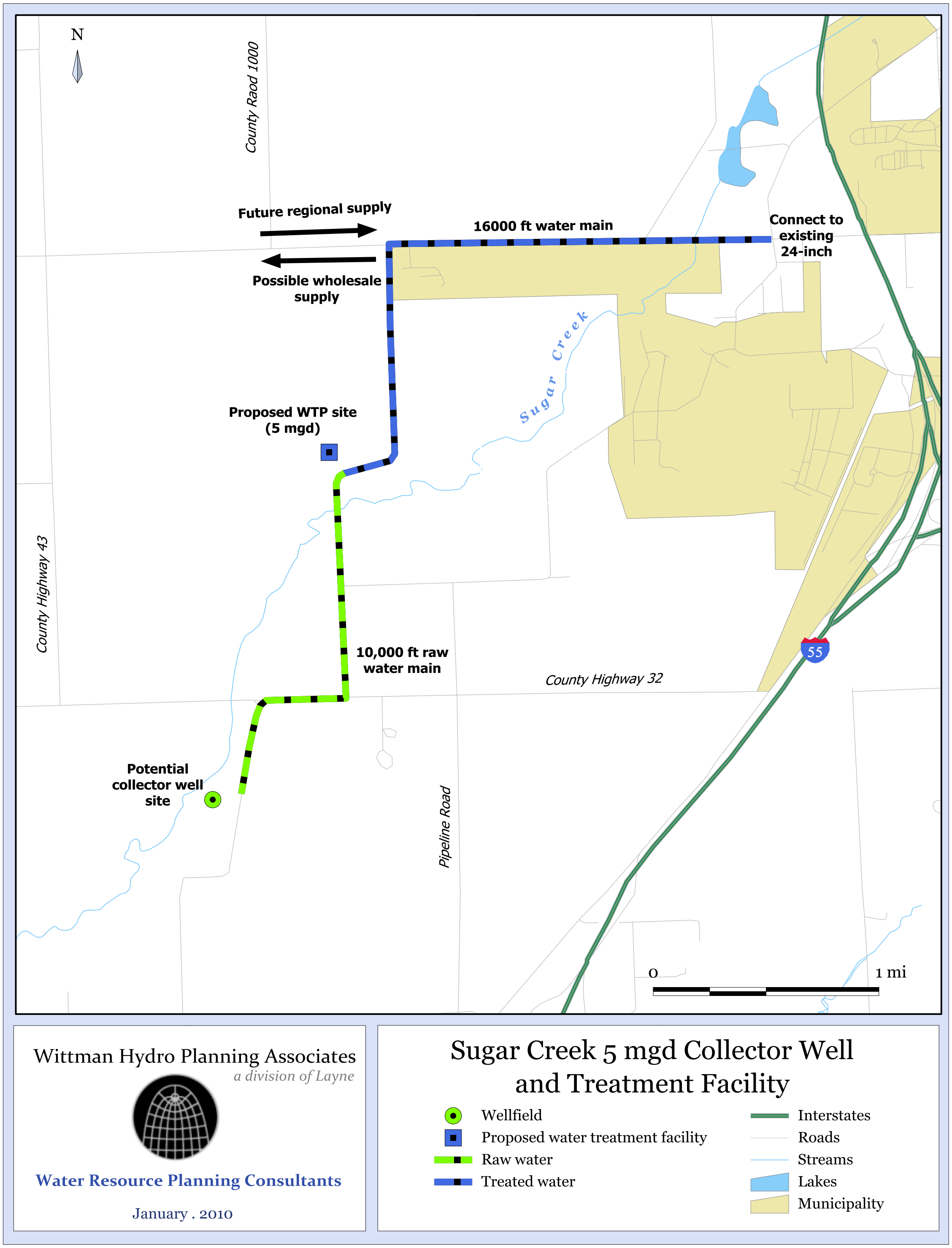


Figure 5.8: Sugar Creek 5 mgd collector well and treatment facility

Table 5.5: Sugar Creek wellfield and treatment facility - advantages and disadvantages.

Advantages	Disadvantages
• Adds total supply and treatment capacity to the system • Adds safe yield of supply • Less energy required to pump water a shorter distance to the southern portion of the system • Allows deferment of expansion of treatment capacity at the existing plant • Reduces demands on the existing plant, which reduces the need for and cost of nitrate removal • Opportunity for interim bulk water sales to neighboring communities, prior to integration of long term regional water system	• Additional facility to manage and operate • Initial construction cost

Figure 5.9: Mackinaw River pumping pool.

Table 5.6: Mackinaw River pumping pool - advantages and disadvantages.

Advantages	**Disadvantages**
• Some infrastructure already in place	• Does not help with management of elevated nitrates • Does not add to total treatment capacity

yield of Evergreen Lake. Greater flexibility in pumping capacity and controls would allow pumping operations to continue at a reduced rate when inflows to the pumping pool are not sufficient to support full pumping capacity. SCADA improvements would provide information and control capabilities necessary to optimize the utilization of the facility. Options for increasing the inflow from the Mackinaw River to the pumping pool are limited by the terms of the permit, which specifies weir elevations to maintain minimum stream flows. Improvements to widen the weir without changing the elevation may provide additional inflow under certain conditions, while maintaining compliance with the permit. If permitted by minimum flows in the Mackinaw River, increasing the average utilization of the pumping pool from 25% to 50% would result in an additional $1.0\,mgd$ contribution to the safe yield of Evergreen Lake.

Modifications to the terms of the permit have the potential to increase the contribution to safe yield provided by the pumping pool. Appendix A discusses the potential gains in safe yield provided by reducing the combined deficits established in the permit for initiating and ceasing pumping from the pool. Modifications to the permit would require approval of the Army Corps of Engineers. Table 5.6 presents some of the advantages and disadvantages of this water supply option.

5.6 Conservation

Water conservation is one of the ways that utilities extend their water supplies. Where water conservation was once considered only as a response to local drought conditions or to emergency water shortages, it is now viewed as an essential component of integrated water supply planning. Water conservation and loss management are part of a strategy to minimize long-term costs by improving efficiency, reducing water demands, and extending the useful life of water resources and infrastructure.

While the City is exploring new supplies, the Utility staff understands that in order to protect the water sources currently in place, they must also address demands. The most common approach to managing demand is to develop a comprehensive conservation plan addressing efficiency in both water use by customers and water supply by the utility. The conservation plan developed for the City in 2008 is the first step in implementing a comprehensive plan (Appendix D).

Although comprehensive conservation planning is just beginning in Bloomington, Illinois, the City has taken steps to improve the accuracy of metering of water sold to customers. The City is currently engaged in a program to replace old meters. Improved measurement will facilitate an accurate audit and estimation of real water losses. In the 2008 Water Conservation Plan, WHPA recommended seven initial steps towards using water supplies efficiently and developing a comprehensive conservation plan and program. These steps are described in greater detail in Appendix D.

Adopt the drought response ordinance. The ordinance will authorize the City of Bloomington, Illinois Water Department to restrict non-essential water use during drought conditions, which is critical for preserving the city's water supply for human consumption, sanitation, and fire protection.

Include a drought index in the Pantagraph and on the City website. Adding a drought index to the local newspaper and City website brings awareness to the issue of drought and provides regular information to the public regarding current conditions. People can understand the need to conserve water when they understand that a drought is occurring.

Conduct business water audits through Illinois Sustainable Technology Center program. The Illinois Sustainable Technology Center (ISTC) provides businesses with up to eight (8) hours of free consultation to help improve water and energy efficiencies. The City of Bloomington could partner with ISTC to target large water users.

Provide water conservation kits to residential customers. Residential water conservation kits would be distributed to interested customers. These kits could include hardware and/or materials for leak detection. Educational materials should also be provided.

Perform a water audit. A complete water audit will estimate water losses within the delivery system. Previous estimates of water losses range up to 35% [Farnworth and Wiley P.C., 1993]. Reduction of water losses can have an immediate positive financial impact by reducing operating expenses without affecting revenue. A water audit also provides the financial cost of water loss, which is necessary for making economic decisions related to leak repair and main replacement.

Complete a water system profile. A water system profile provides a holistic view of the water system and community, which aids in integrating water conservation into water supply planning.

Table 5.7: Conservation - advantages and disadvantages.

Advantages	Disadvantages
• Complements all options	• None

Develop conservation goals. Setting specific, measurable goals help to identify the conservation measures necessary to achieve the goals and develop an implementation strategy.

Table 5.7 presents some of the advantages and disadvantages of using water conservation to increase water supplies.

5.7 Drought planning

Drought is a common phenomenon in the Midwest. While the drought of 1988-1989 is frequently cited as one of the worst in Illinois, several more significant droughts occurred earlier in the 20th Century [ISWS, 2006]. During the 1988-1989 drought, water levels dropped far below the spillway elevations in the two Bloomington reservoirs. Restrictions were imposed on watering lawns and serving tap water in restaurants. Water quality deteriorated both during and after the drought. To prepare for similar circumstances in the future, the City developed a drought response plan and an ordinance that provides the City with the necessary authority to implement the Plan (Appendix E). WHPA recommends adopting the ordinance to ensure that the City can implement the Drought Response Plan when necessary .

In the Drought Response Plan, drought is defined as:

A reduction in precipitation or aquifer recharge that affects the ability of the public water system to meet the demands of the customers or causes regulatory or aesthetic reductions in water quality.

This definition of drought was developed to address the particular concerns of a public water supply system. The drought levels specific to Bloomington, IL are found in Table 5.8.

Each drought level has an associated response plan that is designed to alleviate the drought and help maintain and/or increase water levels in the reservoir. Each of these drought response plans are described below. In addition to the Drought Response Plan,

Moderate drought response

The goals of the moderate drought response are to

Table 5.8: Drought index for Bloomington, IL.

Drought index	Combined reservoir level
non-drought	fluctuations < 6 feet
moderate	6-8 feet below spillway
severe	8-10 feet below spillway
extreme	> 10 feet below spillway

1. make the public aware of the drought and water shortage;
2. educate the public about drought procedures and water saving tips they can implement to help conserve water; and
3. encourage a voluntary five percent water use reduction by all water customers.

Voluntary reductions in water use are requested of all customers. Specific restrictions are established for water use by the City.

Severe drought response

The goals of the severe drought response are to

1. educate the public about drought procedures and water saving tips they can implement to help conserve water;
2. generate a public response to the drought and water shortage;
3. initiate a mandatory 10 percent water use reduction by all water customers.

Specific restrictions are imposed on water use fro landscape watering, recreational activities, and irrigation. The City will monitor compliance and provide courtesy warnings.

Extreme drought response

In the case of an extreme drought, the response goal is a 15 percent water use reduction by all customers. Specific restrictions imposed for the severe drought response are continued and in some cases increased. The City will prohibit water-based street cleaning.

Table 5.9 presents some of the advantages and disadvantages of drought planning.

Table 5.9: Drought planning - advantages and disadvantages.

Advantages	**Disadvantages**
• Complements all options	• None

5.8 Regional water supply

The McLean County Regional Comprehensive Plan includes a proposed regional water system which would consolidate service areas of Bloomington, Normal and other communities in the county [McLean County Regional Planning Commission, 2009]. In addition to the consolidation of water service territories, the plan proposes the construction of a regional water supply and treatment facility west of Bloomington in neighboring Tazewell county (Figure 5.10). The regional water supply has been proposed as the long-term solution for water supply in McLean county, and has been described in detail in previous planning studies [Farnsworth & Wylie P.C., 1990] and

[Farnsworth and Wiley, Farnsworth and Kohlhase, 1992].

The interim water supply options investigated for this study are intended to bridge the gap until the regional water supply is developed. For the purpose of comparing the costs of interim water supply options with those of the proposed regional supply, an updated conceptual cost estimate was developed for the regional supply [Farnsworth & Wylie P.C., 1990].

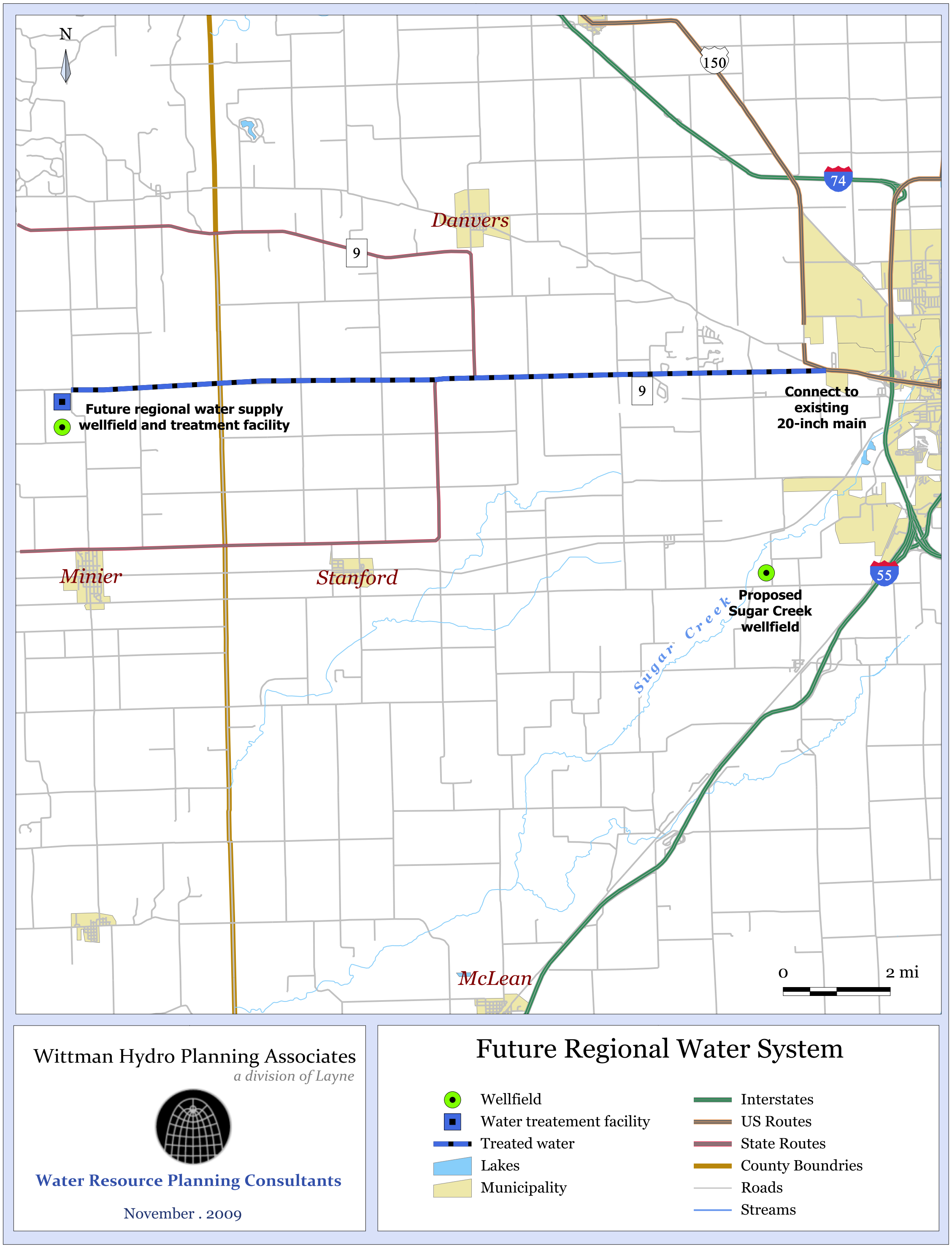


Figure 5.10: Future regional water system.

Chapter 6

Evaluation of Alternatives

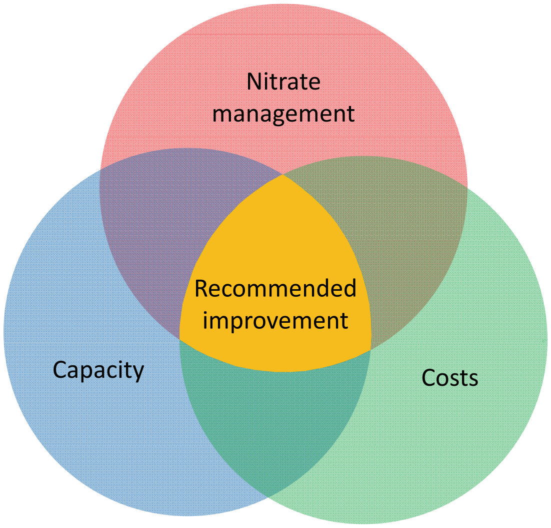


Figure 6.1: Process of evaluating alternatives.

Each of the options described in the previous chapter contribute to meeting the water supply planning objectives of the City, but none of them satisfy all objectives on their own. Alternatives comprised of combinations of these options do satisfy planning objectives, and it is these that are evaluated in this section. The alternatives are evaluated to compare their performance to minimum criteria for quantity and quality of water supply. The total capacity and safe yield (3) of each alternative are evaluated against demand projections presented in Chapter 2. The ability of each alternative to effectively manage high nitrate levels is evaluated with blending and treatment models presented in Chapter 4. The result is a recommended path of phased implementation of individual measures that will move the City's water supply toward a more secure future (Figure 6.1).

6.1 Alternatives evaluated

Twenty-two alternatives comprised of water supply options singly and in multiple combinations were evaluated. The alternatives are grouped into seven general categories as follows:

- Group 0 - current conditions
- Group 1 - Danvers Valley wells for blending
- Group 2 - Danvers Valley wells for blending, and treatment for nitrate removal
- Group 3 - Danvers Valley wells for blending, treatment for nitrate removal, and 3 mgd Sugar Creek wellfield and treatment facility

- Group 4 - Danvers Valley wells for blending, treatment for nitrate removal, and 5 mgd Sugar Creek wellfield and treatment facility
- Group 5 - Treatment for nitrate removal, and 3 mgd Sugar Creek wellfield and treatment facility
- Group 6 - Treatment for nitrate removal, and 5 mgd Sugar Creek wellfield and treatment facility

All of the alternatives are listed in Table 6

6.2 Evaluation criteria

Criteria were established to evaluate the performance of alternatives. Alternatives that do not meet minimum criteria were eliminated and the rest were further evaluated to compare relative performance. Other criteria were also considered in the development of final recommendations. The *minimum* and *desired* performance criteria used for screening alternatives are presented in Table 6.2.

6.2.1 Safe yield

Criteria for evaluating the safe yield of supplies are based on projected average demand. The *minimum* performance measure for safe yield is 100% of the projected average demand. The *desired* performance measure for safe yield is 125% of the projected average demand.

6.2.2 Total supply and treatment capacity

Performance criteria used for evaluating the total supply and treatment capacity of alternatives take into consideration the significant potential for reductions in demand achievable through management efforts. The *desired* performance measure for total supply and treatment capacity is established at the projected maximum demand which would be anticipated once in twenty years (95% confidence). These projections, described in Chapter 2 do not consider reductions in peak water use which would be anticipated through water conservation and loss reduction efforts. Because water conservation and loss reduction efforts are recommended, the *minimum* performance measure for total supply and treatment capacity is established at the “average” projected maximum demand (50% confidence). Management of demand through water conservation and loss reduction efforts will reduce the capacity required to achieve the *desired* performance measure. For reference, the current supply and treatment capacity of $20.5\,mgd$ was exceeded in 2005 when $21.6\,mgd$ was pumped.

Table 6.1: Evaluated water supply and treatment alternatives.

Alternative Group	**Alternative Number**	**Danvers Valley Blending Wells** (mgd)	**Nitrate Removal Treatment** (mgd)	**Sugar Creek Wells and Treatment** (mgd)
0	0	0	0	0
1	1-a	1	0	0
	1-b	2	0	0
2	2-a	2	2	0
	2-b	2	4	0
	2-c	2	6	0
3	3-a	2	0	3
	3-b	2	2	3
	3-c	2	4	3
	3-d	2	6	3
4	4-a	2	0	5
	4-b	2	2	5
	4-c	2	4	5
	4-d	2	6	5
5	5-a	0	0	3
	5-b	0	2	3
	5-c	0	4	3
	5-d	0	6	3
	5-e	0	8	3
6	6-a	0	2	5
	6-b	0	4	5
	6-c	0	6	5

mgd=million gallons per day

It is less than the maximum demand (95%) of 22.3 mgd projected for 2010, but greater than the maximum demand (50%) of 19.1 mgd.

6.2.3 Supply and treatment capacity during periods of elevated nitrates

Supply and treatment capacity during periods of elevated nitrates is evaluated against both average demands and maximum demands (50%) using historical data for nitrates in Lake Bloomington and models developed for simulating blending and treatment for nitrate removal (ref nitrate appendix). The criteria based on average demands are considered more critical than those based on maximum demands. This is because their are fewer options available to manage the consequences. If capacity is limited by high nitrates to less than average demands, severely restricted water use and/or regulatory non-compliance is likely. This criteria is applied to the full year. If capacity is limited by high nitrates to less than maximum demands (50%), temporary restrictions applied to non-essential water use are practical, though not desired. This criteria is applied only to those months in which maximum demands above the 50% confidence level have historically occurred (Appendix B).

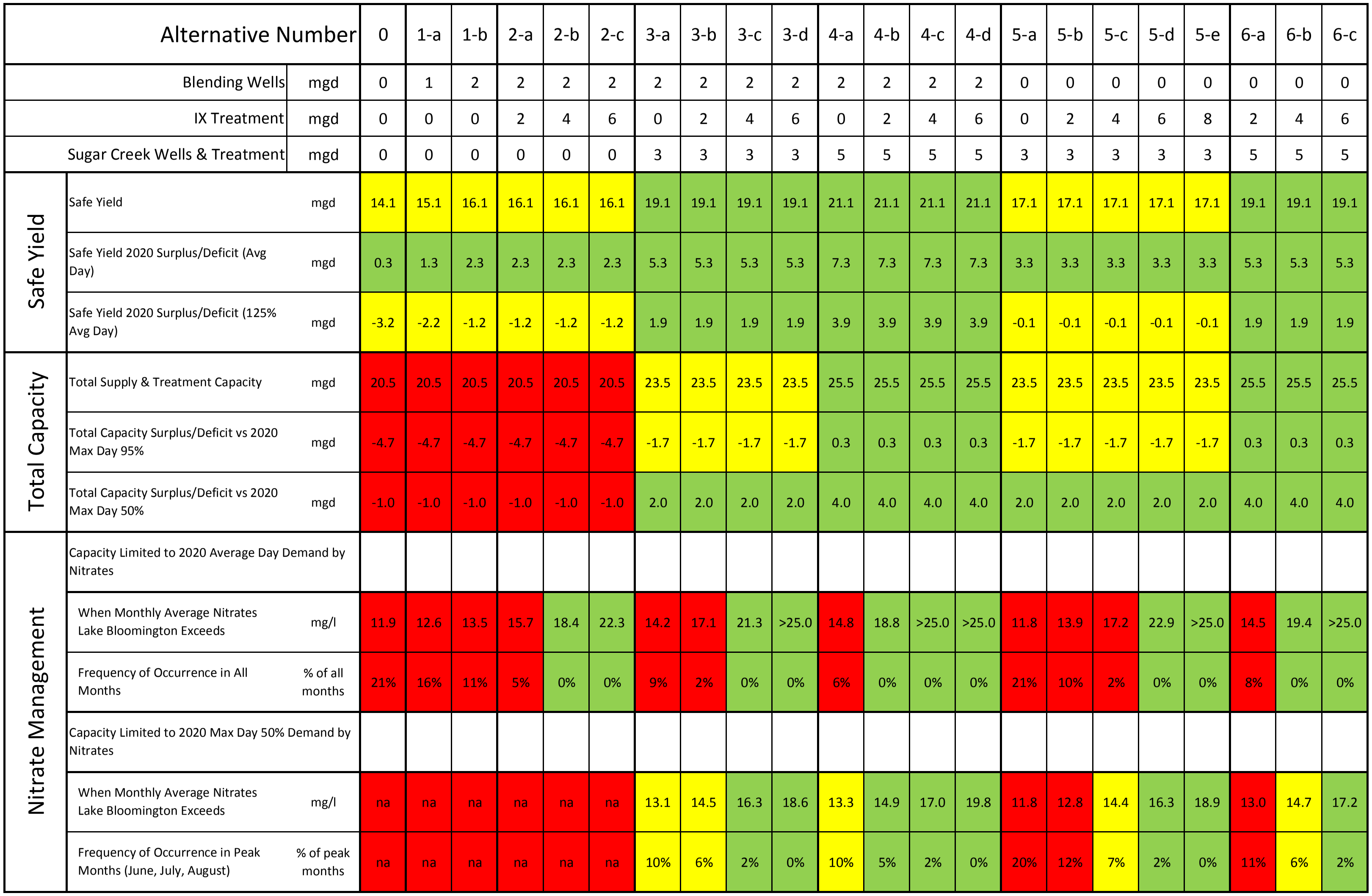
Minimum performance is achieved if average demands may be met 100% of the time, *and* maximum demands (50%) may be met in 90% of peak demand months (June, July and August) with finished water quality at or below a target finished water nitrate concentration of 9 mg/l. *Desired* performance is achieved if average demands may be met 100% of the time, *and* maximum demands (50%) may be met in 95% of peak demand months (June, July and August) with finished water quality at or below a target finished water nitrate concentration of 9 mg/l.

6.3 Performance of alternatives

Performance was evaluated against these criteria for projected demands in the years 2020 and 2030. Figure 6.2 shows the performance of all alternatives with respect to projected demands in 2020. Figure 6.3 shows the performance of all alternatives with respect to projected demands in 2030. Alternative performance against criteria is color-coded as follows: green if desired performance is achieved, yellow if minimum performance is achieved, and red if minimum performance is not achieved. Overall, desired performance is achieved if desired performance is met for all criteria. Minimum performance is achieved if desired or minimum performance is met for all criteria. Minimum performance is not achieved if any criteria fails to meet minimum performance.

Table 6.2: Minimum performance criteria.

Criteria	**Desired Performance Measure**	**Minimum Performance Measure**
Safe Yield	Projected safe yield is greater than 125% projected average demand in the planning year	Projected safe yield is greater than projected average demand in the planning year
Total Supply & Treatment Capacity	Total supply and treatment capacity is greater than the projected maximum demand (95%) in the planning year	Total supply and treatment capacity is greater than the projected maximum demand (50%) in the planning year
Supply & Treatment Capacity During Periods of Elevated Nitrates	Supply & treatment capacity is reduced to less than projected average demand in 0% of months Supply & treatment capacity is reduced to less than maximum demand (50%) in less than 10% of all peak months	Supply & treatment capacity is reduced to less than projected average demand in 0% of months Supply & treatment capacity is reduced to less than maximum demand (50%) in less than 10% of all peak months



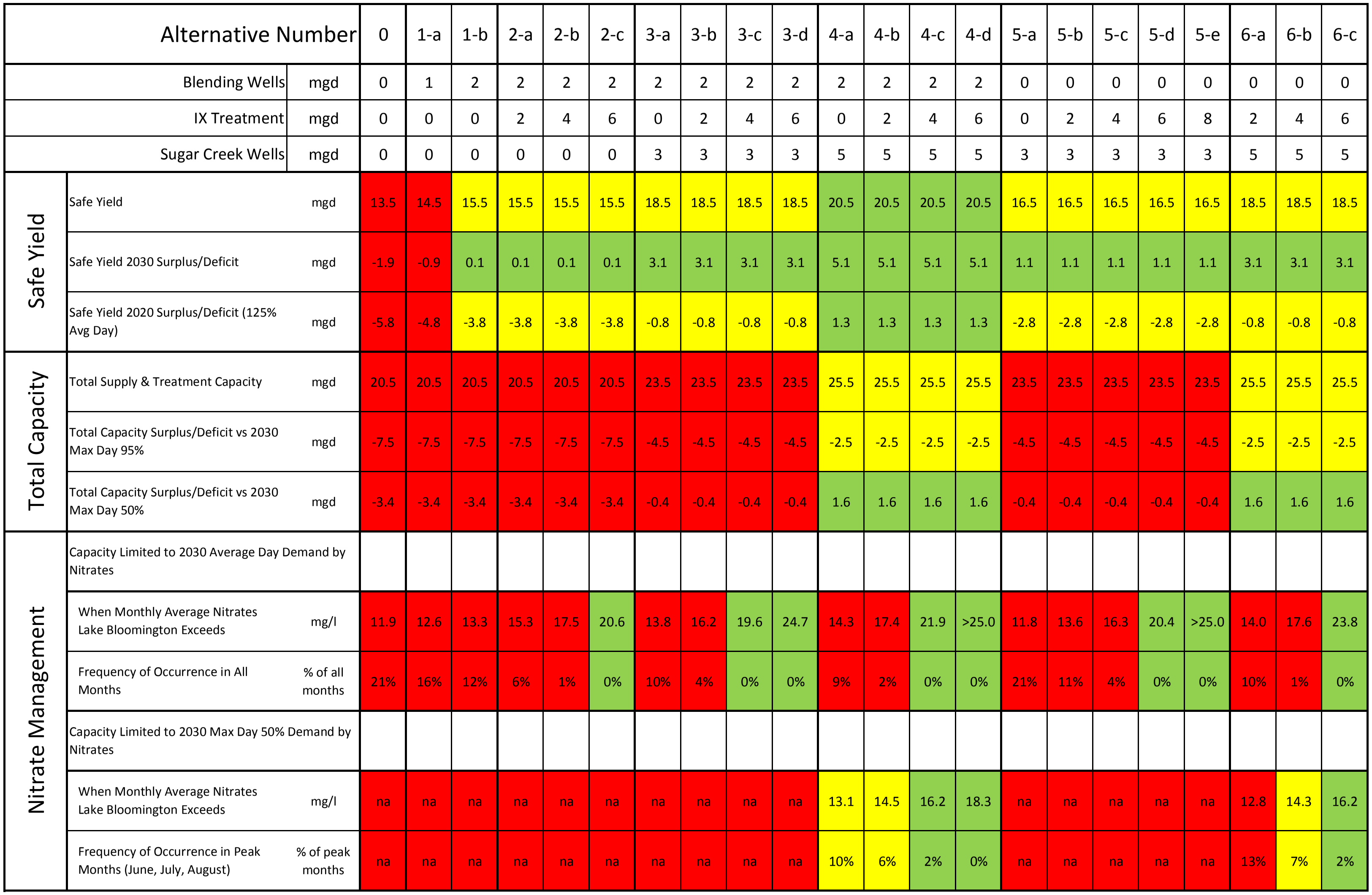
	Alternative Number		0	1-a	1-b	2-a	2-b	2-c	3-a	3-b	3-c	3-d	4-a	4-b	4-c	4-d	5-a	5-b	5-c	5-d	5-e	6-a	6-b	6-c
	Blending Wells	mgd	0	1	2	2	2	2	2	2	2	2	2	2	2	2	0	0	0	0	0	0	0	0
	IX Treatment	mgd	0	0	0	2	4	6	0	2	4	6	0	2	4	6	0	2	4	6	8	2	4	6
	Sugar Creek Wells & Treatment	mgd	0	0	0	0	0	0	3	3	3	3	5	5	5	5	3	3	3	3	3	5	5	5
Safe Yield	Safe Yield	mgd	14.1	15.1	16.1	16.1	16.1	16.1	19.1	19.1	19.1	19.1	21.1	21.1	21.1	21.1	17.1	17.1	17.1	17.1	17.1	19.1	19.1	19.1
	Safe Yield 2020 Surplus/Deficit (Avg Day)	mgd	0.3	1.3	2.3	2.3	2.3	2.3	5.3	5.3	5.3	5.3	7.3	7.3	7.3	7.3	3.3	3.3	3.3	3.3	3.3	5.3	5.3	5.3
	Safe Yield 2020 Surplus/Deficit (125% Avg Day)	mgd	-3.2	-2.2	-1.2	-1.2	-1.2	-1.2	1.9	1.9	1.9	1.9	3.9	3.9	3.9	3.9	-0.1	-0.1	-0.1	-0.1	-0.1	1.9	1.9	1.9
Total Capacity	Total Supply & Treatment Capacity	mgd	20.5	20.5	20.5	20.5	20.5	20.5	23.5	23.5	23.5	23.5	25.5	25.5	25.5	25.5	23.5	23.5	23.5	23.5	23.5	25.5	25.5	25.5
	Total Capacity Surplus/Deficit vs 2020 Max Day 95%	mgd	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	-1.7	-1.7	-1.7	-1.7	0.3	0.3	0.3	0.3	-1.7	-1.7	-1.7	-1.7	-1.7	0.3	0.3	0.3
	Total Capacity Surplus/Deficit vs 2020 Max Day 50%	mgd	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	2.0	2.0	2.0	2.0	4.0	4.0	4.0	4.0	2.0	2.0	2.0	2.0	2.0	4.0	4.0	4.0
Nitrate Management	Capacity Limited to 2020 Average Day Demand by Nitrates																							
	When Monthly Average Nitrates Lake Bloomington Exceeds	mg/l	11.9	12.6	13.5	15.7	18.4	22.3	14.2	17.1	21.3	>25.0	14.8	18.8	>25.0	>25.0	11.8	13.9	17.2	22.9	>25.0	14.5	19.4	>25.0
	Frequency of Occurrence in All Months	% of all months	21%	16%	11%	5%	0%	0%	9%	2%	0%	0%	6%	0%	0%	0%	21%	10%	2%	0%	0%	8%	0%	0%
	Capacity Limited to 2020 Max Day 50% Demand by Nitrates																							
	When Monthly Average Nitrates Lake Bloomington Exceeds	mg/l	na	na	na	na	na	na	13.1	14.5	16.3	18.6	13.3	14.9	17.0	19.8	11.8	12.8	14.4	16.3	18.9	13.0	14.7	17.2
	Frequency of Occurrence in Peak Months (June, July, August)	% of peak months	na	na	na	na	na	na	10%	6%	2%	0%	10%	5%	2%	0%	20%	12%	7%	2%	0%	11%	6%	2%

Figure 6.2: Performance of alternatives - 2020.

Note: GREEN=desired performance; YELLOW=minimum performance; RED=inadequate performance

Desired performance is achieved by alternatives include 5 mgd at Sugar Creek, plus a minimum of 2 mgd IX treatment with blending wells or 6 mgd IX treatment without blending wells.

Minimum performance is achieved by alternatives including 1) 3 mgd supply at Sugar Creek, plus a minimum of 4 mgd IX treatment with blending wells or 6 mgd IX treatment without blending wells, and 2) 5 mgd supply at Sugar Creek, plus a minimum of 4 mgd IX treatment without blending wells.



	Alternative Number		0	1-a	1-b	2-a	2-b	2-c	3-a	3-b	3-c	3-d	4-a	4-b	4-c	4-d	5-a	5-b	5-c	5-d	5-e	6-a	6-b	6-c
	Blending Wells	mgd	0	1	2	2	2	2	2	2	2	2	2	2	2	2	0	0	0	0	0	0	0	0
	IX Treatment	mgd	0	0	0	2	4	6	0	2	4	6	0	2	4	6	0	2	4	6	8	2	4	6
	Sugar Creek Wells	mgd	0	0	0	0	0	0	3	3	3	3	5	5	5	5	3	3	3	3	3	5	5	5
Safe Yield	Safe Yield	mgd	🟥 13.5	🟥 14.5	🟨 15.5	🟨 15.5	🟨 15.5	🟨 15.5	🟨 18.5	🟨 18.5	🟨 18.5	🟨 18.5	🟩 20.5	🟩 20.5	🟩 20.5	🟩 20.5	🟨 16.5	🟨 16.5	🟨 16.5	🟨 16.5	🟨 16.5	🟨 18.5	🟨 18.5	🟨 18.5
	Safe Yield 2030 Surplus/Deficit	mgd	🟥 -1.9	🟥 -0.9	🟩 0.1	🟩 0.1	🟩 0.1	🟩 0.1	🟩 3.1	🟩 3.1	🟩 3.1	🟩 3.1	🟩 5.1	🟩 5.1	🟩 5.1	🟩 5.1	🟩 1.1	🟩 1.1	🟩 1.1	🟩 1.1	🟩 1.1	🟩 3.1	🟩 3.1	🟩 3.1
	Safe Yield 2020 Surplus/Deficit (125% Avg Day)	mgd	🟥 -5.8	🟥 -4.8	🟨 -3.8	🟨 -3.8	🟨 -3.8	🟨 -3.8	🟨 -0.8	🟨 -0.8	🟨 -0.8	🟨 -0.8	🟩 1.3	🟩 1.3	🟩 1.3	🟩 1.3	🟨 -2.8	🟨 -2.8	🟨 -2.8	🟨 -2.8	🟨 -2.8	🟨 -0.8	🟨 -0.8	🟨 -0.8
Total Capacity	Total Supply & Treatment Capacity	mgd	🟥 20.5	🟥 20.5	🟥 20.5	🟥 20.5	🟥 20.5	🟥 20.5	🟥 23.5	🟥 23.5	🟥 23.5	🟥 23.5	🟨 25.5	🟨 25.5	🟨 25.5	🟨 25.5	🟥 23.5	🟥 23.5	🟥 23.5	🟥 23.5	🟥 23.5	🟨 25.5	🟨 25.5	🟨 25.5
	Total Capacity Surplus/Deficit vs 2030 Max Day 95%	mgd	🟥 -7.5	🟥 -7.5	🟥 -7.5	🟥 -7.5	🟥 -7.5	🟥 -7.5	🟥 -4.5	🟥 -4.5	🟥 -4.5	🟥 -4.5	🟨 -2.5	🟨 -2.5	🟨 -2.5	🟨 -2.5	🟥 -4.5	🟥 -4.5	🟥 -4.5	🟥 -4.5	🟥 -4.5	🟨 -2.5	🟨 -2.5	🟨 -2.5
	Total Capacity Surplus/Deficit vs 2030 Max Day 50%	mgd	🟥 -3.4	🟥 -3.4	🟥 -3.4	🟥 -3.4	🟥 -3.4	🟥 -3.4	🟥 -0.4	🟥 -0.4	🟥 -0.4	🟥 -0.4	🟩 1.6	🟩 1.6	🟩 1.6	🟩 1.6	🟥 -0.4	🟥 -0.4	🟥 -0.4	🟥 -0.4	🟥 -0.4	🟩 1.6	🟩 1.6	🟩 1.6
Nitrate Management	Capacity Limited to 2030 Average Day Demand by Nitrates																							
	When Monthly Average Nitrates Lake Bloomington Exceeds	mg/l	🟥 11.9	🟥 12.6	🟥 13.3	🟥 15.3	🟥 17.5	🟩 20.6	🟥 13.8	🟥 16.2	🟩 19.6	🟩 24.7	🟥 14.3	🟥 17.4	🟩 21.9	🟩 >25.0	🟥 11.8	🟥 13.6	🟥 16.3	🟩 20.4	🟩 >25.0	🟥 14.0	🟥 17.6	🟩 23.8
	Frequency of Occurrence in All Months	% of all months	🟥 21%	🟥 16%	🟥 12%	🟥 6%	🟥 1%	🟩 0%	🟥 10%	🟥 4%	🟩 0%	🟩 0%	🟥 9%	🟥 2%	🟩 0%	🟩 0%	🟥 21%	🟥 11%	🟥 4%	🟩 0%	🟩 0%	🟥 10%	🟥 1%	🟩 0%
	Capacity Limited to 2030 Max Day 50% Demand by Nitrates																							
	When Monthly Average Nitrates Lake Bloomington Exceeds	mg/l	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟨 13.1	🟨 14.5	🟩 16.2	🟩 18.3	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 12.8	🟨 14.3	🟩 16.2
	Frequency of Occurrence in Peak Months (June, July, August)	% of peak months	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟨 10%	🟨 6%	🟩 2%	🟩 0%	🟥 na	🟥 na	🟥 na	🟥 na	🟥 na	🟥 13%	🟨 7%	🟩 2%

Figure 6.3: Performance of alternatives - 2030.

Note: GREEN=desired performance; YELLOW=minimum performance; RED=inadequate performance

Minimum performance is achieved by alternatives including 5 mgd supply at Sugar Creek, plus a minimum of 4 mgd IX treatment with blending wells or 6 mgd IX treatment without blending wells.

6.3.1 Safe yield

For the year 2020, the alternatives that achieved desired performance criteria for safe yield include all of Groups 3, 4 and 6. Each of these alternatives include a total of $5 to 7\,mgd$ of additional groundwater supply from wells for blending and/or Sugar Creek. All other alternatives achieved minimum performance in 2020.

For the year 2030, the alternatives that achieved desired performance criteria for safe yield include all of Group 4. Each of these alternatives include a total of $7\,mgd$ of additional groundwater supply from wells for blending and Sugar Creek. All other alternatives with a minimum of $2\,mgd$ of groundwater for blending achieved minimum performance in 2030. Alternative 1-a, with $1\,mgd$ of additional groundwater, did not achieve minimum performance in 2030.

6.3.2 Total supply and treatment capacity

For the year 2020, the alternatives that achieved desired performance criteria for total capacity include all of Groups 4 and 6. Each of these alternatives include $5\,mgd$ of additional supply and treatment capacity supply at Sugar Creek. Alternatives that achieved minimum performance criteria for total capacity include all of Groups 3 and 5. Each of these alternatives include $3\,mgd$ of additional supply and treatment capacity supply at Sugar Creek. All other alternatives did not achieve minimum performance in 2020.

For the year 2030, none of the alternatives achieved desired performance criteria for total capacity. Alternatives that achieved minimum performance criteria for total capacity include all of Groups 4 and 6. Each of these alternatives include $5\,mgd$ of additional supply and treatment capacity supply at Sugar Creek. All other alternatives did not achieve minimum performance in 2030.

The alternatives in groups 1 and 2, which include additional source of supply (i.e. blending wells), and supplemental treatment for nitrate removal do not increase the rated capacity of the existing treatment facility.

6.3.3 Supply and treatment capacity during periods of elevated nitrates

For the year 2020, the alternatives that achieved performance criteria for nitrate management come from Groups 3, 4, 5, and 6. Alternatives with $3\,mgd$ of additional supply and treatment capacity supply at Sugar Creek met the desired criteria if they also had a minimum of 4 mgd of IX treatment with blending wells (3-c and 3-d) or 6 mgd of IX treatment without blending wells (5-d and 5-e). Alternatives with $5\,mgd$ of additional supply and treatment capacity supply at Sugar Creek met the desired criteria if they also had a minimum of $2\,mgd$ of IX treatment with blending wells (4-b, 4-c and 4-d) or 6 mgd of IX treatment without blending wells (6-c). Minimum performance was achieved with 5 *mgd* supply and treatment at Sugar Creek and 4 *mgd* of IX treatment without blending wells. All other alternatives did not achieve minimum performance in 2020.

For the year 2030, the alternatives that achieved desired performance criteria for nitrate management come from Groups 4 and 6. All of the alternatives include 5 *mgd* of additional supply and treatment capacity supply at Sugar Creek. They met the desired criteria if had a minimum of 4 mgd of IX treatment with blending wells (4-c and 4-d) or 6 mgd of IX treatment without blending wells (6-c). All other alternatives did not achieve minimum performance in 2030.

6.3.4 Overall performance

For the year 2020, the alternatives that achieved overall performance criteria come from Groups 3, 4, 5, and 6. All of the alternatives that achieved desired overall performance include 5 *mgd* of additional supply and treatment capacity supply at Sugar Creek. Alternatives 4-b, 4-c and 4-d also include a minimum of 2 mgd of IX with blending wells and alternative 6-c includes a minimum of 6 mgd of IX treatment without blending wells. Minimum performance was achieved by alternatives 3-c and 3-d with 3 *mgd* supply and treatment at Sugar Creek and a minimum of 4 *mgd* of IX treatment with blending wells. Alternatives 5-d and 5-e include 3 *mgd* supply and treatment at Sugar Creek and a minimum of 6 *mgd* of IX treatment without blending wells. Alternative 6-b includes 5 *mgd* supply and treatment at Sugar Creek and a minimum of 4 *mgd* of IX treatment without blending wells. All other alternatives did not achieve minimum performance in 2020.

For the year 2030, none of the alternatives achieved desired overall performance criteria. The alternatives that achieved minimum overall performance criteria come from Groups 4 and 6. All of these alternatives include 5 *mgd* of additional supply and treatment capacity supply at Sugar Creek. Alternatives 4-c and 4-d also include a minimum of 4 mgd of IX treatment with blending wells and alternative 6-c includes a minimum of 6 mgd of IX treatment without blending wells. All other alternatives did not achieve minimum overall performance in 2030.

Based on the evaluation, it is recommended that a program of improvements include the phased construction of 2 *mgd* of blending wells, ion-exchange treatment, and a 5 *mgd* source of supply and treatment facility near Sugar Creek, represented by Alternative 4-d. Early construction of wells for blending and IX treatment will significantly reduce the risk of severely restricted water use and/or regulatory non-compliance caused by high nitrates.

Conservation affords significant value to the City in terms of reducing the risk of exceeding capacity, and in reducing the long-term cost of construction and operation of infrastructure.

Chapter 7

Recommendations

The evaluation of alternatives identified the group of infrastructure and management measures that will achieve the water supply objectives of the City. Phased implementation of these measures is recommended, based on prioritization to select those measures for early implementation that reduce the risk of severe capacity limitations or regulatory non-compliance. Phased implementation also provides an opportunity for management measures such as conservation and water loss reduction to achieve results. Successful demand management efforts have the potential to limit the growth in demand for water, thereby changing demand projections and the timing of needed infrastructure. Demand management will not eliminate the need for the recommended investments in interim water supply infrastructure, but it does have the potential to reduce costs by delaying the investments in later years. The recommended program of infrastructure and management measures is shown in Figure 7.1.

Water conservation

It is recommended that the City develop and implement a comprehensive water conservation plan. An effective conservation plan has multiple benefits. It will reduce the risks of severe capacity restrictions or regulatory non-compliance that could result from high nitrate concentrations in Lake Bloomington and Evergreen Lake. By improving water use efficiency, the community will be better prepared for drought conditions and less likely to suffer negative economic impacts as a result. Improved water use efficiency will also reduce the demand for additional capacity, allowing investments in later years of the plan to be deferred or scaled back in capacity.

The water conservation plan should aggressively target water loss reduction by continuing the City's current meter replacement efforts and expanding efforts to reduce leakage in the distribution system to the lowest economical level. Conservation efforts to improve water use efficiency by customers will result in long-term reductions in cost to the City and it's rate-paying customers. Additional information is included in Appendix D.

Drought planning

It is recommended that the City approve a drought ordinance and implement a drought management program. The safe yield of the supplies currently available to the City are marginal in capacity. In the event of a severe drought, supplies could be reduced to an extent that has a negative economic impact on the community. Production of high-quality water is more challenging for treatment plant operators when reservoirs are depleted. Planning for drought management is critical to ensure that the City is prepared to recognize drought conditions and to proactively implement measures to conserve supplies before they are depleted. Additional information is included in Appendix E.

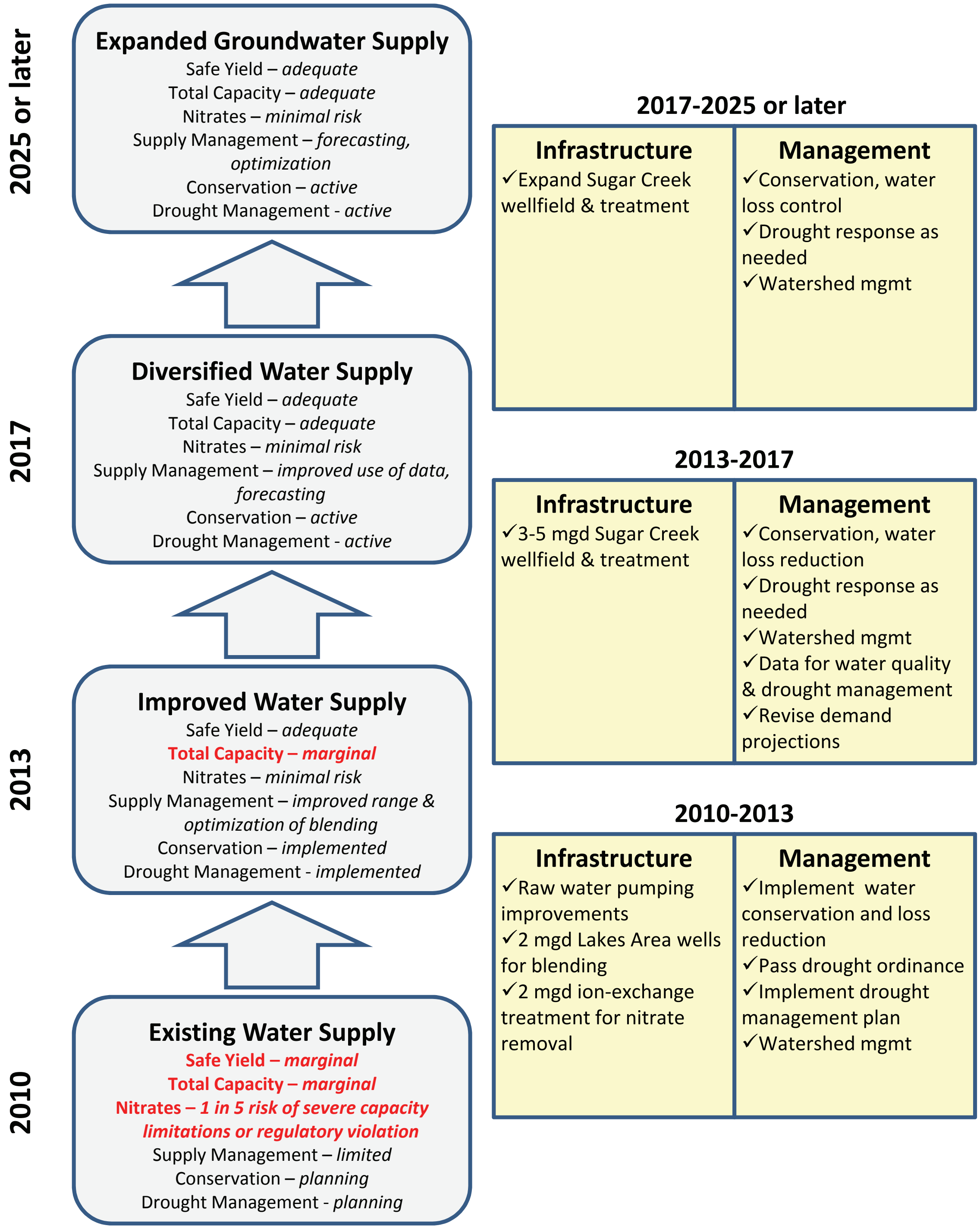


Figure 7.1: Recommended program of improvements

Watershed management

It is recommended that the City continue current watershed management efforts and seek opportunities to obtain funding to expand upon them. Agricultural activities in the watersheds of both reservoirs result in sedimentation and runoff of fertilizers and pesticides into the reservoirs. The projected safe yield of the reservoirs continuously declines due to sedimentation. The current combined safe yield of $14.8\,mgd$ is projected to decline to $14.1\,mgd$ by 2020 and $13.5\,mgd$ by 2030 (3). Runoff of fertilizers into the reservoirs results in increased concentrations of nitrates. Improvements have been recommended to manage nitrates in the source water, but the operating costs of these facilities is directly related to the concentrations of nitrates in the raw water. Over the long-term, watershed management efforts will reduce the operating cost of treatment for nitrate removal, and will preserve the safe yield of the reservoirs.

Raw water pumping improvements

Pumping and nitrate monitoring improvements are recommended for the Lake Bloomington and Evergreen Lake raw water pumping stations. The current practice of blending supplies from the reservoirs is and will remain the least-cost means of managing nitrates. Improving the flexibility of pumping operations and providing treatment plant operators with continuous monitoring of nitrate concentrations in both reservoirs will provide them with the tools needed to optimize blending. Additional details are provided in Chapter 5.

Wells for blending

The construction of wells in the area between the lakes is recommended as an immediate measure to reduce the risk of severe capacity restrictions or regulatory non-compliance that could result from high nitrate concentrations in Lake Bloomington and Evergreen Lake. It is estimated that a $2mgd$ groundwater supply available for blending with raw water from Evergreen Lake will reduce this risk from 1 in 5 to 1 in 10 in the year 2013. In conjunction with proposed ion-exchange (IX) treatment for nitrate removal, the risk will be reduced to minimal levels. The low-nitrate water from wells will reduce the operating cost of IX treatment. Additional information and specific recommendations are included in Appendix C.

Treatment for nitrate removal

The construction of ion-exchange treatment facilities is recommended to further reduce the risk of severe capacity restrictions or regulatory non-compliance that could result from high nitrate concentrations in Lake Bloomington and Evergreen Lake. Based on historical nitrate events it is estimated that, in conjunction with the wells for blending, $6\,mgd$ of IX treatment capacity will reduce this risk to minimal levels and $2\,mgd$ will provide adequate capacity to manage nitrate events in 50% of years. It is proposed that the facilities be constructed with $2\,mgd$ of permanent capacity and provisions for connecting an additional $2\,or\,4\,mgd$ of rented temporary capacity when needed. In the planning and design phase for this project, it is recommended that the mix of permanent to temporary capacity be reviewed to select the most cost effective configuration. Additional details are provided in Chapter 5.

Sugar Creek wells and treatment

The construction of a groundwater supply and treatment facility near Sugar Creek is recommended to provide needed total capacity, additional safe yield, and to diversify the City's water supply. The initial required capacity will be $3\,to\,5\,mgd$, depending on actual growth in population and water demand and the effectiveness of conservation and water loss reduction programs. Alternative transmission main routes have been proposed, one direct to minimize costs, and the other slightly longer to provide the potential for water sales to communities to the west in the near-term and for connection to the proposed regional water supply in the long-term. Additional details are provided in Appendix C and Chapter 5.

Bibliography

[Consoer Townsend Envirodyne Engineers Inc, 2007] Consoer Townsend Envirodyne Engineers Inc (2007). Draft Master Planning Study for the Water Treatment Plant. Technical report. City of Bloomington, Illinois.

[Dzielgielewski et al., 2005] Dzielgielewski, B., Yang, X., Bik, T., Margono, H., and Richey, M. (2005). County Level Forecasts of Water Use in Illinois: 2005-2025. Technical report, Southern Illinois University - Carbondale and Illinois State Water Survey.

[Farnsworth & Wylie P.C., 1990] Farnsworth & Wylie P.C. (1990). Report on Feasibility of Establishing a Regional Water Supply for Central Illinois. Technical report. McLean County Board, City of Bloomington, Town of Normal Regional Water Supply Joint Steering Committee.

[Farnsworth and Wiley, Farnsworth and Kohlhase, 1992] Farnsworth and Wiley, Farnsworth and Kohlhase (1992). Regional water supply study recommendations: Report to Mclean County Board, City of Bloomington, Town of Normal.

[Farnworth and Wiley P.C., 1993] Farnworth and Wiley P.C. (1993). City of Bloomington Water Needs Assessment Study. Technical report, Farnsworth and Wiley P.C. Bloomington, Illinois.

[ISWS, 2006] ISWS (2006). The Water Cycle and Water Budgets in Illinois: a Framework for Drought and Water-Supply Planning. I/EM 2006-02.

[McLean County Regional Planning Commission, 2009] McLean County Regional Planning Commission (2009). Mclean county regional comprehensive plan. http://www.mcplan.org. Draft 6/24/09.

Appendix A

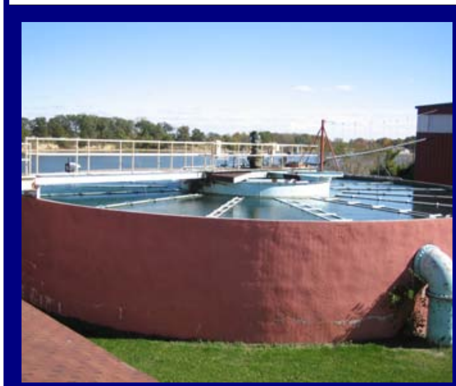
Reservoir Safe Yield Report

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK

Reservoir Yield Analysis

Prepared For:

City of Bloomington, Illinois
January, 2010



Prepared By:

Wittman Hydro Planning Associates
a division of Layne Christensen Company

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK

Reservoir Yield Analysis

prepared for
Bloomington, Illinois

January 5, 2010

Prepared by
Wittman Hydro Planning, a division of Layne Christensen Company
Bloomington, Indiana

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK

Contents

List of Figures

List of Tables

1 Introduction

WHPA performed a water supply safe yield analysis for City of Bloomington. Water is supplied to the City of Bloomington water treatment plant from Evergreen Lake, Lake Bloomington and the Mackinaw River. The amount of water that can be reliably provided by these two reservoirs and the River depends upon the volume of the lakes, local stream flow, climate, drinking water demand and the operational rules governing withdrawal of water from the two lakes and the Mackinaw River. We analyzed previous studies and data and applied a water balance model to determine the safe yield of the City of Bloomington's water supply and to answer the following questions:

1. How does the safe yield calculated by the Illinois State Water Survey (ISWS) in 1989 [Sally M. Broeren and Krishan P. Singh, 1989] compare to the safe yield calculated by PRC in 1988 [PRC Engineering, 1988]?
2. What is a useful estimate of safe yield?
3. How is the safe yield affected by the choice of the minimum level in Lake Bloomington?
4. How fast is sedimentation reducing yield and water storage volume in the lakes?
5. Can the operational rules of the Mackinaw Pumping pool be revised to increase yield?

2 Approach

To answer these questions we reviewed previous safe yield calculations for Lake Bloomington and Evergreen Lake and confirmed these results by calculating safe yield using the same non-sequential method used in previous studies. Because both of the non-sequential evaluations done previously [Terstriep et al., 1982] (ISWS Bulletin 67) could not track mass balance in the complete system, we also employed a sequential lake model to simulate historical flows to the lakes and revise the estimated safe yield. In addition to evaluating the effects of weather variations, WHPA's Sequential Lake Yield Model (SLYM) was used to consider the effect of limiting drawdown on Lake Bloomington, the effect of sedimentation and the effect of operational rules for Mackinaw River withdrawals. Specifically, we did the following:

- Review of previous safe yield calculations.

- Calculate safe yield for Lake Bloomington and Evergreen Lake using:
    1. Stage/Volume curves, sedimentation rates and non-sequential mass curve from ISWS bulletin 67.
    2. Stage/Volume curves, sedimentation rates, demand distribution, operational rules and sequential analysis of lake budget.

Fundamental concepts

The following concepts are used in understanding the safe yield analysis:

Drought Return Period: The frequency of occurrence of drought within a certain time interval which can be described as an estimate of the average time until the next occurrence of a drought of the specified magnitude. If the return period has been computed from a distribution, then the return period is equal to the inverse of the probability of the drought event occurring in the next time period. For example, a 25 year drought will occur on average, once in 25 years and there is a 1 in 25 chance (4%) that the drought will occur in any one year.

Gross draft rate: The rate at which water is removed from storage from a reservoir.

Net yield: Reservoir yield after correcting gross draft rate for evaporation losses.

Critical period: The duration of the critical drawdown period, which represents the time period during which the draft from the reservoir would exceed the inflow by the greatest amount.

Dead zone: Portion of lake below which withdrawals are not allowed, due to physical, recreational, aesthetic or other concerns.

Safe yield: The annual draft of water that can be withdrawn without exceeding minimum water levels.

2.1 Non-sequential safe yield analysis

All non-sequential safe yield analyzes described in this report were derived by analyzing a low flow series developed from daily stream flow data using the methodology of ISWS Bulletin 67 [Terstriep et al., 1982]. Flow data from 1933-1958 were used for this study due to the historical drought that occurred in 1939-1941. A partial low flow duration series was developed by identifying the most extreme low flow event for the period of record at a selected critical duration. The low flow for each year was ranked to determine the return period of the low flow event, relative to the other low flow events. This methodology assures that the data for each year is statistically independent. The difference between the accumulative draft and accumulative inflow (at the selected return period) is compared to the reservoir capacity. The period of time where the draft exceeds inflow by the greatest amount is called the critical period. In theory, many other periods may occur that are shorter or longer than the critical period, however none of these periods would be more severe than the critical duration. The non-sequential procedure is limited in that it is derived from historical minimum flows and does not allow for monthly or seasonal variations in stream flow, evaporation, precipitation and demand. The non-sequential procedure does not consider operational rules, interaction between reservoirs or provide information concerning lake levels at non-critical times.

Previous non-sequential analysis

2.1.1 PRC/CTE: 1988

A project jointly conducted in 1988 by PRC and CTE used bathymetric data from Lake Bloomington to determine a 0.502% annual capacity loss due to sedimentation. The calculated Lake Bloomington yield based on 1985 storage capacity of $7600 ac-ft.$ was determined using a mean stream flow contribution of $0.75 in/mo$. These calculations assumed no dead zone, therefore these safe yield results assume that the lakes are completely drained to provide the resultant yield. These calculations assume that the reservoir is full at the beginning of the critical period and empty at the end of the critical period. Critical duration is not based on a continuous record. The gross draft rate includes all losses from the reservoir, including pumping, evaporation and leakage. PRC determined a safe yield for Lake Bloomington of $7 mgd$ for a 1-in-25 year drought of 18 months duration. PRC calculated the yield of Lake Bloomington alone. The analysis did not consider Evergreen Lake and Mackinaw Pumping Pool.

2.1.2 Broeren and Singh (ISWS, 1989)

Broeren and Singh conducted a non-sequential mass analysis of a 20 month duration low flow series developed from daily stream flow data using the methodology of ISWS Bulletin 67 [Terstriep et al., 1982] . The yield for Lake Bloomington as reported is the sum of Lake Bloomington and Evergreen Lake. Demands were estimated for 1990, 2000, 2010 and 2020 assuming a peak demand that is 1.2 times the average demand. ET was calculated be multiplying the pan evaporation times the lake surface area at normal pool. The lake surface area for each of the calculation years was calculated as

$$log S = a + 0.33(log C) \tag{1}$$

where:

S = Surface area at normal pool

C= Capacity of the lake

Equation 1 and the value for a were derived empirically from multiple lakes in the region. They assumed that the dead zone occupied 10% of the total capacity, leaving 90% active capacity.

For the 1990 lake configuration, Broeren and Singh reported a combined safe yield for a 1-in-20 drought of $13.88 mgd$ for Lake Bloomington and Evergreen Lake combined. No data is available in ISWS Bulletin 67 for Evergreen Lake, so it is unclear how the Evergreen Lake calculations were made. Using the methods cited, WHPA calculated 1-in-20 year safe yield for Lake Bloomington of $6.89 mgd$ which would mean a safe yield of $6.99 mgd$ for Evergreen Lake, according to Broeren and Singh. This is consistent with the PRC report/CTE analysis for Lake Bloomington. The contribution of the Mackinaw Pumping pool was not considered and the increase in capacity for Evergreen Lake as a result of raising the dam was not considered. The safe yield for a 1-in-50 yr drought was reported to be $10.8 mgd$ for the two lakes.

Projections of future safe yields were based on estimated decreases in capacity due to sedimentation. Sedimentation between 1990 and 2020 decreased the 1-in-20 safe yield by $0.69 mgd$. Estimates of sedimentation and the effect on capacity were made based on data from other lakes in the region. They estimated the capacity of Lake Bloomington in 1990 to be $7411 ac-ft$. Subsequent measurements in 1990 indicated the capacity of Lake Bloomington had been reduced to $6800 ac-ft$, indicating an underestimation of sedimentation effects, which, if corrected would lead to a decrease in the predicted future safe yields .

2.1.3 Hanson Engineers/Farnsworth and Wiley (1989)

Hanson Engineers, working with Farnsworth and Wiley [Farnworth et al., 1989], report a 5-year and 25-year drought yield for Lake Bloomington and Evergreen Lake Table (1). These results are similar to previous studies and indicate that Lake Bloomington and Evergreen Lake each yield about $7 mgd$ for a 20-25 yr drought with a critical period of 18-20 months before adding the additional storage due to raising the Evergreen Lake dam.

Table 1: Hanson Engineers Drought Yields for Lake Bloomington and Evergreen Lake.

Drought Frequency	Yield (MGD) LB/EL/Total	Critical Duration (months) LB/EL
5 yr	11.2/15.3/26.5	7/10
25 yr	6.6/7.4/14	18/20

2.1.4 WHPA non-sequential analysis

The safe yield for Lake Bloomington was also calculated by WHPA, using the non-sequential method reported in ISWS Bulletin 67 [Terstriep et al., 1982]. These calculations for Lake Bloomington are in general agreement with previous calculations. A safe yield of $10.5\,mgd$ was calculated for Evergreen Lake after the $5\,ft$ increase in the dam elevation of 1995. The original ISWS and the PRC reports of safe yield are not valid today because Evergreen Lake dam has been raised and sedimentation has decreased the capacity in both lakes since the time the calculations were made in 1988. In addition, the supply of water from the Mackinaw River pumping pool depends on the combined drawdowns in Lake Bloomington and Evergreen Lake and so cannot be accurately considered without a more sophisticated approach to the safe yield calculation. For the updated analysis, we have chosen to use the sequential analysis method because it has become the preferred method for determining reservoir storage requirements [U.S. Army Corps of Engineers, 1997].

2.2 Sequential analysis

WHPA has developed a sequential model that simulates the water levels in both lakes and the contribution of the Mackinaw pumping pool to calculate safe yield for the current system. The sequential method offers the possibility of more precision than non-sequential methods, because it is based on monthly or daily water budgets rather than annual data. Thus, seasonal effects or the impacts of intense short- or intermediate-term droughts can be more accurately represented. Furthermore, the sequential method can be configured to explicit simulate the decision structure associated with management of systems that possess multiple reservoirs and/or diversion structures. Thus, the sequential method has the potential to better predict the complex interactions that may develop in Bloomington.

Sequential analysis of safe yield is based on the water budget over sequential time periods. Figure 1 illustrates the basic processes that are considered in the analysis. For each time step in the model (e.g. daily, weekly, or monthly) the model tracks lake inflows (from streams, precipitation, and diversions), withdrawals (pumping, evaporation, diversions, and

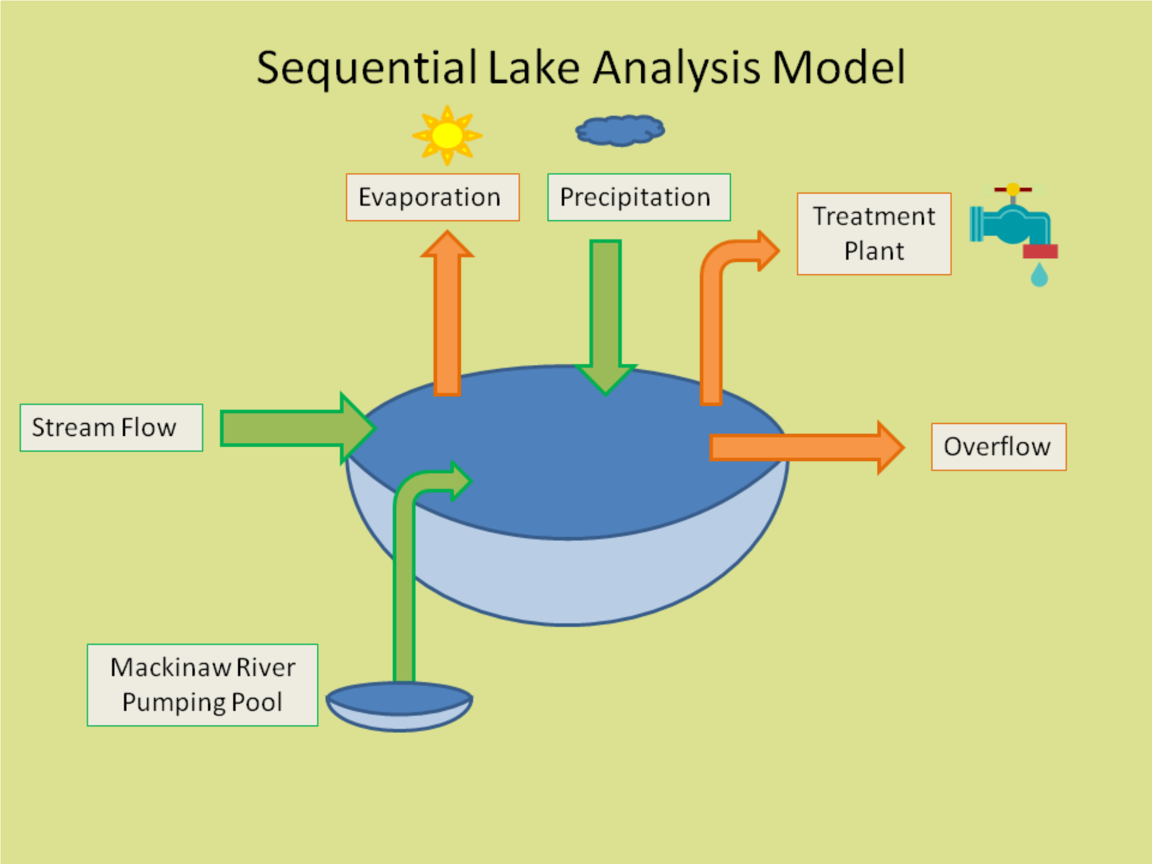


Figure 1: Diagram of Sequential Lake Model

overflow). Using a stage/volume curve for each lake, the model determines lake water levels based on the water budget for the time step. It is possible to develop a rule-based mechanism in the model that represents the management of diversions, e.g. the contribution of water from the Mackinaw River pumping pool which is calculated based on the flow in the Mackinaw River and the calculated water levels in both Lake Bloomington and Evergreen Lake.

Using historic climate and flow data, the sequential model allows the modeler to assess yield in a way that incorporates changes in volume from historic sediment deposition and the current configuration of the lakes. By running the model with historical stream flow and meteorological data, we can test any hypothetical annual demand scenario (water treatment plant pumping rate). In addition, the demand scenario can include variations during the year, allowing for a realistic simulation of the system's response to demand patterns.

All the advantages of the sequential method come at a cost, however. The model is dependent on the availability of daily or monthly data for all the input variables. Some of those data may be unavailable, e.g. tributary streams that are ungaged, or measurement

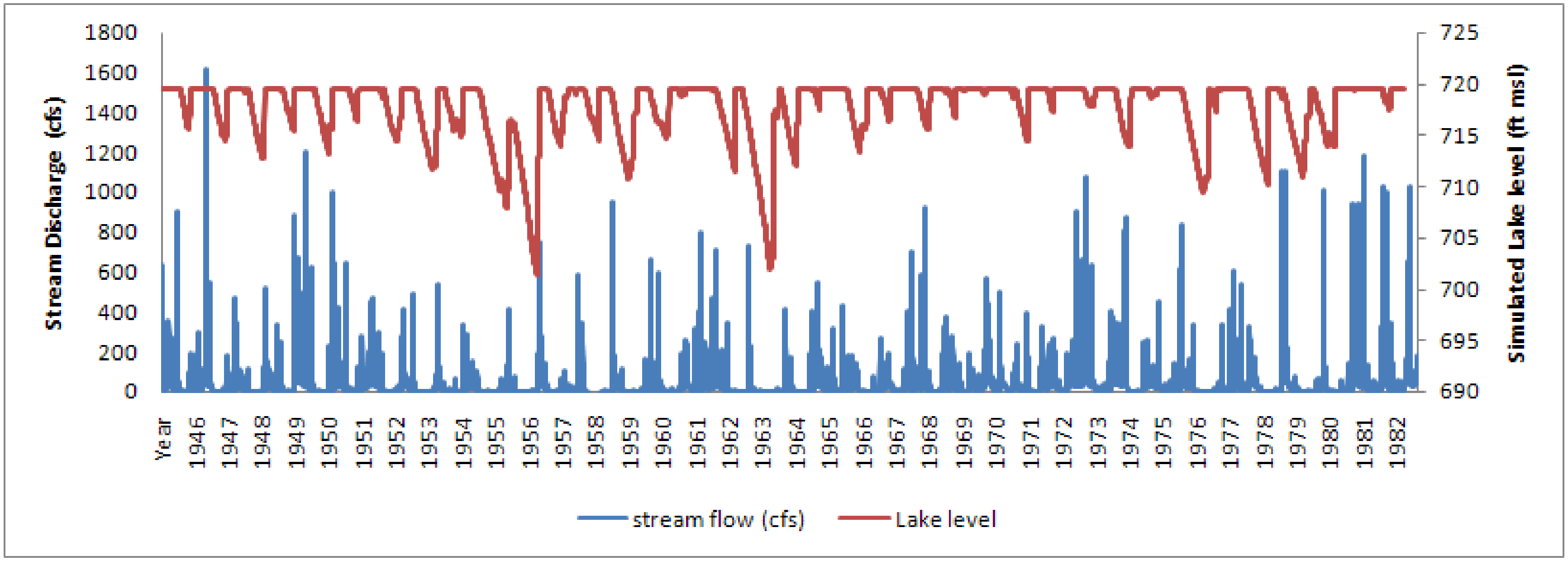


Figure 2: Money Creek stream flow (blue) and simulated water levels (red) in Lake Bloomington for the simulation period (1946-1983).

stations that cover only some parts of the period of record. In a multiple-lake system, it is nearly inevitable that this will occur. As described below, we were able to represent some of the unavailable data, but the lack of pre-1946 Mackinaw River stream flow data placed limitations on our analysis.

2.2.1 Evaluating reservoir yield with the sequential model

We used climate and flow data measured from 1946 to 1983 to evaluate yield for the combined system, consisting of Evergreen Lake, Bloomington Lake, and the Mackinaw River pumping pool. This period includes a wide range of climate conditions reflected in the stream flow data for Money Creek and the Mackinaw River. Figure 2 shows how the modeled water levels respond to two particularly severe droughts in the late 1950's and again in the early 1960's. Flows in the Mackinaw River were the input variable that determined the length of the predictive model runs; daily values for all other input data were available from 1933-1983. The lack of Mackinaw Rover flow data prior to 1946 is an important limitation, because there was a severe drought in 1939-1941. This limitation ultimately had an effect on the predicted yields from the sequential model, as will be described below.

As described above, the water supply withdrawal rate is an input data set for the sequential model. A trial-and-error approach is used to determine the safe yield of the combined system as follows. Each lake that is subject to withdrawals has a minimum water level specified in the model input. During times of drought, critical periods may occur in which the lake water level falls close to or below the minimum water level. For a particular simulation, the model determines whether the water level in either lake fell below the minimum water level at any time during the simulation. If so, it is an indication that the selected withdrawal rates in the model are unsustainable. The modeler then adjusts the water-supply demand input and runs the model again. The safe yield is the largest demand rate that can be sustained without the pool elevation falling below the minimum level of either lake at any time during the simulation period.

The sequential model should not be interpreted as an attempt to simulate the actual water levels that occurred from 1946-1983. Rather, we are simulating the response of the current system to the meteorological and hydrologic variability found in the historical record. Since Evergreen Lake was not built until 1971 and the dams for both lakes have been raised during the simulation period, the modeled water levels should not be compared to historical water levels. Similarly, we do not attempt to "calibrate" the model to the water levels in the lakes.

2.3 Sequential Lake Yield Model (SLYM)

WHPA's sequential lake yield model (SLYM) was applied to determine the combined safe yield from Lake Bloomington, Evergreen Lake and the Mackinaw pumping pool. Scenarios were developed using measured historical stream flows, precipitation, demand distributions, sedimentation rates, evaporation rates and operational parameters as input.

SLYM can be run on a monthly or daily time interval, based on the availability of data. Volumetric water balance is calculated at the end of time step *m*:

$$\Delta S_m = [\bar{A}_m(P_m - E_m) + Q_m - D_m - O_m]\Delta t_m \tag{2}$$

where:

$\Delta S_m\,[L^3]$ is the change in the lake storage over time step *m*;

$Q_m\,[L^3/T]$ is the volumetric inflow into the lake from surface waters over time step *m*;

$\bar{A}_t\,[L^2]$ is the average lake surface area over time step *m*;

$E_m\,[L/T]$ is the rate of evapotranspiration in the lake over time step *m*;

$P_m\,[L/T]$ is the rate of precipitation in the lake over time step *m*;

$D_m\,[L^3/T]$ is the water-supply demand rate over time step *m*;

$O_m\,[L^3/T]$ is the rate of outflow from the lake over time step *m*; and

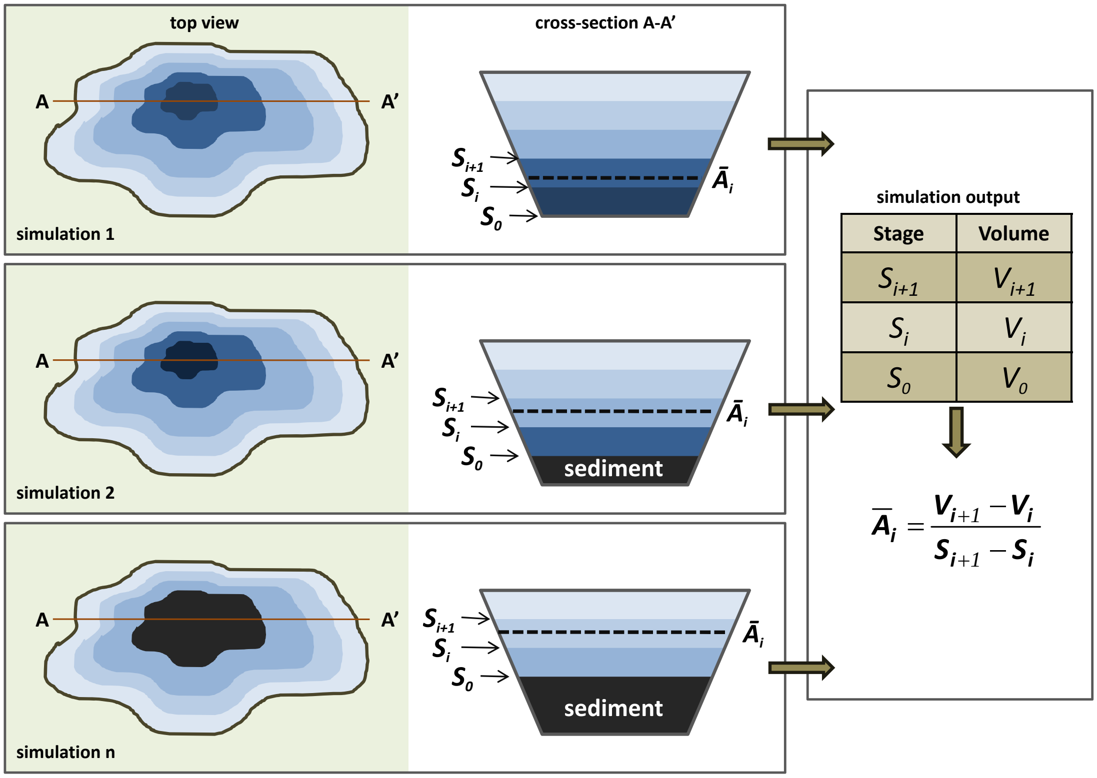
$\Delta t_m\,[T]$ is the length of time step *m*.

At the end of the time step, the new value of the lake storage S_m is computed as $S_m = S_{m-1} + \Delta S_m$ and the new volume and all the flow terms are stored to the output file.

2.3.1 Lake configuration

In each time step, SLYM requires that the change in lake stage be updated based on the water balance for that time step. It is therefore necessary for the modeler to provide a table that relates the stage to the volume of water in the lake for each lake in the simulation. In addition, SLYM requires information about the sedimentation rate and the year that the basin bathymetry data were gathered.

Each simulation is performed based on a lake configuration that is determined for a specific year. For example, assume that the sedimentation rate is $0.05\,ft/yr$ and the bathymetry were measured in 1950. If the model were based on a 2008 configuration, the bottom elevation of the lake is "raised" by $0.05\,ft/yr*(2008-1950)$, or $2.9\,ft$. The stage/volume table



Stage	Volume
S_{i+1}	V_{i+1}
S_i	V_i
S_0	V_0

$$\bar{A}_i = \frac{V_{i+1} - V_i}{S_{i+1} - S_i}$$

Figure 3: Using the stage-volume table to estimate lake surface area and volume during the simulation.

is adjusted similarly. For each elevation in the stage/volume table, the amount of water represented by the new bottom elevation in the original table is subtracted from each volume, and the "zero volume" stage is set to the adjusted bottom elevation. During the simulations, the stage-to-volume and volume-to-stage conversions are performed by simply interpolating the input stage/volume table. For the lake's area, the task is more complicated. The entire process is illustrated in Figure 3.

Some water inputs and withdrawals are measured in terms of the surface area of the lake, for example, rainfall into the lake or evaporation from the lake surface. The surface area is dependent on the stage/volume relationship, and must be adjusted accordingly during the simulation. This is done as follows. Between each pair of consecutive entries in the stage/volume table, (s_i, v_i) and (s_{i+1}, v_{i+1}), the difference in volume $v_{i+1} - v_i$ corresponds to the stage change $s_{i+1} - s_i$. Thus, over the interval $[s_i, s_{i+1}]$ the average lake surface area may be estimated as:

$$\bar{A}_i = \frac{v_{i+1} - v_i}{s_{i+1} - s_i} \tag{3}$$

It is implicit in this analysis that the average area $\bar{A}_i$ is assigned at the center of the elevation interval $\bar{s}_i = \frac{1}{2}(s_i + s_{i+1})$. A table of $(\bar{s}_i, \bar{A}_i)$ entries is computed from the adjusted stage/volume relationship. The surface area A_{i+1} corresponding to each lake stage s_{i+1} may then be computed by interpolating between entries $(\bar{s}_i, \bar{A}_i)$ and $(\bar{s}_{i+1}\bar{A}_{i+1})$. By this approach, a table of $(s_{i,}, V_i, A_i)$ triplets is produced from the adjusted stage/volume relationship. The critical feature of the table that is generated in this manner is that it guarantees that integrating the surface area over each volume interval is consistent with the volume difference,

$$V_{i+1} - V_i = \int_{s_i}^{s_{i+1}} A ds \tag{4}$$

This formulation therefore ensures that water balance errors will not result from the manner in which the stage/volume data are managed.

2.3.2 Implicit solution scheme

The water balance is dependent on the amount of all the volumetric sources and withdrawals from the model. However, the precipitation input and evaporation withdrawal volumes are dependent on the surface area of the lake during the time step. An implicit formulation is used to achieve a solution that conserves flow. It is assumed that, if the area changes during a time step, there is an average area during the time step that is a linear function of the areas at the beginning and at the end of the time step. For time step m, the average area $\bar{A}_m$ is defined as

$$\bar{A}_m = \alpha A_m + (1 - \alpha A_{m-1}) \tag{5}$$

where α is a constant between 0 and 1. For a completely explicit solution, $\alpha = 0$, and for a completely implicit solution, $\alpha = 1$. Typically, the user will select a value of $\alpha = 0.5$, which assumes a roughly-linear variation in the lake surface area over the time step. For our simulations, we used $\alpha = 0.5$.

2.3.3 Rules for the simulation

During the simulation, the following rules are used to configure the boundary conditions for the lake.

- When the reservoir capacity is exceeded, the excess water flows over the dam and the lake is at normal pool level.

- Safe yield is exceeded when the maximum acceptable drawdown is exceeded.

- Lake stage and surface area are determined by the stage volume curves. Lake surface area is only used for calculation of precipitation and evaporation at the Lake. For the Bloomington model the stage/volume tables produced by Hanson Engineering were used.

- Lake evaporation (in inches) is calculated from the input evaporation series and input pan coefficients. The input rate can be given as a daily, monthly or annual times series. A monthly evaporation rate is derived from measurements reported for Champaign, Illinois. The average evaporation from these data were used to generate a time series of daily rates that repeat on an annual basis. For the Bloomington model, pan evaporation at Champaign was multiplied by a pan coefficient ranging from 0.55-0.65.

- Stream flow is provided as daily or monthly time series. As discussed above, some data inputs have not been gaged, and so synthetic data sets must be created. Time series for areas of ungaged stream flow are created using gaged stream flows and a scaling factor. For the Bloomington model, flows were available for Money Creek. The ungaged flow into Evergreen Lake is proportional to the Money Creek flows using the ratio of the drainage areas for Money Creek and the Evergreen Lake watershed as a proportionality constant. Similarly, the ungaged flows into Lake Bloomington were based on Money Creek flows and the ratio of gaged to ungaged watershed areas.

Mackinaw pumping pool rules Rules for use of the Mackinaw Pumping pool were implemented as described in the permit. The permit allows for withdrawals from the Mackinaw River based on the combined drawdown in the two lakes, the discharge in the Mackinaw River, and the day of the year as the rules vary seasonally.

This is implemented in the water balance model for time step m as follows:

1. If $D_{m-1} > D_{on}$ and $Q_{mac(t)} > Q_{reg(t)}$ then turn the pump on
2. If the pump is operating and $D_{m-1} > D_{off}$ then turn the pump off

where:

D is the combined drawdowns of Lake Bloomington and Evergreen Lake below normal pool level.

D_{on} is the level of D needed to turn on pumping from Mackinaw pool (currently $8\,ft$) .

Q_{mac} is the discharge of the Mackinaw River at Congerville.

Q_{reg} is $100\,cfs$ from March through June, $20\,cfs$ at all other times.

D_{off} = regulated combined drawdowns for turning pump off (currently $4\,ft$).

Once the "drawdown" threshold is reached (item 1 above) and the pump is turned on, it remains on for future time steps, until it is turned off when the "lakes are full" threshold is reached (item 2 above). When the pump is operating, the model adds water to Evergreen Lake at a rate of $14,000\,gpm$. In the model code, the Mackinaw diversion code was implemented in a manner that allows the modeler to reconfigure the operational rules. In predictive simulations, we assessed the potential for increasing total yield by modifying the rules.

Simulating water supply demand Water supply withdrawals vary with demand during the course of the year. Typically, summer demand is larger than in winter, but peak demands may occur throughout the year. For the sequential analysis, the daily or monthly water budget for the two Bloomington reservoirs are tracked explicitly. Water availability is often smaller in summer due to increased evaporation, and it is very likely that the combination of high demand and reduced supply might lead to shortage. Indeed, the need to simulate these interactions is an important reason for using the sequential analysis.

Withdrawals for water treatment can be entered into the model as annual, monthly, or daily time series. For the Bloomington model, the demand distribution is modeled as a time series of daily demands that vary from month to month and repeat from year to year. The annual data entry, in MGD, for each lake is scaled with the monthly demand schedule, according to the monthly distributions shown in Figures 4 and 5 as follows. For each month $j\,(j = 1,2,\ldots,12)$, a table of peak demand values $\hat{q}_j$ and average demand values $\bar{q}_j$ are tabulated. The modeler selects either the monthly average or monthly peak values to be used to allocate monthly demand.

After selecting the daily or peak flow table as an allocation source, the modeler enters a value for annually averaged demand Q_{annual} to be used in the model. For month j, the demand q_j is determined from the allocation tables as

$$q_j = \frac{\bar{q}_j}{\sum_{j=1}^{12} \bar{q}_j} Q_{annual} \tag{6}$$

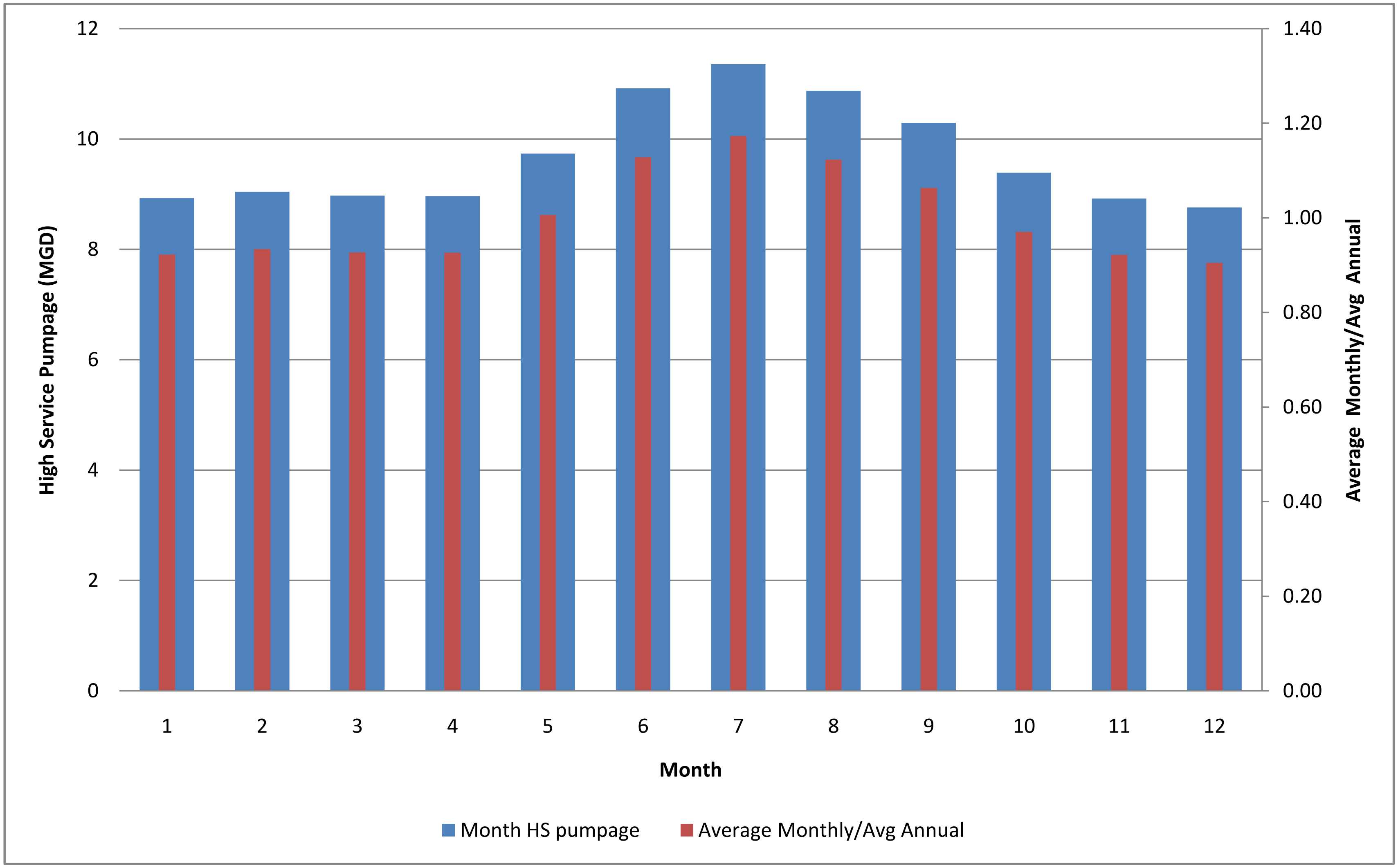


Figure 4: Average demand distribution for Bloomington, Illinois

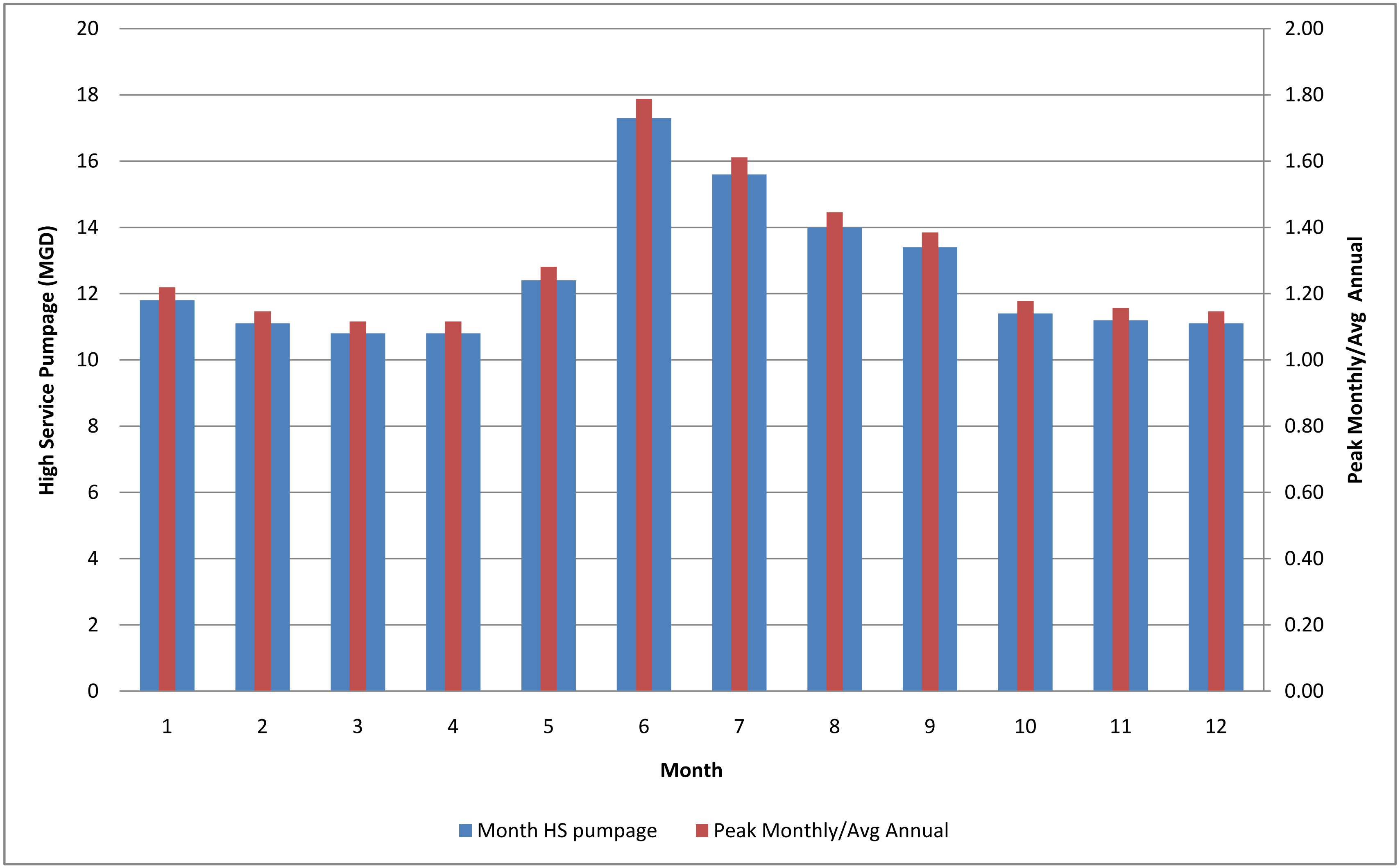


Figure 5: Peak demand distribution curve for Bloomington, Illinois

Table 2: Lake configuration parameters for Bloomington SLYM model.

Lake	Drainage Area (sq mi)	Capacity(Acre-ft)**	Surface area (acres)
Lake Bloomington	69	6767	540
Evergreen Lake	40	15627	900

** This is the 1999 capacity. Capacities were adjusted to reflect sedimentation or dead zones.

for allocation based on monthly average flows or

$$q_j = \frac{\hat{q}_j}{\sum_{j=1}^{12} \hat{q}_j} Q_{annual} \tag{7}$$

for allocation based on monthly peak flows.

For this analysis, we have used the monthly average flows to allocate the annual water supply withdrawals.

2.3.4 Model parameters

The drainage area, capacity and surface areas of each lake are the parameters used for initial lake configuration and are shown in Table 2. In addition to these parameters, parameters that are used for each simulation are listed below with the input units required:

- Lake Bloomington annual average demand [MGD]
- Evergreen Lake annual average demand [MGD]
- Initial year - This is the year that the initial stage volume curves and configuration data were measured [yr].
- Sedimentation year - this is the year for which the model sedimentation and stage/volume/surface area curve is calculated [yr].
- model time step - this is the difference between t and t-1 in equation (1) [daily or monthly].
- Lake Bloomington pan factor [-].
- Evergreen Lake pan factor [-].

2.3.5 Model output

Figure 6 is an example of the graphical output from SLYM. The information displayed includes key input parameters and model results.

Simulation information displayed in graphics:

Annual demand The simulated average annual demand for Lake Bloomington (LB) and Evergreen Lake (EL) are displayed in the left column above the graphic.

Year Year used to calculate lake capacity based on sedimentation rate.

Eff. Cap Effective capacity of lake, based on sedimentation and limits on lake level drawdown.

Eff. Bottom Bottom of lake, based on sedimentation and limits on lake level drawdown.

Min Elev Lowest water level (expressed in elevation above mean sea level) occurring during the simulation.

Cap Exceeded Is 0 if Lake capacity is not exceeded, or 1 if lake capacity is exceeded. After the minimum elevation is reached, subsequent water levels computed by the model are not relevant, since the water demand has been exceeded.

Max Days DD: Maximum number of continuous days that the water level in the lake is decreasing.

The results of the sequential analysis are presented as a graphical display of lake water levels and simulation parameters for the safe yield condition, as in Figure 6. Plots for simulations in which the demand exceeds the capacity are not provided. Lake water levels are plotted in feet above mean sea level ($ft\,amsl$) over time, with the red plot representing Lake Bloomington levels and the blue plot representing Evergreen Lake levels. The years indicated on the time axis are the years used to provide model input for stream flow, precipitation and evaporation. Key results are displayed and discussed in the following section .

2.4 Predictive modeling

We addressed the following questions in our model simulations:

1. What is the maximum safe yield for the combined Lake Bloomington, Evergreen Lake and the Mackinaw Pumping Pool?

2. What is the longest period of continuous drawdown for Lake Bloomington and Evergreen Lake?

3. How do the operational rules for the Mackinaw River pumping pool affect its yield?

4. What changes to the Mackinaw River pumping rules would increase this yield?

5. How do limits on Lake Bloomington drawdowns effect this yield?

Tables shows key scenarios simulated by the SLYM model. Scenarios vary by the demand type (peak or avg), simulation year, limits on Lake Bloomington drawdown, contribution of Mackinaw pumping pool, simulation start date and lake drawdowns triggering the operation of the Mackinaw pumping pool, D_{off} and D_{on}. In addition, the sensitivity of simulations to estimated parameters is explored by varying the pan coefficient used to estimate evaporation from the lake surface.

The simulation year is used to reflect sedimentation effects. The 2008 simulations provide the safe yield for the current system. Assuming a 20 year planning horizon, we use the 2028 simulation year for most scenarios. Simulations that explore the effect of operations vary the operational parameters, D_{off} and D_{on}, which are the combined lake level drawdowns that switch the Mackinaw pumping pool on and off.

The start year is the beginning of the simulation time period, which is determined by the availability of stream flow and precipitation data required by the model. For simulations that include Lake Bloomington, Evergreen Lake and the Mackinaw Pumping pool, this period is from 1946-1983. For simulations that do not include the Mackinaw pumping pool, the period is extended to 1933-1983. This is because there is stream flow and precipitation available for the two lakes beginning in 1933, but the stream flow data for the Mackinaw River regulation is only available after 1946.

Scenarios evaluating the effect of demand distribution use either the peak or the average demand distribution, which are described in section 2.3.3. For scenarios that use average demand distributions and do not exceed the lake capacity, the demand is the safe yield. For scenarios that use a peak demand distribution and don't exceed the lake capacity, the safe yield is 1.3× demand. Scenarios in which the lake capacity is exceeded are reported here in order to report on the maximum days of drawdown that will occur before the lake fails.

Table 3: Simulations used in the sensitivity analysis.

Case Name	**Safe Yield**		**Model Year**	**Demand Type**	**Max LB DD**	**Effective Bottom**		**Max Days Drawdown**		**Pan Coefficient**	**Mackinaw Diversion**	**Start Year**	**D_on [ft]**	**D_off [ft]**
	LB	**EL**				**LB**	**EL**	**LB**	**EL**					
Sedimentation effects														
base_1999	5.3	8.7	1998	avg	no limit	688	671	811	1344	0.6	off	1901	8	4
base_2008	5.2	8.5	2008	avg	no limit	694	687	809	1144	0.6	off	1901	8	4
base_2018	5.1	8.2	2018	avg	no limit	697	692	803	1139	0.6	off	1901	8	4
base_2028	4.9	7.8	2028	avg	no limit	699	695	803	996	0.6	off	1901	8	4
base_2038	4.8	7.5	2038	avg	no limit	701	698	704	992	0.6	off	1901	8	4
base_2048	4.7	7.1	2048	avg	no limit	703	701	697	989	0.6	off	1901	8	4
Impact of maximum LB drawdown														
dd_10_2028	4	7.8	2028	avg	10	709	695	687	996	0.6	off	1901	8	4
dd_15_2028	4.6	7.8	2028	avg	15	704	695	692	996	0.6	off	1901	8	4
dd_20_2028	4.9	7.8	2028	avg	20	699	695	903	996	0.6	off	1901	8	4
Peak demand simulations														
peak_2028	3.8	6	2028		no limit	699	695	808	995	0.6	off	1901	8	4
peak_dd_10_2028	3.1	6	2028		no limit	709	695	687	995	0.6	off	1901	8	4
peak_dd_15_2028	3.5	6	2028		no limit	704	695	691	995	0.6	off	1901	8	4
peak_dd_20_2028	3.8	6	2028		no limit	699	695	808	995	0.6	off	1901	8	4
Pan evaporation sensitivity														
pan_57_2028	5	7.9	2028	avg	no limit	699	695	803	997	0.57	off	1901	8	4
pan_63_2028	4.9	7.8	2028	avg	no limit	699	695	803	997	0.63	off	1901	8	4
pan_66_2028	4.9	7.8	2028	avg	no limit	699	695	803	998	0.66	off	1901	8	4
Operational scheme changes														
ops_8_0_2028	6.5	15.2	2028	avg	no limit	699	695	668	996	0.6	off	1946	8	0
ops_6_0_2028	6.5	15.6	2028	avg	no limit	699	695	668	997	0.6	off	1946	6	0
ops_6_4_2028	6.5	13.5	2028	avg	no limit	699	695	668	694	0.6	off	1946	6	4
Mackinaw Yield Runs														
base_1946_1999_div_25	6.8	10.9	1998	avg	no limit	688	671	669	1071	0.6	on	1946	8	4
base_1946_1999_nodiv	6.9	9.7	1998	avg	no limit	688	671	669	1835	0.6	off	1946	8	4
base_1946_2008_div_25	6.8	10.6	2008	avg	no limit	694	687	669	1000	0.6	on	1946	8	4
base_1946_2008_nodiv	6.8	9.4	2008	avg	no limit	694	687	669	1441	0.6	off	1946	8	4

Table 3: Simulations used in the sensitivity analysis.

Case Name	**Safe Yield**		**Model Year**	**Demand Type**	**Max LB DD**	**Effective Bottom**		**Max Days Drawdown**		**Pan Coefficient**	**Mackinaw Diversion**	**Start Year**	**D_on [ft]**	**D_off [ft]**
	LB	**EL**				**LB**	**EL**	**LB**	**EL**					
base_1946_2018_div_25	6.7	10.3	2018	avg	no limit	697	692	669	996	0.6	on	1946	8	4
base_1946_2018_nodiv	6.7	9.2	2018	avg	no limit	697	692	669	1368	0.6	off	1946	8	4
base_1946_2028_div_25	6.5	9.9	2028	avg	no limit	699	695	668	994	0.6	on	1946	8	4
base_1946_2028_nodiv	6.5	8.8	2028	avg	no limit	699	695	668	1344	0.6	off	1946	8	4
base_1946_2038_div_25	6.4	9.6	2038	avg	no limit	701	698	668	992	0.6	on	1946	8	4
base_1946_2038_nodiv	6.4	8.4	2038	avg	no limit	701	698	668	1141	0.6	off	1946	8	4
base_1946_2048_div_25	6.2	9.3	2048	avg	no limit	703	701	667	991	0.6	on	1946	8	4
base_1946_2048_nodiv	6.2	8	2048	avg	no limit	703	701	667	1001	0.6	off	1946	8	4

Adapting model results for the 1939-1941 drought As discussed above, the period of record for the daily Mackinaw River discharge began in 1946, five years after the drought of record. This presents some difficulty in predicting the overall yield of the system. We have computed the total yield of the system by separately determining the yield of Lake Bloomington and Evergreen Lake using the 1939-1941 drought, then adding a separately-determined yield value for the Mackinaw River diversion. With the exception of the runs that were used to determine the Mackinaw pumping pool yield, all simulations were executed with the Mackinaw River diversion disabled, and using precipitation data from 1901-2002.

For the yield of the Mackinaw River pumping pool, it was necessary to use the 1946-2002 data. We have used the model to separately estimate the safe yield for the Mackinaw River diversion based on the 1963-1964 drought, as follows:

1. Run the model using 1946-2002 precipitation data, and with the diversion enabled.
2. Re-run the model using 1946-2002 precipitation data, and with the diversion disabled.
3. Compute the yield of the Mackinaw river diversion by subtracting the Evergreen Lake yield in run #2 from the Evergreen Lake yield in run #1.

For the runs in which the Mackinaw diversion was enabled, it was pumped at a rate of $3500\,gpm$. This represents 25% of the $14,000\,gpm$ allowable pumping rate. The reduction accounts for the fact that the intake structure cannot be pumped continuously; the pump

Table 4: Simulated yield of the Mackinaw River diversion, 1999-2048.

Year	With diversion	Without diversion	Mackinaw yield	Adjusted yield
1999	10.9	9.7	1.2	1.0
2008	10.6	9.4	1.2	1.0
2018	10.3	9.2	1.1	0.9
2028	9.9	8.8	1.1	0.9
2038	9.6	8.4	1.2	1.0
2048	9.3	8.0	1.3	1.1

must be turned on and off during the day whenever the diversion is in use. The 25% operational factor was recommended by Rick Twait [personal communication].

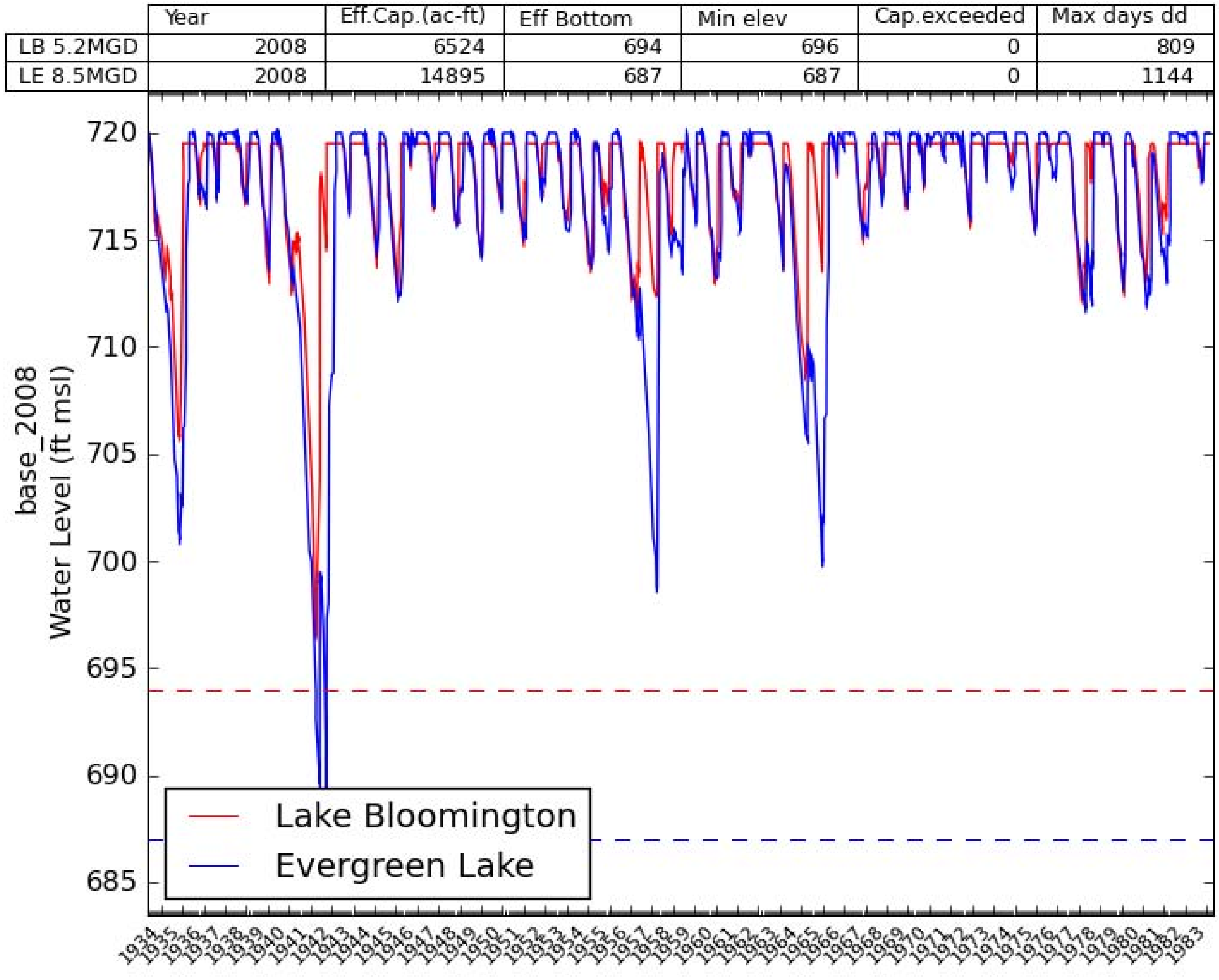
Once the yield of the Mackinaw River diversion was known, the total yield of the system is computed by adding the 1939-1941 yields of Evergreen Lake and Lake Bloomington to the separately simulated Mackinaw River pumping pool yield. As a safety factor, we computed the total yield using only 80% of the simulated Mackinaw River pumping pool. This is a conservative assumption, representing the likelihood that in a drought that is more severe than in 1963-1964, the discharge of the river might frequently fall below the minimum value, making it impossible to operate the diversion.

Estimating the extent of the Mackinaw River pumping pool Because there is no stream flow data for the Mackinaw River, we cannot include the effect of the Mackinaw pumping pool for the 1939-41 drought. However, we can estimate the increased water availability from the Mackinaw River in the mid-60s drought. We configured one model run to disable the Mackinaw pumping pool, but with the remaining input time series data truncated at 1946. This allowed us to estimate the overall yield of the system without the Mackinaw River. For example, based on the 2028 configuration, the combined yield of $13.1\,mgd$ was reduced to $8.8\,mgd$ by eliminating the Macinkaw River pumping pool. Thus, in 2028 we estimate the impact of the Mackinaw River pumping pool to be $4.3\,mgd$ (Table 5).

provides yield estimates for the Mackinaw River diversion for the period 1999-2048. The adjusted yield values include the 80% safety factor and are used in the analysis below to establish the total safe yield for the system.

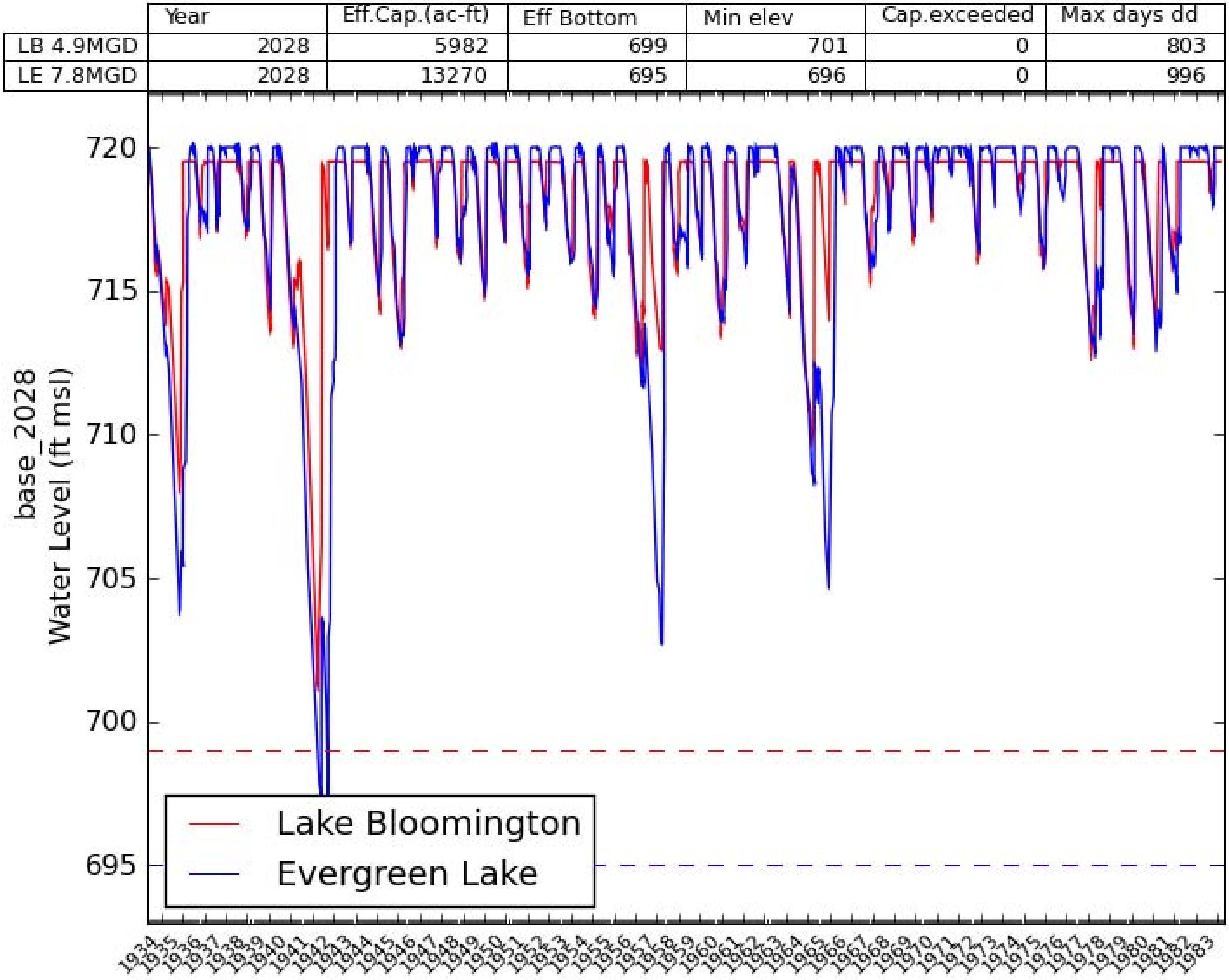
2.4.1 Safe yield with current operations

The calculated safe yields are affected by the assumed sedimentation rates, operating conditions and the inputs used in the model. Figure 6 shows the response of the lakes for the time period 1934-1984, with a safe yield of $5.2 mgd$ from Lake Bloomington and $8.5 mgd$ from Evergreen Lake. As discussed above, these values exclude the yield of the Mackinaw River pumping pool, which is $5.0 mgd$ for 2008. Adjusting the Mackinaw River pool with the 80% safety factor, the total safe yield is $17.8 mgd$. Assuming current operations and reported sedimentation rates, the safe yield in 2028 (see Figure 7) would decrease to $16.9 mgd$. The modeled water levels for both lakes are provided in figures 6 through . For most of the simulations that were run, the 1963-1964 drought proved to be the critical drought for Evergreen Lake, however in many simulations the smaller capacity of Lake Bloomington was exceeded in 1957.



	Year	Eff.Cap.(ac-ft)	Eff Bottom	Min elev	Cap.exceeded	Max days dd
LB 5.2MGD	2008	6524	694	696	0	809
LE 8.5MGD	2008	14895	687	687	0	1144

Figure 6: Sequential analysis for year 2008 without Mackinaw pumping pool. Lake Bloomington demand is $5.2\,mgd$ and Evergreen Lake demand is $8.5\,mgd$. Inclusion of the Mackinaw River pumping pool adds $4.0\,mgd$, for a total yield of $17.7\,mgd$.



	Year	Eff.Cap.(ac-ft)	Eff Bottom	Min elev	Cap.exceeded	Max days dd
LB 4.9MGD	2028	5982	699	701	0	803
LE 7.8MGD	2028	13270	695	696	0	996

Figure 7: Sequential analysis for year 2008 without Mackinaw pumping pool. Lake Bloomington demand is 4.9 *mgd* and Evergreen Lake demand is 7.8 *mgd*. Inclusion of the Mackinaw River pumping pool adds 3.4 *mgd*, for a total yield of 16.1 *mgd*.

2.4.2 Effect of sedimentation

The effect of sedimentation on lake capacity is seen by comparing the safe yields using for various configuration years. The effect of sedimentation is based on rates calculated from sedimentation studies [Hanson Engineers, Inc., 1989] and [Committee, 2008]. Capacities were calculated by SLYM based on a loss of 0.4% per year for Lake Bloomington and 0.502% per year for Evergreen Lake. The 1999 capacity of $6767\,acre-ft$ for Lake Bloomington was reduced to $6524\,acre-ft$ for 2008 and the 1999 capacity of $15,627\,acre-ft$ for Evergreen Lake was reduced to $14,895\,acre-ft$ for 2008. In a similar manner the model was run for configuration years 2018, 2028, 2038 and 2048. Figure 8 shows the modeled effect of sedimentation on safe yield in which the yield is reduced by about $0.5-2.0\,mgd$ per decade.

The effect of sedimentation on the safe yield for Lake Bloomington and Evergreen Lake differ because of the total capacity of the lakes and the percentage loss of capacity due to sedimentation. Figure 9 shows the projected reduction in capacity for both lakes that occurs due to sedimentation. Because the volume of capacity loss is much greater for Evergreen Lake than Lake Bloomington, the impacts of sedimentation on safe yield are much greater for Evergreen Lake. The simulated response of Lake Bloomington to sedimentation is shown in Figure 10. Sedimentation does not have a large effect on safe yield, which remains at $7.1\,mgd$ until 2048. In 2088 the sedimentation effect is large enough to decrease the capacity by $0.5\,mgd$. Most of the reduction in safe yield due to sedimentation is attributed to losses in Evergreen Lake capacity. Figure 11 shows this effect of sedimentation,which ranges from $0.5-2.0\,mgd$ per decade. Although the reported percentage sedimentation loss is similar for the two lakes, for Evergreen Lake this 0.5% loss in capacity represents a large loss in volume and thus a large decrease in safe yield.

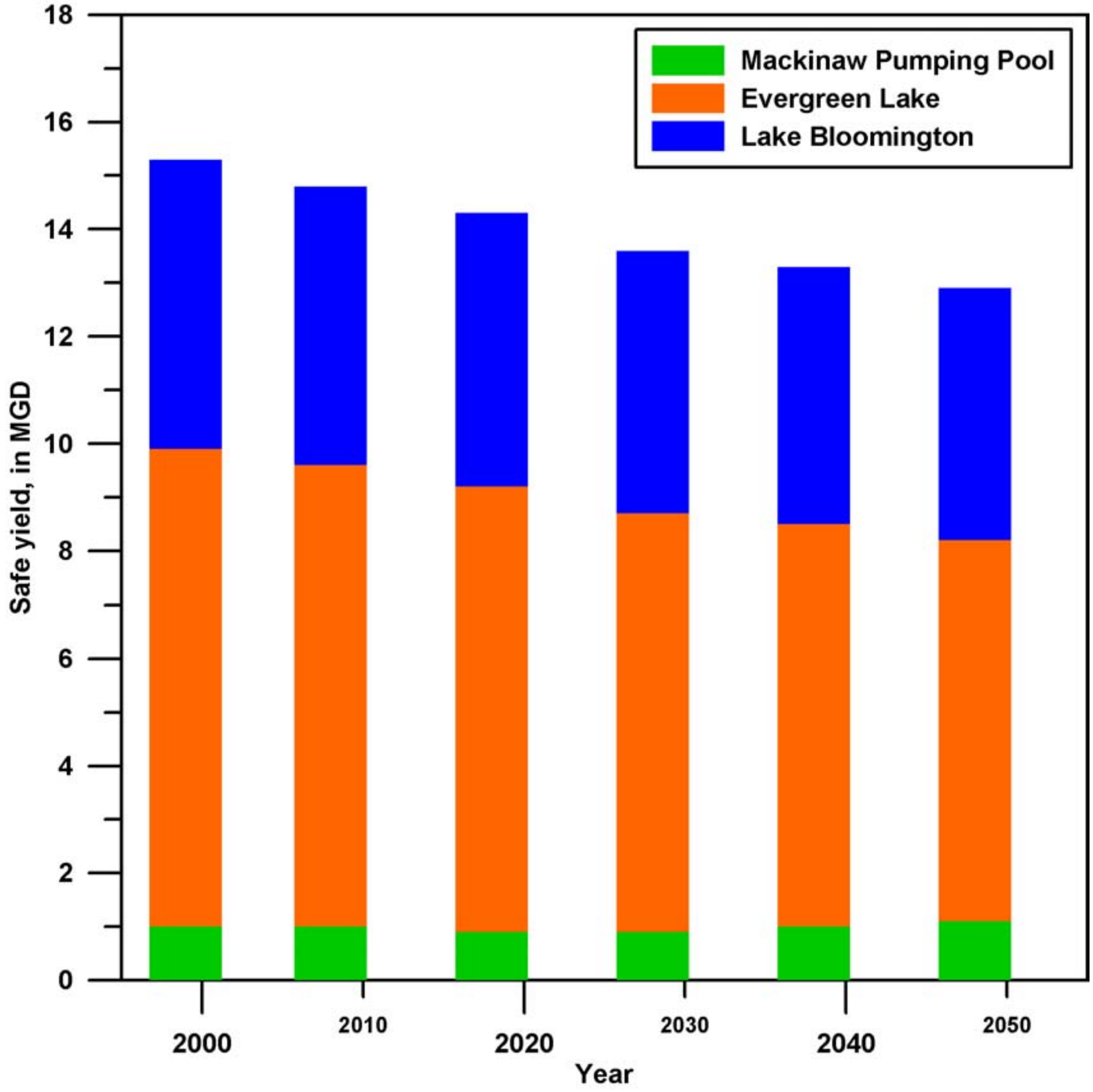


Figure 8: Effect of sedimentation on safe yield. Each line represents a contribution to the total yield, in combination with the lines below.

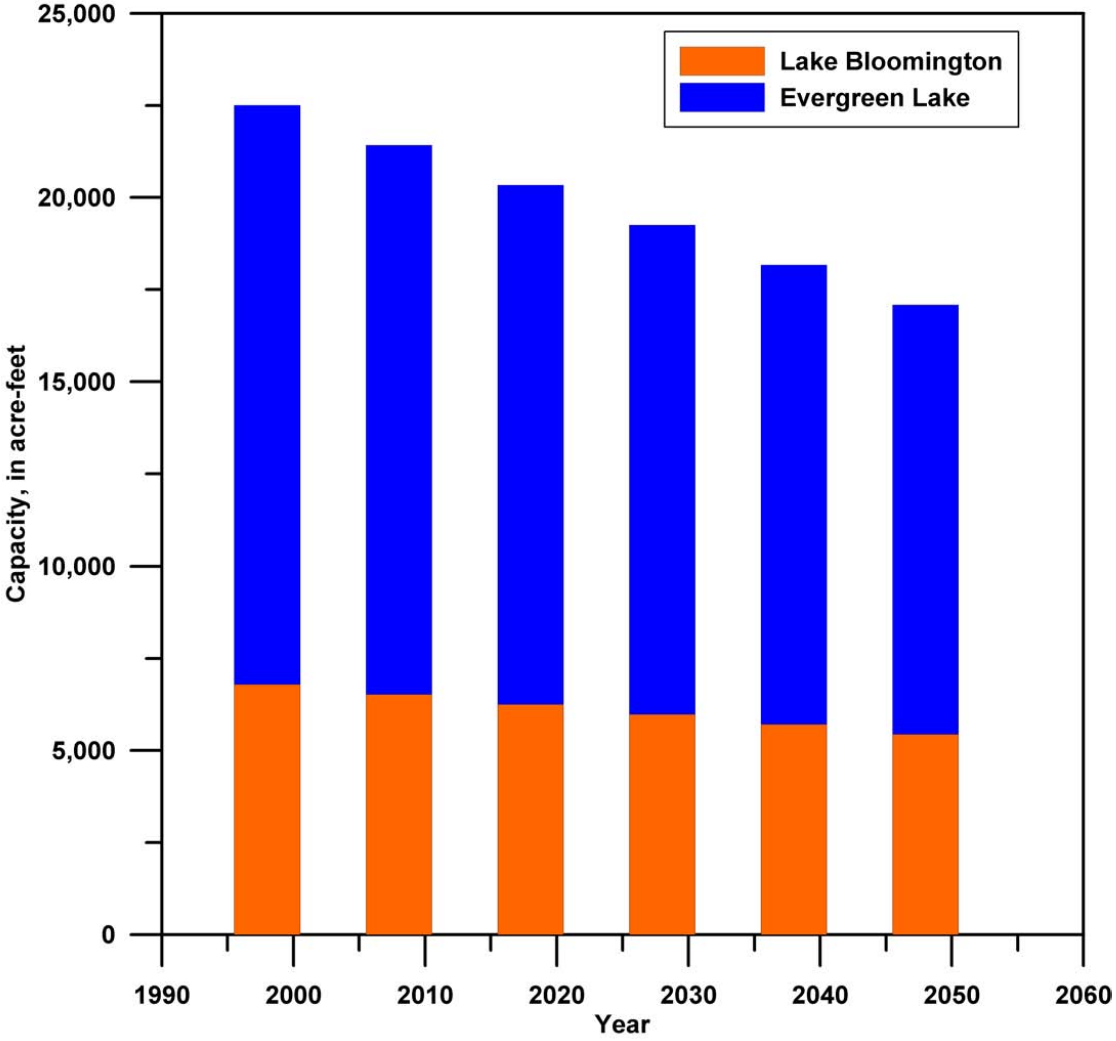


Figure 9: Simulated capacity loss due to sedimentation

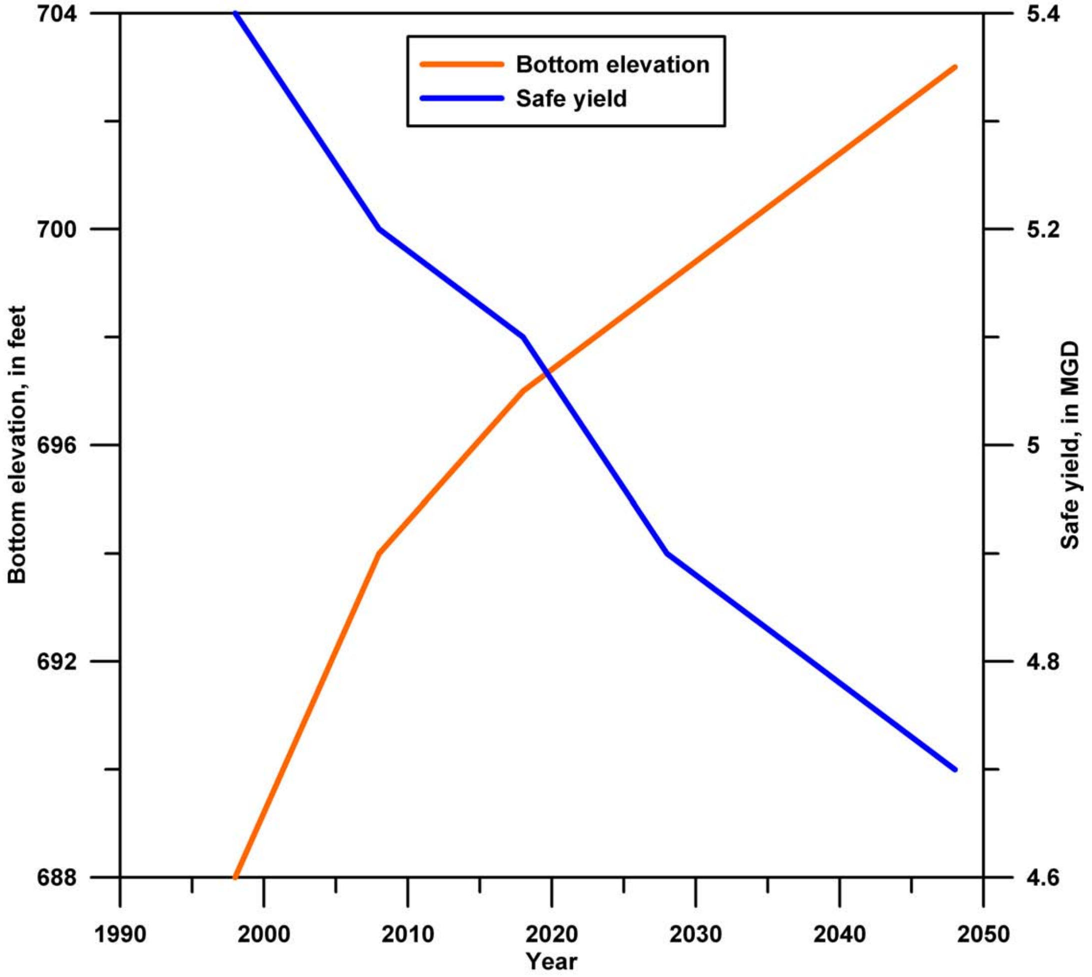


Figure 10: Simulated effect of sedimentation of Lake Bloomington bottom elevation, minimum water levels and safe yield.

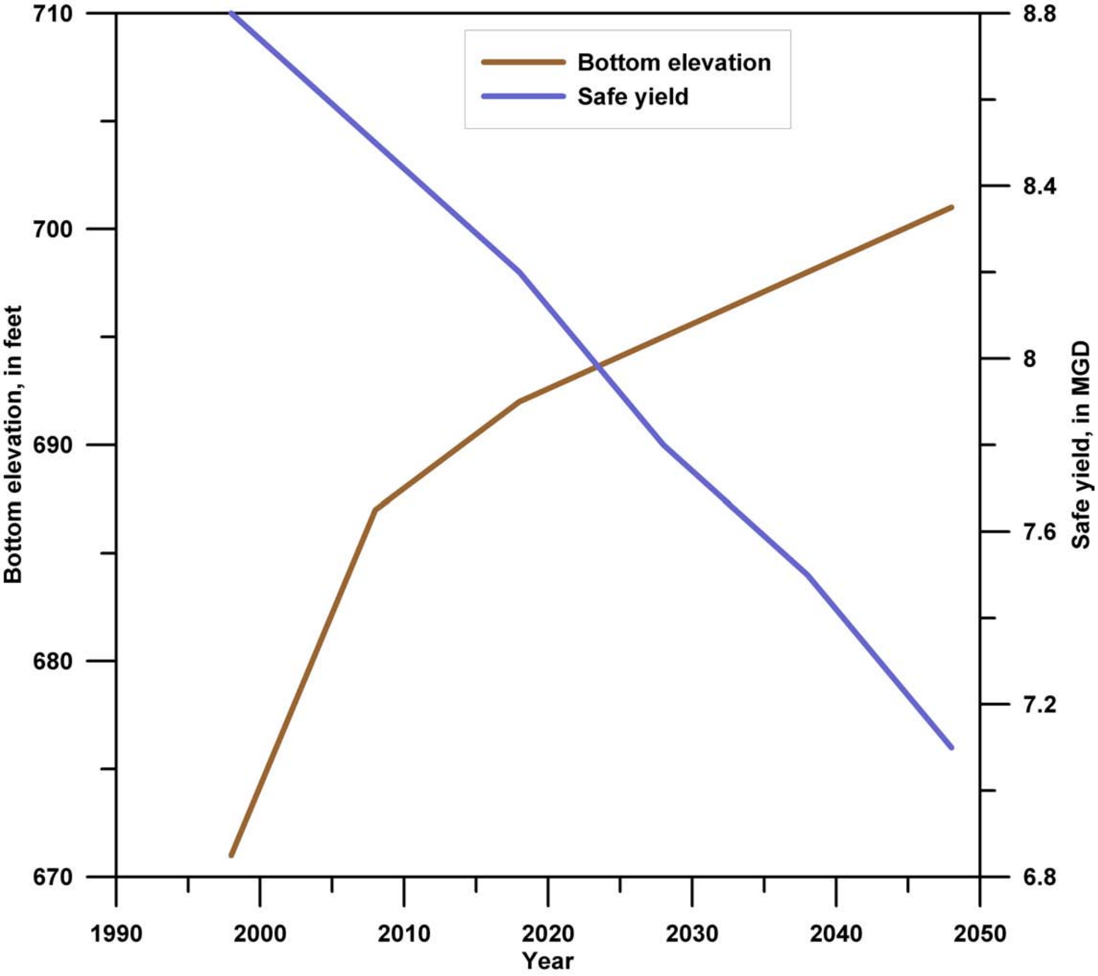


Figure 11: Simulated effect of sedimentation of Evergreen Lake bottom elevation, minimum water levels and safe yield.

2.4.3 Effect of drawdown limitations

The minimum level of drawdown for a lake can be defined based on lake bathymetry, the elevation of intake structures, government regulations, recreational needs or social expectations. There are no regulations regarding the maximum drawdown for either Lake Bloomington or Evergreen Lake and therefore previous safe yield estimates have been based on the assumption that all or most of the lake capacity could be used for water supply. PRC (1988) assumed all of the capacity was available. Boeren and Singh (1989) assumed 90% of the lake capacity was available.

Figure 12 shows the effect of drawdown limitations on safe yield for Lake Bloomington. For the sequential analysis, we looked at the effect on average yield for the 1934-1983 simulation period for the year 2028. If the allowable drawdown in Lake Bloomington is limited to the lake bottom (699 ft in 2028), the average annual safe yield will be $4.9\,mgd$. If drawdown is limited to $15\,ft$, the average annual safe yield for the year 2028 will be $4.6\,mgd$. If drawdown is limited to $10\,ft$, the average annual safe yield will for 2028 is reduced to $4.0\,mgd$.

2.4.4 Effect of selected demand distribution

As described in section 2.3.3 demand distribution was modeled using the average demand distribution and the peak demand distribution. Results from these simulations are shown in Table 3. Because the peak demand scenarios use the maximum pumping from the historical record for each month, divided by the average pumping for the month, the actual annual pumping rates are larger than the average annual demand specified as input. For the peak demand simulations, the safe yield is $1.3\times$ average demand in MGD. When this adjustment is made, the safe yield for the peak and average demand distributions are the same.

2.4.5 Effect of Mackinaw pumping pool regulations

The sequential model provides information on the effect of regulations that control pumping of the Mackinaw Pool during times of drought. By changing the parameters used to control the Mackinaw River diversion in the model, we can explore the benefit of changing certain regulated parameters. We modeled three scenarios:

1. Change the pump off criteria to allow Lake Bloomington and Evergreen Lake to return to normal pool before turning off the Mackinaw pump (D_{off}=0).

2. Change the combined drawdown required to turn the Mackinaw pump on from $8\,ft$ to $6\,ft$ ($D_{on} = 6$).

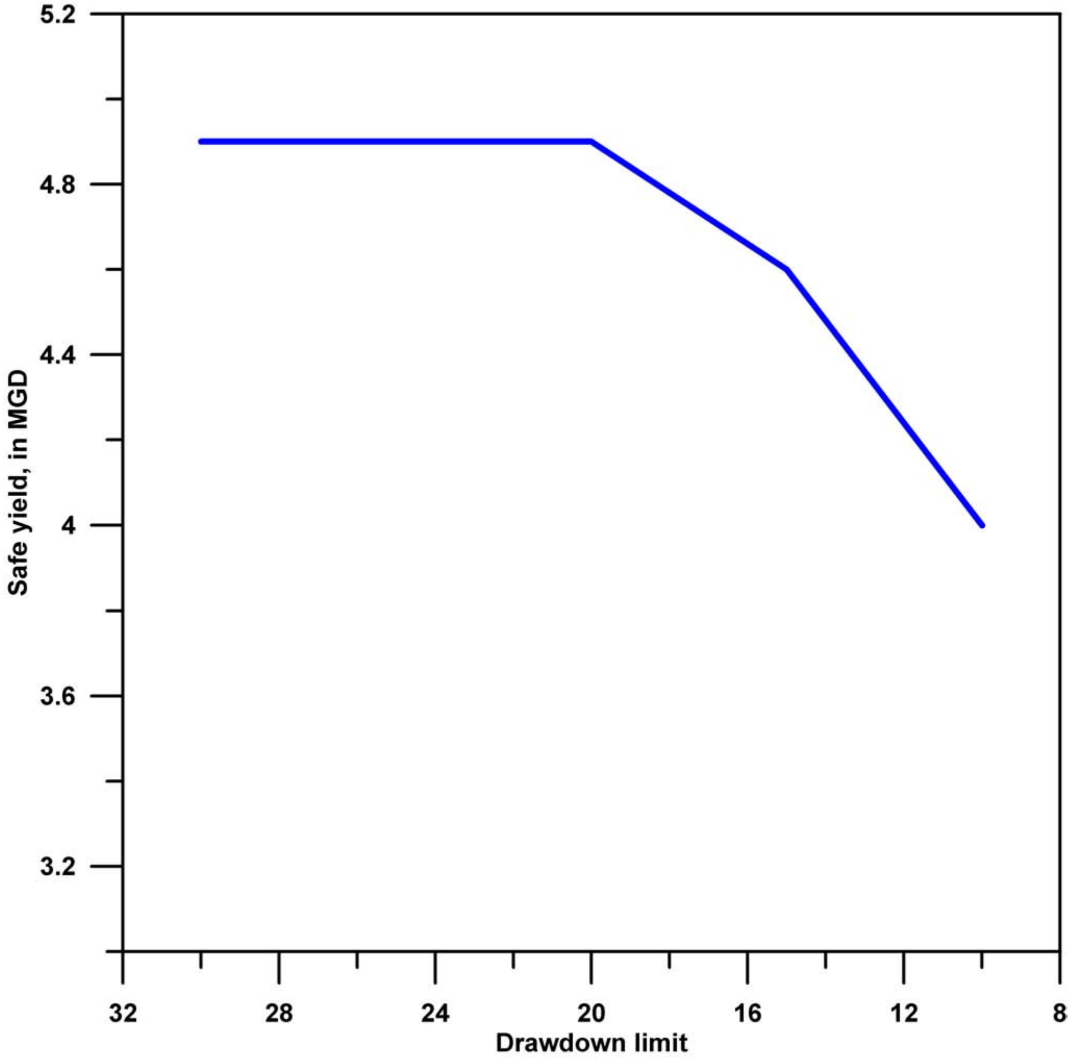


Figure 12: Effect of minimum water level on safe yield in Lake Bloomington.

3. Combine the above two changes ($D_{off} = 0$, $D_{on} = 6$)

The simulated safe yield for Evergreen Lake is increased by $2.1\,mgd$ if lake levels are allowed to return to normal pool before turning off the Mackinaw pump. The model indicates that the safe yield for Evergreen Lake is increased by $0.4\,mgd$ if the Mackinaw pump is turned on at a drawdown of $6\,ft$ rather than $8\,ft$. By combining these two operational modifications to allow for returning the pool to normal and turning on the pump at $6\,ft$ the safe yield is increased by $2.5\,mgd$.

2.4.6 Sensitivity to pan coefficient

The pan coefficient, which was based on statewide literature estimates [Angel, 2006], was assigned a value of 0.60. We tested the sensitivity of our results to this parameter over the range $0.57 - 0.66$, based on the 2028 scenarios. The model results shown in Table 3 demonstrate that the yield predictions are insensitive to the choice of pan coefficient, at least over the range of reasonable values. The yield for Lake Bloomington ranges from $4.9 - 5.1\,mgd$ and for Evergreen Lake from $7.8 - 7.9\,mgd$.

3 Comparison of methods and results

The sequential method does not provide a return period; however, we can determine a return period for the period of critical drawdown, based on precipitation or stream discharge. Because precipitation records are more extensive than stream discharge, they are commonly used to compare droughts. Winstanley et al (2006) developed precipitation drought recurrence maps from precipitation records dating from 1895-2001, mapping precipitation as the percentage of statewide normal rainfall from 1971-2000. The minimum simulated drawdown in 1964 was preceded by 2½ years of below average precipitation. The three year total precipitation for 1962-64 is $79.4\,in$, which is similar to the 36 month cumulative precipitation of $79.2\,in$ that occurred in January 1990. This precipitation corresponds to 67% of the statewide normal precipitation. A 36month drought of this magnitude is expected to occur once in 100 years [Winstanley et al., 2006].

The two- year total rainfall for the 1988-89 drought was $44.7\,in$ which corresponds to 57% of the state total from 1971-2000. A 24month drought of this magnitude is expected to occur only once in 200 years. It would be more conservative, from a water supply planning perspective to include this drought in the time series used to calculate the sequential safe yield, but no stream flow data are available in the watershed.

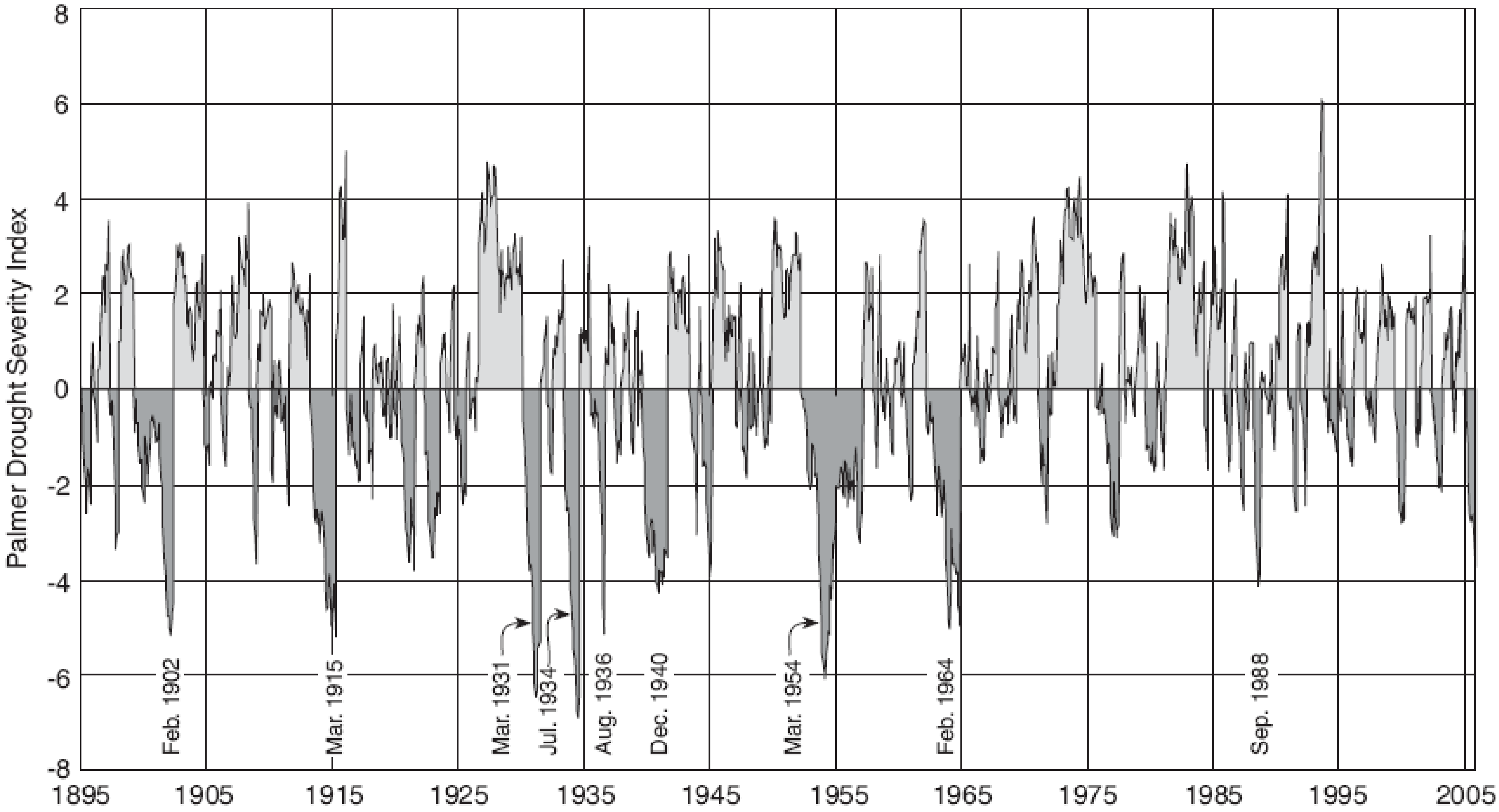


Figure 13: Palmer drought severity index

Table 5: Summary table of previous and WHPA safe yield analysis

Study	*PRC/CTE, 1988*	*Hanson Engineers, 1989*	*Broeren and Singh, 1989*	*WHPA Current*	*WHPA Current*
Methodology	Non-sequential	Non-sequential	Non-sequential	Sequential	Non-sequential
Flow Station(s)	Hickory Ck /Money Ck average	Hickory Ck /Money Ck average	Hickory Ck /Money Ck average	Money Ck	Hickory Ck /Money Ck average
Flow period	1933-1958*	1933-1958*	1933-1958*	1946-1983	1933-1958*
Flow mean (cfs/sq mi)	0.6634	0.6634	0.6634	na	0.6634
Precipitation period	na	na	na	na	na
Capacity year	1985	na/1995**	1990	2008/2008	1985/1995**
Capacity (acre-ft)	7600	na/15480	90% of total (not reported)	6524/14895**	7600/15480**
Return Period (year)	25	25	18/20 **		25
Return Period method	Low flow	Low flow	Low flow	Flow, ET and precipitation	Low flow
Gross Draft Rate (MGD)	7.5	Not reported	Not reported	na	7.5/10.5**
Net Yield (MGD)	7/na	na/9.8**	13.99***	6.5/14/20.5^{++}	7.0/10**
Critical Period (months)	18/na	na/28**	18/20**	11/11**^{1}	18/28**

* Flow time series extended by indexing to Mackinaw River at Congerville and at Green Valley

** Lake Bloomington/Evergreen Lake

*** Total for Lake Bloomington and Evergreen Lake

++ Lake Bloomington/Evergreen Lake/(Lake Bloomington + Evergreen Lake + Mackinaw pool)

The non-sequential safe yields calculated by PRC, Hanson and included in our non-sequential analysis are based on a low flow drought recurrence interval of 25 years. Figure 13 indicates that, at a statewide level, the period used for the non-sequential bulletin 67 analysis (1933-58) was much drier than the period used for the sequential analysis (1946-1983) and that the drought severity in 1964 exceeded the drought severity in 1988. In short, the errors introduced by choices of time period and methods of analysis result in uncertainties in safe yield estimations that are not strictly quantifiable. Therefore it is prudent to consider a range of values, reflecting a wide range of conditions to determining safe yield.

4 Discussion

The safe yield for the combined system is effected by climate, stream flow, sedimentation, limits on lake drawdown and operational rules for the Mackinaw pumping pool. We simulated the lake system response to pumping for the period from 1934 through 1983. During that time there were three major periods of drawdown, in 1939-1941, 1957-58, and 1963-64. In terms of water supply yield, the 1939-41 drought proved to be the critical drawdown period for this system. Precipitation records show that a three-year precipitation low of $79.4\,in$ occurred from 1962-64 and had a return period of 100 years. This precipitation low is similar to the 1988-90 low of $79.2\,in$ and the 1939-41 low of $78.3\,in$.

No Mackinaw River discharge data were available prior to 1946, which was after the critical period for water supply yields. In order to separately estimate the yield of the Mackinaw River, we made sequential model runs with and without the diversion in place, based on the 2028 lake configurations and for the 1946-2003 period of record. Those runs provided yield estimates for the that range from $1.1\,mgd$ to $1.3\,mgd$. However, because the drought of record is not included in this analysis, we applied a safety factor of 80% to the separate yield estimate for the Mackinaw River pumping pool, resulting in safe yield estimates ranging from $0.9\,mgd$ to $1.1\,mgd$. For estimates of the overall safe yield of the integrated system, the adjusted safe yield for the Mackinaw River pumping pool was added to the yield estimates for the lakes as determined from a separate model run for 1934-2003, which includes the 1939-1941 drought.

We modeled the current system by using the 1999 stage/volume curves for Lakes Evergreen and Bloomington, adjusting the capacities to account for sedimentation. System capacity is reduced at a rate of 0.5% per year, causing safe yield reduction rates that vary from $0.5 - 2.0\,mgd$ per decade. The safe yield for 2028 of $13.8\,mgd$ was obtained by adding the yield estimates of $4.9\,mgd$ for Lake Bloomington, $7.8\,mgd$ for Evergreen Lake, and the adjusted yield of $1.0\,mgd$ for the Mackinaw pumping pool. Overall, the simulated safe yield ranges from $15.0 mgd$ in 1999 to $12.9 mgd$ in 2048.

Simulations in which the Mackinaw pumping triggers were adjusted allowed for an increase in the 2028 yield from $13.8 mgd$ to $16.3 mgd$. This safe yield increase is a combination of two operations. A $0.4 mgd$ gain is attained by turning the Mackinaw pump on at a drawdown of $6 ft$, rather than $8 ft$. An additional $2.1 mgd$ gain is attained by allowing the lakes to return to normal pool before shutting the Mackinaw pump off.

We also simulated the effects of drawdown limits on Lake Bloomington. When drawdown is limited to $15 ft$ below normal pool, the safe yield is reduced by $0.3 mgd$. When the drawdown is limited to $10 ft$ the safe yield is reduced by $0.9 mgd$. This reduces the 2028 overall safe yield for the system from $13.8 mgd$ to $12.9 mgd$.

5 Conclusions and Recommendations

The objective of this study is to provide insights into the factors that determine the sustainable water-supply yield in Lake Bloomington and Evergreen Lake, and to use those insights to inform long-term decision making, support possible changes in the operational regime, and to provide decision-makers with recommendations related to future alternatives for development and source-water protection. Based on our sequential modeling analysis of Lake Bloomington and Evergreen Lake, we conclude the following:

1. In the future, the sustainable water supply yield from Lake Bloomington and Evergreen Lake will decline as a result of bank erosion and sedimentation due to runoff entering the lake. The rate of sedimentation will be affected by many factors, including land use, the presence of ground cover, and agricultural practices in the watersheds of the lakes. If changes in climate result in a higher frequency of severe precipitation events, these effects will be accentuated by increasing storm runoff.

   Recommendation: The City of Bloomington should work to reduce the rate of sedimentation and yield loss in the lakes. This includes efforts related to bank stabilization in the lakes and their major tributary streams and storm water controls. Furthermore, the City should work with stakeholders in the watersheds to reduce the rate of soil erosion, either by the implementation of best management practices (BMP), or by considering land-use restrictions in critical areas.

2. Sustained yield is not the same as a "short term" maximum yield. In a period of extremely high demand, e.g. a summer heat wave, it may be possible to exceed the sustained yield rates predicted by the model for a short period of time. Drought yields

predicted on the basis of historical data may overstate or understate actual yields in the context of a changing climate. Specifically, drought periods may exhibit changes in: duration (length of time of reduced precipitation); intensity (the reduction of precipitation as compared to “normal” conditions); and extent (the size of the region affected by drought).

Recommendation: For planning purposes, this report should not be considered to predict the yield in extreme events, such as a “worst-case” severe drought or a period of extremely high demand. It is a guide to the long-term sustainability of the water resource.

3. Finally, long-term surface water supplies in Bloomington and most of central Illinois are limited. Given population and demand growth, and in the context of a changing climate, it is likely that the total amount of available water will decline with time. Furthermore, the lakes in Bloomington, are susceptible to the expected, long-term effects of siltation, which will reduce yields.

Recommendation: The City of Bloomington should work to expand its portfolio of water-supply alternatives to include groundwater supplies and the potential for wastewater reuse.

References

[Angel, 2006] Angel, J. (2006). Pan Evaporation Across Illinois. http://www.sws.uiuc.edu/atmos/statecli/Pan-Evap/Panevap.htm, accessed on 3/30/2008.

[Committee, 2008] Committee, L. B. W. P. (2008). Lake Bloomington Watershed Plan.

[Farnworth et al., 1989] Farnworth, P.C., W., and Engineers, H. (1989). Drought emergency water sources and options to improve existing lake supplies for the city of bloomington, illinois. Technical report, Farnworth and Wiley P.C. and Hanson Engineers.

[Hanson Engineers, Inc., 1989] Hanson Engineers, Inc. (1989). Design Report Proposed Modifications Evergreen Lake Dam, Bloomington, Illinois.

[PRC Engineering, 1988] PRC Engineering (1988). Water supply, Treatment and Distribution for the City of Bloomington, Illinois.

[Sally M. Broeren and Krishan P. Singh, 1989] Sally M. Broeren and Krishan P. Singh (1989). Adequacy of Illinois Surface Water Supply Systems to Meet Future Demands. Technical report, Illinois State Water Survey.

[Terstriep et al., 1982] Terstriep, M. L., Demissie, M., Noel, D. C., and Knapp, H. V. (1982). Hydrologic Design of Impounding Reservoirs in Illinois. Technical report, Illinois State Water Survey.

[U.S. Army Corps of Engineers, 1997] U.S. Army Corps of Engineers (1997). Hydrologic Engineering Requirements For Reservoirs. Technical report, U.S. Army Corps of Engineers.

[Winstanley et al., 2006] Winstanley, D., Angel, J., Changnon, S., Knapp, H., Kunkel, K., Palecki, M., Scott, R., and Wehrmann, H. (2006). The Water Cycle and Water Budgets in Illinois. Technical report, Illinois State Water Survey.

Appendix B

Nitrate Model

Mass-Balance Nitrate Models

Safe and reliable surface water treatment relies on trained and experienced operators that monitor supply and treatment performance and adapt processes to changing conditions. Many factors impact water treatment operations. Peak water demands can push treatment processes to their capacity. Source water quality can present multiple challenges, including objectionable taste and odor and elevated levels of regulated contaminants, such as nitrates. Fluctuations in source-water temperature and flow rates can require treatment adjustments. Finally, programmed or emergency maintenance of equipment can temporarily reduce capacity.

The purpose of planning is to inform decision-making by determining the infrastructure components the utility must have to provide reliable, safe water to its customers. It relies on historical data, and does not anticipate all possible scenarios that may be encountered by treatment plant operators. However, planning can anticipate the range of conditions that will be encountered in all but extreme circumstances. Evaluating supply and treatment alternatives identifies the improvements that will provide water treatment plant operators with the tools they need to manage the production of safe drinking water under a range of conditions.

Nitrate models for evaluating the performance of supply and treatment alternatives

The City of Bloomington's Water Department (the Utility) currently pumps water from two reservoirs: Lake Bloomington and Lake Evergreen. At certain times during the year, nitrate concentrations in the reservoirs exceed the U.S. EPA's maximum contaminant level (MCL) of $10\,mg/l$. We developed two models to evaluate the performance of different supply and treatment alternatives. Both models are based on a mass balance of nitrates, and are used to determine the nitrate concentration level in waters blended from different sources and treatment processes. The models are built such that the monthly average nitrate concentrations in Lake Bloomington and Evergreen Lake vary according to the mean ratio. This allows the development of a simplified model. The validity of the resulting conclusions are verified through sensitivity analysis of performance to different nitrate ratios. The inputs to the models are shown in Table 1.

The first model, the Source Blending Model, is designed for evaluating the capacity of the Utility's system to blend source waters (Lake Bloomington, Lake Evergreen, and the production wells) to maintain nitrate concentrations below a target level. At higher levels of nitrates, the model reduces the volume of water utilized from each source to the degree necessary for blending to achieve the target nitrate level. A capacity curve is developed that represents the capacity of the supply and treatment facilities to produce water at or below the target nitrate level from the source waters at a range of Lake Bloomington average monthly nitrate concentrations.

The second model, the Treatment Model, is designed to blend the source waters, remove and treat a portion of the blended raw water to reduce the nitrate concentration, and re-blend the treated water. When necessary, the model reduces the volume of raw water in order to maintain a blended nitrate concentration below the target level.

Table 1: Nitrate model inputs.

Model Parameter	**Input**
Lake Bloomington yield	22 MGD
Evergreen Lake yield	19 MGD
Lake Bloomington monthly average nitrate concentration	Variable
Water Treatment Plant capacity	20.5 MGD
Mean Ratio of Monthly Average Nitrate Concentrations *Lake Evergreen to Lake Bloomington*	0.762
Danvers Valley Wells capacity	Variable: 0-2 MGD
Danvers Valley Wells nitrate concentration	1.0 mg/l
Sugar Creek Wellfield and Treatment capacity	Variable: 0-5 MGD
Ion Exchange Treatment capacity	Variable: 0-8 MGD
Ion Exchange Treatment nitrate removal efficiency	90%
Target nitrate concentration	9.0 mg/l

Source Blending Model

We developed the Source Blending Model to analyze how the combined availability of water from Lake Bloomington, Lake Evergreen, and the proposed blending wells changes as nitrate concentration increases. The blending model curve represents the treatment and supply capacity of the Utility's water system to produce water with a nitrate concentration below the target concentration as the nitrate level increases. This curve is referred to as the source blending capacity curve.

The first step in developing the source blending capacity curve was to calculate Lake Evergreen's nitrate concentration at different Lake Bloomington nitrate concentrations using the Lake Evergreen to Lake Bloomington mean ratio. Hypothetical Lake Bloomington nitrate concentrations ranged from 0.0-25.0 mg/l and increased by 0.1 mg/l increments; the calculated Lake Evergreen nitrate concentration ranged from 0.0-19.1 mg/l.

Next, we developed a series of equations to calculate the usable capacity of Lake Bloomington (Figure 2) and Lake Evergreen (Figure 1). For the model we assumed that Lake Evergreen will be the primary source for water because nitrate concentrations in Lake Evergreen are generally lower than those in Lake Bloomington, and the Utility will favor it during periods of elevated nitrate concentrations. The maximum capacity of Lake Evergreen is utilized until nitrates increase to the point that its capacity must be reduced to maintain nitrate concentrations below the target concentration (Figure 1). The groundwater nitrate level is assumed to be 1 mg/l. Lake Bloomington's capacity is used to supplement the capacity of both Lake Evergreen and the blending wells up to the rated capacity of the treatment facilities. When the nitrate concentration in Lake Bloomington increases to the point that the target nitrate concentration cannot be managed through blending with Lake Evergreen and the blending wells, the utilization of the lake is reduced to maintain blended nitrate concentrations below the target level (Figure 2).

To calculate the usable capacity of Lake Bloomington and Lake Evergreen, we needed to establish flow rates at different nitrate concentrations that resulted in blended nitrate levels at or below the target nitrate concentration. Flow rates for each lake were calculated using a mass balance of nitrates. The mass balance equations account for the flow of water and nitrates into and out of the supply and treatment process. Flow in Lake Bloomington was calculated as

$$Q_t N_t = Q_b N_b + Q_e N_e + Q_w N_w \tag{1}$$

$$Q_t N_t = Q_b N_b + Q_e R_{eb} N_b + Q_w N_w \tag{2}$$

$$(Q_b + Q_e + Q_w) N_t = Q_b N_b + Q_e R_{eb} N_b + Q_w N_w \tag{3}$$

$$Q_b N_t + Q_e N_t + Q_w N_t = Q_b N_b + Q_e R_{eb} N_b + Q_w N_w \tag{4}$$

$$Q_b N_t - Q_b N_b = Q_e R_{eb} N_b - Q_e N_t + Q_w N_w - Q_w N_t \tag{5}$$

$$Q_b (N_b - N_t) = Q_e (R_{eb} N_b - N_t) + Q_w (N_w - N_t) \tag{6}$$

$$Q_b = \frac{Q_e (R_{eb} N_b - N_t) + Q_w (N_w - N_t)}{N_b - N_t} \tag{7}$$

and in Lake Evergreen as

$$Q_t N_t = Q_b N_b + Q_e N_e + Q_w N_w \tag{8}$$

$$Q_t N_t = Q_b N_b + Q_e R_{eb} N_b + Q_w N_w \tag{9}$$

$$(Q_b + Q_e + Q_w) N_t = Q_b N_b + Q_e R_{eb} N_b + Q_w N_w \tag{10}$$

$$Q_b N_t + Q_e N_t + Q_w N_t = Q_b N_b + Q_e R_{eb} N_b + Q_w N_w \tag{11}$$

$$Q_e N_t - Q_e R_{eb} N_b = Q_b N_b - Q_b N_t + Q_w N_w - Q_w N_t \tag{12}$$

$$Q_e (N_t - R_{eb} N_b) = Q_b (N_b - N_t) + Q_w (N_w - N_t) \tag{13}$$

$$Q_e = \frac{Q_b (N_b - N_t) + Q_w (N_w - N_t)}{R_{eb} N_b - N_t} \tag{14}$$

where:

Q_t= $Q_b + Q_e + Q_w$ = the total flow (MGD);

N_t= the target nitrate concentration (mg/l);

Q_b= the total flow from Lake Bloomington (MGD);

N_b= the nitrate concentration in Lake Bloomington (mg/l);

Q_e= the total flow from Lake Evergreen (MGD);

N_e= the nitrate concentration in Lake Evergreen (mg/l);

Q_w= the total flow from the well (MGD);

N_w= the nitrate concentration in the well (mg/l); and

R_{eb}= the Lake Evergreen to Lake Bloomington nitrate ratio.

Equation 8 is part of the Lake Bloomington capacity calculation shown in Figure 2, and equation 15 is part of the Lake Evergreen capacity calculation shown in Figure 1.

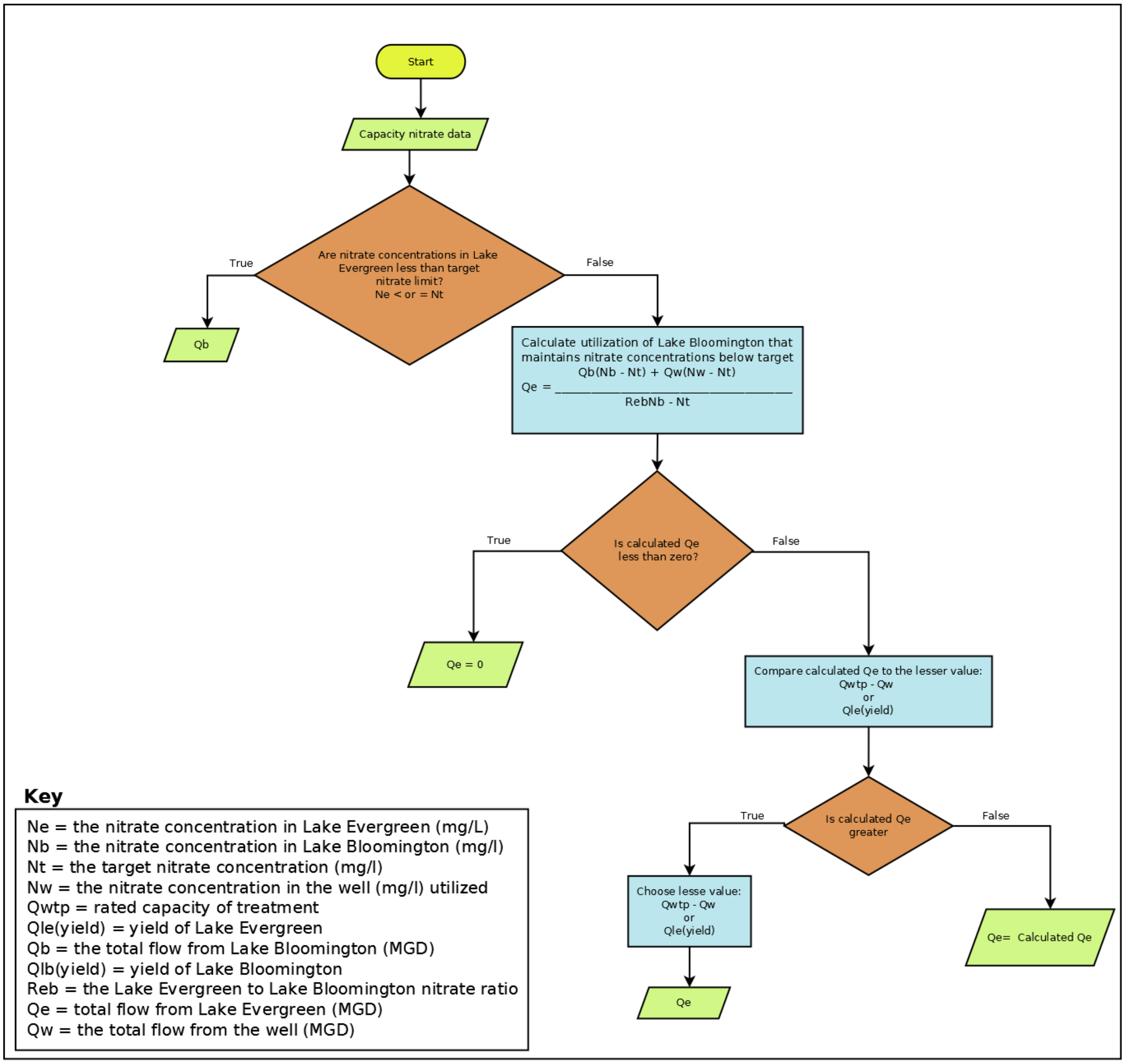


Figure 1: The process used to calculate Lake Evergreen's capacity in the Source Blending Model.

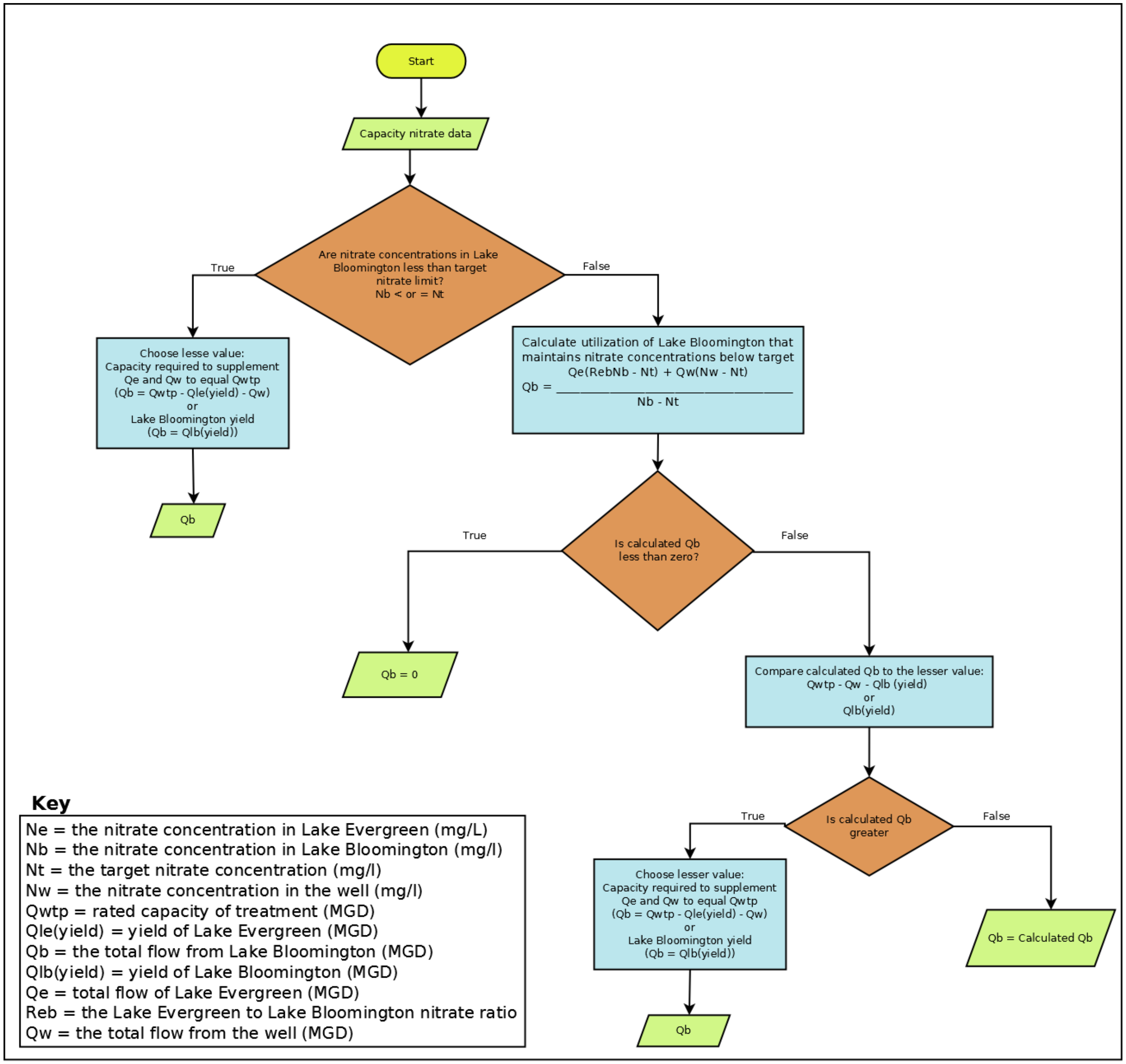


Figure 2: The process used to calculate Lake Bloomington's capacity in the Source Blending Model.

Total capacity is calculated by summing the capacities utilized from Lake Bloomington, Lake Evergreen, and the blending wells at each hypothetical nitrate concentration. At lower nitrate concentrations, total capacity is constrained by the rated capacity of the treatment plant; however, as nitrate concentrations increase, the reduction in use of Lake Bloomington and Lake Evergreen limits total capacity. Maximum supply and treatment capacity is available until nitrate concentrations in Lake Bloomington reach levels that can no longer be managed to the target nitrate concentration through blending with lower nitrate water from Lake Evergreen and the blending wells; at this concentration the amount of water contributed by Lake Bloomington begins to decrease, which in turn reduces total supply and treatment capacity. As the nitrate concentration continues to increase, the contribution from Lake Bloomington is eventually reduced to zero, leaving water available from only Lake Evergreen and the blending wells. Further nitrate concentration increases reduce the contribution from Lake Evergreen and the total capacity of the system.

Treatment Model

The Treatment Model differs from the Source Blending Model because it includes removing nitrates using a proposed supplemental treatment process. All blended water undergoes a standard nitrate treatment process in both models; however a portion of the blended water in the Treatment Model is diverted to in order to receive ion exchange treatment to further reduce its nitrate concentration. The resulting low-nitrate water is then blended back with the untreated blended water. It is important to note that nitrate removal treatment does not increase the overall rated capacity of the treatment plant.

To develop the Treatment Model, we used maximum yields from Lake Bloomington, Lake Evergreen, and the blending wells; and we used the treatment plant's rated capacity and the ion exchange treatment capacity. We calculated Lake Evergreen's nitrate concentration at different hypothetical Lake Bloomington nitrate concentrations using the Lake Evergreen to Lake Bloomington ratio. Hypothetical Lake Bloomington nitrate concentration ranged from 0.0-25.0 mg/l and increased by 0.1 mg/l increments; the calculated Lake Evergreen nitrate concentration ranged from 0.0-19.1 mg/l.

For the model, we assumed Lake Evergreen will be the primary source of water because nitrate concentrations in Lake Evergreen are generally lower than those in Lake Bloomington and the Utility will favor it during periods of elevated nitrates. Groundwater nitrate levels are assumed to be 1 mg/l. Lake Bloomington's capacity is used to supplement the capacity of both Lake Evergreen and the blending wells up to the rated capacity of the treatment facilities. When the nitrate concentration increases to the point that the target nitrate concentration cannot be managed through blending with Lake Evergreen and the blending wells, the utilization of both Lake Bloomington and Lake Evergreen is proportionately reduced to maintain the target nitrate level.

We developed a series of equations to calculate the usable capacity of Lake Bloomington, Lake Evergreen, and the blending wells after supplemental treatment. Figure 3 shows lists the equations and illustrates the process used to calculate the capacity of Lake Bloomington and Lake Evergreen as the nitrate concentration increases. To determine the nitrate concentration in the blended raw water we used the following mass balance equation

$$N_{t-raw} = ((Q_b \cdot N_b) + (Q_e \cdot N_e) + (Q_w . N_w))/Q_t \tag{15}$$

where:

N_{t-raw}= the total blended nitrate concentration (mg/l);

Q_b= the total flow from Lake Bloomington (MGD);

N_b= the nitrate concentration in Lake Bloomington (mg/l);

Q_e= the total flow from Lake Evergreen (MGD);

N_e= the nitrate concentration in Lake Evergreen (mg/l);

Q_w= the total flow from the well (MGD);

N_w= the nitrate concentration in the well (mg/l); and

Q_t= the total flow (MGD).

To calculate the nitrate concentration in the ion exchange treatment effluent, we used

$$(1 - E_{ix}) \cdot Q_{ix} \tag{16}$$

where:

E_{ix}= ion exchange treatment removal efficiency (%); and

Q_{ix}= capacity of ion exchange treatment (MGD).

The total nitrate concentration of the blended treated and non-treated water was calculated as

$$N_{t-treated} = ((N_{t-raw} \cdot Q_{non-ix}) + (Q_{ix} + N_{ix}))/Q_t \tag{17}$$

where:

$N_{t-treated}$= nitrates-blended treated water (mg/l);

N_{t-raw}= nitrates - blended raw water (mg/l);

$Q_{non-ix} = Q_t - Q_{ix}$ = capacity not receiving IX treatment (MGD);

Q_{ix} = capacity of ion exchange treatment (MGD);

N_{ix}= nitrates - IX treatment effluent (mg/l); and

Q_t= the total flow (MGD).

When the calculated nitrate concentration in the treated water exceeds the target nitrate concentration, an iterative process is applied to to reduce the utilization of Lake Evergreen and Lake Bloomington until the calculated nitrate concentration in the treated water achieves the target nitrate concentration (Figures 3, 4, and 5).

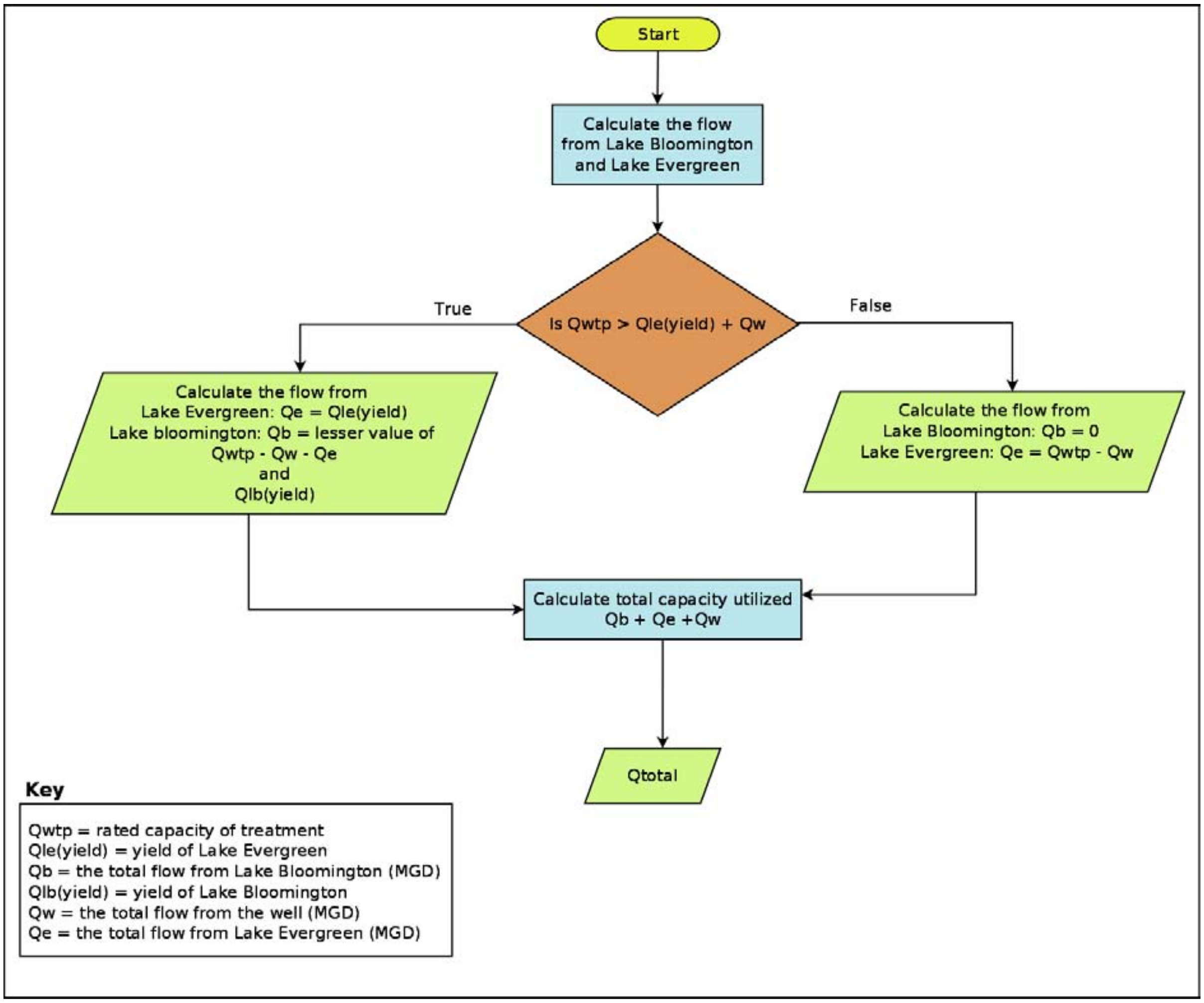


Figure 3: The process used in the Treatment Model to calculate total capacity utilized from Lake Bloomington, Lake Evergreen, and the production wells.

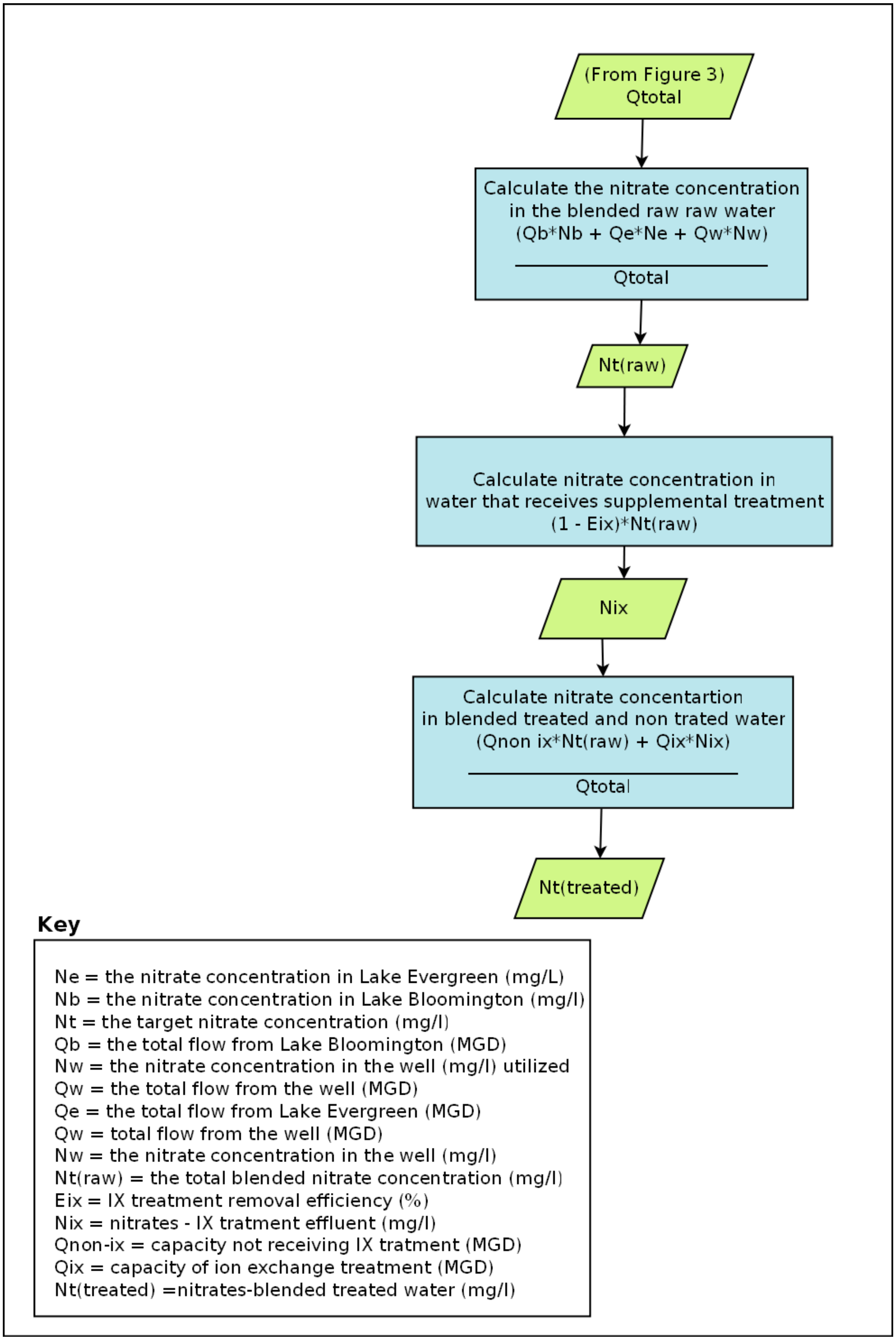


Figure 4: The process used in the Treatment Model to calculate the nitrate concentration of the blended water.

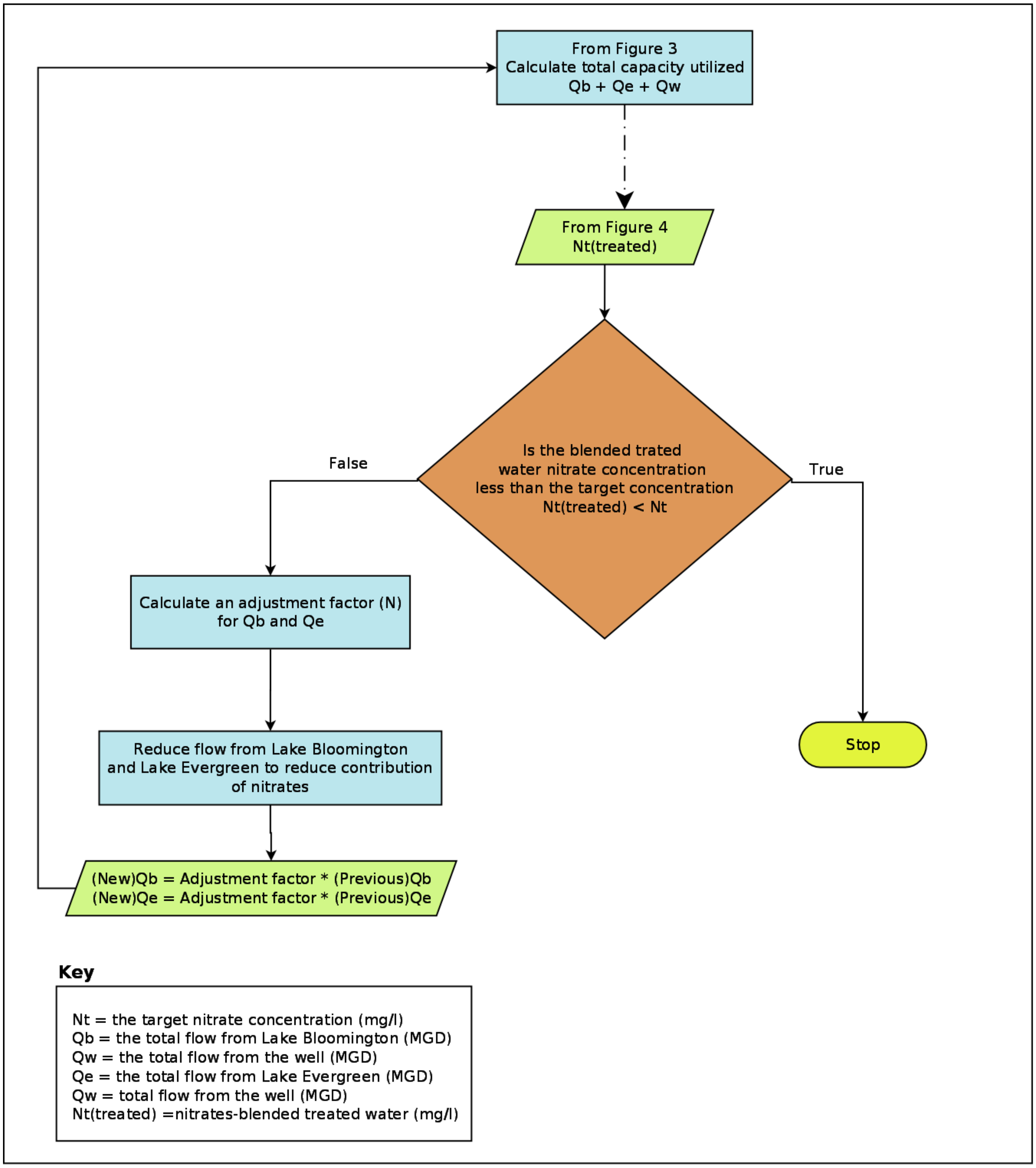


Figure 5: The iteration process used in the Treatment Model.

At lower nitrate concentrations, the total capacity is constrained by the rated capacity of the treatment plant; however, as nitrate concentrations increase, the reduction in Lake Bloomington and Lake Evergreen use limits total capacity. The maximum supply and treatment capacity is available until nitrate concentrations in the treated blended water reach the target concentration; at this concentration the amount of water contributed by both Lake Bloomington and Lake Evergreen begins to decrease in order to maintain levels at the target concentration. This reduces the total supply and treatment capacity.

Lake Evergreen to Lake Bloomington Ratio

Initial analysis of historical Lake Bloomington and Lake Evergreen nitrate data indicated concentrations in the two reservoirs have paralleled one another with Lake Bloomington's nitrate concentration generally greater than Lake Evergreen's concentration. This relationship allowed us to calculate a distribution of monthly Lake Evergreen to Lake Bloomington nitrate concentration ratios (Figure 6). We used the monthly ratios to calculate an average ratio (Table 2), which we used in the models to estimate Lake Evergreen's nitrate concentration using hypothetical Lake Bloomington concentrations. The average ratio allowed us to calculate the Utility's diminishing capacity to produce finished water that is in regulatory compliance as the reservoirs' nitrate concentrations increase.

We were interested in obtaining a conservative ratio because, in the model, it reduces the nitrate concentration at which the Utility must cut back or stop using water from Lake Bloomington. Using monthly ratios in which either Lake Bloomington, Lake Evergreen, or both had an average monthly nitrate concentration greater than $5\,mg/l$ produced the most conservative (or larger) average ratio. Table lists the average nitrate concentrations used to calculate monthly ratios and the final average ratio.

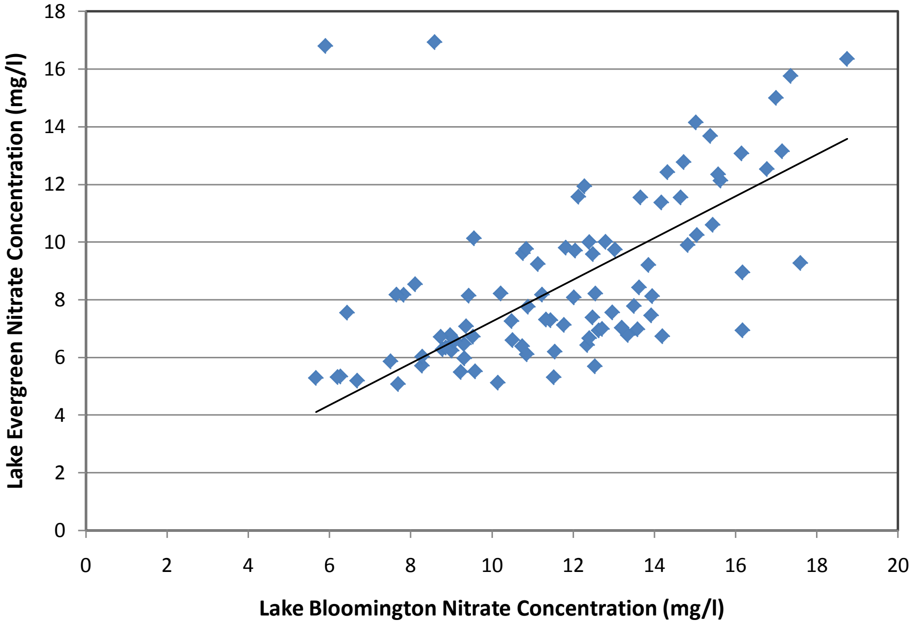


Figure 6: Relationship of Lake Evergreen to Lake Bloomington nitrate concentrations.

Table 2: Average monthly nitrate concentrations used to calculate the Lake Evergreen to Lake Bloomington ratio.

Year	Month	Average Lake Evergreen Nitrate Concentration	Average Lake Bloomington Nitrate Concentration	Ratio
1984	1	8.18	7.65	1.07
1984	4	12.53	16.78	0.75
1984	5	13.15	17.15	0.77
1985	3	9.76	10.85	0.90
1985	4	11.38	14.18	0.80
1985	5	11.55	13.66	0.85
1985	6	10.00	12.40	0.81
1985	7	6.35	8.87	0.72
1986	2	8.43	13.63	0.62
1986	6	16.80	5.90	2.85
1986	7	5.72	8.28	0.69
1990	2	16.93	8.59	1.97
1990	3	14.15	15.03	0.94
1990	4	16.35	18.75	0.87
1990	5	15.76	17.36	0.91
1990	6	15.00	17.00	0.88
1990	7	13.68	15.38	0.89
1990	8	12.43	14.33	0.87

Table 2: Average monthly nitrate concentrations used to calculate the Lake Evergreen to Lake Bloomington ratio.

Year	**Month**	**Average Lake Evergreen Nitrate Concentration**	**Average Lake Bloomington Nitrate Concentration**	**Ratio**
1990	9	10.13	9.56	1.06
1990	10	7.55	6.43	1.17
1990	11	8.54	8.11	1.05
1990	12	9.62	10.77	0.89
1991	1	9.28	17.60	0.53
1991	2	6.94	16.18	0.43
1991	3	12.13	15.63	0.78
1991	4	12.35	15.58	0.79
1991	5	13.08	16.15	0.81
1991	6	12.78	14.73	0.87
1991	7	11.94	12.28	0.97
1991	8	8.17	7.83	1.04
1992	1	7.32	11.33	0.65
1992	2	9.90	14.83	0.67
1992	3	11.57	12.13	0.95
1992	4	8.22	12.55	0.65
1992	5	8.08	12.02	0.67
1992	6	6.57	9.09	0.72
1992	7	5.29	5.67	0.93
1992	8	6.77	8.97	0.75
1992	9	5.87	7.51	0.78
1992	12	6.99	12.72	0.55
1993	1	8.22	10.22	0.80
1993	2	11.55	14.65	0.79
1993	3	9.71	12.05	0.81
1993	4	9.74	13.03	0.75
1993	5	10.01	12.80	0.78
1993	6	9.81	11.82	0.83
1993	7	9.24	11.13	0.83
1993	8	8.14	9.43	0.86
1993	9	5.34	6.27	0.85
1993	10	5.08	7.69	0.66
1993	11	6.72	8.74	0.77
1993	12	5.50	9.23	0.60
1994	6	6.60	10.51	0.63
1995	4	6.43	12.35	0.52
1995	5	9.21	13.86	0.66
1995	6	9.59	12.49	0.77
1995	7	8.18	11.24	0.73
1996	6	6.67	12.40	0.54
1996	7	7.03	13.20	0.53

Table 2: Average monthly nitrate concentrations used to calculate the Lake Evergreen to Lake Bloomington ratio.

Year	**Month**	**Average Lake Evergreen Nitrate Concentration**	**Average Lake Bloomington Nitrate Concentration**	**Ratio**
1998	3	6.20	11.55	0.54
1998	4	8.95	16.18	0.55
1998	5	10.25	15.05	0.68
1998	6	0.60	15.44	0.69
1998	7	8.13	13.95	0.58
1998	8	6.72	9.53	0.71
1999	5	6.74	14.20	0.47
1999	6	7.76	10.89	0.71
1999	7	5.97	9.32	0.64
2001	3	5.70	12.54	0.45
2001	4	6.78	13.35	0.51
2001	5	6.94	12.63	0.55
2001	6	7.13	11.78	0.61
2001	7	5.13	10.15	0.51
2001	8	5.20	6.68	0.78
2002	4	6.39	10.75	0.59
2002	5	7.79	13.50	0.58
2002	6	7.56	12.97	0.58
2002	7	6.11	10.86	0.56
2004	6	5.32	11.53	0.46
2005	1	6.29	8.79	0.72
2005	2	7.08	9.37	0.80.76
2005	3	7.29	11.44	0.64
2005	4	7.26	10.49	0.69
2005	5	6.46	9.32	0.69
2006	6	5.52	9.59	0.58
2007	2	6.98	13.59	0.51
2007	3	6.03	8.29	0.73
2007	4	7.46	13.93	0.54
2007	5	7.39	12.48	0.59
2007	6	6.24	9.01	0.69
Average Ratio				0.762
Standard Deviation				0.30059

Model Analysis

Both nitrate models generate a capacity curve. An example of a capacity curve is shown in Figure 7. This example is presented for demonstrating the use of the model to evaluate any supply and treatment alternative; it does not represent a specific alternative or evaluation criteria. As illustrated in Figure 7, at lower nitrate concentrations source and treatment capacity is constant and equal to the rated capacity of the facility. When nitrate concentrations in the source waters reach levels that will result in finished water nitrate concentrations greater than the target level, the volume of water utilized from high-nitrate sources is reduced to maintain the target nitrate concentration. Projected average and maximum demands for the year 2020 are also shown on the graph. Capacity curves for scenarios that involve the Utility developing a satellite supply and treatment facility near Sugar Creek display two curves - one for the capacity of the main treatment facility and another for the capacity of the main and Sugar Creek facilities.

We evaluated two points on the capacity curves in conjunction with the frequency curves, as illustrated in Figure 8. First, we determined the nitrate concentration at the point where capacity is reduced to average maximum demand (50 percent). This point is critical during periods of high demands; in seasons with lower demands, the impact of reducing supply and treatment capacity to this level is less critical. Managing demands to the maximum demand (50 percent) through voluntary or mandatory temporary water use reductions should be practical to achieve. The frequency curve shows the percentage of peak demand months (June, July and August) in which different average monthly nitrate concentrations in Lake Bloomington are exceeded. In the example, the capacity of supply and treatment is reduced to maximum demand (50 percent) when nitrates exceed $13.8\,mg/l$. The frequency curve (Figure 8) indicates that a nitrate concentration of $13.8\,mg/l$ occurs in approximately 7 percent of peak months.

Second, we determined the nitrate concentration at which capacity is reduced to average demand. This point is critical throughout the year. Managing demands to this level would likely require significant mandatory water use restrictions, particularly during periods of higher demands. The frequency curve shows the percentage of all months in which a range of average monthly nitrate concentrations in Lake Bloomington are exceeded. In the example, the capacity of supply and treatment is reduced to average demand when nitrates exceed $15.3\,mg/l$. The frequency curve indicates that a nitrate concentration of $15.3\,mg/l$ occurs in approximately 5% of all months.

All supply and treatment alternatives are evaluated in the same manner, which allows different combinations of supply and treatment infrastructure to be compared in terms of the relative risk of exceeding capacity and evaluated against utility criteria for acceptable levels of risk.

Scenario Analysis Multiple scenarios were run using the Source Blending Model and Treatment Model. The scenarios involve different combinations of the proposed blending wells, ion exchange treatment (IX treatment), and Sugar Creek well and treatment capacities. Lake Bloomington's and Lake Evergreen's yield remain constant throughout the scenarios. The scenarios fall into seven general alternatives.

- Alternative 0 - use only Lake Evergreen and Lake Bloomington;
- Alternative 1 - use only blending wells;
- Alternative 2 - use blending wells and IX treatment;

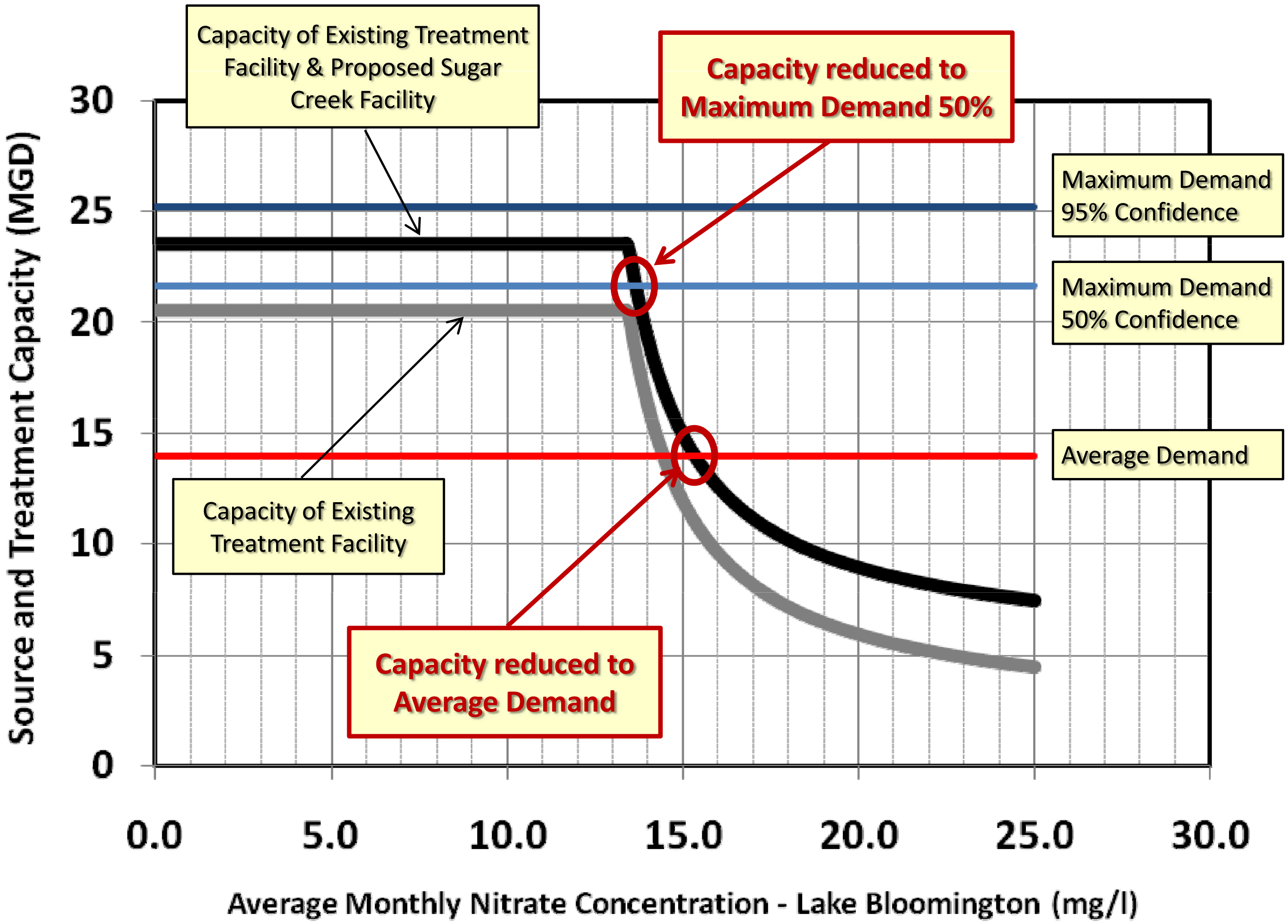


Figure 7: Example of a modeled capacity curve for a supply and treatment alternative.

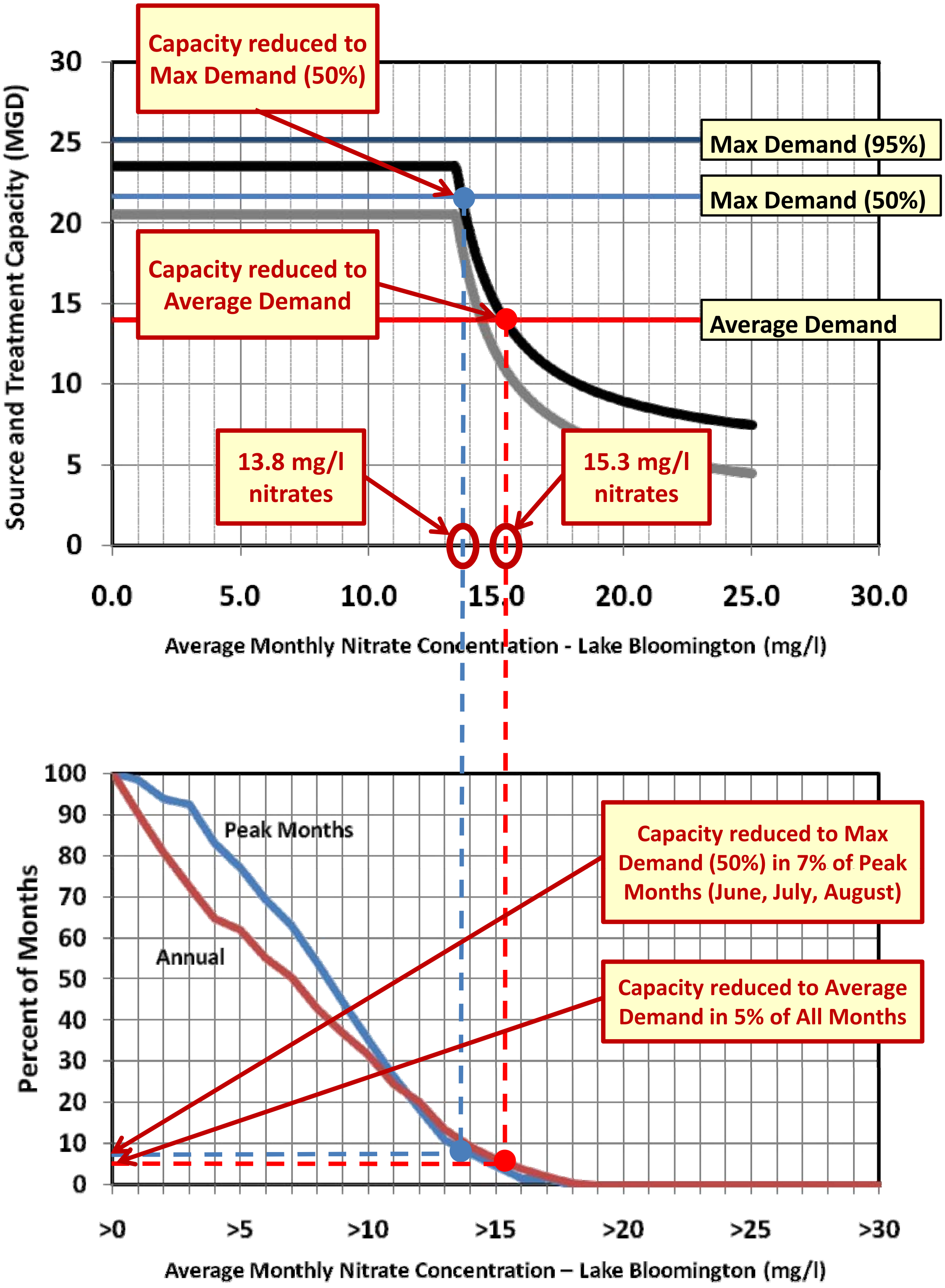


Figure 8: Example of the evaluation of the modeled performance of a supply and treatment alternative.

Table 3: Parameters used in the Source Blending Model and Treatment Model scenarios.

Parameter	**Value**
Target nitrate level (N_l)	9.0 mg/l[a]
Lake Bloomington yield ($Q_{lbyield}$)	22.0 MGD[b]
Lake Evergreen yield ($Q_{leyield}$)	19.0 MGD
Well capacity (Q_w)	varied
Well nitrate concentration (N_w)	1.0 mg/l
Lake Evergreen to Lake Bloomington ratio	0.762
Sugar Creek Wellfield capacity (Q_{sc})	varied
Treatment plant rated capacity (Q_{wtp})	20.5 MGD
Ion exchange treatment capacity (Q_{ix})	varied
IX removal efficiency (E_{ix})	90%

[a] milligrams per liter

[b] million gallons per day

- Alternative 3 - use blending wells, IX treatment, and 3 MGD from Sugar Creek Wellfield;
- Alternative 4 - use blending wells, IX treatment, and 5 MGD from Sugar Creek Wellfield;
- Alternative 5 - use IX treatment and 3 MGD from Sugar Creek Wellfield;
- Alternative 6 - use IX treatment and 5 MGD from Sugar Creek Wellfield.

The scenarios are shown in Figures 9-30. The parameters used in the scenarios are shown in Table 3.

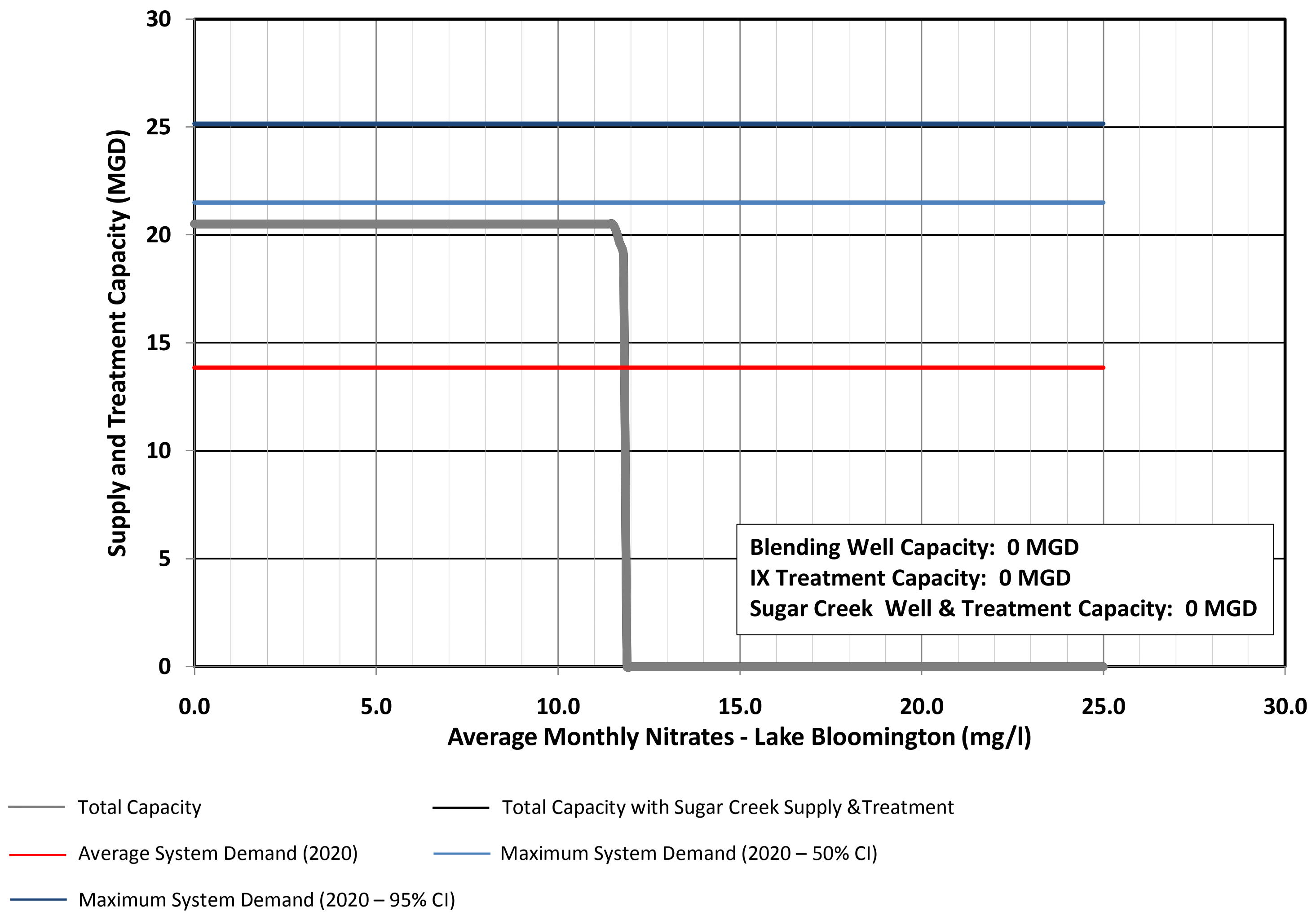


Figure 9: Alternative 0: Only Lake Bloomington and Lake Evergreen supply water.

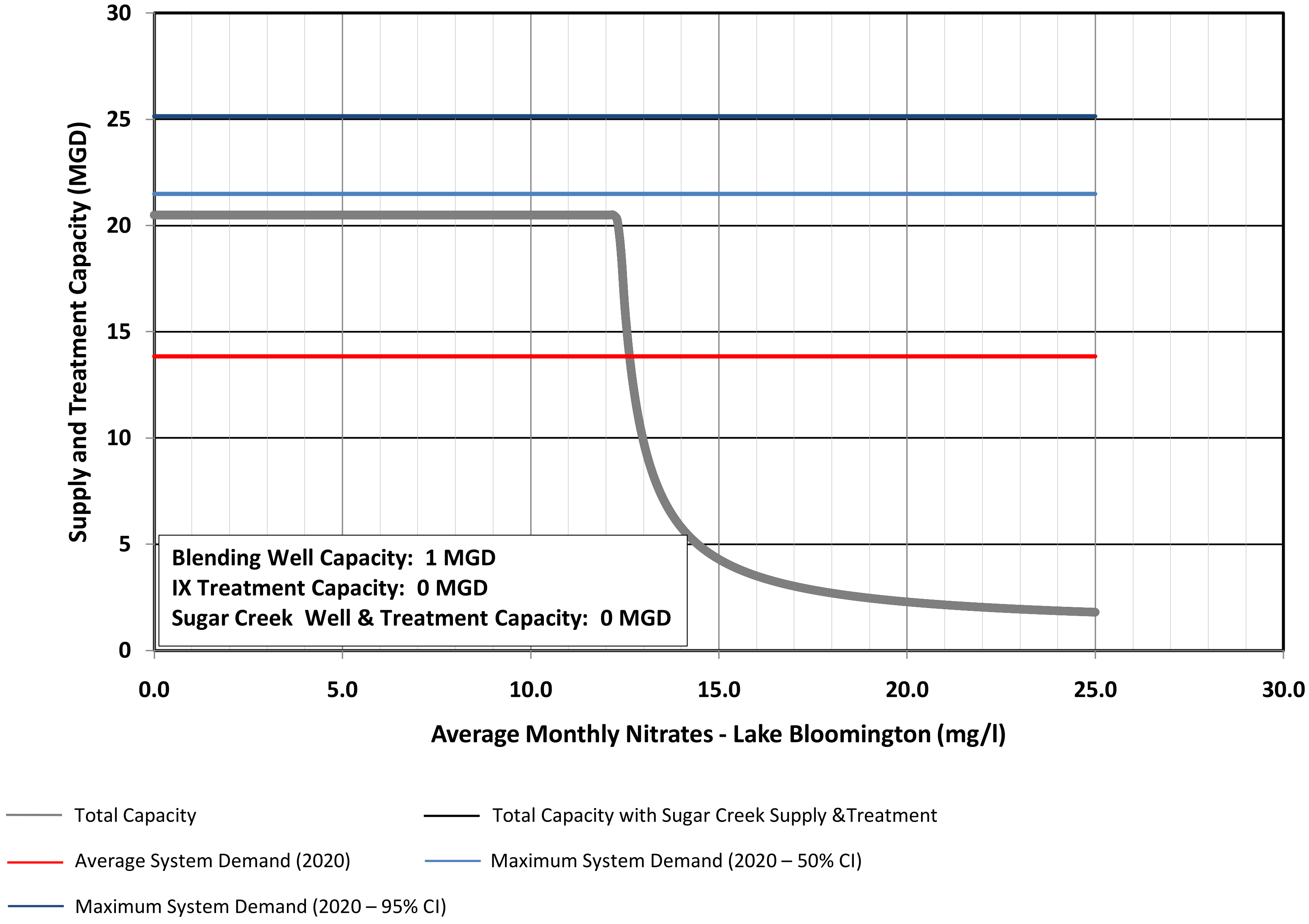


Figure 10: Alternative 1-a: Lake Bloomington, Lake Evergreen, and the blending wells.

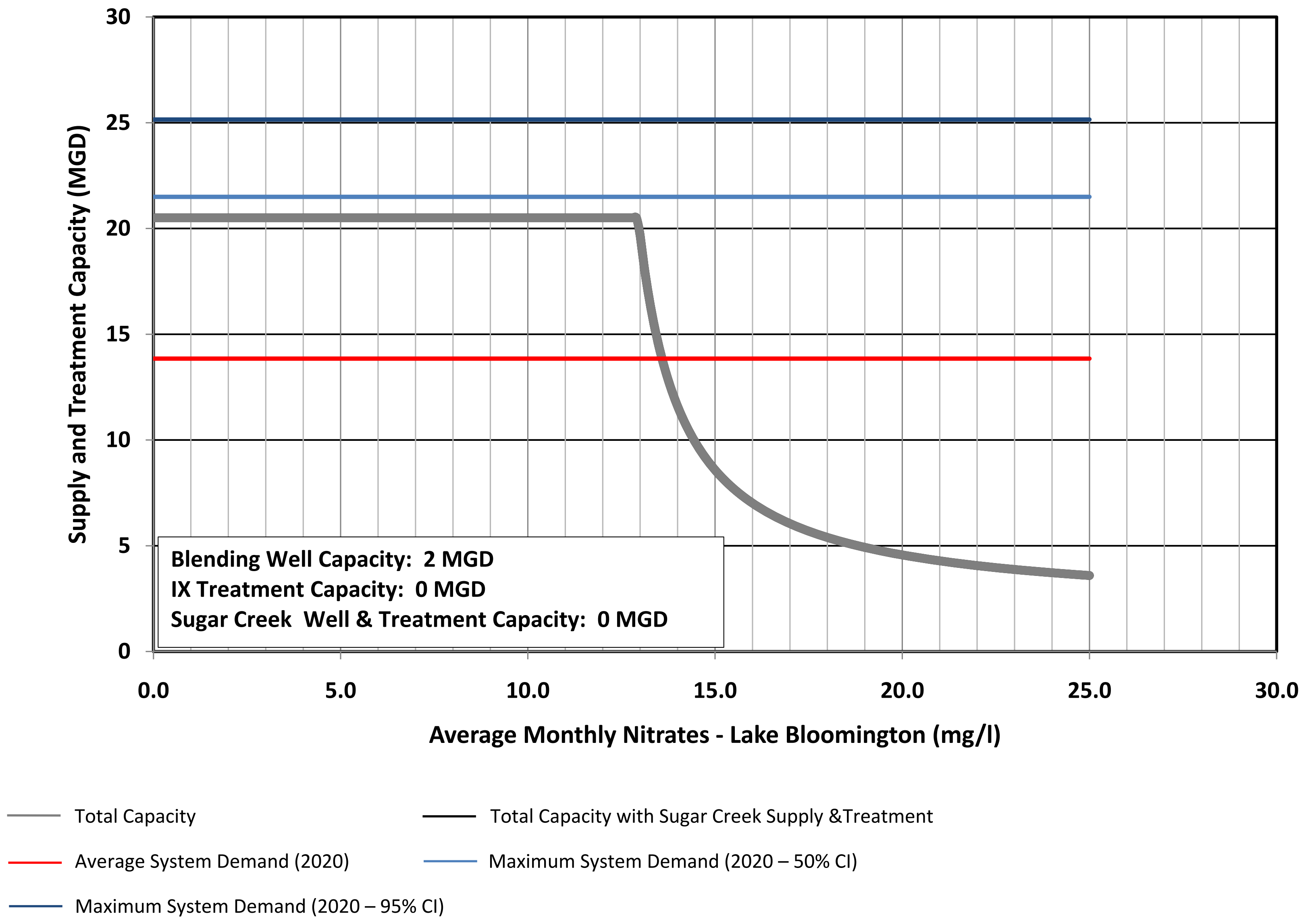


Figure 11: Alternative 1-b: Lake Bloomington, Lake Evergreen, and the blending wells.

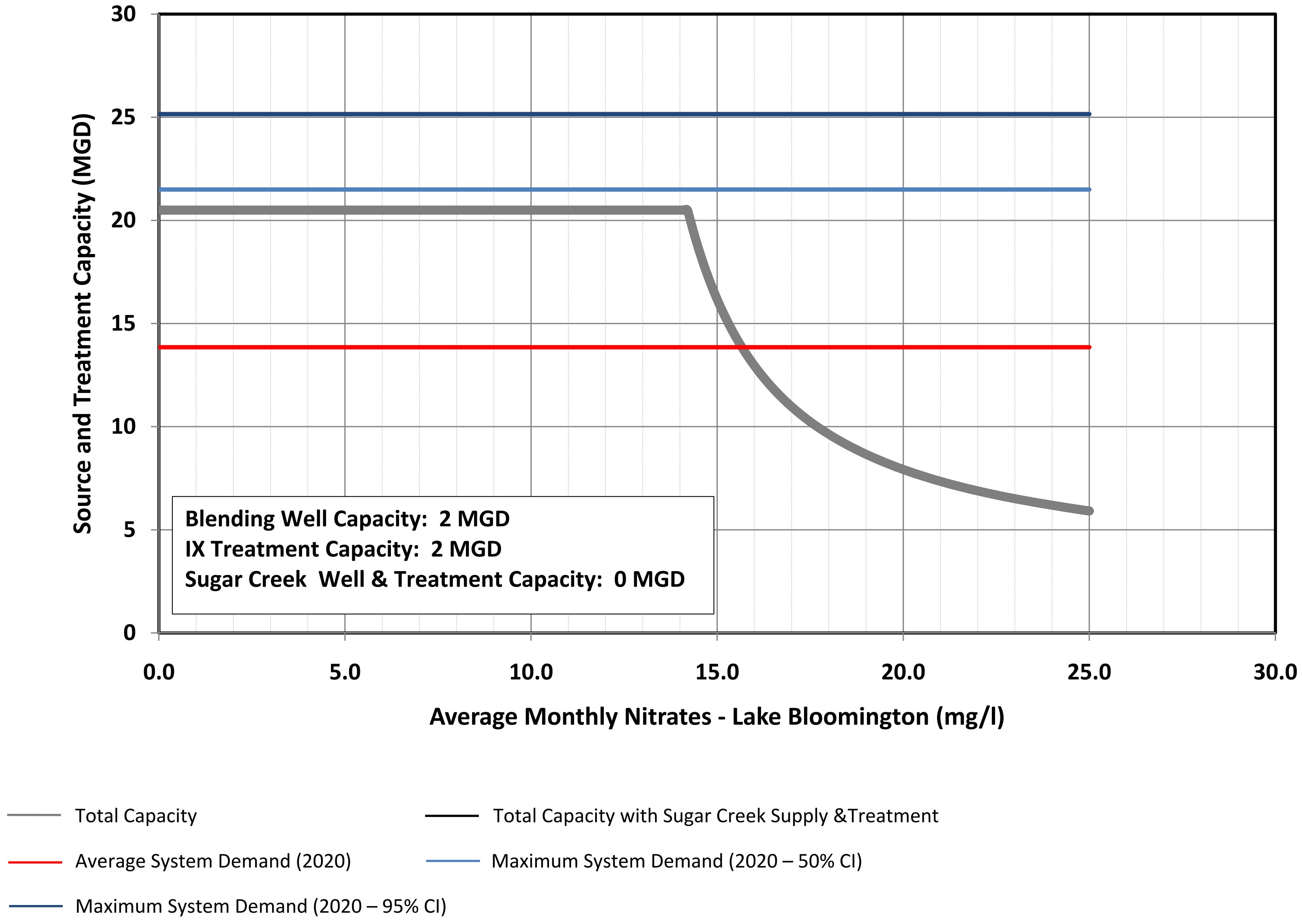


Figure 12: Alternative 2-a: Lake Bloomington, Lake Evergreen, the blending wells, and IX treatment.

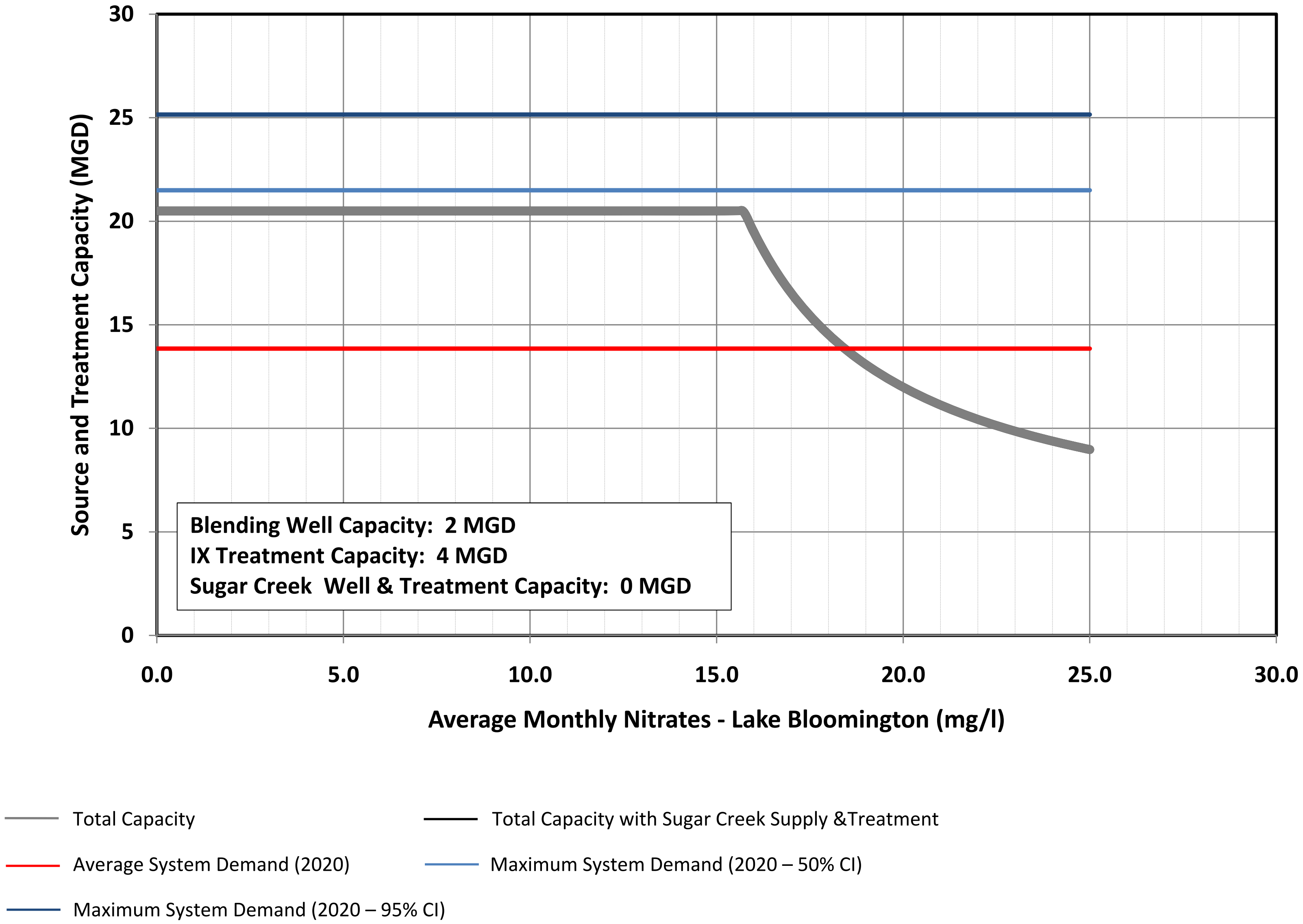


Figure 13: Alternative 2-b: Lake Bloomington, Lake Evergreen, the blending wells, and IX treatment.

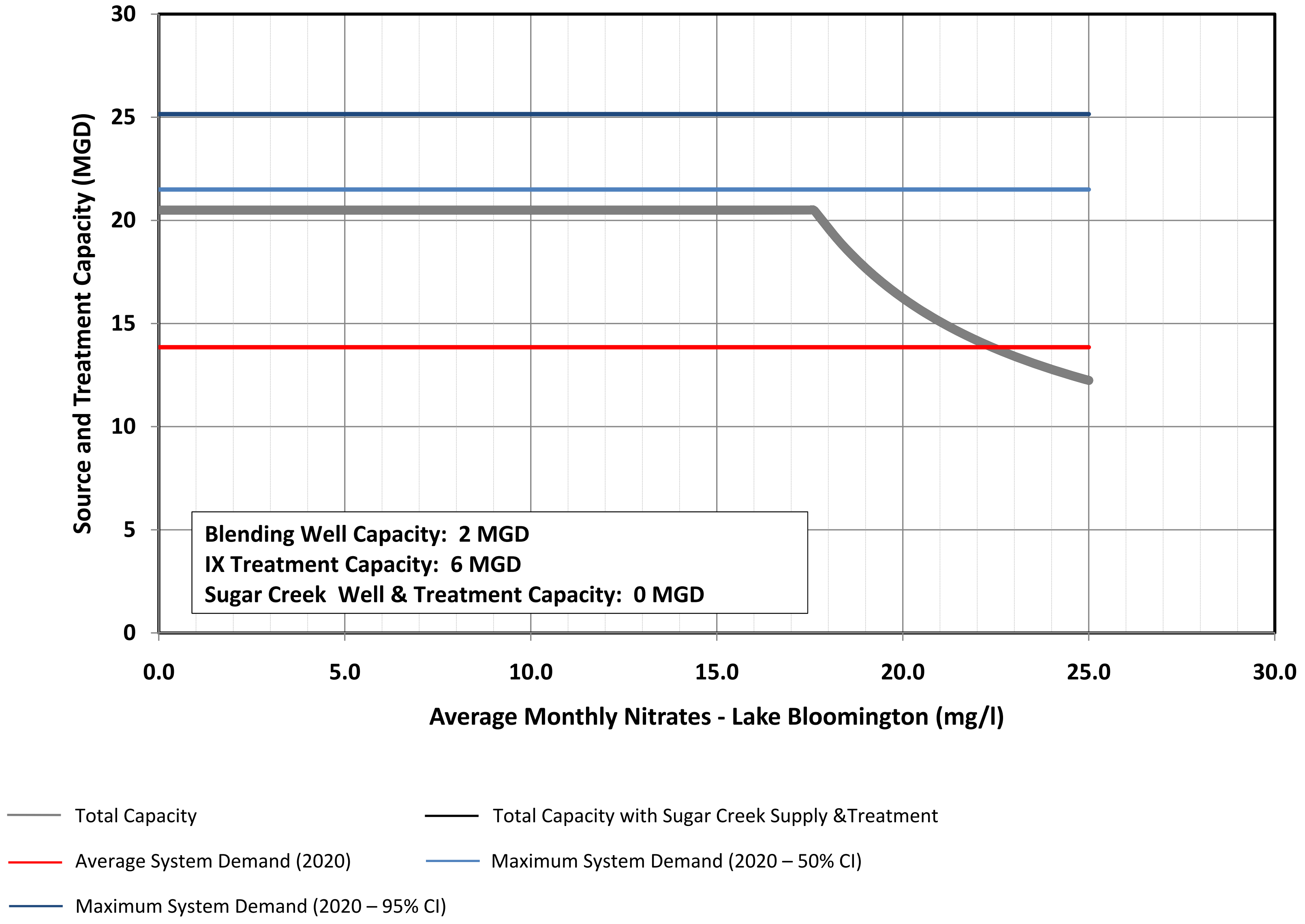


Figure 14: Alternative 2-c: Lake Bloomington, Lake Evergreen, the blending wells, and IX treatment.

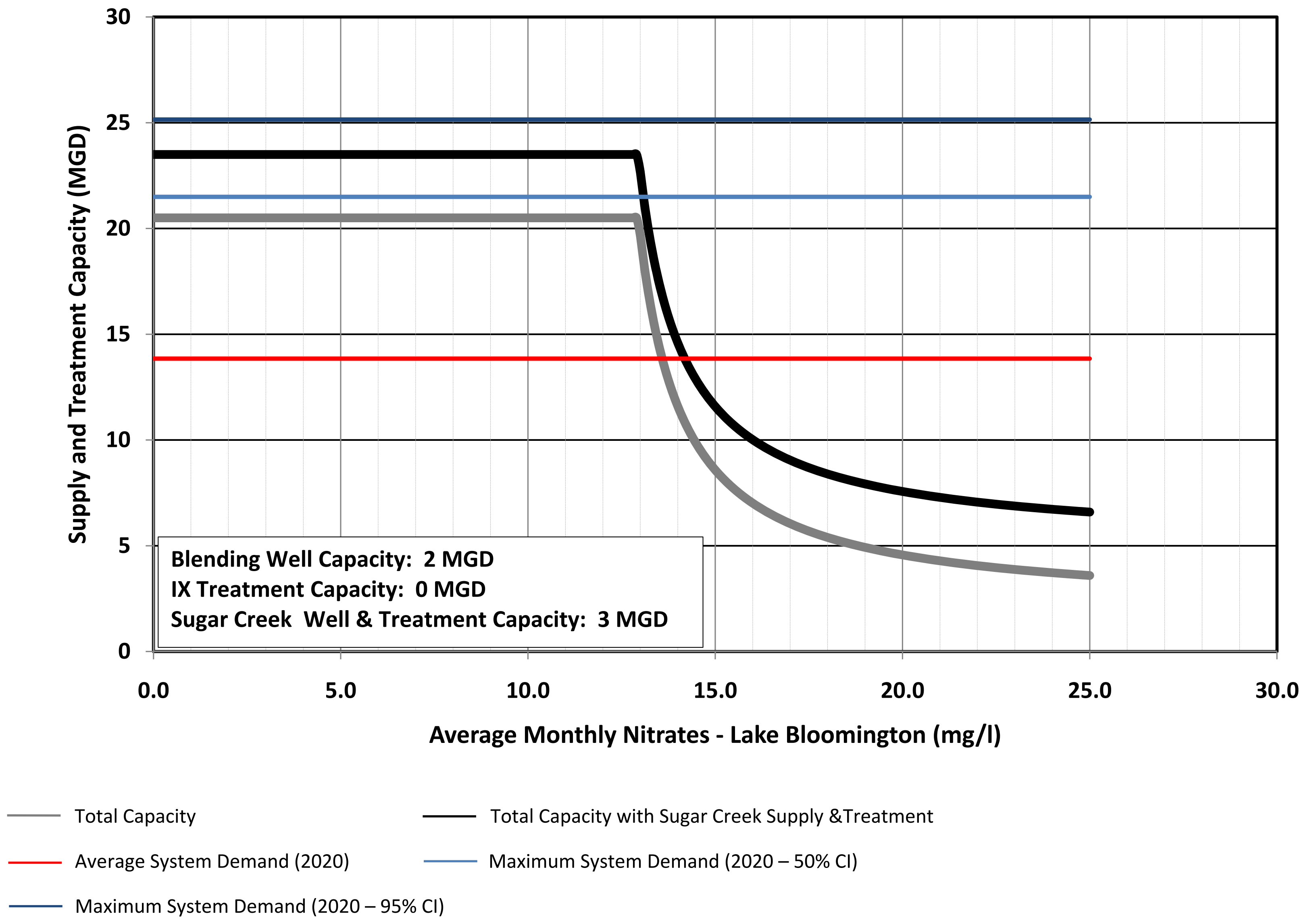


Figure 15: Alternative 3-a: Lake Bloomington, Lake Evergreen, the blending wells, IX treatment, and 3 MGD from Sugar Creek Wellfield.

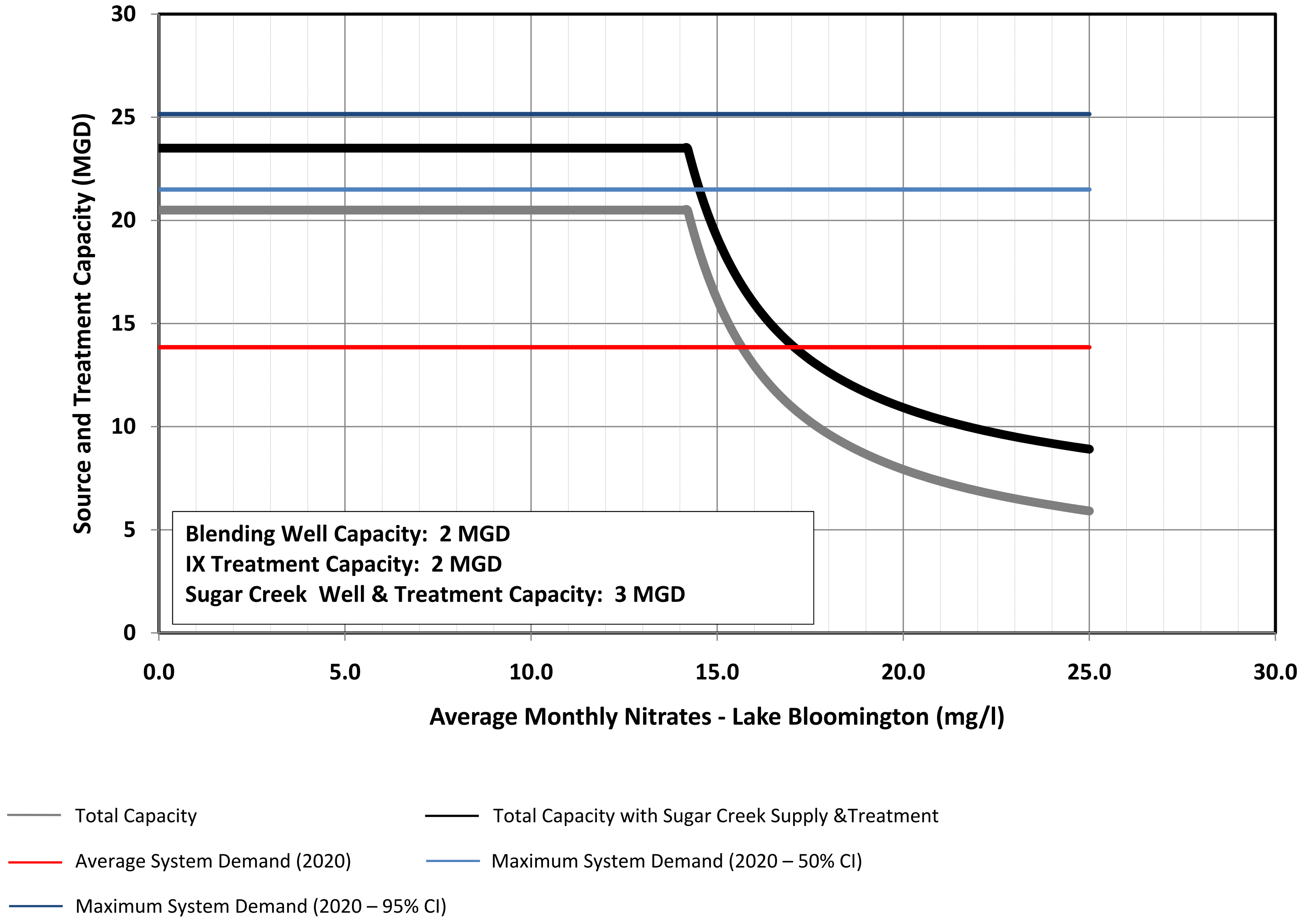


Figure 16: Alternative 3-b: Lake Bloomington, Lake Evergreen, the blending wells, IX treatment, and 3 MGD from Sugar Creek Wellfield.

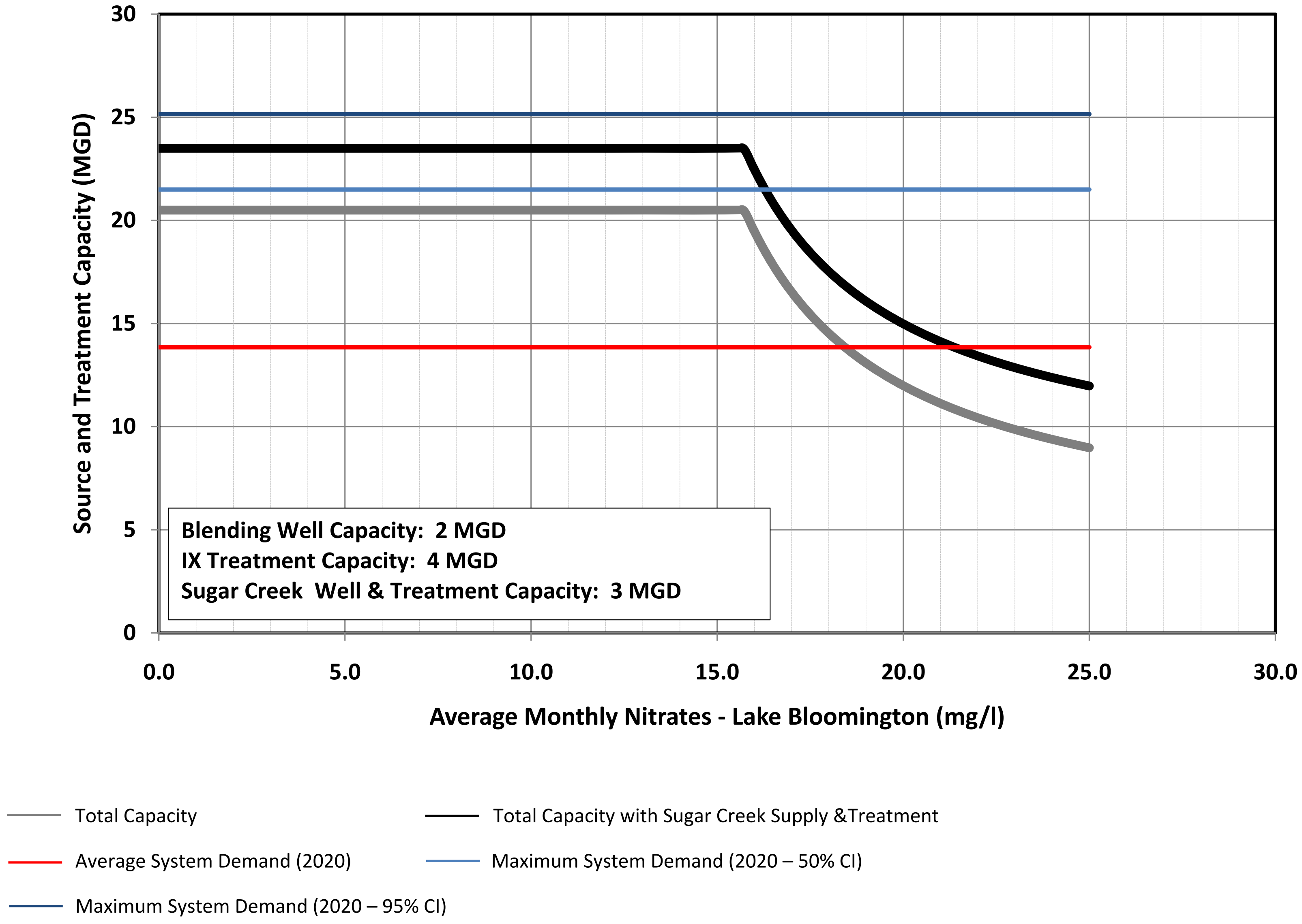


Figure 17: Alternative 3-c: Lake Bloomington, Lake Evergreen, the blending wells, IX treatment, and 3 MGD from Sugar Creek Wellfield.

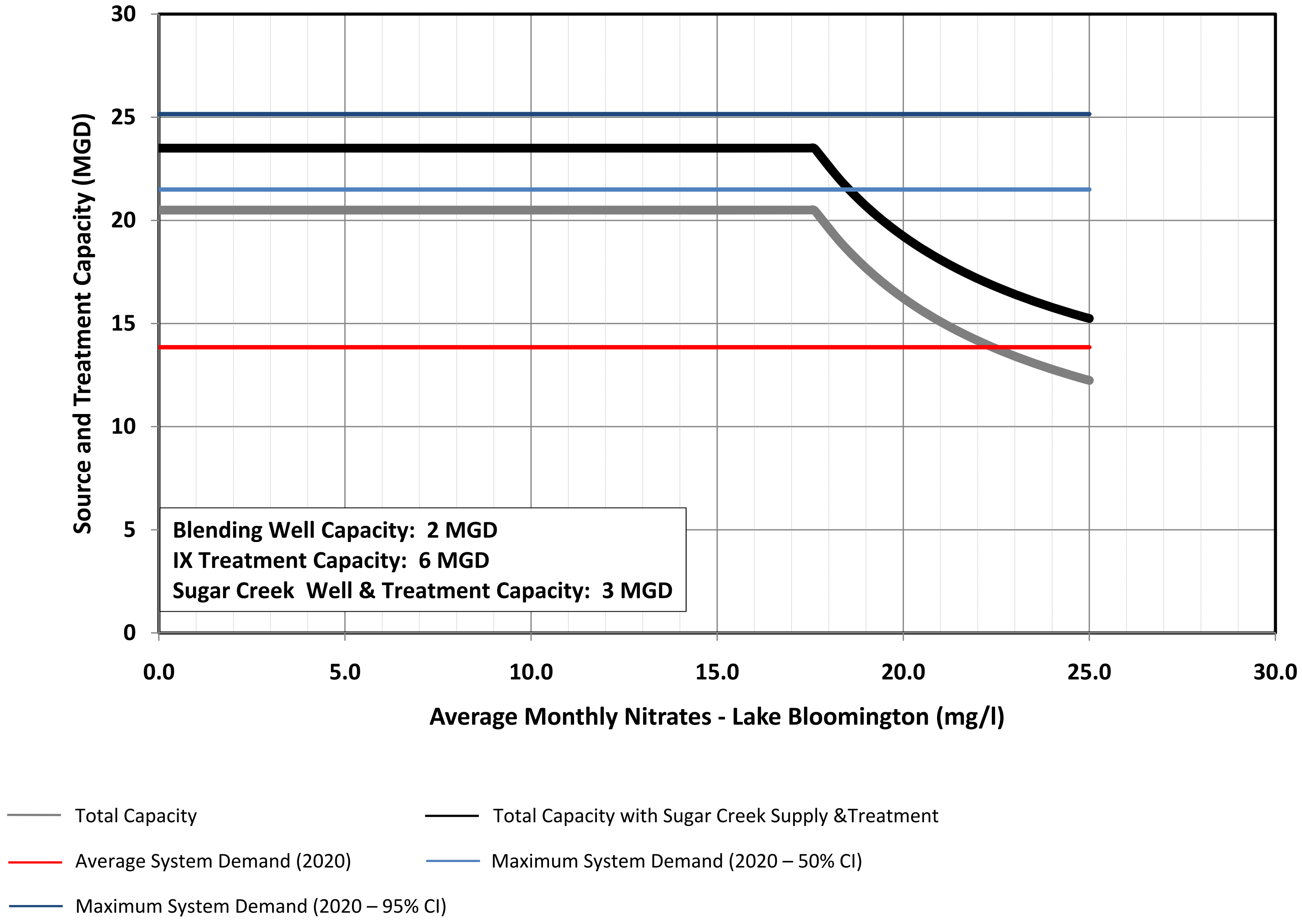


Figure 18: Alternative 3-c: Lake Bloomington, Lake Evergreen, the blending wells, IX treatment, and 3 MGD from Sugar Creek Wellfield.

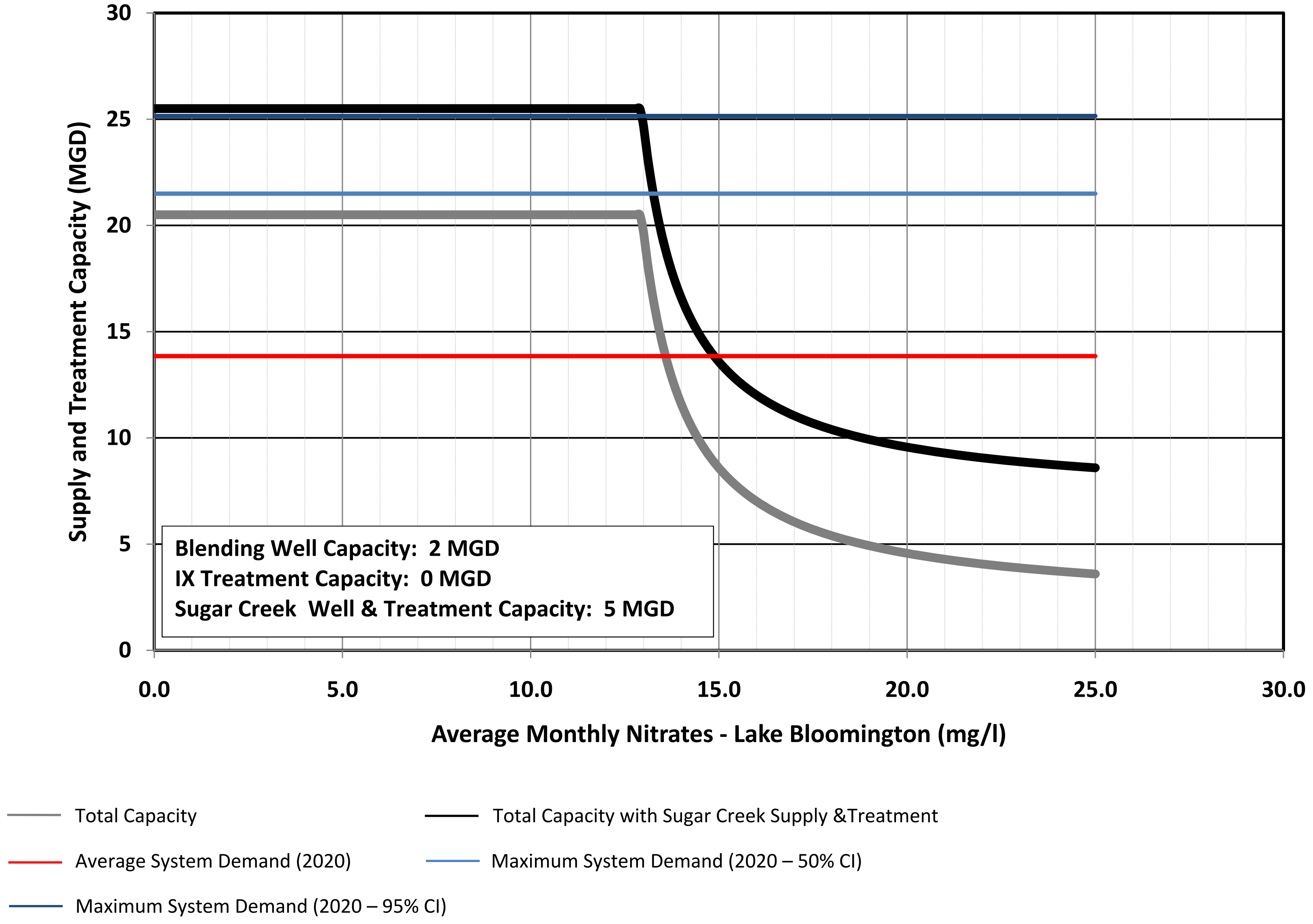


Figure 19: Alternative 4-a: Lake Bloomington, Lake Evergreen, the blending wells, IX treatment, and 5 MGD from Sugar Creek Wellfield.

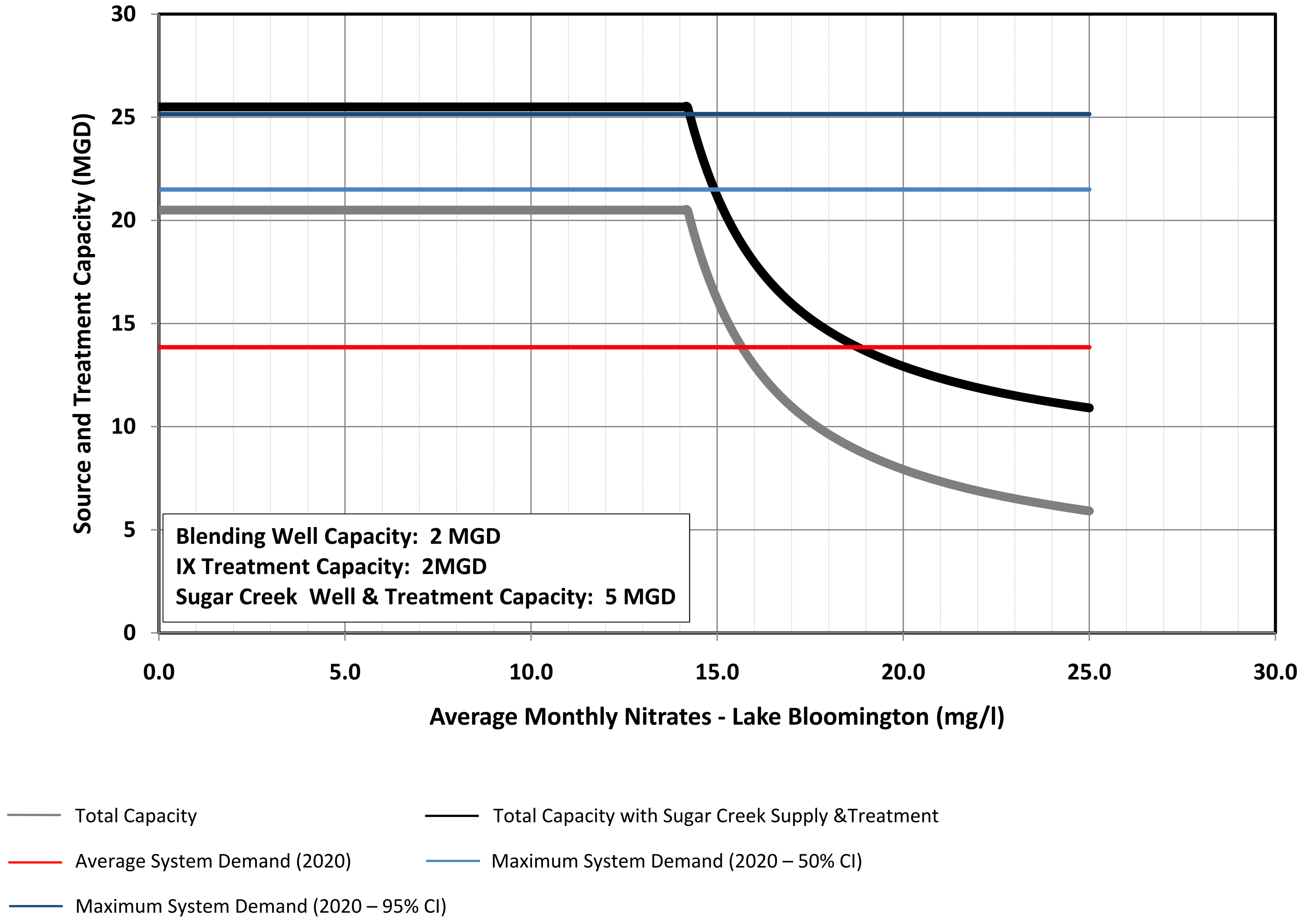


Figure 20: Alternative 4-b: Lake Bloomington, Lake Evergreen, the blending wells, IX treatment, and 5 MGD from Sugar Creek Wellfield.

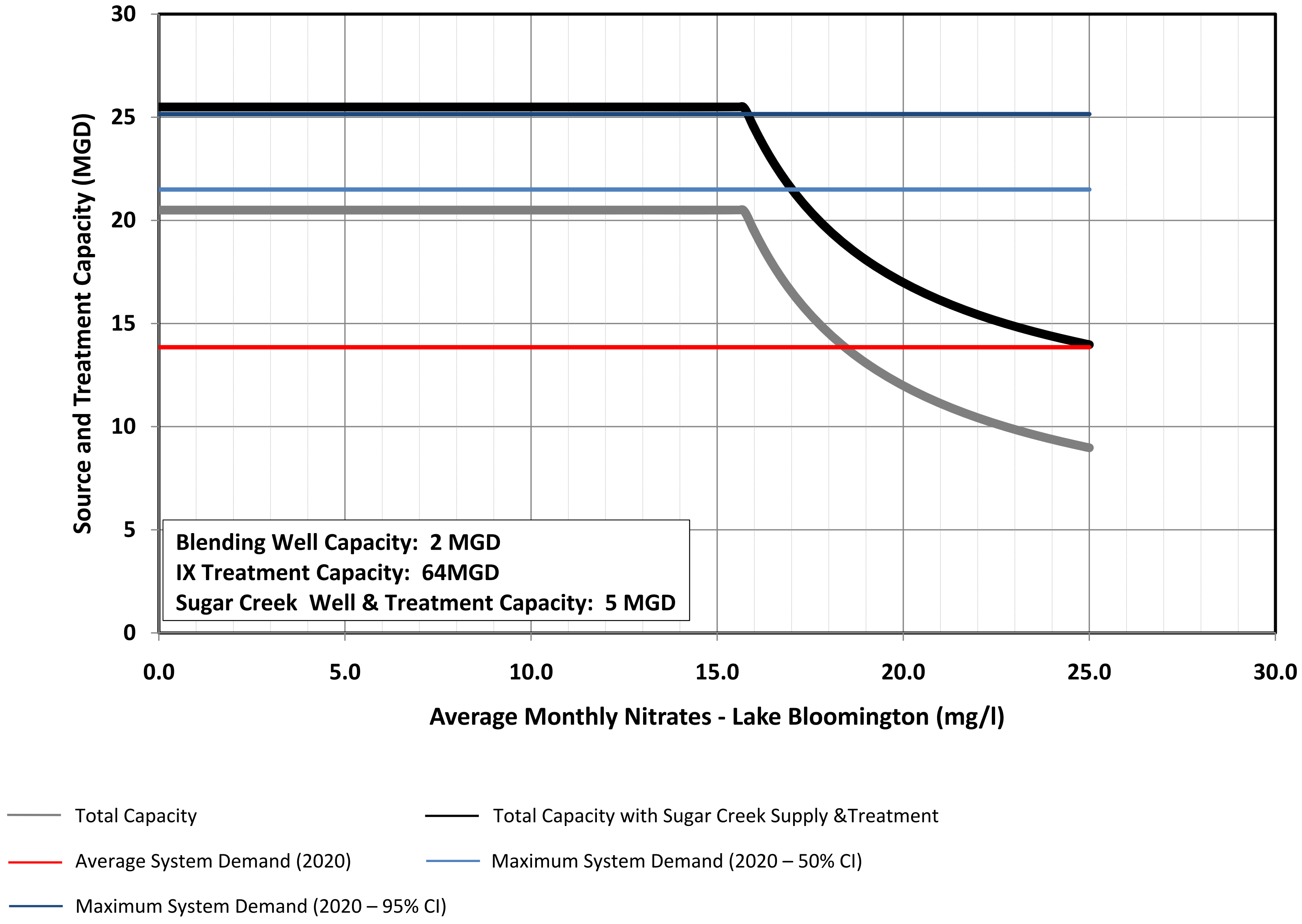


Figure 21: Alternative 4-c: Lake Bloomington, Lake Evergreen, the blending wells, IX treatment, and 5 MGD from Sugar Creek Wellfield.

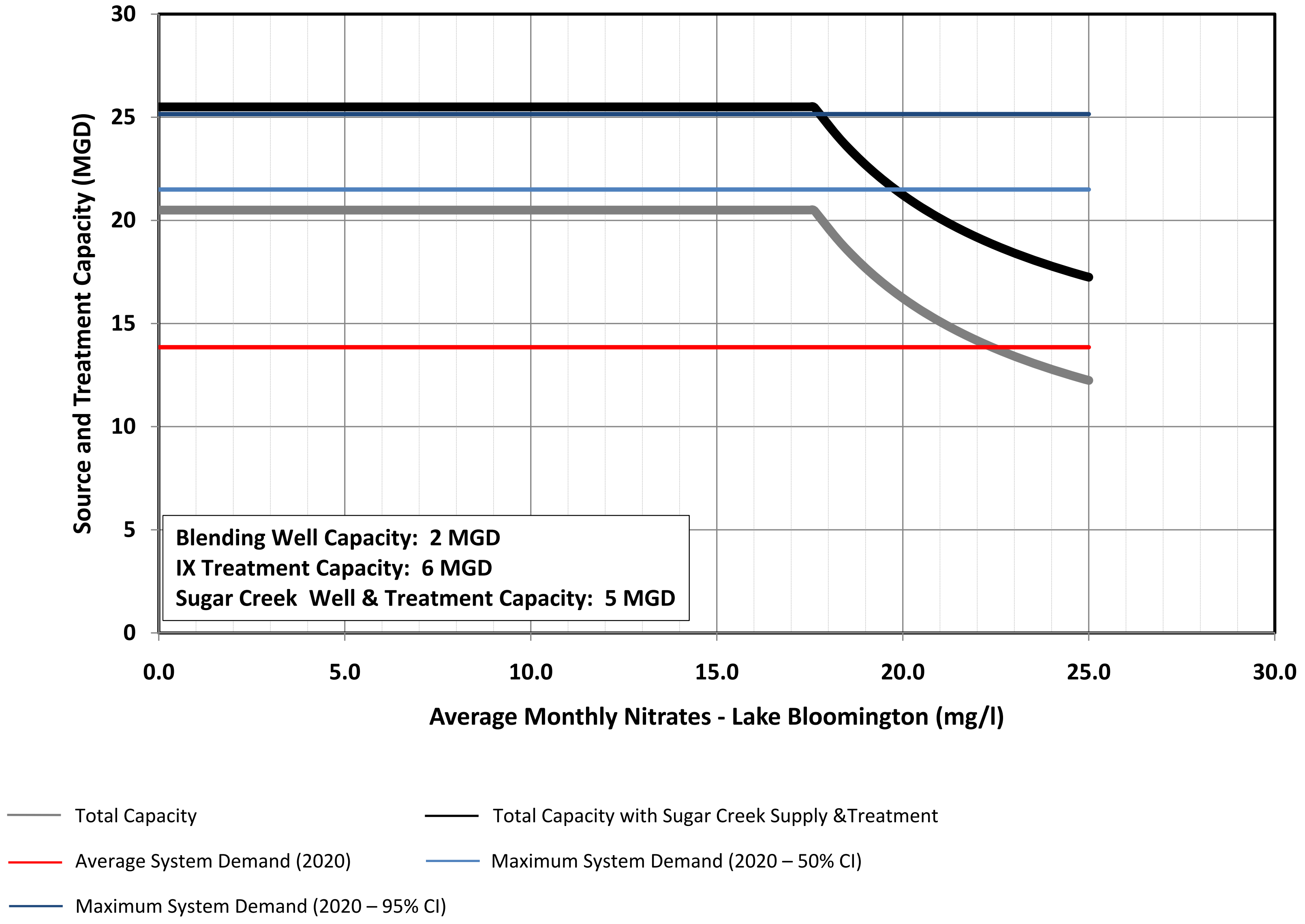


Figure 22: Alternative 4-d: Lake Bloomington, Lake Evergreen, the blending wells, IX treatment, and 5 MGD from Sugar Creek Wellfield.

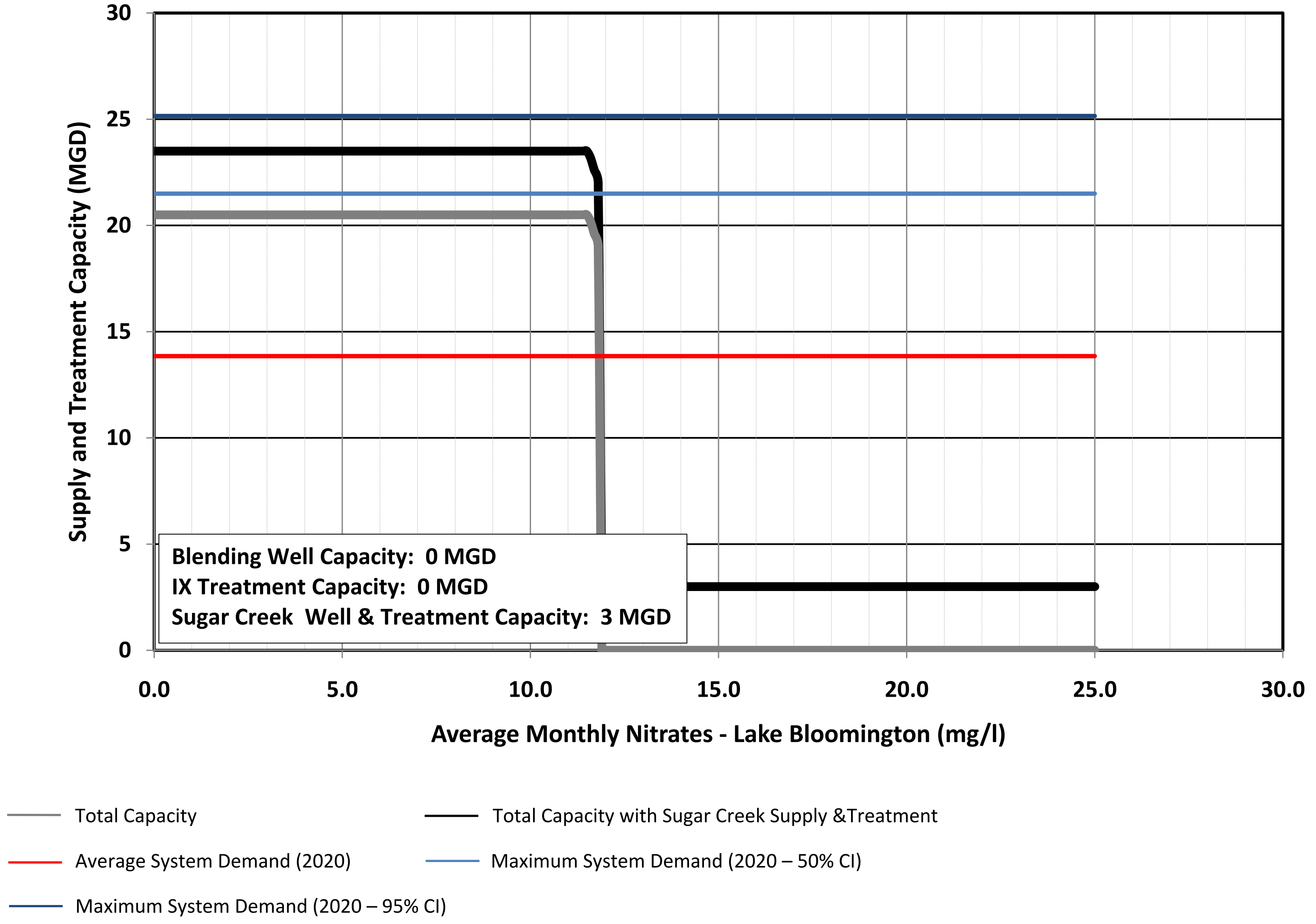


Figure 23: Alternative 5-a: Lake Bloomington, Lake Evergreen, IX treatment, and 3 MGD from Sugar Creek Wellfield.

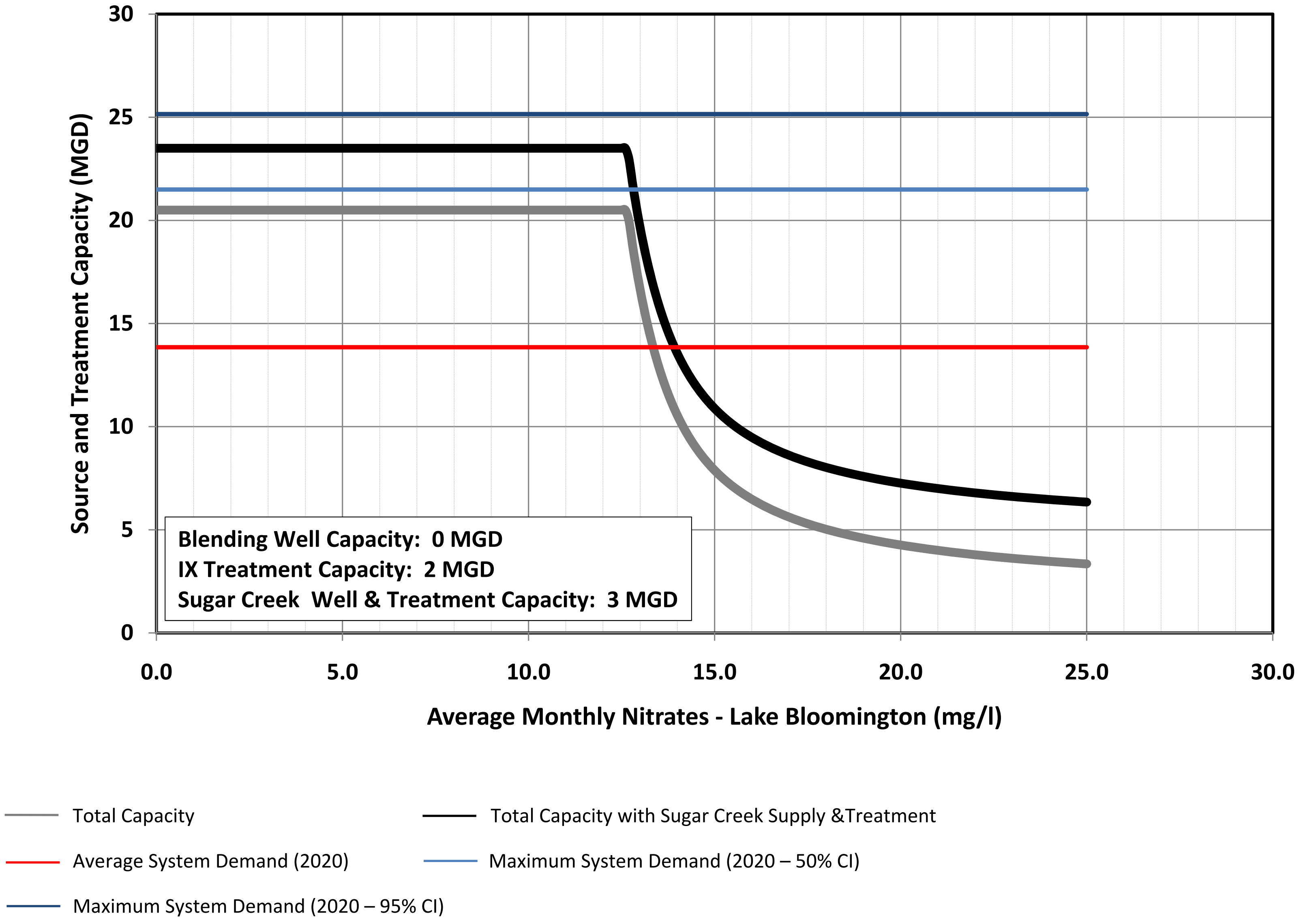


Figure 24: Alternative 5-b: Lake Bloomington, Lake Evergreen, IX treatment, and 3 MGD from Sugar Creek Wellfield.

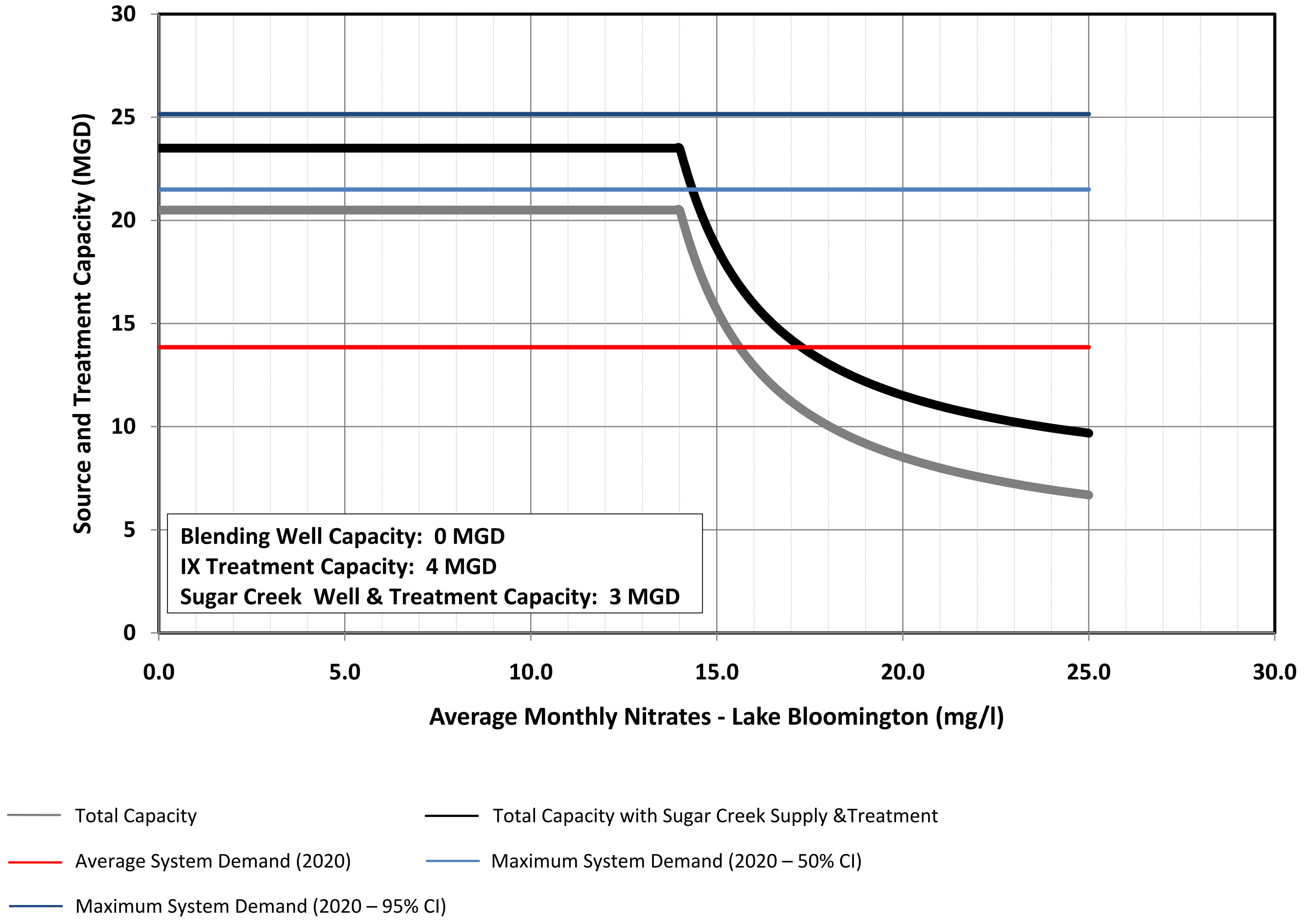


Figure 25: Alternative 5-c: Lake Bloomington, Lake Evergreen, IX treatment, and 3 MGD from Sugar Creek Wellfield.

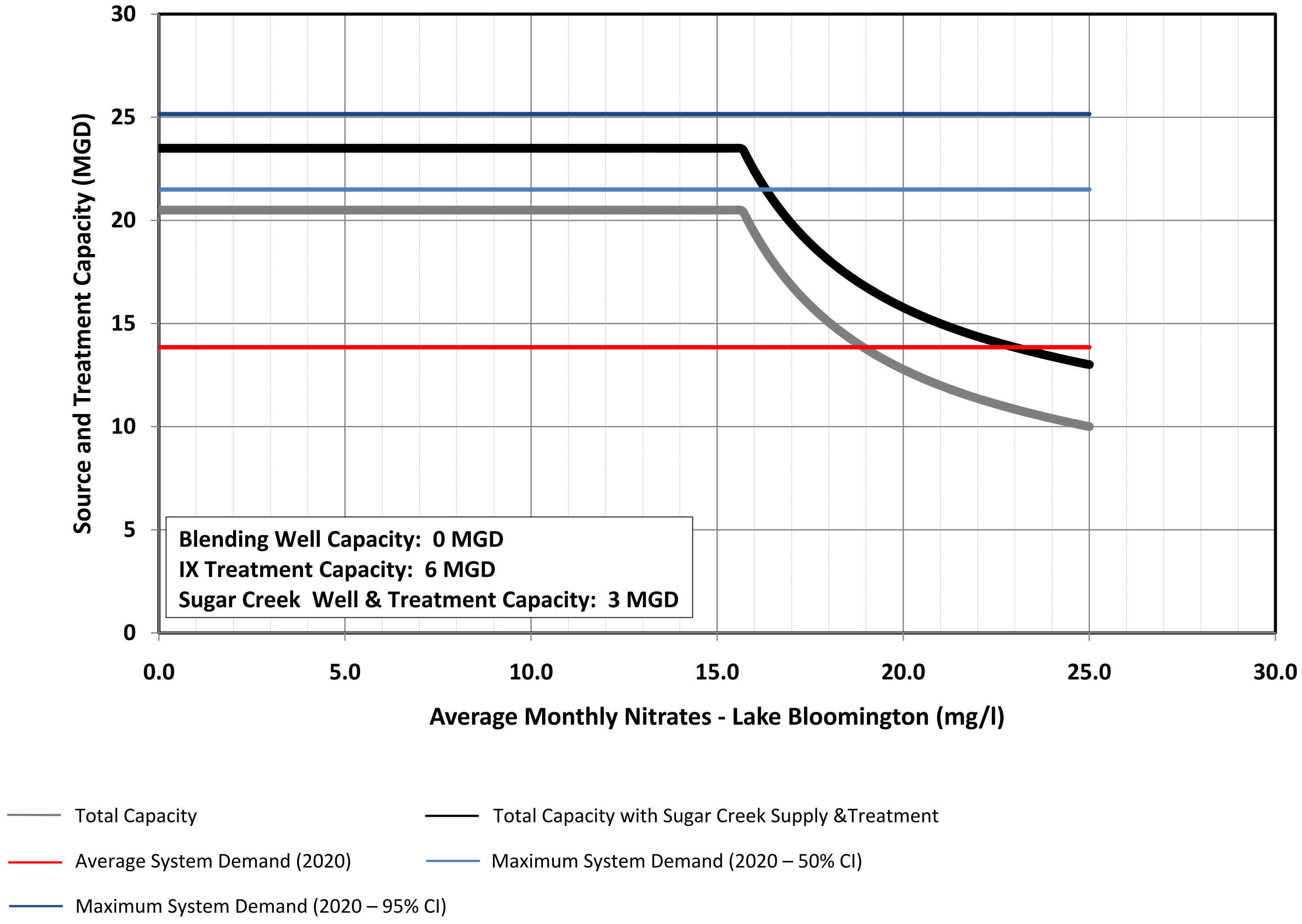


Figure 26: Alternative 5-d: Lake Bloomington, Lake Evergreen, IX treatment, and 3 MGD from Sugar Creek Wellfield.

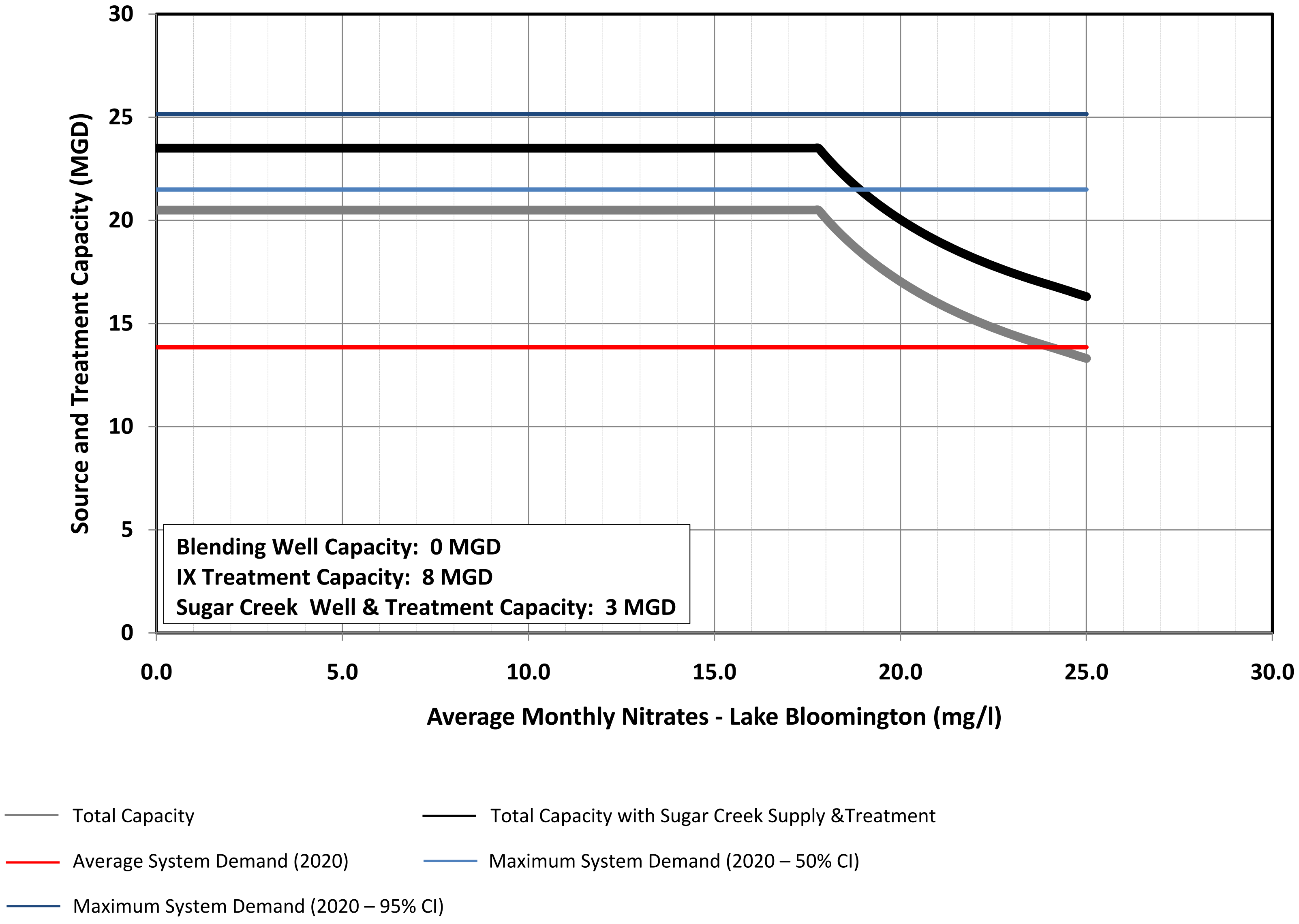


Figure 27: Alternative 5-e: Lake Bloomington, Lake Evergreen, IX treatment, and 3 MGD from Sugar Creek Wellfield.

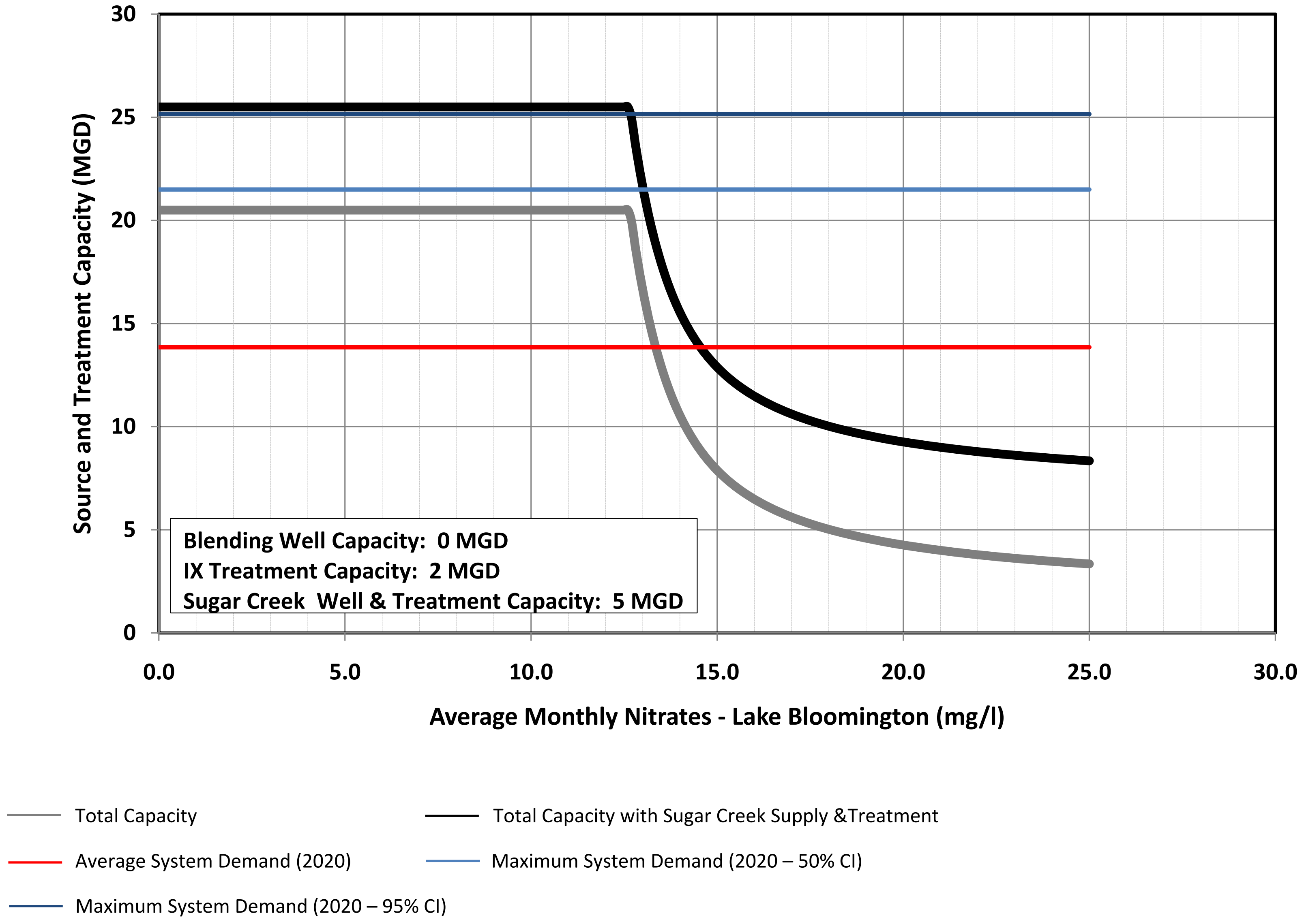


Figure 28: Alternative 6-a: Lake Bloomington, Lake Evergreen, IX treatment, and 5 MGD from Sugar Creek Wellfield.

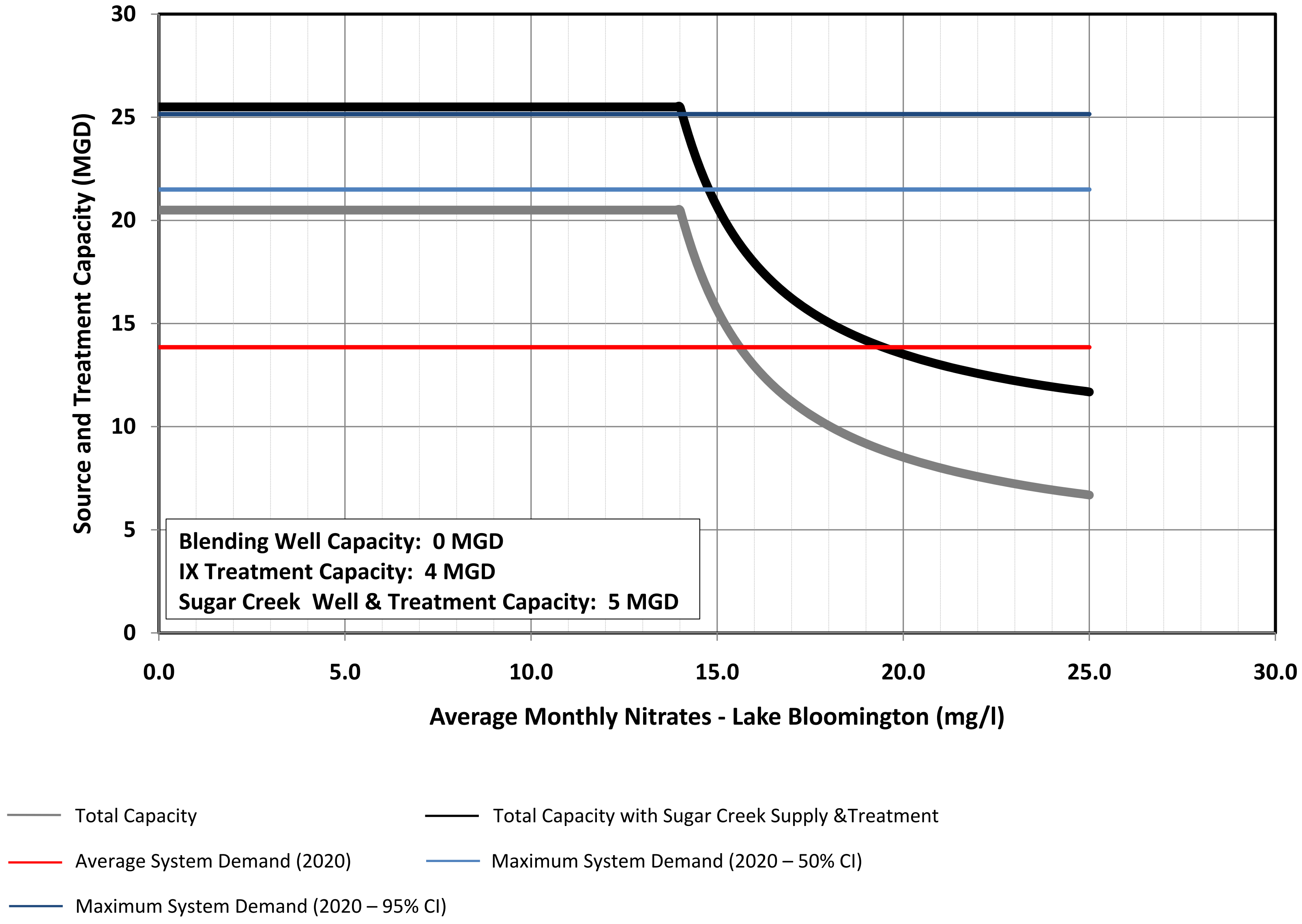


Figure 29: Alternative 6-b: Lake Bloomington, Lake Evergreen, IX treatment, and 5 MGD from Sugar Creek Wellfield.

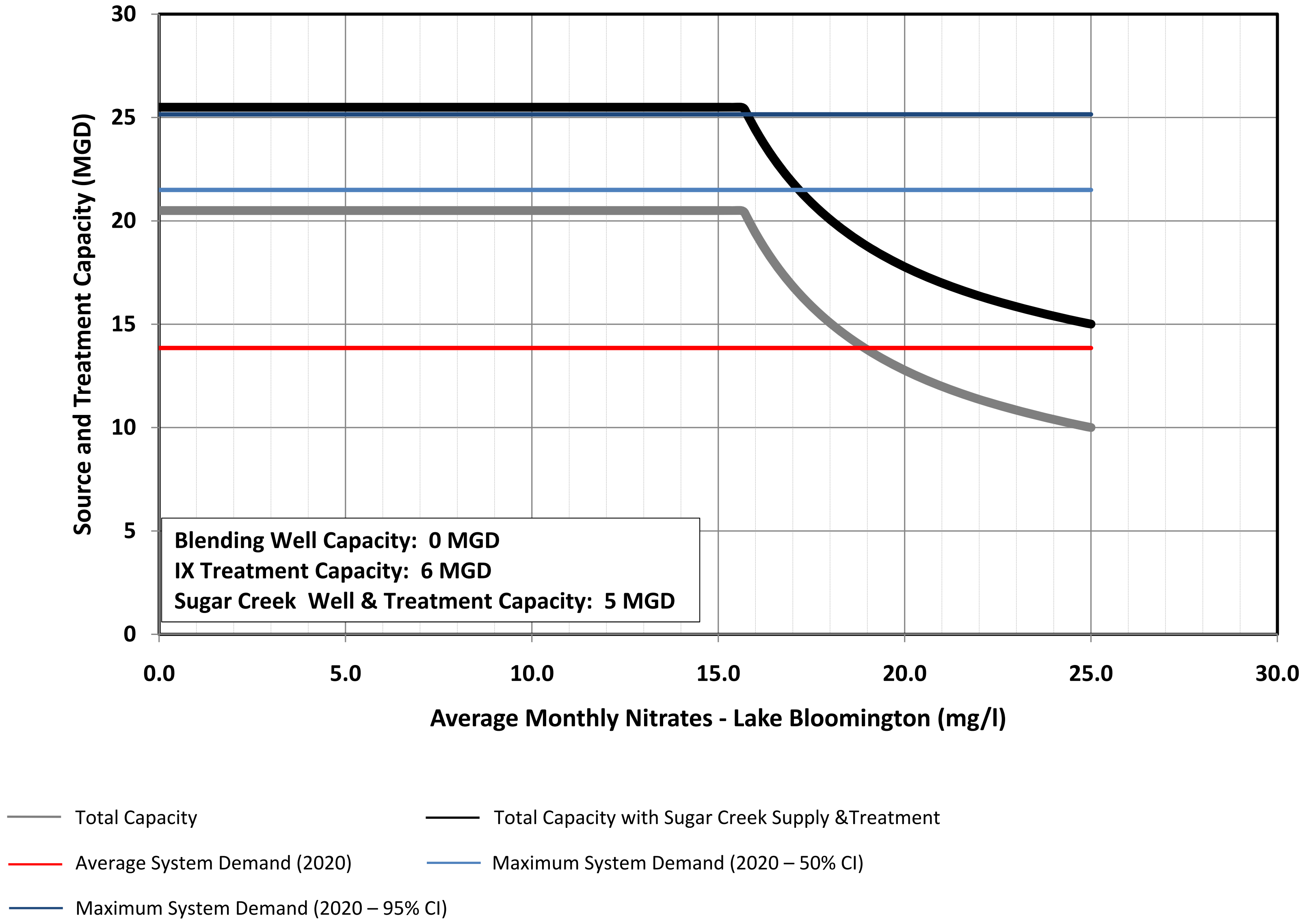


Figure 30: Alternative 6-c: Lake Bloomington, Lake Evergreen, IX treatment, and 5 MGD from Sugar Creek Wellfield.

Table 4: Months where the maximum day pumping exceeded the 50 percent maximum day pumping.

Year	Month	Maximum Day Pumping	50% Maximum Day Pumping
1987	July	18.0	13.8
1987	August	14.0	13.8
1988	May	17.3	15.5
1988	June	18.4	15.5
1988	July	17.9	15.5
1991	June	14.4	14.2
1991	July	15.2	14.2
1992	June	14.3	14.0
1992	July	14.7	14.0
1994	June	16.8	15.7
1996	July	15.2	15.1
1997	July	15.8	15.5
1997	August	16.2	15.5
1998	July	16.7	16.1
2000	August	17.8	17.5
2001	August	18.4	17.7
2002	July	19.0	18.1
2005	June	21.6	18.8
2007	June	19.6	17.5
2007	July	18.3	17.5
2007	August	18.0	17.5

Nitrate Data Analysis

Nitrate levels

To evaluate the performance of different supply and treatment alternatives, we used nitrate level data from 1983-2009 to determine the percent of months in which average monthly nitrate concentration in Lake Bloomington exceeded a specific nitrate concentration (Figure 31). In order to evaluate performance during both average and maximum demand conditions, the occurrence of different monthly nitrate levels was analyzed for all months and also for months during which peak demands typically occur.

To calculate the annual percentage, all months were included; however, to calculate the percent of peak demand months in which different nitrate levels were exceeded, we first had to determine the months in which peak demand occurred from 1983-2009. We calculated the ratio of the annual maximum day to average day demand (MD:AD) using monthly average day and maximum day demand data. Monthly average demand was then multiplied by the average yearly MD:AD to calculate the average maximum pumping for each month. This value was then compared to the actual maximum pumping rate for each month; we considered a month to be a peak month if its average maximum monthly pumping rate was greater than the 50 percent maximum day pumping. Maximum pumping for June, July, and August regularly exceeded the 50 percent maximum day pumping and were used for calculating the peak months percentage (Table 4).

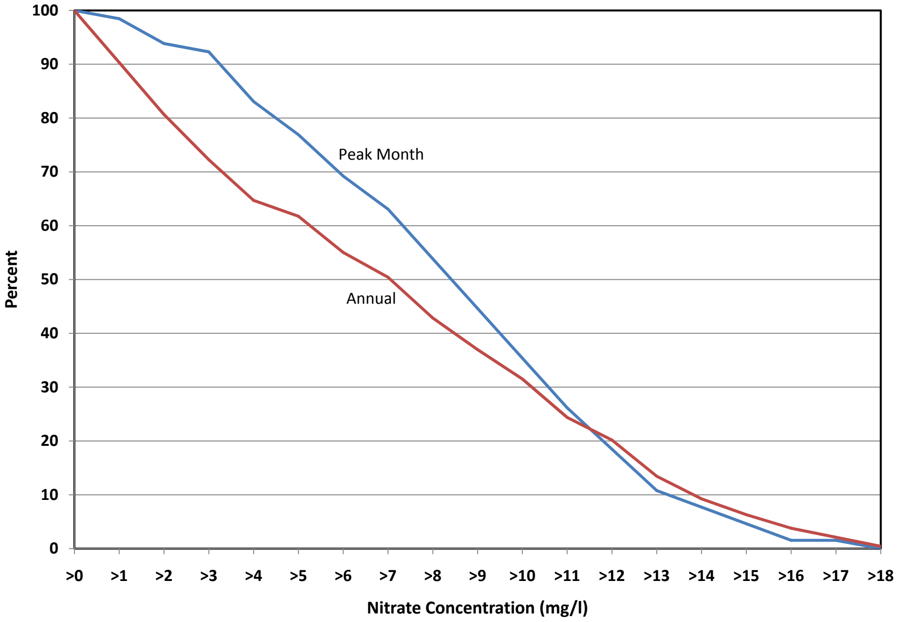


Figure 31: Percentage of monthly average nitrate concentrations in Lake Bloomington that exceed a specific nitrate concentration. Peak months are June, July, and August.

Figure 31 shows the percentage of monthly average nitrate concentration in Lake Bloomington that exceeded a specific concentration. The annual months and peak months exceeded $7.0\,mg/l$ and $8.5\,mg/l$ 50 percent of the time, respectively.

Nitrate events

In order to better understand how nitrate concentrations in Lake Bloomington change overtime, we analyzed average monthly nitrate data from 1990-08 to identify nitrate events: the period before, during, and after nitrate concentration in Lake Bloomington exceeds $10\,mg/l$. We examined the time between the onset (starting at $4\,mg/l$), the actual event (nitrate concentration greater than $10\,mg/l$), and the ending (nitrate concentration returning to $4\,mg/l$) (POSSIBLY REFERENCE FIGURE). Table 5 summarizes each event between 1990-2008. Events occurred once a year with the exception of 2007 in which two events occurred. The length of an event is the number of days the nitrate concentration was greater than $10\,mg/l$; in Lake Bloomington, an event lasted between 57 to 254 days. The time between two events was measured from the first day Lake Bloomington's nitrate concentration was below $10\,mg/l$ (at the end of an event), to the first day of the following event when the nitrate concentration was greater than $10\,mg/l$. Each individual event in Lake Bloomington from 1990-2008 is shown in Figures 32-49.

We also calculated the number of days between a threshold concentration, such as 4, 6, $and\,8\,mg/l$, and the start of the event to understand how quickly historical events have occurred (Table 5). For example, in 1993 it took $59\,$days days for the nitrate concentration to increase from $4\,mg/l$ to $10\,mg/l$; 39 days to increase from $6\,mg/l$ to $10\,mg/l$ and 20 days to increase from $8\,mg/l$ to

Table 5: Number of days prior to reaching 10 mg/l nitrate concentration

Year	**Nitrate Concentration Lake Bloomington (mg/l)**				**Event Length**	**Days to next Event**
	4	**6**	**8**	**10**		
1990	-	6	3	0	197	84
1991	-	36	21	0	235	167
1992	59	39	20	0	150	178
1993	143	16	8	0	254	123
1994	91	85	42	0	186	237
1995	19	14	3	0	168	306
1996	178	157	12	0	64	241
1997	28	21	12	0	85	262
1998	36	20	12	0	152	229
1999	49	42	16	0	104	592
2001	9	6	3	0	149	237
2002	37	31	11	0	129	626
2004	101	55	12	0	104	133
2005	27	24	13	0	154	362
2006	19	11	7	0	57	175
2007a	20	13	3	0	69	28
2007b	-	25	15	0	89	199
2008	18	14	9	0	179	-
Average	**56**	**34**	**12**	**-**	**140**	**246**
Min	**9**	**6**	**3**	**-**	**57**	**28**
Max	**178**	**157**	**42**	**-**	**254**	**626**

$10\,mg/l$ (Figure X). The frequency of the number of weeks for nitrate levels in Lake Bloomington to increase from the various thresholds to $10\,mg/l$ is shown in Figure 50.This information is critical for understanding the time available to begin ion exchange treatment before the nitrate concentration in Lake Bloomington reaches $10\,mg/l$. Time is a factor in determining the appropriate mix of permanent and temporary ion exchange treatment.

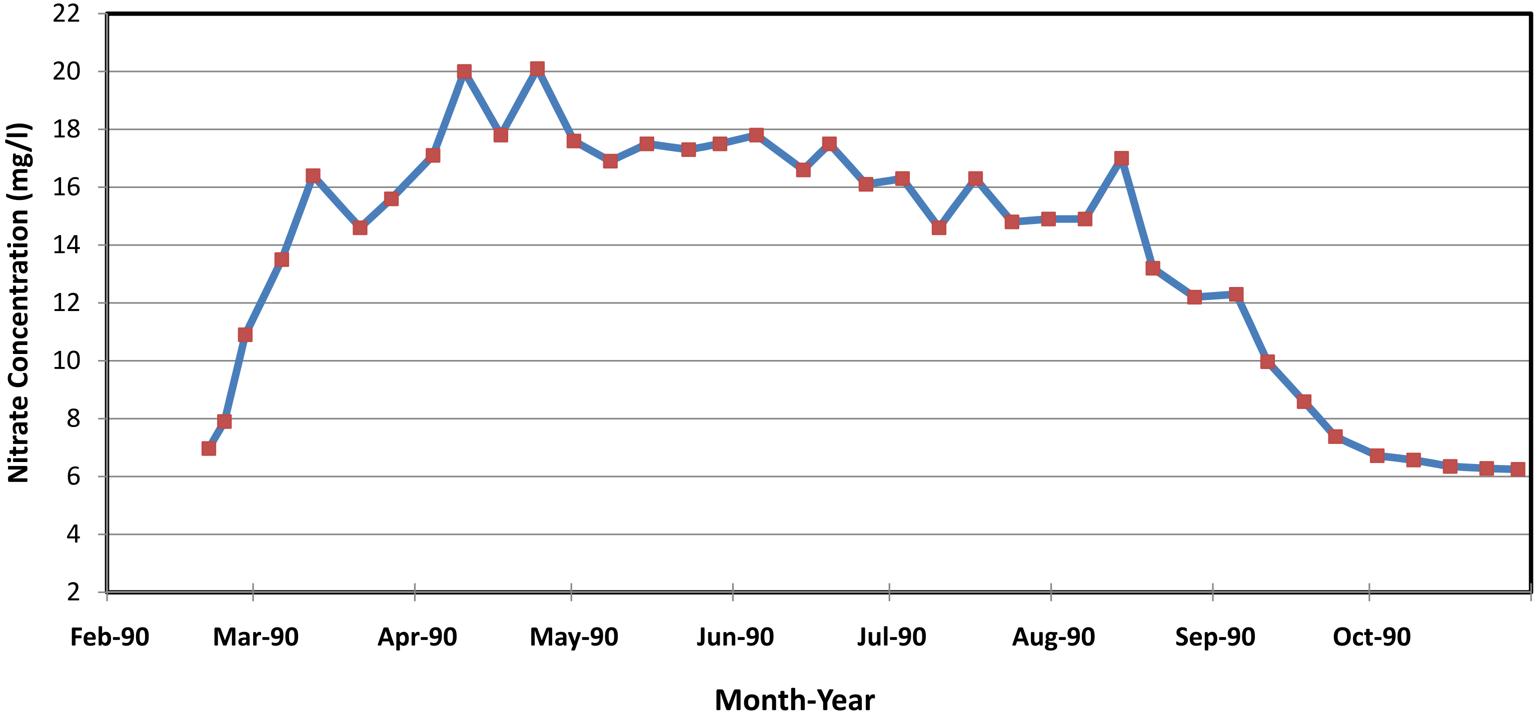


Figure 32: The 1990 event.

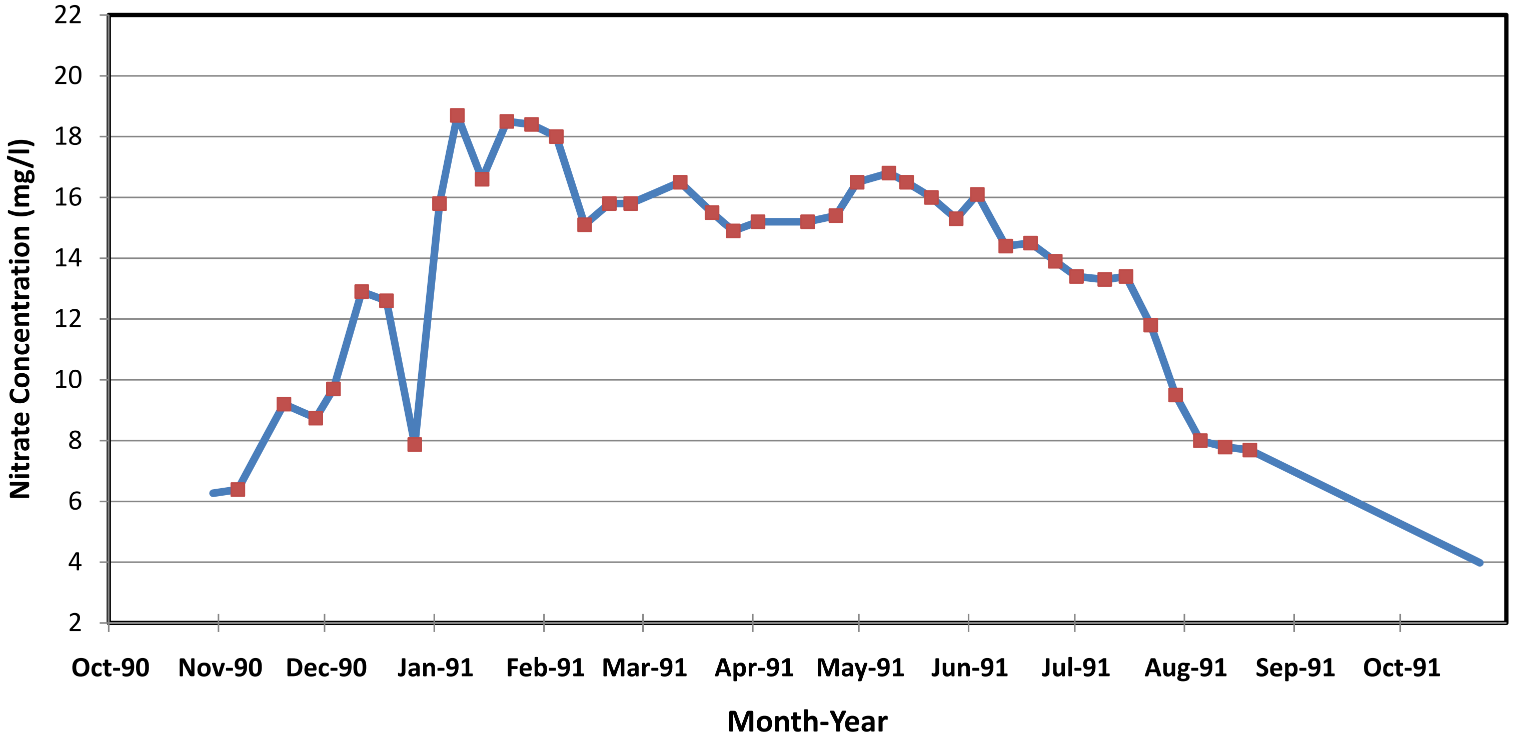


Figure 33: The 1991 event.

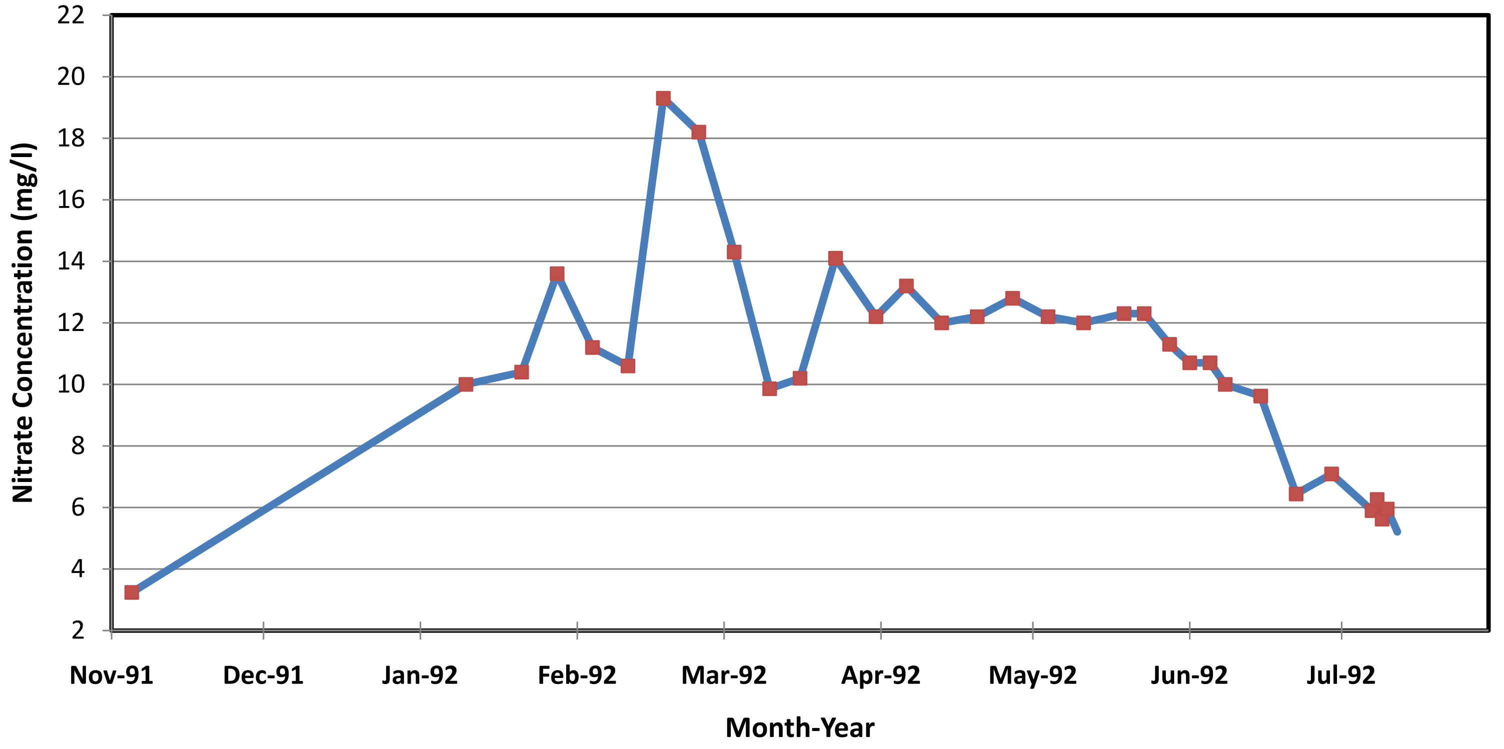


Figure 34: The 1992 event.

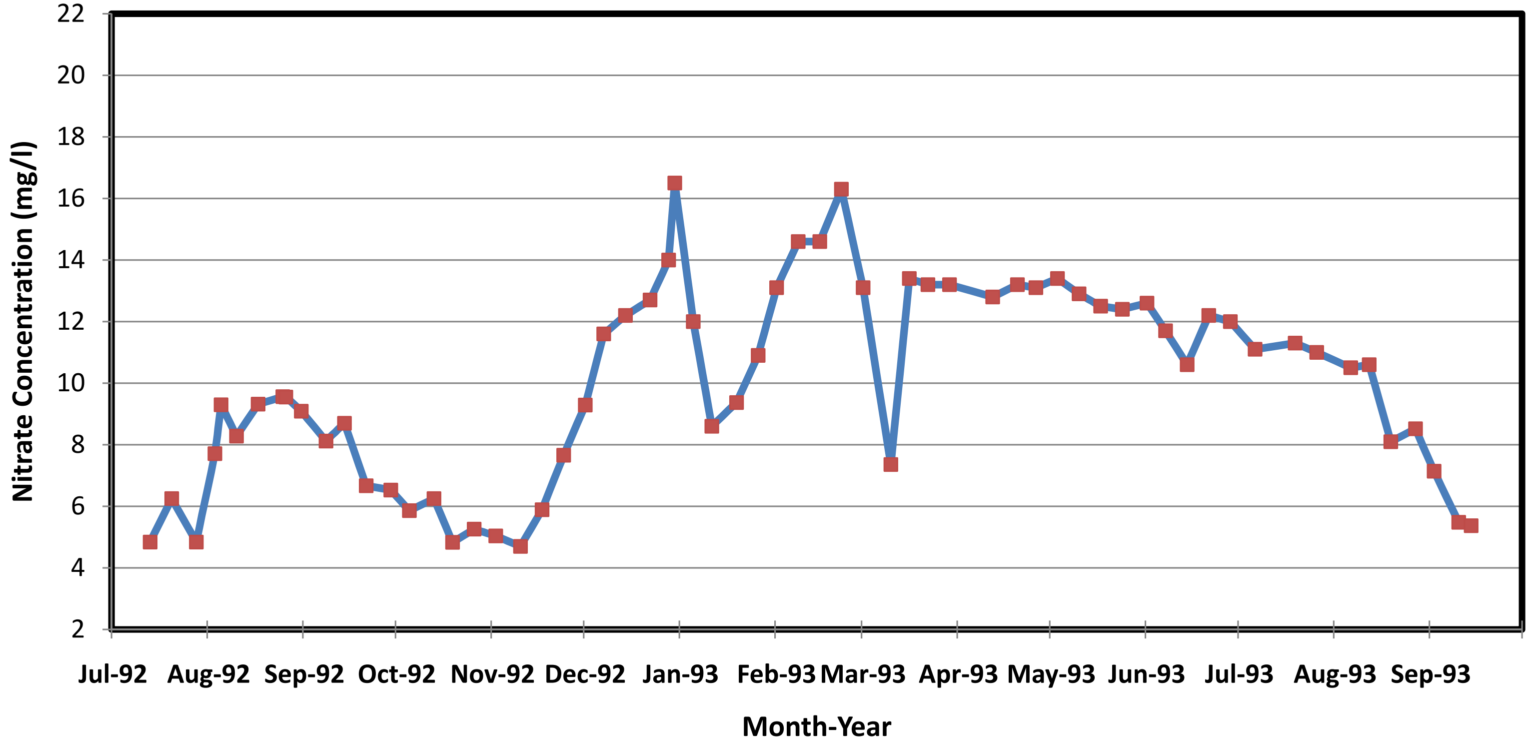


Figure 35: The 1993 event.

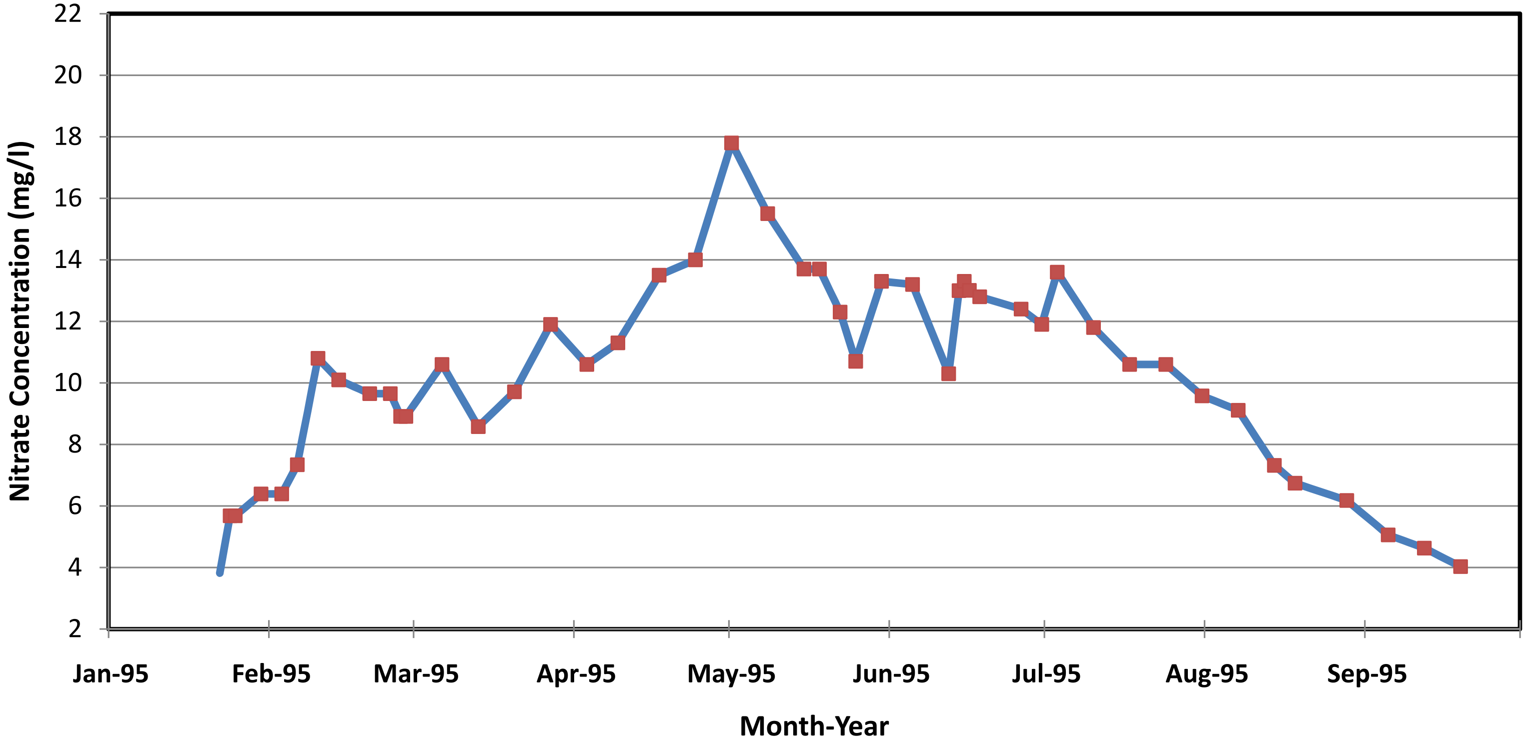


Figure 36: The 1994 event.

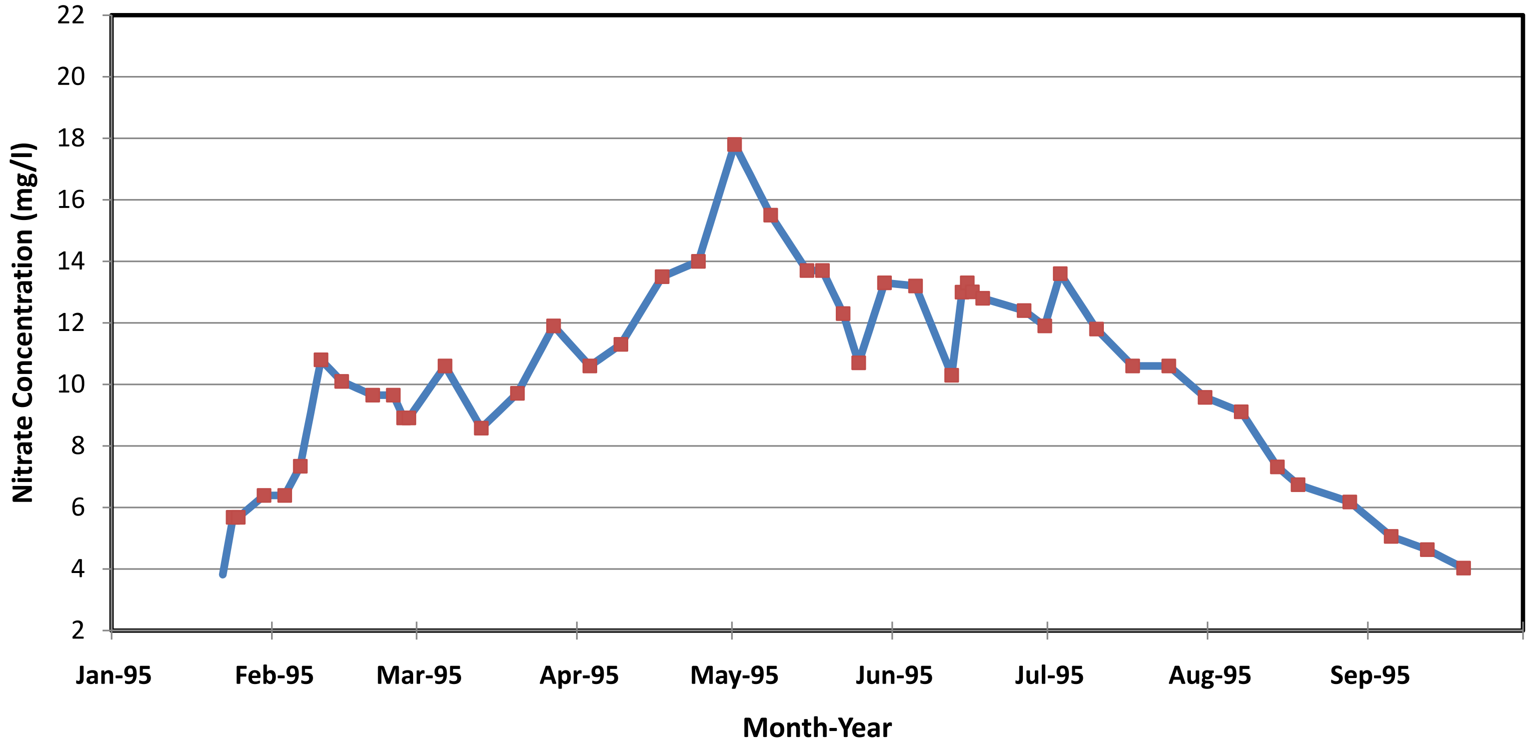


Figure 37: The 1995 event.

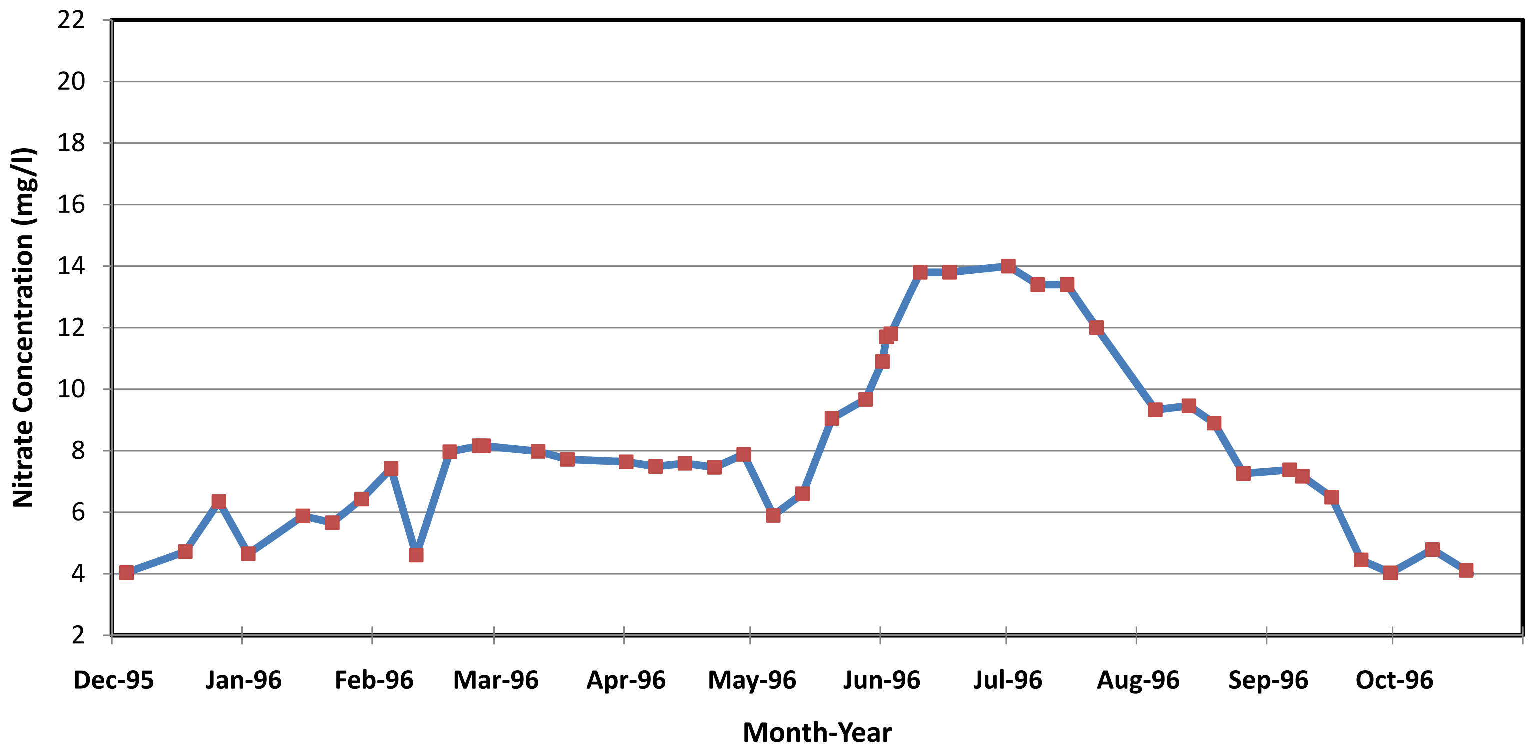


Figure 38: The 1996 event.

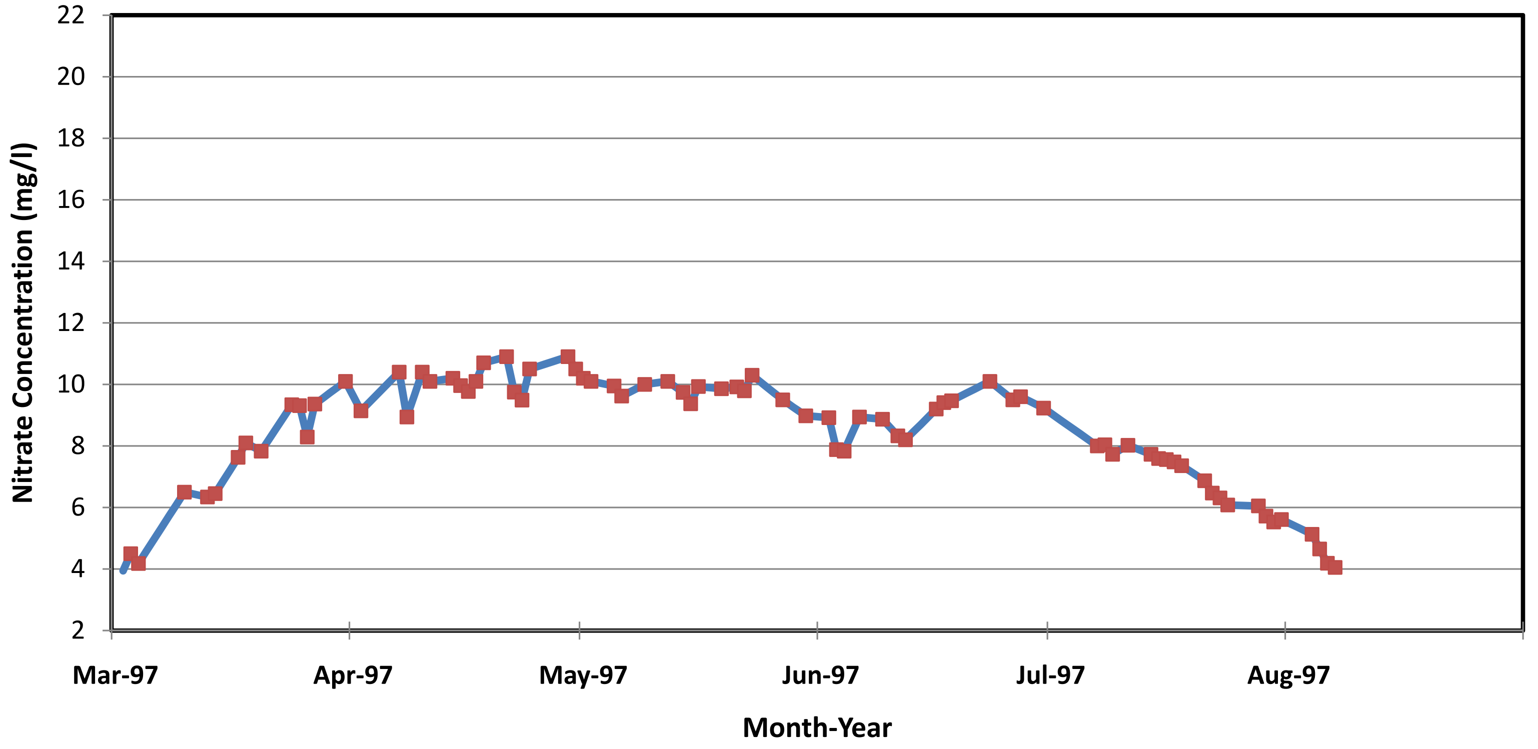


Figure 39: The 1997 event.

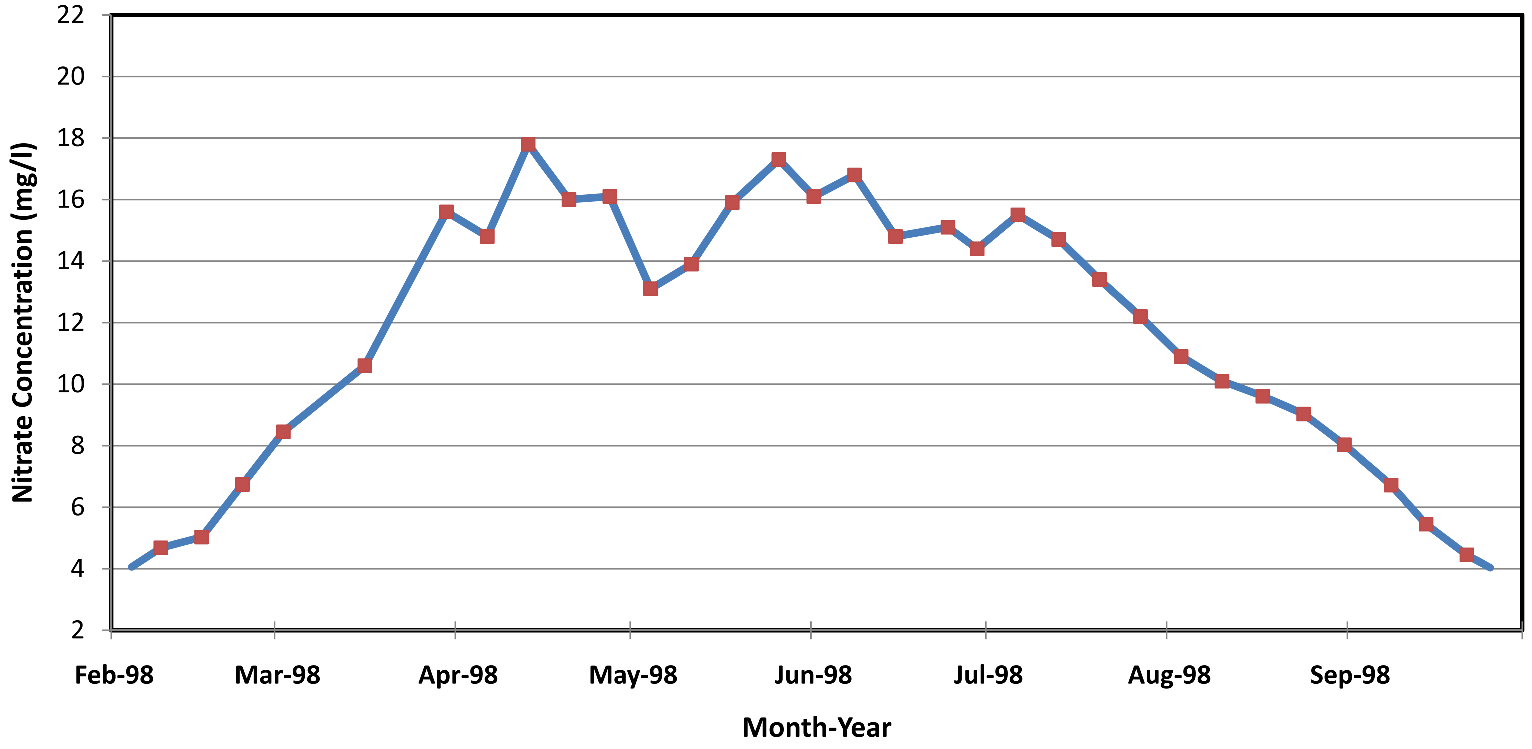


Figure 40: The 1998 event.

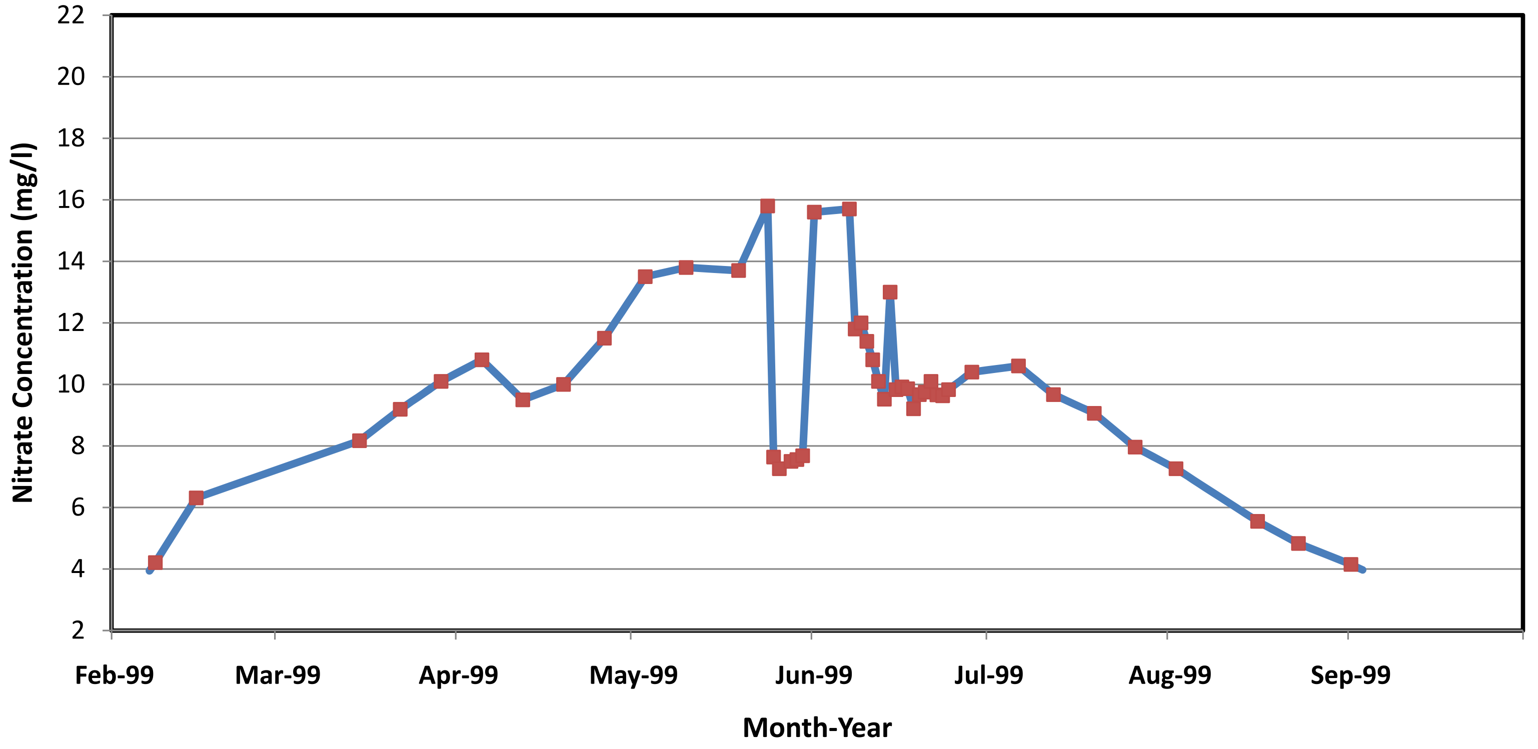


Figure 41: The 1999 event.

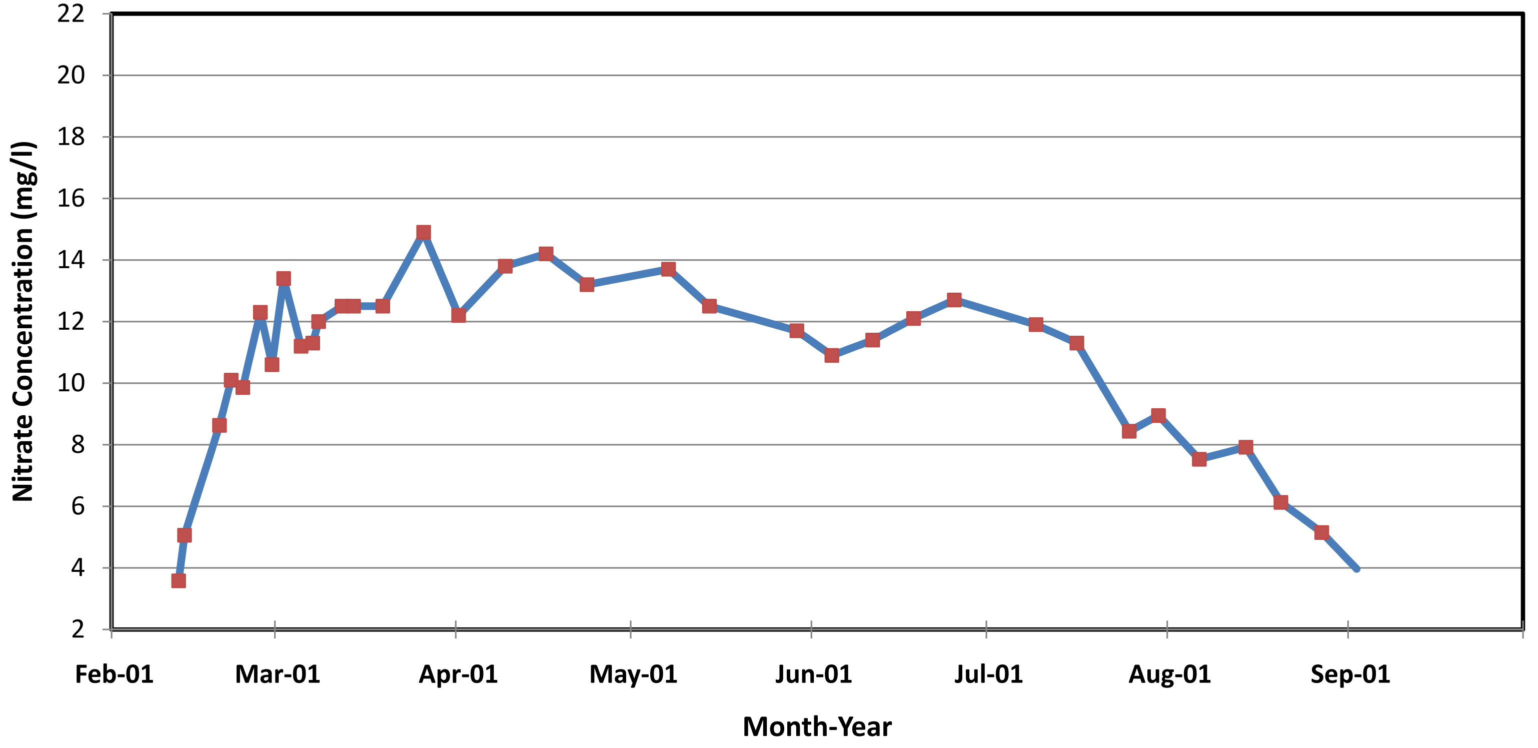


Figure 42: The 2001 event.

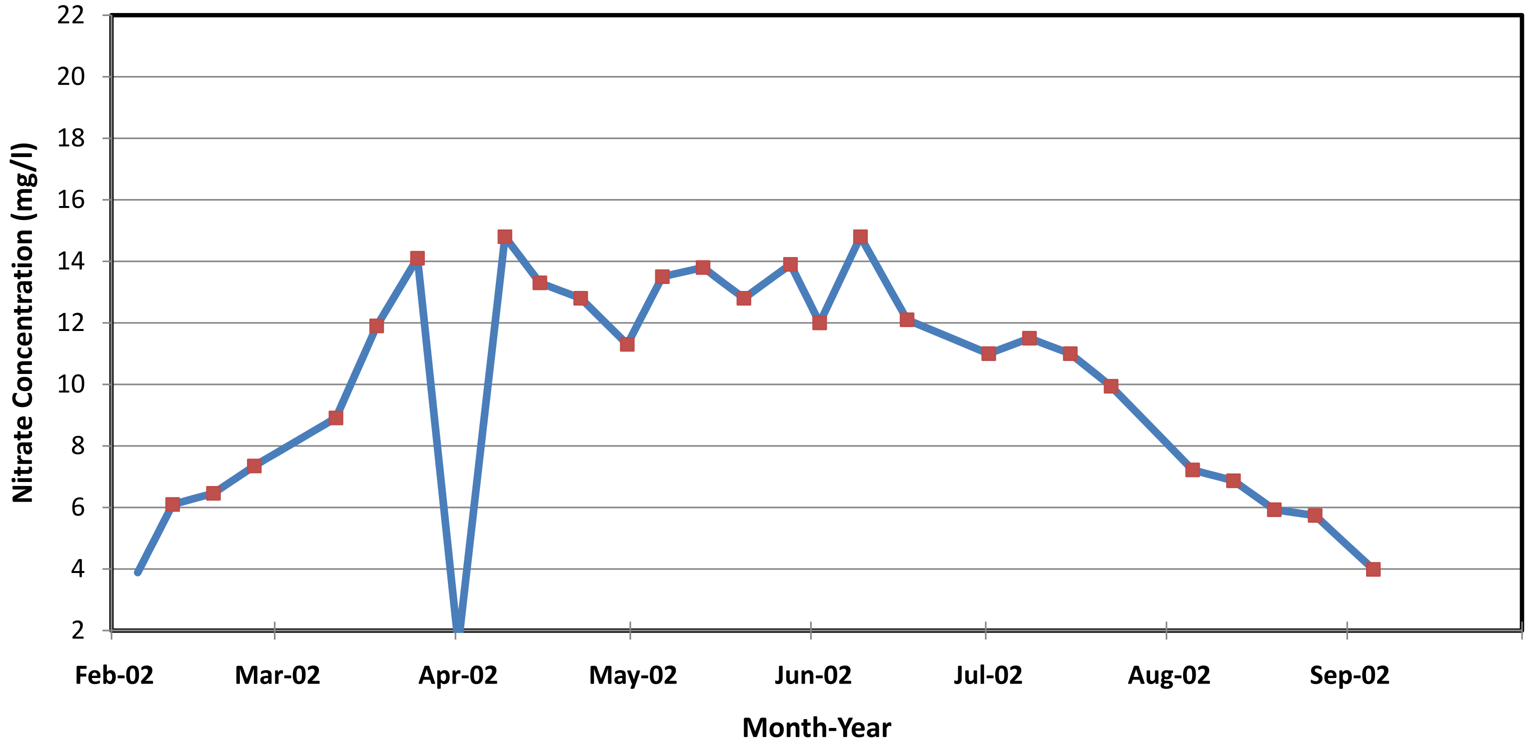


Figure 43: The 2002 event.

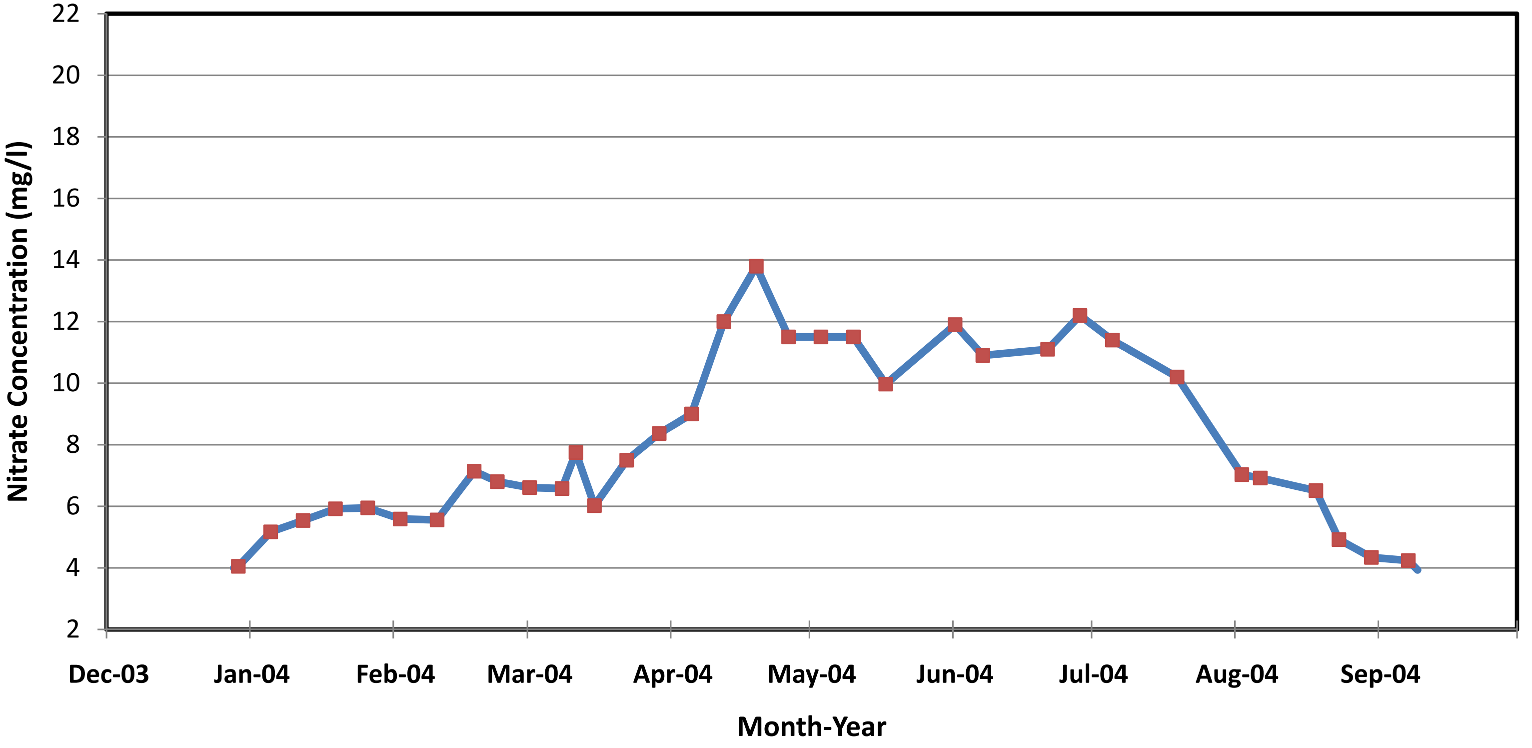


Figure 44: The 2004 event.

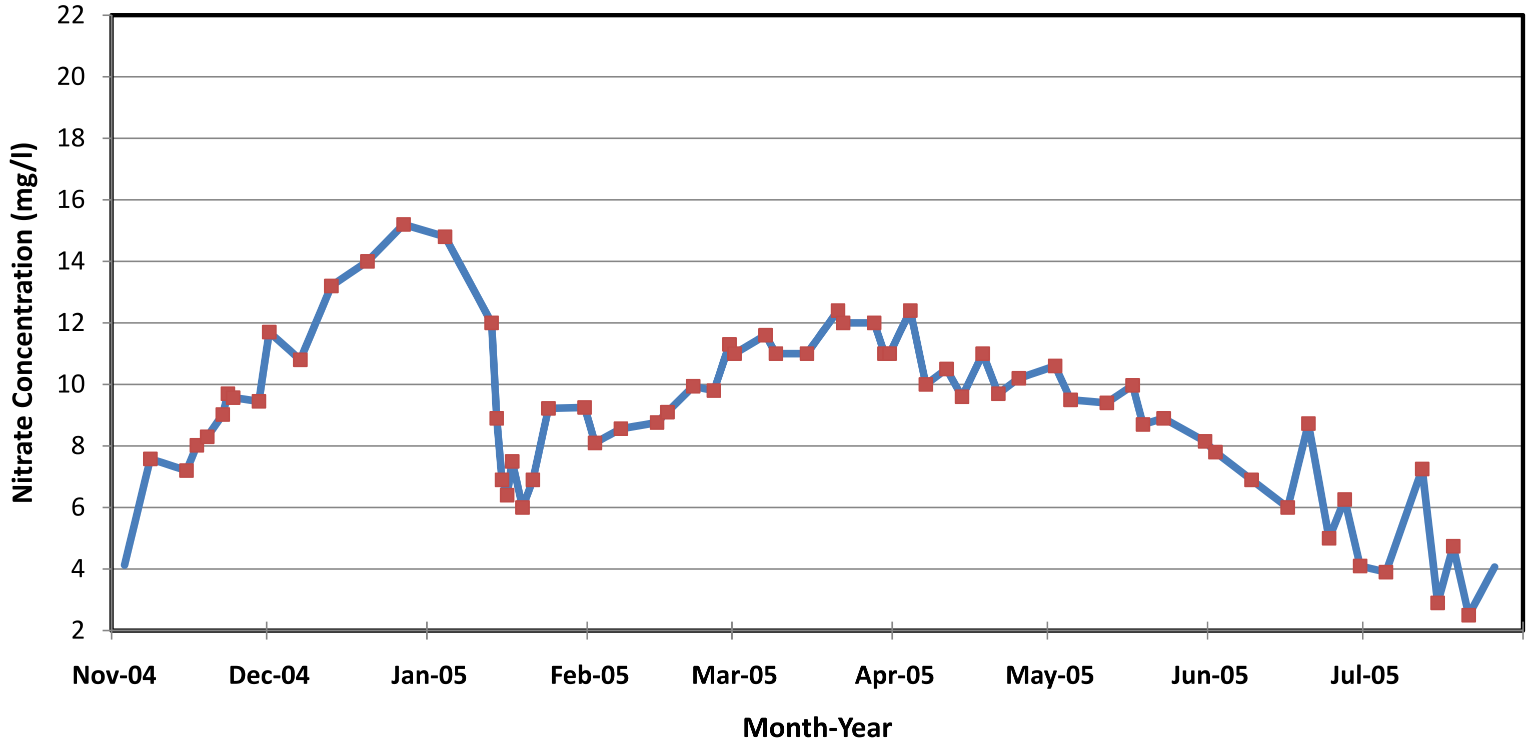


Figure 45: The 2005 event.

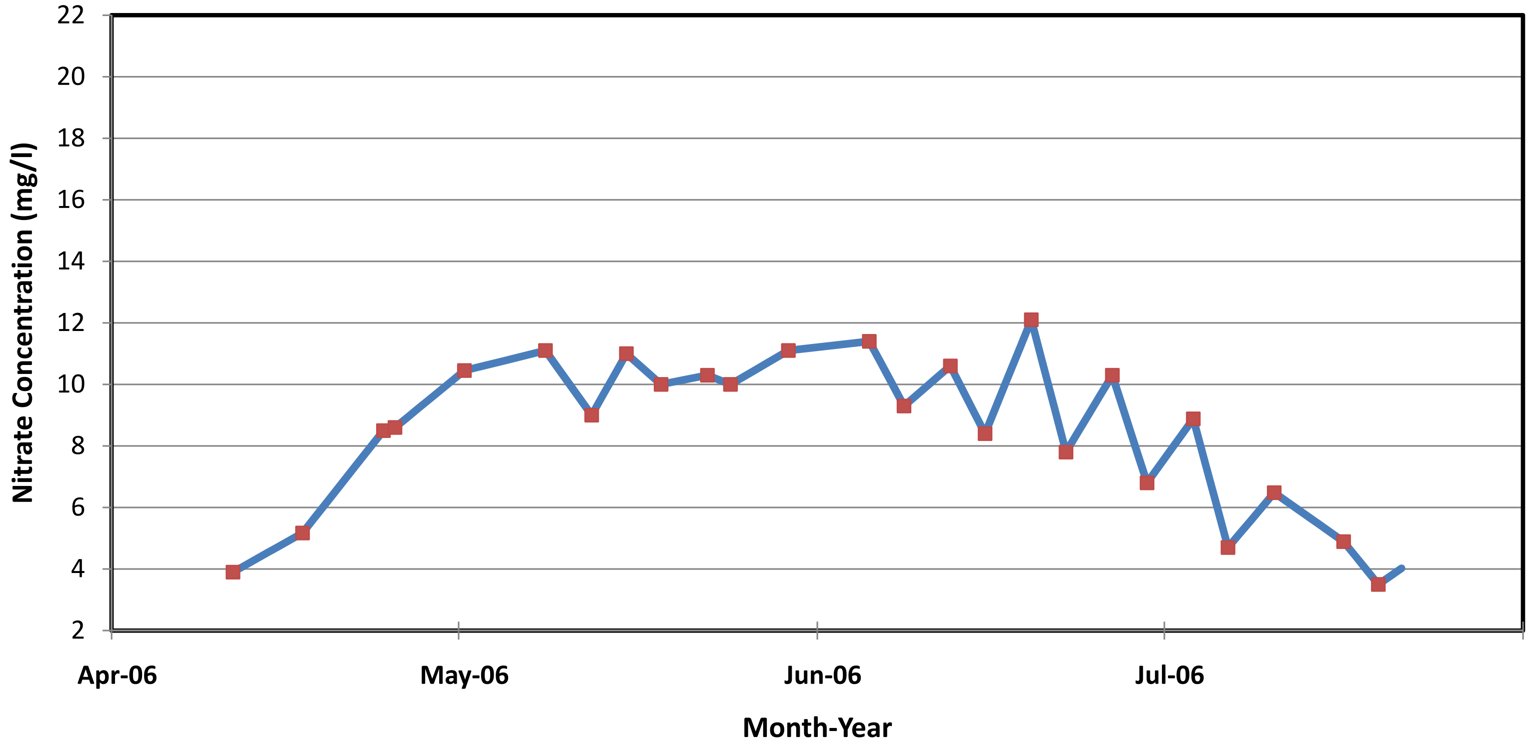


Figure 46: The 2006 event.

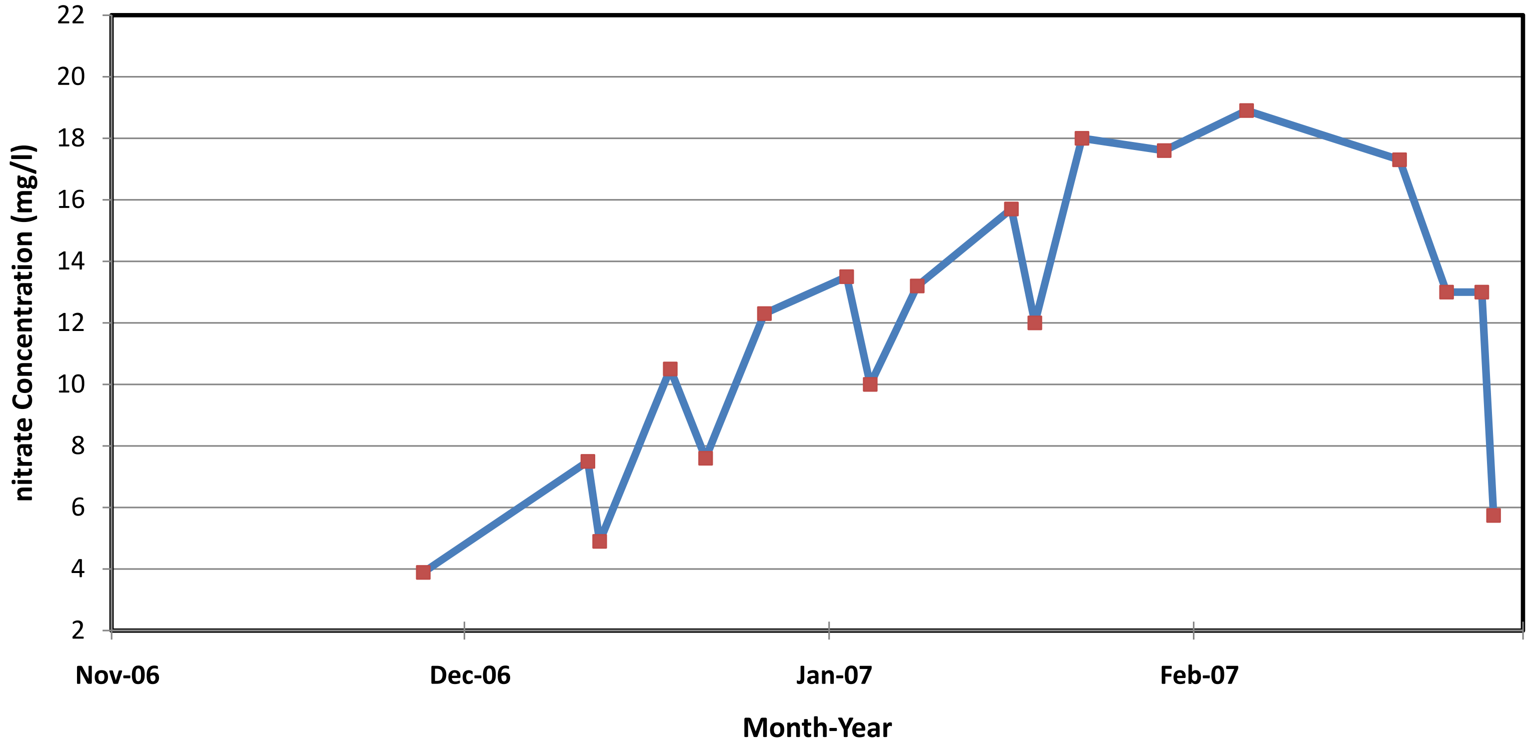


Figure 47: The first 2007 event.

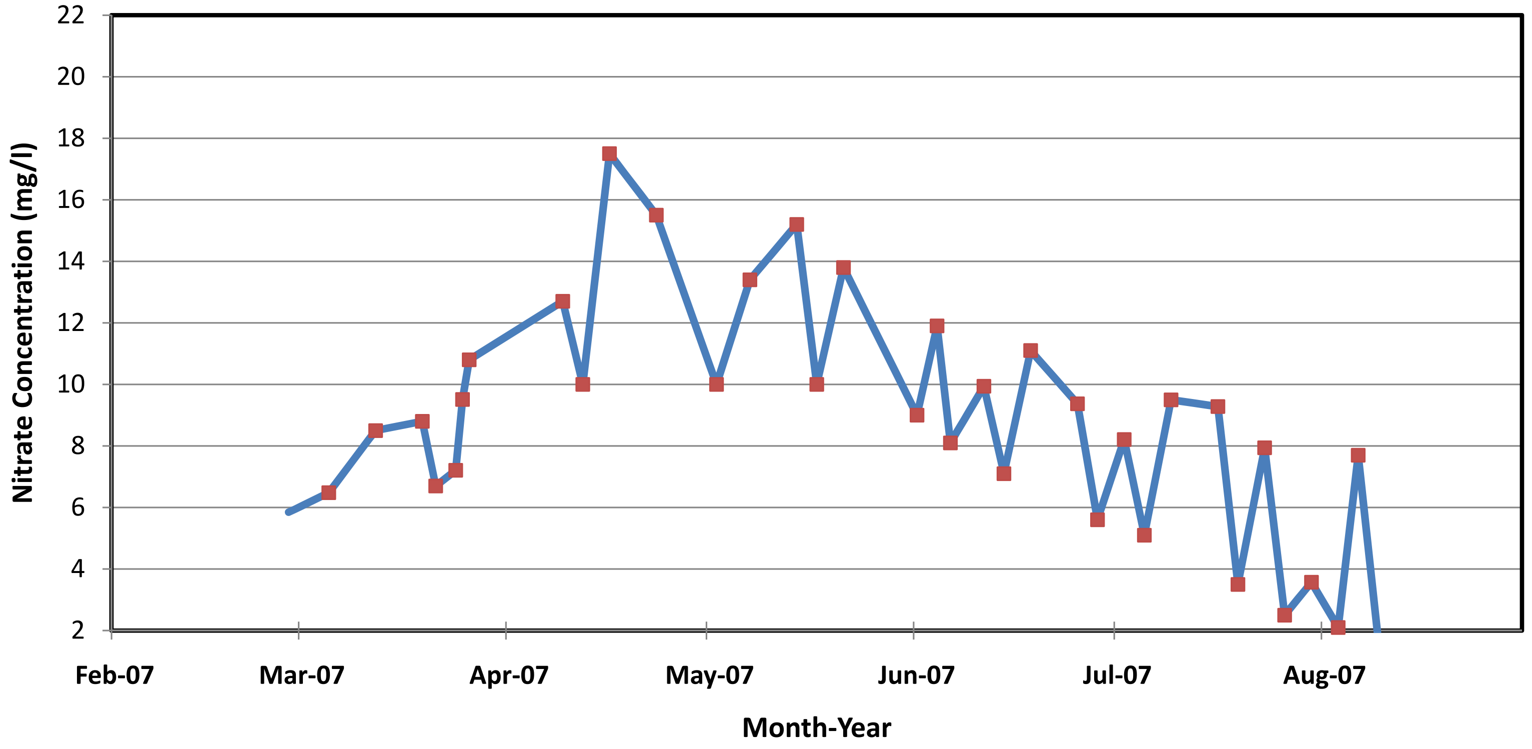


Figure 48: The second 2007 event.

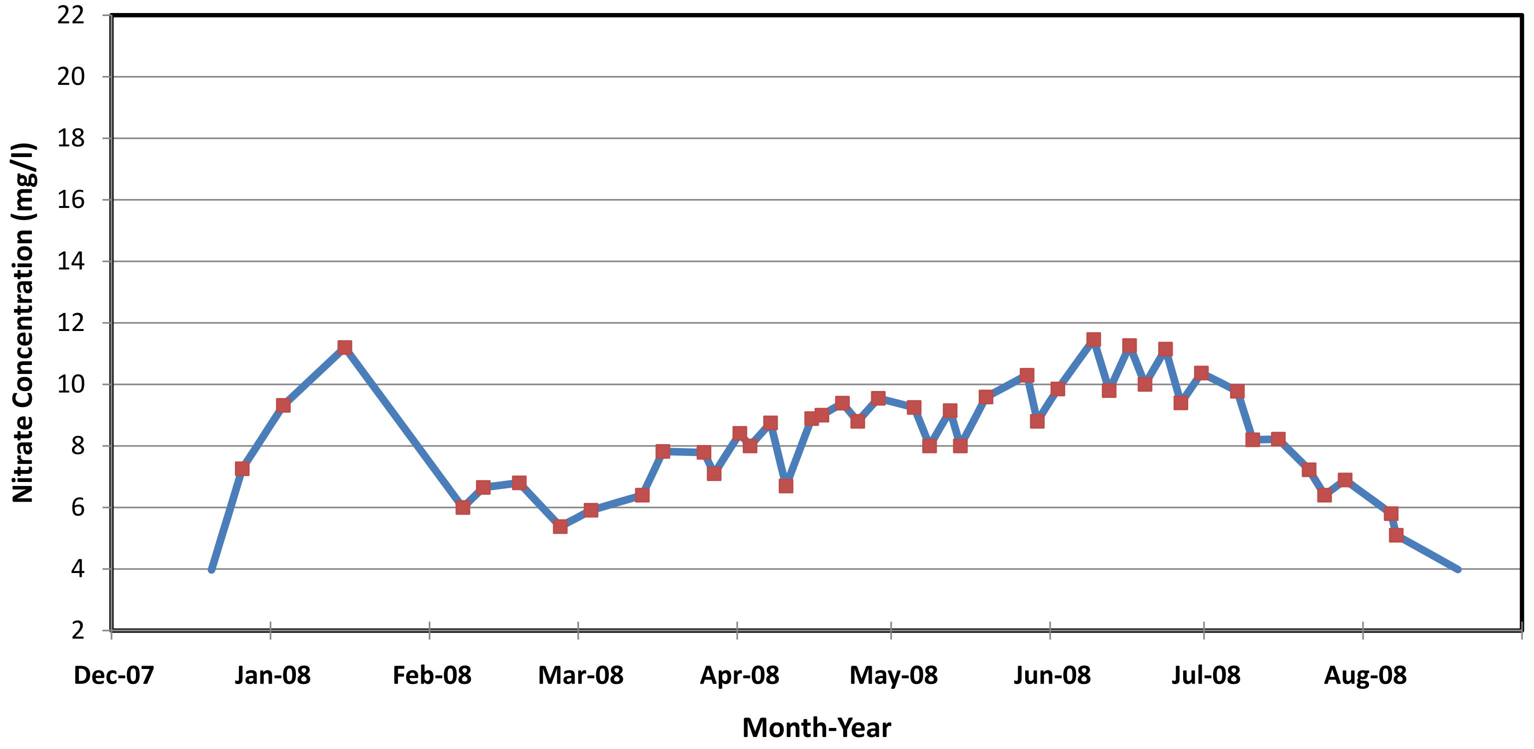


Figure 49: The 2008 event.

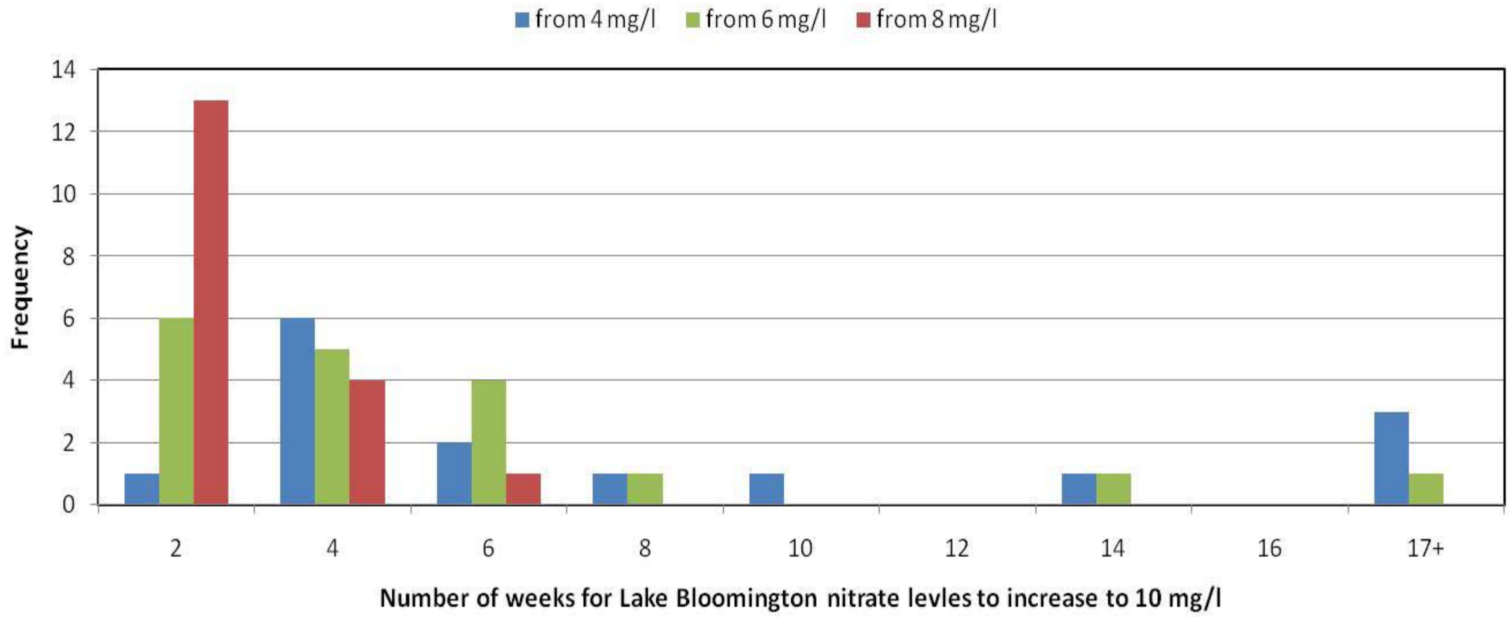


Figure 50: Frequency of the number of weeks for nitrate levels in Lake Bloomington to increase from various thresholds to 10 mg/l.

Appendix C

Hydrogeologic Investigation Report

Hydrogeologic Investigation for a Supplemental Water Supply

Prepared For:

City of Bloomington, Illinois
January, 2010

Prepared By:

Wittman Hydro Planning Associates
a division of Layne Christensen Company

Hydrogeologic Investigation for a Supplemental Water Supply

prepared for
Bloomington, Illinois

January 4, 2010

Prepared by
Wittman Hydro Planning, a division of Layne Christensen Company
Bloomington, Indiana

Contents

List of Figures

List of Tables

Executive Summary

This report is one section of a comprehensive water-supply planning effort. This section of the larger plan describes a series of hydrogeologic investigations to evaluate the feasibility of local groundwater as a supplementary source of supply for the City of Bloomington Water Utility.

Currently the City depends on two surface water reservoirs. While the combined storage capacity of the two reservoirs has been adequate to satisfy recent demands, the system remains vulnerable to drought. This report presents a systematic assessment of the potential to use local groundwater to add capacity and manage drinking water quality. The objective of our planning effort is to identify less expensive intermediate steps that move the utility affirmatively towards its long-term plans for a regional groundwater supply from the Mahomet Aquifer.

Four different local aquifers were studied; a deep aquifer near the existing water treatment plant and more localized shallow aquifers on the southwest and southeast sides of town. After reviewing the avail ale hydrogeologic reports written by consultants, local engineers, and the Illinois State Water Survey describing the local aquifers, additional subsurface data was collected in each area. AT each site the field studies continued or were terminated depending on the outcome of the additional exploration and hydrologic analysis. While some exploration was limited by availability of public land and site access, in general, more data was collected and more analysis was done at the most promising sites.

The work described in this report began in 2008 and continued through 2009. In that time our firm reviewed important data and literature on these aquifers, installed 3 piezometers, 12 monitoring wells, conducted 3 multi-day aquifer pumping tests, evaluated the test data to determine aquifer properties, developed local conceptual models of the aquifer system, constructed regional and local groundwater flow models, and evaluated various wellfield designs to consider yield, water quality, and the potential impacts of pumping.

This document presents an organized technical description of the potential role of local groundwater as an economical interim water supply. Recommendations for groundwater development outlined in this document are based on the goal of sustainability for the local and regional aquifers. This means that in the areas that groundwater development is recommended, we evaluate the effects new pumping would have on aquifer water levels, the average available yield, drought impacts, use for water quality (nitrate) management, and in one case, the effect of seasonal recharge variation on well yields.

Based on the results of the field investigations, and modeling of the Sugar Creek Aquifer including transient and steady-state groundwater flow modeling, we conclude the following:

- Our results are consistent with previous studies that suggest a production rate of $3MGD$ might be achieved at the subject site along Sugar Creek. A production rate of $3MGD$ can be produced from 3 vertical wells or a single collector well constructed at the Stark site along Sugar Creek.

- The quality of the groundwater at the site is suitable for public supply. However, treatment would be necessary to address taste and aesthetic issues associated with iron, manganese, total dissolved solids (TDS), and hardness.

- Nitrate, though detected at very low concentrations in the groundwater, could become a problem in the future. The shallow aquifer is vulnerable to contamination at the land surface. Excess nitrogen applied at the land surface could be induced into the deeper zones of the aquifer where the proposed wells would pump.

- The transient effects on yield of seasonal recharge variations are small.
- The more highly-transmissive portion of the aquifer might extend southwest under the creek. If additional exploration confirms this, it may be possible to construct a collector well at that location, specifically for the purpose of inducing recharge from the creek (a process known as “river bank filtration”, or RBF). Depending on the degree of hydraulic connection between the creek and the aquifer, a larger pumping rate of $5MGD$ or more might be achieved.

We recommend development of the Stark property site. For this site, a collector well may be the best option for development, for the following reasons: 1) The collector well would require less land for its construction because it would require only one wellhead, and 2) by placing the laterals at a lower elevation, the available drawdown at the well is increased.

More capacity from the aquifer is potentially available beyond the Stark property investigated for this project. If the City anticipates needing more than $3MGD$ from the Sugar Creek location, we recommend additional exploration and testing in section 27 south of the project site. If the hydrogeologic conditions are favorable for RBF in section 27 and if sufficient recharge can be induced from the creek, a collector well at this location may yield as much as $5MGD$.

1 Introduction

The City of Bloomington Water Department is developing an interim water supply plan to guide future operations and management of their water system. The plan will lay out a cost-effective strategy for meeting the future water needs of the community. The plan will address the threat posed by seasonally high nitrate levels in Lake Bloomington and Lake Evergreen, meeting interim-term needs for additional demand and reducing the risk associated with drought. As part of the planning process, WHPA has assessed the potential for developing new groundwater supplies in the vicinity of the current distribution system. The City is interested in the possibility of installing new wells between the lakes to augment lake yields and provide low nitrate water for blending when nitrate levels in the lakes are high. The wells would be located near the pipeline that connects the Mackinaw Pumping Pool and Lake Evergreen with Lake Bloomington and the treatment plant (Figure 1). The City is also interested in developing a new groundwater source on the south side of Bloomington. These wells would require a small treatment facility, but would supplement lake yields by providing a new source of supply in an area of the City that is growing.

Our hydrogeologic investigation considered three general areas as potential locations for new supply wells-the Danvers Bedrock Valley between the lakes, the Sugar Creek Valley on the southwest side of McLean County, and the Downs area on the southeast side of McLean County (Figure 1). Test borings were drilled at each of the three locations to characterize the thickness and composition of the permeable deposits. The extent of the investigation at each site depended on the initial test boring results and access for additional testing. Additional field work,including water-quality testing and aquifer testing, was conducted where warranted by the test boring results, . Groundwater flow modeling was used to estimate the potential yield of viable sites. This report presents the results of a hydrogeologic data review of the Bloomington area, results from field investigations at each site, and results from the yield analysis.

2 Hydrogeologic Setting

Our first objective was to review existing information to understand the hydrogeologic setting of the aquifers near Bloomington. The purpose of this data review was to assess the regional and local groundwater flow systems and to develop an understanding of the critical factors that will determine if a site is suitable for development as a source for water supply. The review included the following sources:

- Previous federal, state and consultant reports
- Well drillers logs and test well boring logs from Illinois State Geological Survey (ISGS) online database
- Static water-level measurements from Illinois State Water Survey (ISWS) private and public water wells and monitoring wells
- Farnsworth Group Project Files dating from 1961
- City of Bloomington Water/ Engineering Files

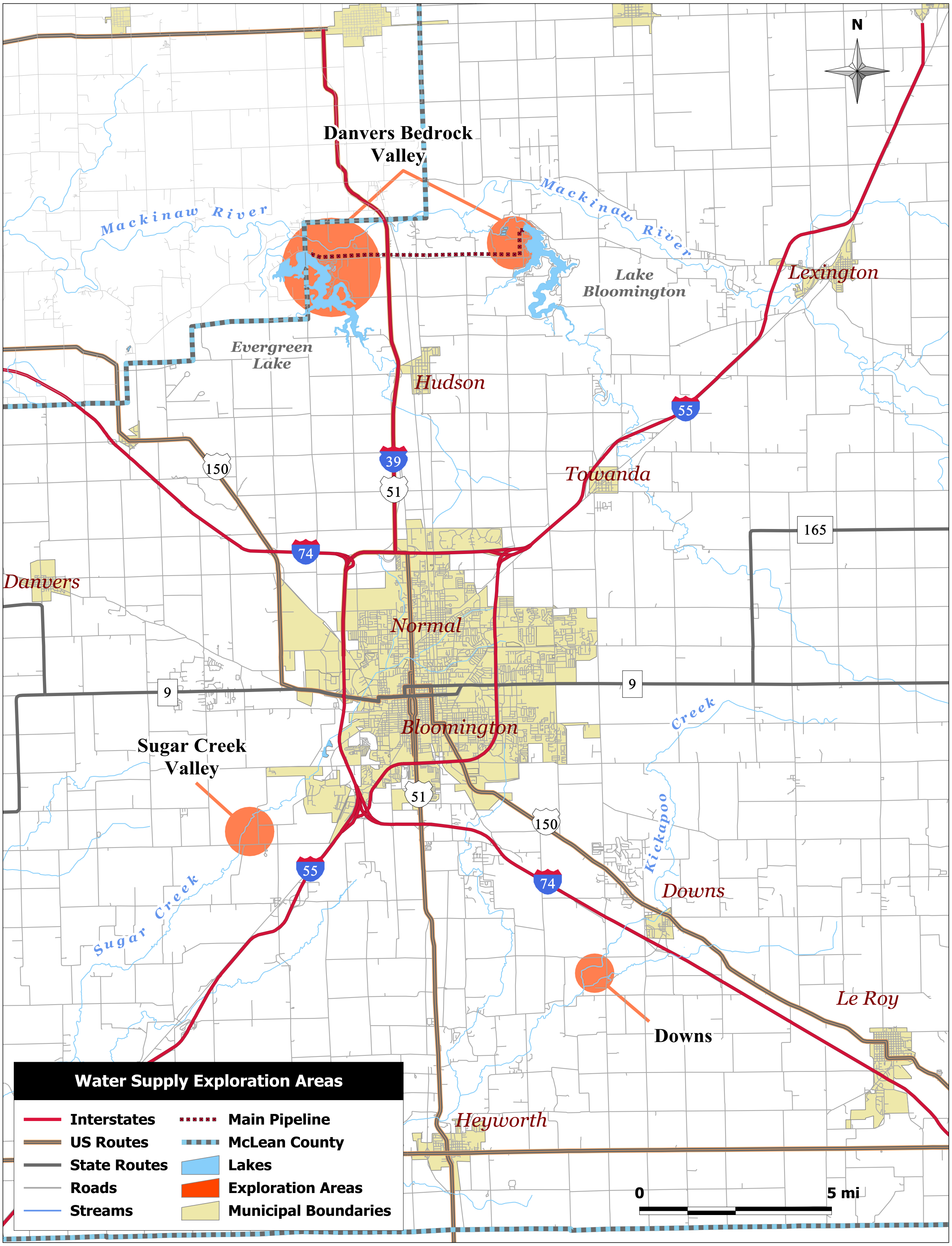


Figure 1: Interim water supply study areas.

This section presents background information on the regional geology, groundwater in the Danvers Bedrock Valley and the Sugar Creek Valley, the local climate, and the flow in Sugar Creek. No existing hydrogeologic information was available for the Downs area.

2.1 Geology

The predominant geologic features within the study area are bedrock valleys, including the Mahomet Valley, Mackinaw Valley, and Danvers Valley (Figure 2). The bedrock valleys are carved predominately into Pennsylvania shale and are filled with unconsolidated sediments. These unconsolidated materials are glacial drift deposits, including till or diamicton, sand and gravel outwash, and lacustrine deposits. These deposits are grouped into three major stratigraphic units based upon the glacial history of the region; the Banner Formation, the Glasford Formation, and the Wedron Formation. The generalized cross-section in Figure 3 is representative of the bedrock valleys in the study area.

In the deepest valleys the basal deposits consist of sand and gravels from the Pre-Illinoisan Banner Formation. The Banner Formation is the lowermost glacial unit in the study area and is believed to have been deposited more than 500,000 years ago. At the base of the Banner Formation lie the Sankoty Sand and Mahomet Sand, the most significant water-bearing units in the study area (Figure 3). The Mahomet sand member is found in the Mahomet Bedrock Valley and the Sankoty sand member is found in the Mackinaw Bedrock Valley [Kempton and Visocky, 1992].

The Banner Formation is overlain by the Glasford Formation, believed to have been deposited during the Illinois glaciation between 180,000 and 125,000 years ago (Figure 3). The Glasford is comprised predominantly of two diamicton units (the Vandalia Member and the overlying Radnor Member), but does contain sand and gravel units which can be locally pervasive and continuous. The elevation of the top of the Glasford Formation ranges between 600 and 700 feet above mean sea level ($ft\,amsl$) across the area of investigation.

Near the valley edges and in some tributary valleys, sand and gravel is partially replaced with silt and clay. Later deposition (Illinoisan age Glasford Formation, Wisconsinan age Wedron Formations) consisted mainly of till with interbedded sand and gravel deposits (Figure 3). The surficial glacial deposits in the area are part of the Wedron Group, deposited during the Wisconsin glaciation between 25,000 and 12,000 years ago. The Wedron is comprised predominantly of diamicton interspersed with relatively thin and discontinuous sand units. The Wedron formation forms a thin layer over the entire study area and is overlain by wind-blown silt and alluvium, with the alluvium occurring in association with the Mackinaw River and major creeks.

2.2 Groundwater

Productive aquifers in the region are generally formed by the sand and gravel deposits within the glacial drift. Vaiden and Kempton (1989) summarized the geology relative to aquifer occurrences, noting that most of the early glacial deposition (Kansan age-Banner Formation) consisted of sand and gravel outwash deposited in bedrock valleys. Maps of the elevation of the bedrock surface [Herzog et al., 1994] and the occurrence of major sand and gravel aquifers [ISGS, 1996] have been prepared by the ISGS and are overlain in Figure 2, showing that the major sand and gravel aquifers occur in association with deep bedrock valleys or contemporary stream

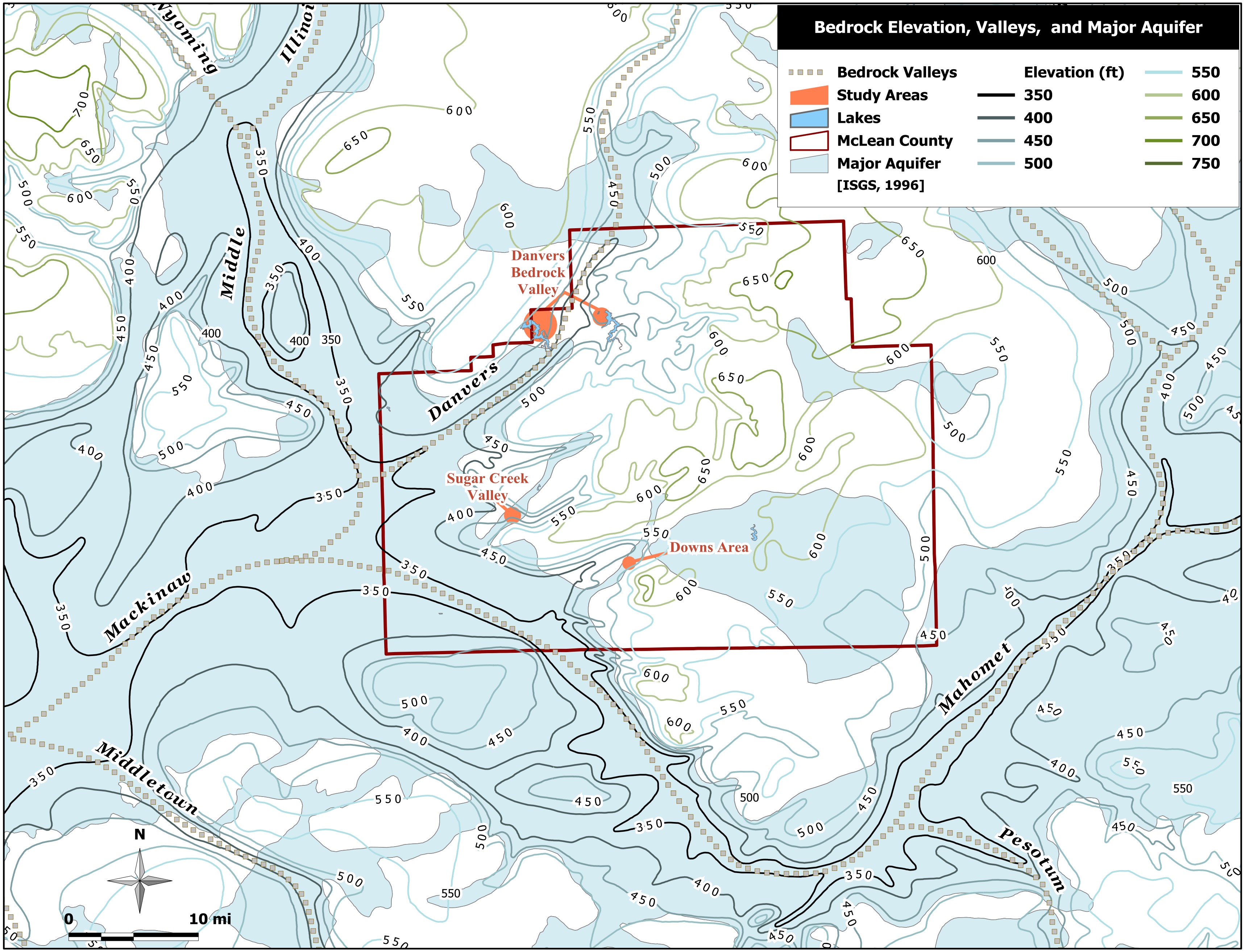


Figure 2: Bedrock topography and location of major buried bedrock valleys in the vicinity of McLean County [ISGS, 1996 and Herzog et. al., 1994].

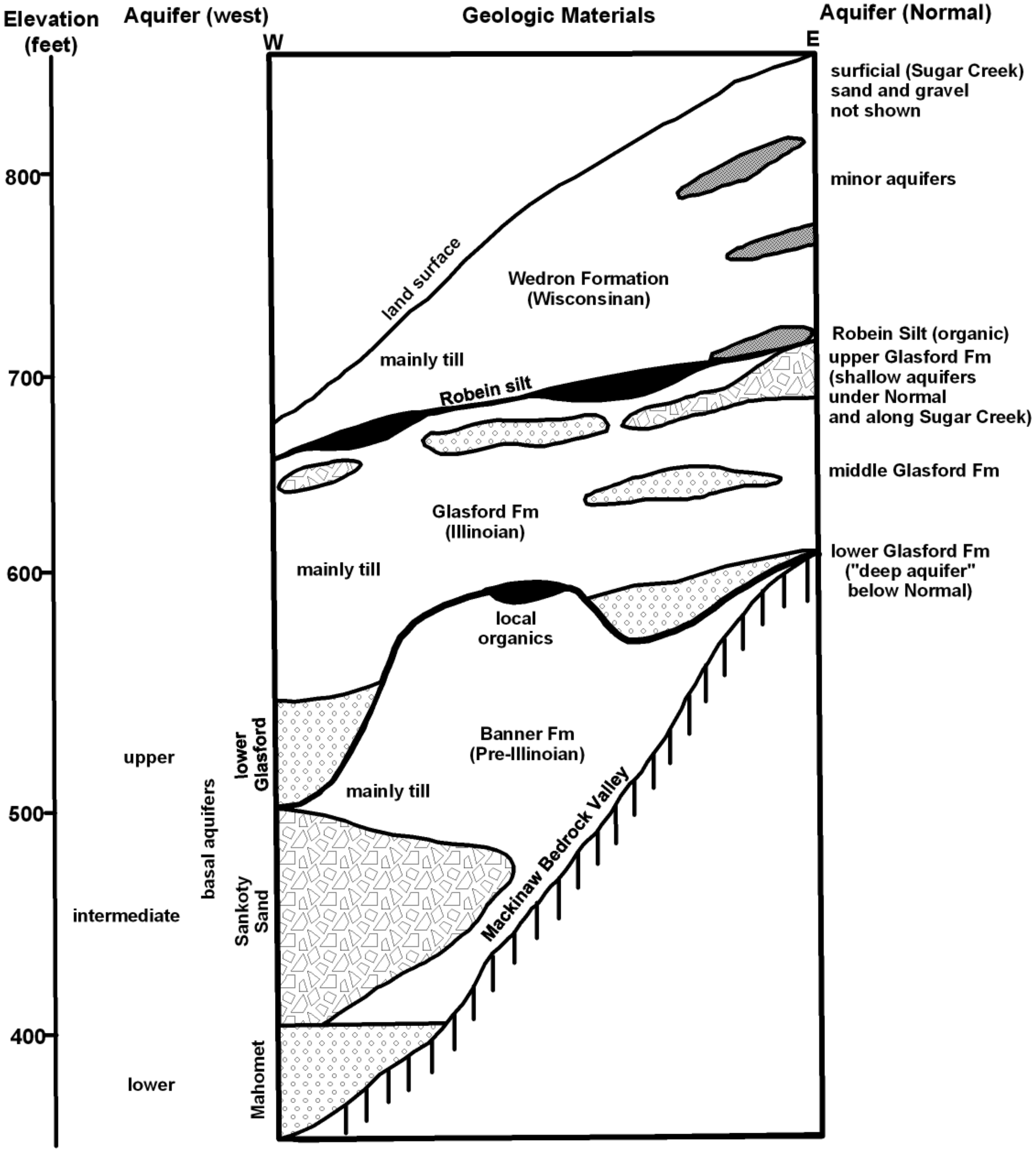


Figure 3: Generalized cross-section of a bedrock valley in the vicinity of Normal, Illinois [Kempton and Visocky, 1992].

valleys. Vaiden and Kempton (1989) described three aquifers in the Mackinaw Bedrock Valley: an upper aquifer at $500-550\,ft\,amsl$; a middle aquifer at $400-500\,ft\,amsl$; and a lower aquifer at $400\,ft\,amsl$ (Figure 3). The intermediate and lower deposits, consisting collectively of the Sankoty Sand, are widely used as an aquifer. The upper deposits, which form the lower Glasford formation, are less extensive, but are also used for water supply.

2.2.1 Danvers Bedrock Valley

The Danvers Bedrock Valley extends north between Evergreen Lake and Lake Bloomington (Figure 2) [Herzog et al., 1994]. The deepest part of the Valley in this area is believed to be between the lakes with the lakes located near the outer edges of the bedrock valley. Banner formation sands typically overlie bedrock in the deeper bedrock valleys in the region [Wilson et al., 1998]. These basal sands may also be present in this section of the Danvers Valley.

A report by Vaiden [1988], generated to provide information on groundwater possibilities in the vicinity of Evergreen Lake and Lake Bloomington, noted the presence of a deep basal sand and gravel aquifer and a shallower intermediate sand and gravel deposit in this area. Vaiden reports that the basal deposit fills the bedrock valley bottom with upper elevations of $450-460\,ft\,amsl$ and occurs irregularly, with a potential thickness of as much as $50\,ft$. Well logs from the area indicate there is an aquifer in the lower zone reported by Vaiden. The thickness of the aquifer formation is related to the depth of the bedrock valley, with the aquifer being thickest (over $40\,ft$) near the channel axis in the area bisecting the lakes.

Larson and Poole (1989) conducted an electrical earth resistivity study in the Mackinaw River Valley to delineate a possible sand and gravel aquifer within the alluvium. They concluded that “some sand and gravel is present, but it is limited in extent and probably contains a significant amount of fine-grained material”. They also conducted a seismic refraction study to delineate the geometry of the Danvers Bedrock Valley, which revealed the presence of a second bedrock channel separated from the previously known southern channel by a bedrock high in the vicinity of Lake Evergreen.

2.2.2 Sugar Creek Valley

A relatively shallow and narrow strip of aquifer in the Sugar Creek Valley has previously been evaluated as a source of water for the City of Normal, IL. A geological investigation by the ISGS in 1965 and 1966 demonstrated the extent and thickness of the aquifer [Walker, 1966]. Vaiden and Kempton (1989) summarized existing information and re-evaluated the potential for using the aquifer as a source for water supply. The aquifer is a thick layer of up to $80\,ft$ of sand and gravel deposited in an ancient drainage way in the Sugar Creek Valley that trends northeast-southwest and runs roughly parallel to the present course of Sugar Creek. Figure 4 shows the mapped distribution of the sand and gravel deposits and an east-west cross-section across the valley [Vaiden and Kempton, 1989]. The thickest part of the mapped deposits, shown at the lower left of the map in Figure 4, is near sections 23 and 27 of T23N and R1E.

The sand and gravel in the Sugar Creek Valley appears to be two distinct deposits that are separated by a thin layer of glacial till, but locally are in contact. The surficial deposit consists of a thin layer (up to $30\,ft$) of predominately gravel on top of till or directly on a deeper, thicker ($50\,ft$), and more extensive section of

Table 1: Hydraulic conductivities calculated from high capacity well tests in the study area

Well Location (Township and Range)	**Owner**	**Well Bottom Elevation** ($ft\,amsl$)	**Hydraulic Conductivity** (ft/d)	**Formation**
22NR2E	Heyworth	616	189	Glasford
23NR1E	Normal well 100	467	488	Banner
23NR1E	Normal TH-20	390	269	Banner
23NR2E	Normal	684	264	Glasford
23NR2E	Normal	685	167	Glasford
24NR1W	Normal	376	351	Banner
24NR1W	Normal	395	456	Banner
25NR3E	Indian Creek	617	50	Glasford
26NR3E	Gridley	460	97	Banner
25NR1W	Congerville	698	294	Glasford

ft/d=feet per day, ft amsl=feet above mean sea level

sand and gravel (Figure 4). Vaiden and Kempton (1989) speculated that the upper deposit is outwash from the Bloomington Moraine terminates at the upland. The lower sand and gravel, presumably part of the upper Glasford formation, is thin or absent in some places, but extends outside of the existing creek valley in some places. Vaiden and Kempton (1989) speculated that the lower deposit is continuous with similar shallow deposits under the moraine, and that the the deposits may extend under the upland north of the City of Normal. However, there is no evidence of interconnection with permeable deposits outside of the valley.

Walker (1966) speculated that a wellfield in the aquifer could provide as much as $3MGD$, dependent on favorable hydraulic conditions. Walker recommended an aquifer test in Section 27, near the thicker section of sand and gravel deposits. Vaiden and Kempton (1989) concluded that the aquifer offered an “excellent prospect for moderate or possibly large water supplies”. However, Vaiden and Kempton also noted that the sand and gravel is variable in character and limited in extent, and potentially vulnerable to drought. Like Walker, Vaiden and Kempton also recommended an aquifer test to help establish the capacity of the aquifer.

2.2.3 Aquifer Properties

The ISWS maintains a database of transmissivities for Illinois wells [ISWS, 1989]. Table 1 shows hydraulic conductivities for wells in the study area derived from aquifer tests of more than 10 hours. The formations indicated in the last column of Table 1 are based on elevation only. Hydraulic conductivities in the Glasford formation range from $50-294$ feet per day (ft/d), with an average of $193\,ft/d$. Hydraulic conductivities in the Banner formation range from $97-488\,ft/d$ with an average of $332\,ft/d$.

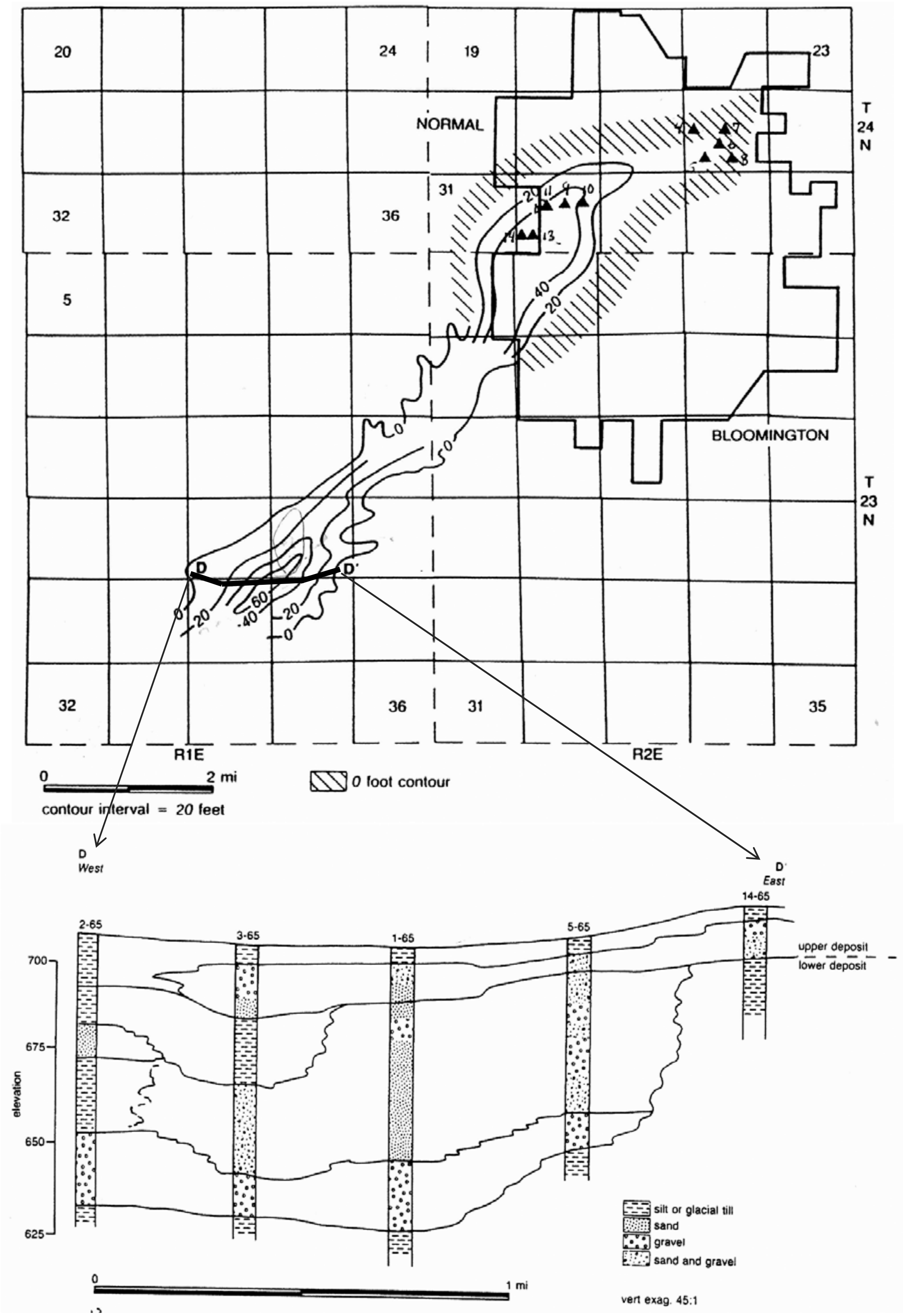


Figure 4: Thickness of sand and gravel in the Sugar Creek Valley [Vaiden and Kempton, 1989].

2.3 Sugar Creek

Based on what is known about the shallow aquifer in the Sugar Creek Valley, the creek is likely an important hydraulic boundary sink for groundwater flow. As illustrated in Figure 5, Sugar Creek originates on the northeast side of the City of Normal and flows to the southwest, away from the City of Bloomington. The Sugar Creek study area is located within the Town of Shirley - Sugar Creek watershed (HUC12, 0713000090703), a subwatershed of the larger Sugar Creek (HUC8, 071300009) (Figure 5). The United States Geological Survey (USGS) maintains an active gaging station on Sugar Creek (5580950), located just downstream of the Bloomington-Normal Water Reclamation District (BNWRD) Oakland Avenue Treatment Plant (Figure 5). The stream flow measured at this station includes the discharge from the treatment plant and flow from a drainage area of 34.4 square miles, which comprises a large portion of the Bloomington-Normal metropolitan area.

Figure 6 illustrates changes in the total annual flow volume for Sugar Creek for the period of record. The average annual flow volume for the stream is $39,946 acre - ft$ with a range from $22,432 acre - ft$ in 1989 to $61,318 acre - ft$ in 1993. Figure 7 shows the seasonal variation in average monthly discharge, with the highest average discharge occurring in March ($64 cfs$, or $41.5 mgd$) and the lowest in October ($27 cfs$, or $17.3 mgd$). Figure 8 shows a flow duration curve for Sugar Creek constructed from daily flow data from 1974 through 2007. Note that the minimum flow is around 10 cubic feet per second (cfs) at 100% probability, indicating that at any time, there is at least $10 cfs$ flowing in the creek.

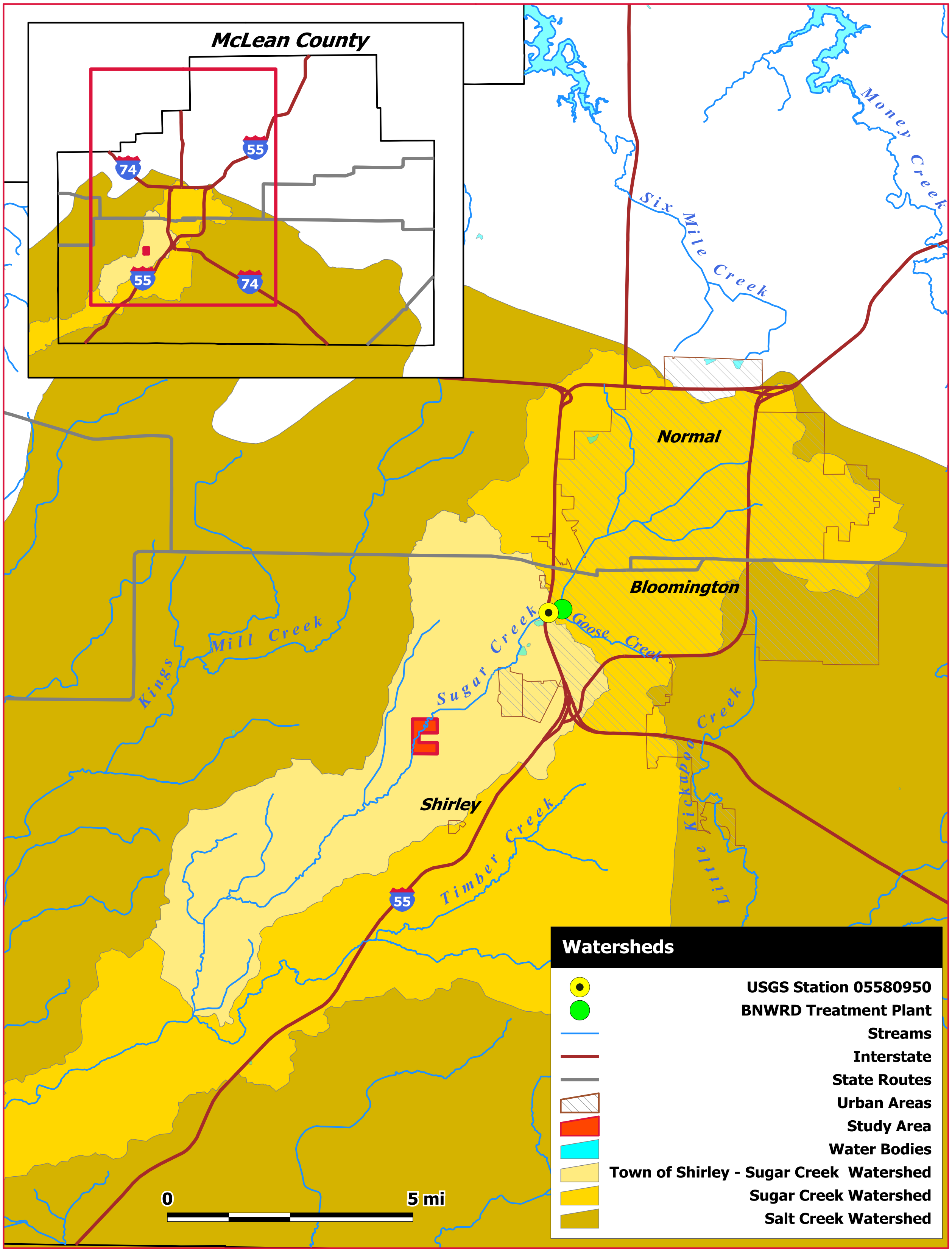


Figure 5: Watershed boundaries near the Sugar Creek study area [NRCS, 2009].

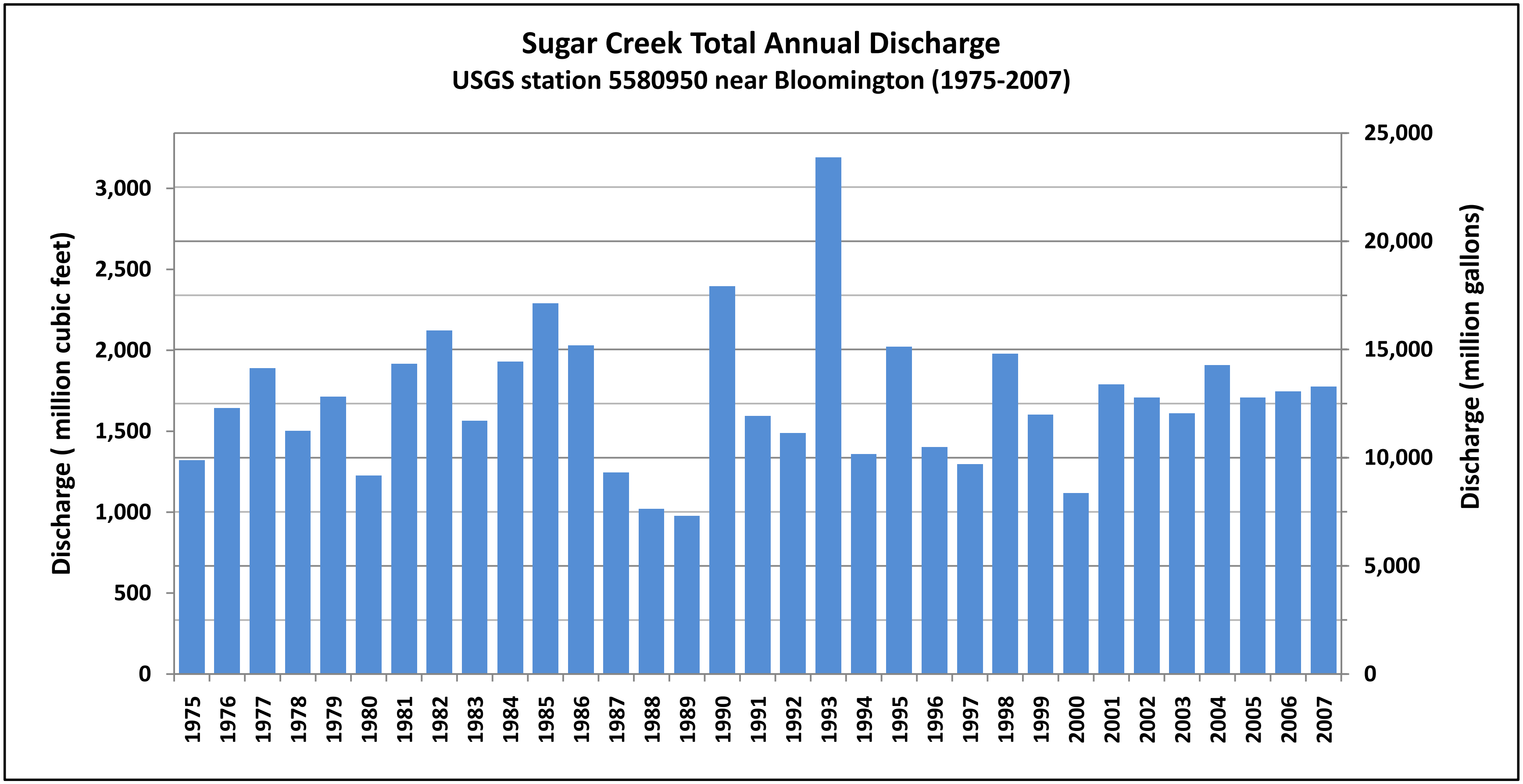
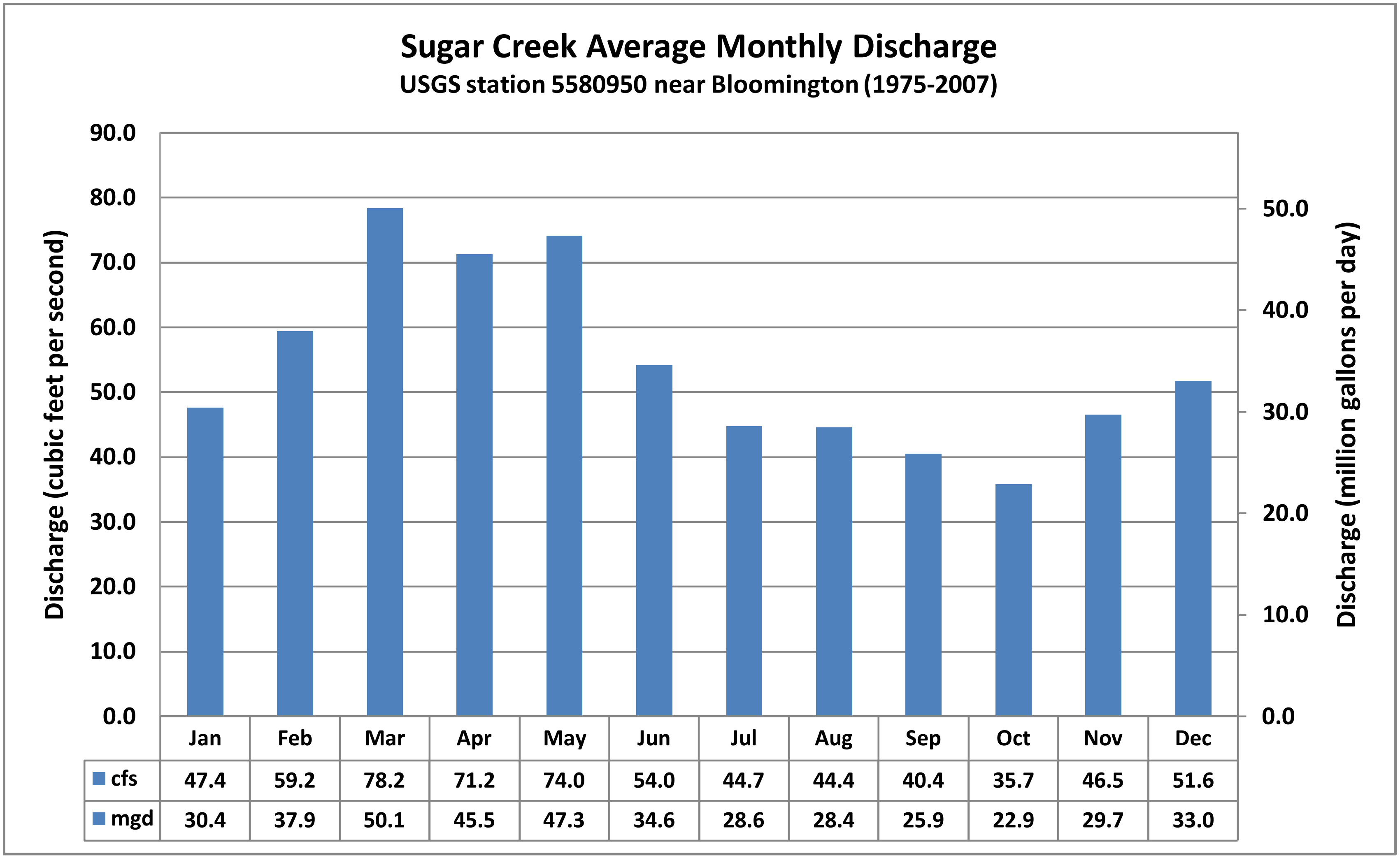


Figure 6: Sugar Creek total annual discharge (1975-2007) [USGS, 2009].



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
■ cfs	47.4	59.2	78.2	71.2	74.0	54.0	44.7	44.4	40.4	35.7	46.5	51.6
■ mgd	30.4	37.9	50.1	45.5	47.3	34.6	28.6	28.4	25.9	22.9	29.7	33.0

Figure 7: Sugar Creek mean monthly discharge (1975-2007) [USGS, 2009].

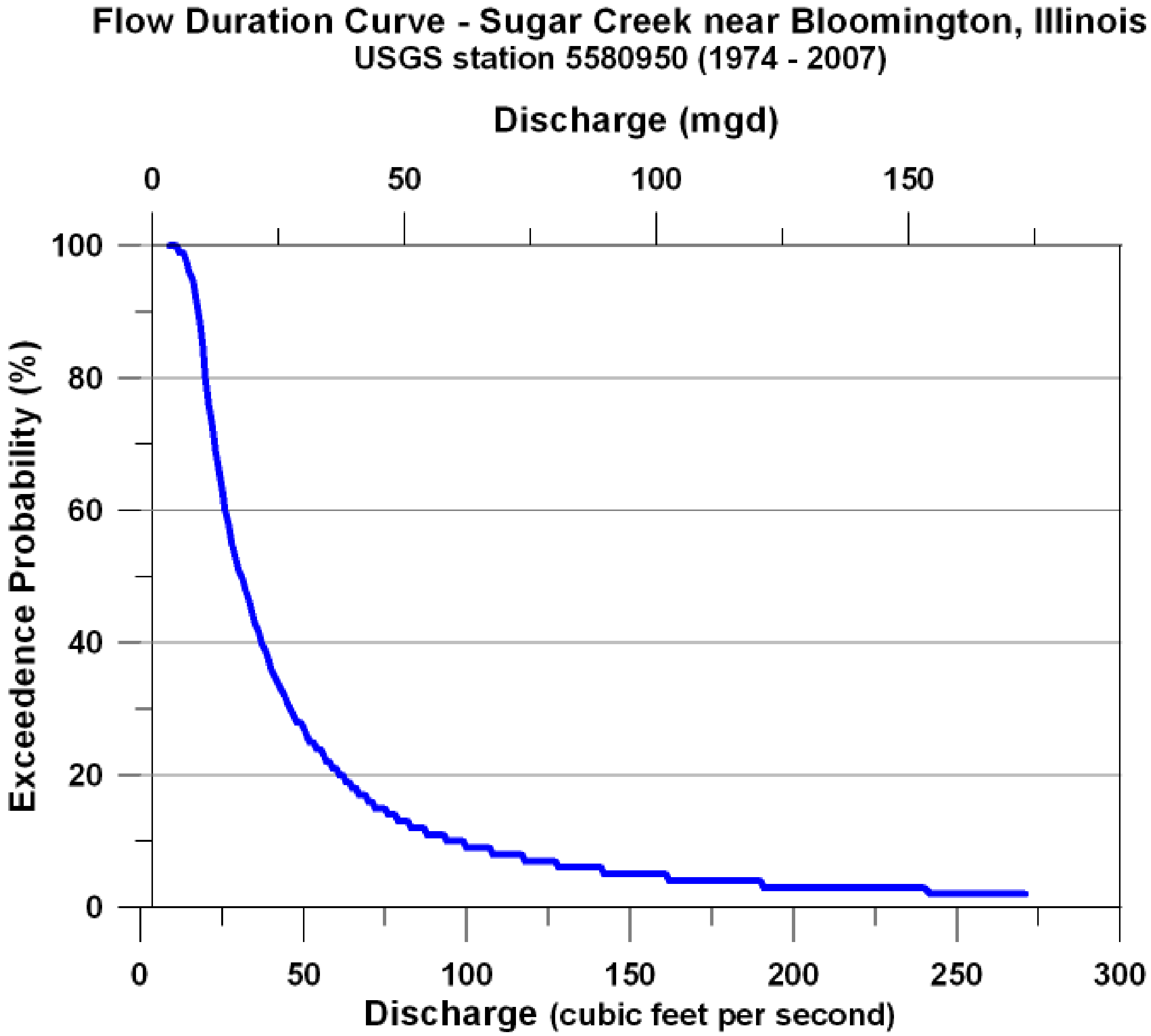


Figure 8: Flow-duration curve for Sugar Creek based on daily stream flow (1974-2007) [USGS, 2009].

Table 2: Average temperature in the Bloomington area, 1971-2000 [ISWS, 2009].

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
High (°F)	31	36.4	48.4	61.2	72.8	82.6	85.6	83.6	77.2	65.1	48.8	36.3	60.8
Low (°F)	13.7	18.2	28.8	39.7	50.8	60.9	64.7	62.8	54	42.3	30.8	19.9	40.6
Mean (°F)	22.4	27.3	38.6	50.5	61.8	71.8	75.2	73.2	65.6	53.7	39.8	28.1	50.7

2.4 Climate

In Illinois, the average annual precipitation varies by latitude (Figure 9) [ISWS, 2002]. In central Illinois, the average annual precipitation is around $38\,in/yr$. Average annual precipitation measured at the Bloomington Water works is 37.5 inches per year (in/yr) and ranges from a low of $21.97\,in/yr$ to a high of $57.97\,in/yr$ over the 58 year period of record from 1949 to 2007 (Figure 10). The peak annual precipitation coincided with the Great Mississippi River Flood of 1993, while other peaks in annual precipitation occurred in 1955, 1981 and 1990. Periods of drought are evident throughout the record with the most notable events occurring in the mid-fifties, early sixties, late seventies and late eighties. State-wide droughts associated with major damage to the economy and natural resources occurred in the mid fifties, 1976-77, 1990-81, and 1988-89 [Stanley A. Changnon, 1987]. The lowest recorded annual rainfall occurred in 1989 and culminated a three year drought that was the most severe recorded at this station.

Precipitation in the Bloomington area varies throughout the year. The climate is characterized by wet springs and summers and dry winters. Precipitation is highest in May at about $4\,in$ and generally declines from May through October with a late fall increase in November (Figure 11).

Temperature data summaries have been published by the National Climate Data Center (NCDC) and the Illinois State Climatologist Office for Station 116200 at Normal for the period 1971-2000 (Table 2). The temperature in Bloomington ranges from an average low of 13.1°F in January to an average high of 80.9°F in August. Snowfall occurs primarily from December through March with an average annual snowfall of $21.9\,in$ for 1977-2000. Pan evaporation is measured at Urbana, Illinois and is reported as inches of water lost per month. Measured amounts are reported April through October and average $36.4\,in$ annually. Actual evapotranspiration rates vary depending on land use and moisture availability.

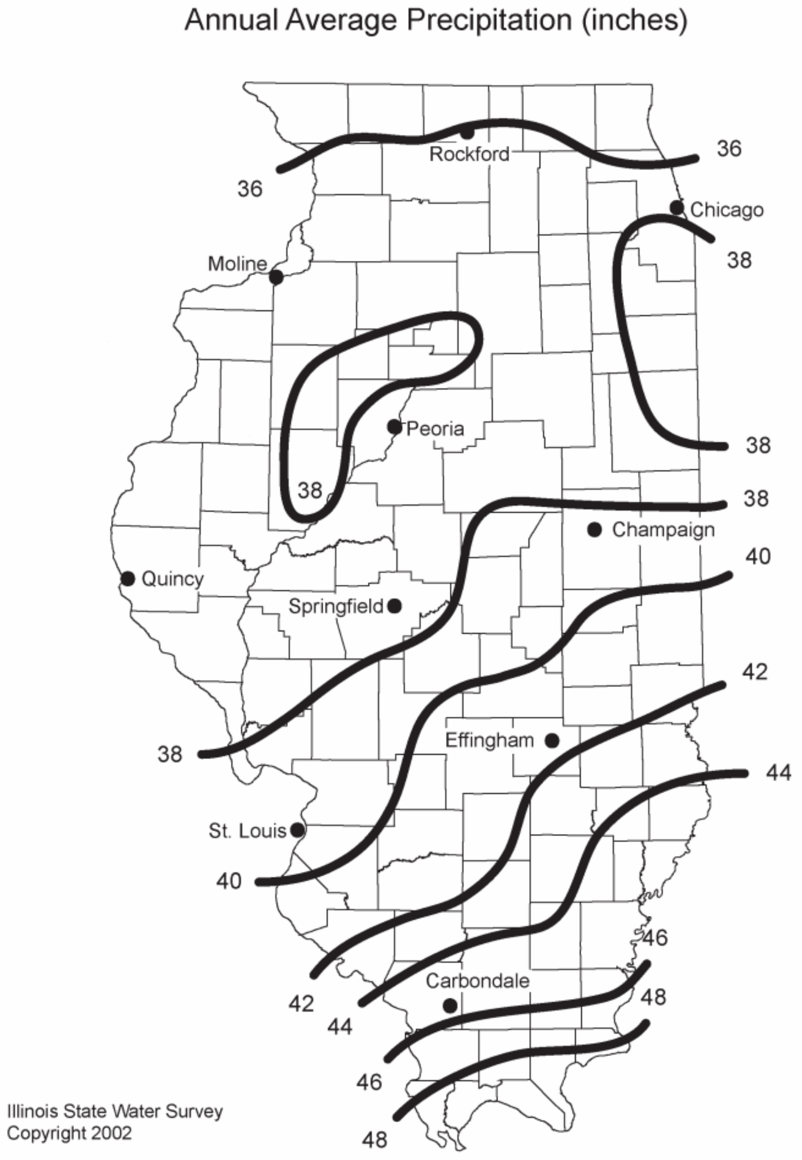


Figure 9: Distribution of average annual precipitation in Illinois [ISWS, 2002].

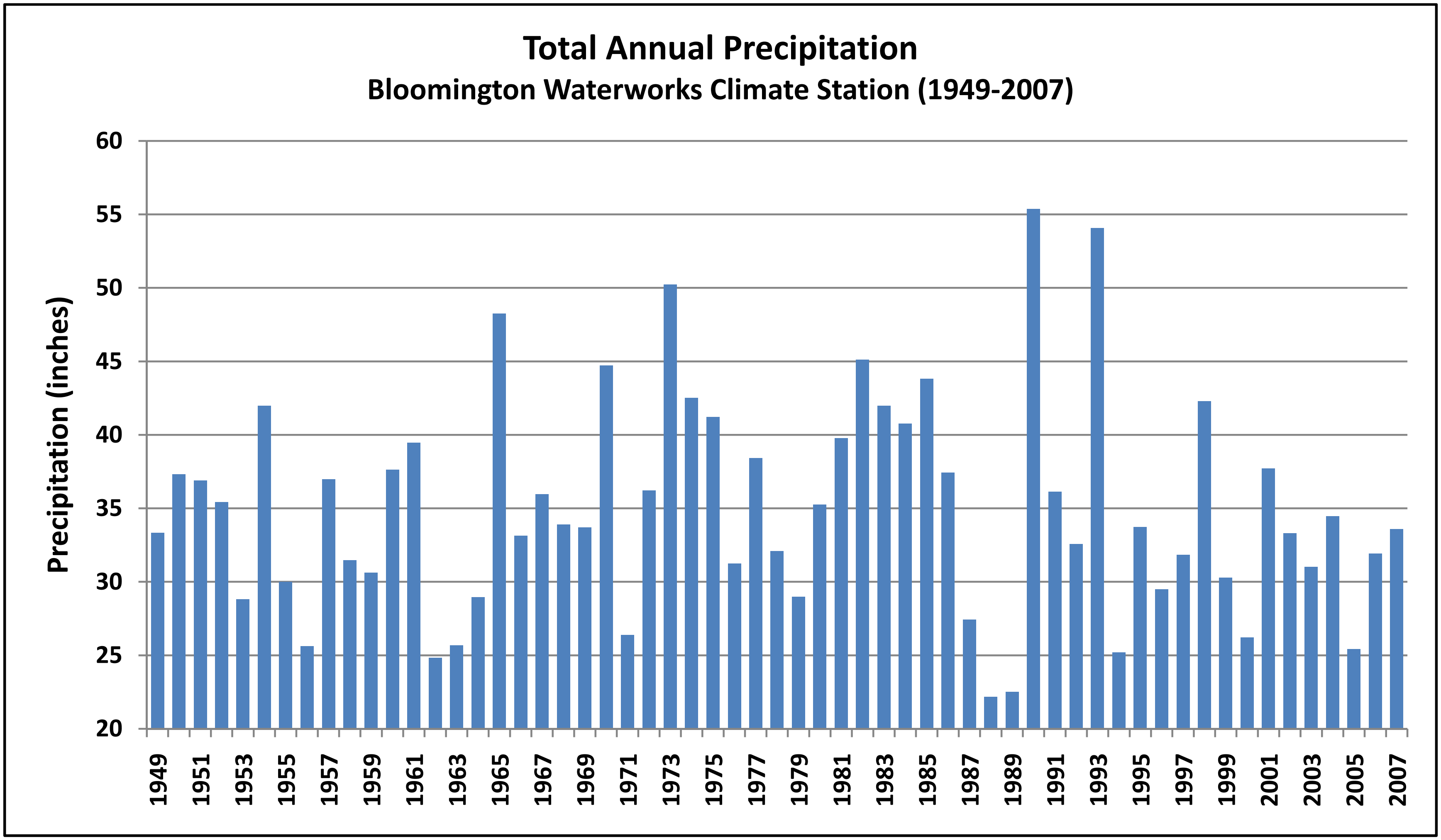


Figure 10: Average annual precipitation in the Bloomington area, 1949-2007 [NCDC, 2009].

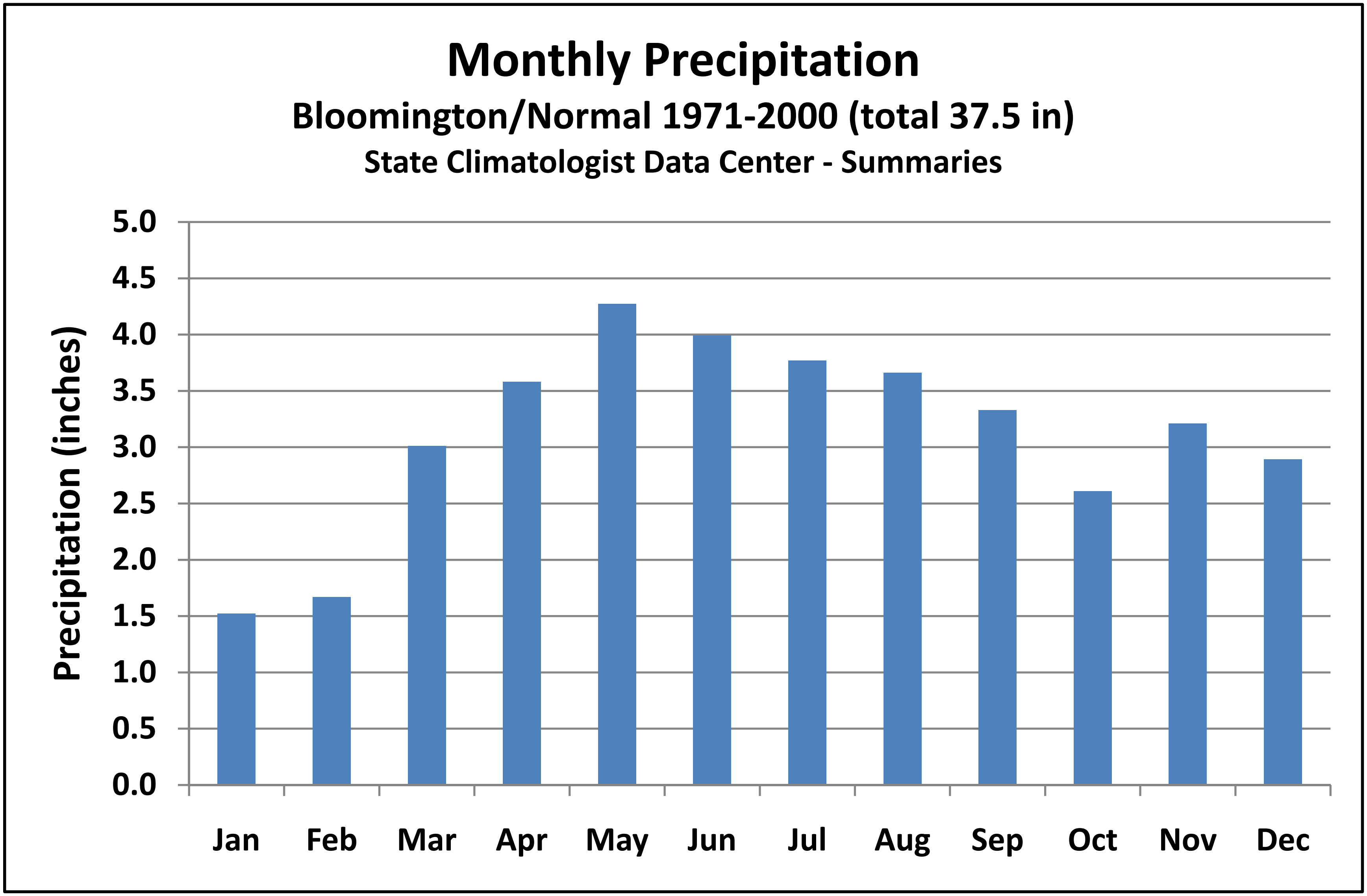


Figure 11: Average monthly precipitation in Bloomington area, 1971-2000 [ISWS, 2009].

3 Downs Area

Efforts to find a sustainable source of drinking water for the City of Bloomington included a site near the town of Downs, located to the southeast of Bloomington, along Illinois Route 150 (Figure 12). Based on available subsurface data and geologic maps from the ISGS, this area is known to have sand and gravel deposits, where several active and abandoned gravel pits are found. We drilled two test borings within the area of interest with the intention of evaluating the extent and continuity of the aquifer material.

3.1 Test borings

In November, 2008, two test borings were drilled near Downs with a reverse air rotary rig. The test borings were drilled on Jack Snyder's property, a parcel located to the southwest of the intersection of N 1900 E. and E 700 N (Figure 12). The boring logs are included in Appendix A. The borings were drilled adjacent to a small lake that was originally a pit used to quarry sand and gravel.

The test borings indicate that permeable unconsolidated deposits in this area are relatively close to the land surface. The first test boring (B5), northwest of the lake, revealed approximately $20\,ft$ of sand and gravel near the land surface. No other layers of potential aquifer material were encountered between the shallow gravel and bedrock, which was tagged at a depth of $98\,ft\,bgs$. Between the surficial sand and gravel and the underlying bedrock is a 70-feet thick section of clayey till. The only possible aquifer material in the till section is a $5\,ft$ layer of sand and gravel found between 60 and $65\,ft\,bgs$ that is only suitable for home owner wells. Results from the second test boring (B6), located on the south side of the lake (Figure 12) about $3000\,ft$ from B5, are similar to results from B5. Test boring B6 included an $18\,ft$ thick layer of sand and gravel near the land surface. A deeper layer of sand and gravel was at encountered at $112\,ft\,bgs$. The boring was terminated at a depth of $120\,ft\,bgs$ due to loss of suction on the drilling rig.

3.2 Existing well logs

An investigation of local well logs available at the Illinois State Geological Survey water well log database reveals that wells in the area surrounding the property of interest are sparse. The few domestic wells that exist in the area are screened in the shallow surficial deposits. Aquifer material thickness and depth varies from one well log to another and there is no evidence that the aquifer is laterally extensive or consistent in terms of thickness.

3.3 Conclusions and Recommendations

Our investigation yielded no evidence of a laterally extensive aquifer with adequate thickness and depth to support municipal supply wells. Taking into consideration the information from the two test borings drilled on the Snyder property and the logs of wells in the proximity of the site, we conclude that there is no evidence of a groundwater aquifer in the area near the drilling site that could be considered a sustainable source of groundwater at the scale needed for the City of Bloomington. We recommend no further action at this location.

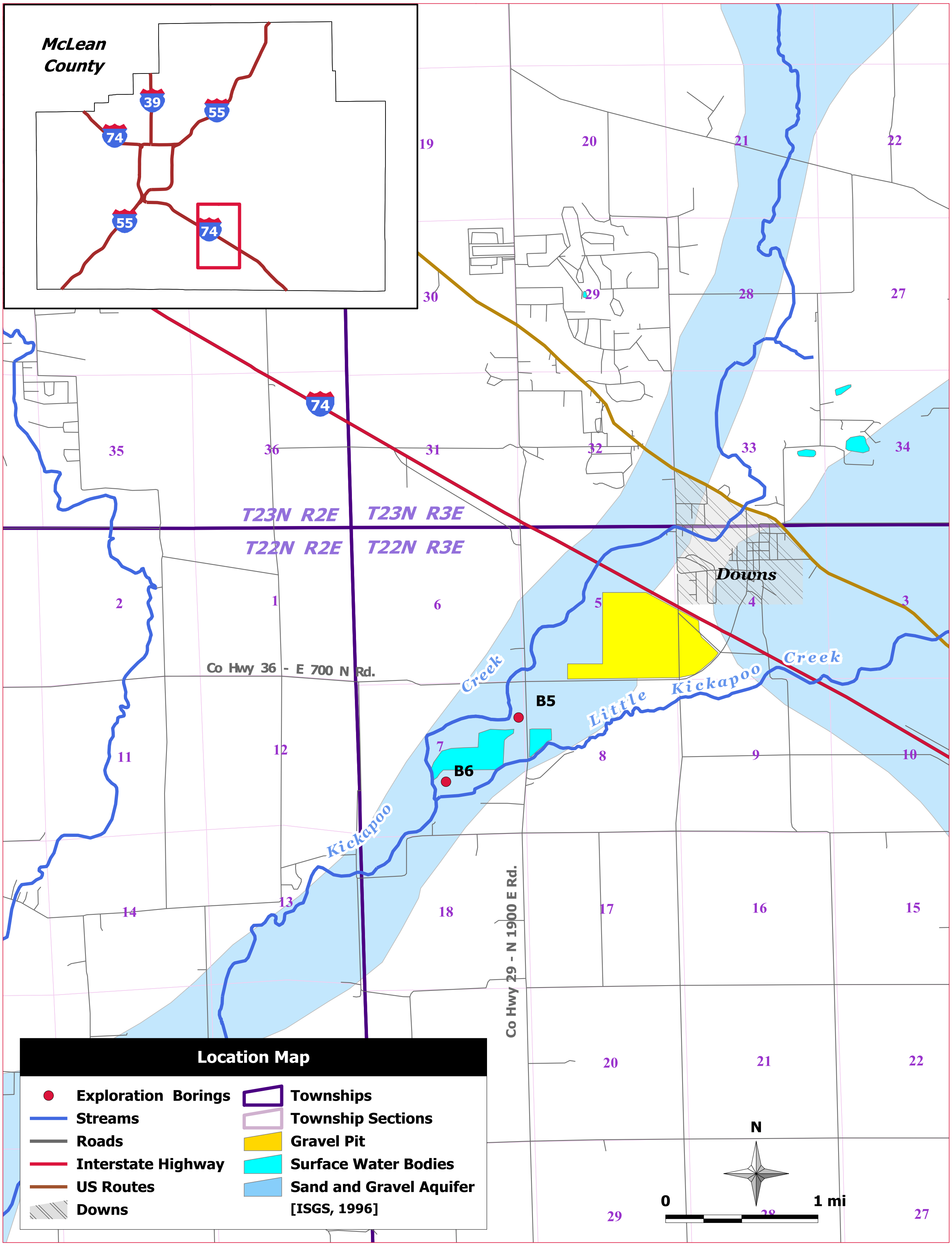


Figure 12: Location of the Downs study area.

4 Danvers Bedrock Valley

The City is interested in the feasibility of pumping $1-2\,mgd$ of groundwater near the lakes primarily to provide low-nitrate source water for blending when nitrate levels in the lakes are high. Based on previous studies and existing boring logs, the area with the greatest groundwater potential is believed to be basal deposits in the middle of the Danvers Bedrock Valley, located between Interstate HWY-39 and N1600E Road, $2\,mi$ west of I-39 (Figure 13). If the formation can support the desired yield, wells could be located near the raw water transmission main that moves water from Lake Evergreen to the treatment plant at Lake Bloomington (Figure 13). To investigate the possibility of developing a groundwater source in the Danvers Bedrock Valley, we conducted a field investigation and performed preliminary groundwater flow modeling to estimate the potential yield of the basal deposits in the bedrock valley between the two lakes.

4.1 Field Investigation

The field investigation included test borings and the installation of monitoring wells at two locations. The test borings were limited to land already owned by the city, all of which was in the immediate vicinity of the two lakes (Figure 13). The field investigation also included a single water-quality sample from one of the monitoring wells installed for this study. Results from the field investigation were used to describe the geometry and characteristics of the aquifer evaluated in subsequent modeling analysis.

4.1.1 Test Borings

Four test borings were drilled on city property in November, 2008 with a reverse air rotary rig. Three of the test borings were located near Evergreen Lake and one boring was located near Lake Bloomington (see B1-B4, Figure 13). Boring logs can be found in Appendix A. Test boring (B2) was drilled at the Comlara Campground, near the Evergreen Lake surface water intake; the location was selected based on proximity to the raw water transmission line between the lakes. At this site a zone of sand and gravel $35\,ft$ thick, was identified at $227\,ft\,(bgs)$ $(458\,ft\,amsl)$. Other smaller sand and gravel layers were also present at $183\,ft$ and $248\,ft\,bgs$. Soil samples from boring B2 were analyzed for grain-size distribution (Appendix B). This boring was finished as a 2" monitoring well screened between $277\,ft\ and\ 322\,ft\,bgs$ with an $8\,ft$ blank section between $308\,ft$ and $315\,ft\,bgs$. The static water level in the monitoring well was measured at approximately $70\,ft\,bgs$.

Test boring B1 was advanced next to the Mackinaw pumping pool in order to evaluate the possibility of a shallow aquifer in the Mackinaw river alluvium and further characterize the deeper formation. Only $10\,ft$ sand and gravel was identified near the surface between $9-19\,ft\,bgs$. This is too shallow and not thick enough to support water supply development. The deeper aquifer formation was encountered at $236\,ft\,bgs$ $(428\,ft\,amsl)$, and was $9\,ft$ thick in this section. This boring was finished as a monitoring well screened between $226\,ft$ and $236\,ft\,bgs$. The static water level was approximately $13.5\,ft$ above ground surface, so the well had to be capped.

The final boring at Evergreen Lake (B3) was located in the area identified by Larson and Poole (1989) as a second channel of the Danvers Valley. A $16\,ft$ thick sand and gravel layer was identified at $227\,ft\,bgs$ $(428\,ft\,amsl)$. Bedrock was encountered at $403\,ft\,amsl$. This elevation is higher than the bedrock elevation at

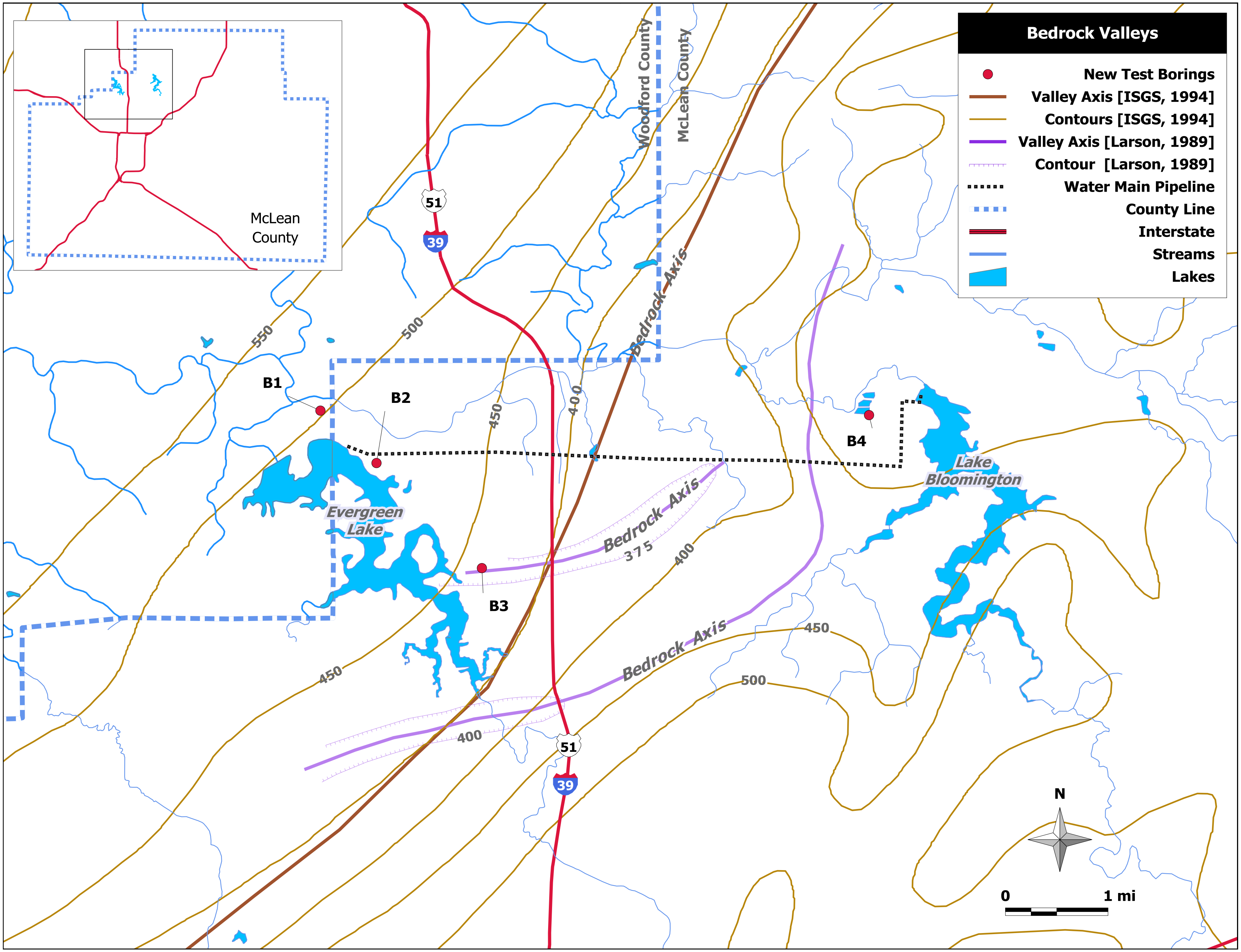


Figure 13: Map of Danvers Bedrock Valley study area with bedrock topography [ISGS, 1996 and Herzog et. al., 1994].

either B1 or B2; results from our borings do not support the presence of the second channel identified in the Larson and Poole seismic refraction study.

One boring was advanced on the west side of the Danvers Bedrock valley, adjacent to the sludge lagoons by Lake Bloomington. This boring (B4) identified only a $6\,ft$ seam of sand and gravel at $467\,ft\,amsl$. Bedrock was encountered at $429\,ft\,amsl$, indicative of a rise in the bedrock valley. This boring was not converted into a monitoring well.

4.1.2 Cross-sections

We used results from the test borings along with existing boring logs in the area to generate a geologic cross-section running west-east through the valley between the lakes (Figures 14 and 15). The cross-section shows a thin productive zone of sand and gravel between $415 - 460\,ft\,amsl$ (Figure 15). The formation appears continuous and varies in thickness between $10 - 40\,ft$. The thickest section of sand and gravel is toward the center of the bedrock valley and thins both east and west towards the lakes (Figure 15). Most existing borings do not extend to bedrock. Consequently, the exact location of the bedrock surface is not known between the lakes.

Several sand and gravel lenses also occur at shallower depths but do not appear to be continuous. Near the middle of the cross-section there is a second layer of sand and gravel between $450 - 480\,ft\,amsl$ (Figure 15). This unit appears connected to boring B2, however it is not possible to determine how far west it extends beyond the center, and if it reconnects with the lower sand unit.

4.1.3 Water Quality

Water-quality samples were collected from monitoring well B-2 to characterize the potential source water, determine its suitability for blending with surface from the lakes, and identify any potential requirements for additional treatment. A submersible, low-flow pump was used to collect the samples with the well purged more than three well volumes prior to sample collection. The samples were analyzed by PDC Laboratories, Inc. in Peoria, Illinois. The water quality results for select parameters are shown in Table 3. The raw data and results for volatile organic compounds (VOCs) are presented in Appendix C. In Table 3, the results are compared to national primary and secondary drinking water standards. Primary standards such as the Maximum Contaminant Level (MCL) are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water. National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines for contaminants that may cause cosmetic or aesthetic effects in drinking water.

The results from the monitoring well suggests that groundwater at the site is suitable for public supply. Treatment may be necessary to reduce the level of iron and manganese for taste and aesthetic reasons if this source were used alone without blending with lake water. The measured concentration for iron and manganese were above the respective secondary standard (NSDWR) (Table 3). The iron concentration, only slightly above the primary standard, is low compared to the iron concentration observed in area wells [Holm,] [Kempton and Visocky, 1992]. Manganese is high compared to area wells [Holm,]. However, iron and manganese would be reduced by dilution with lake water and removed by the existing treatment process.

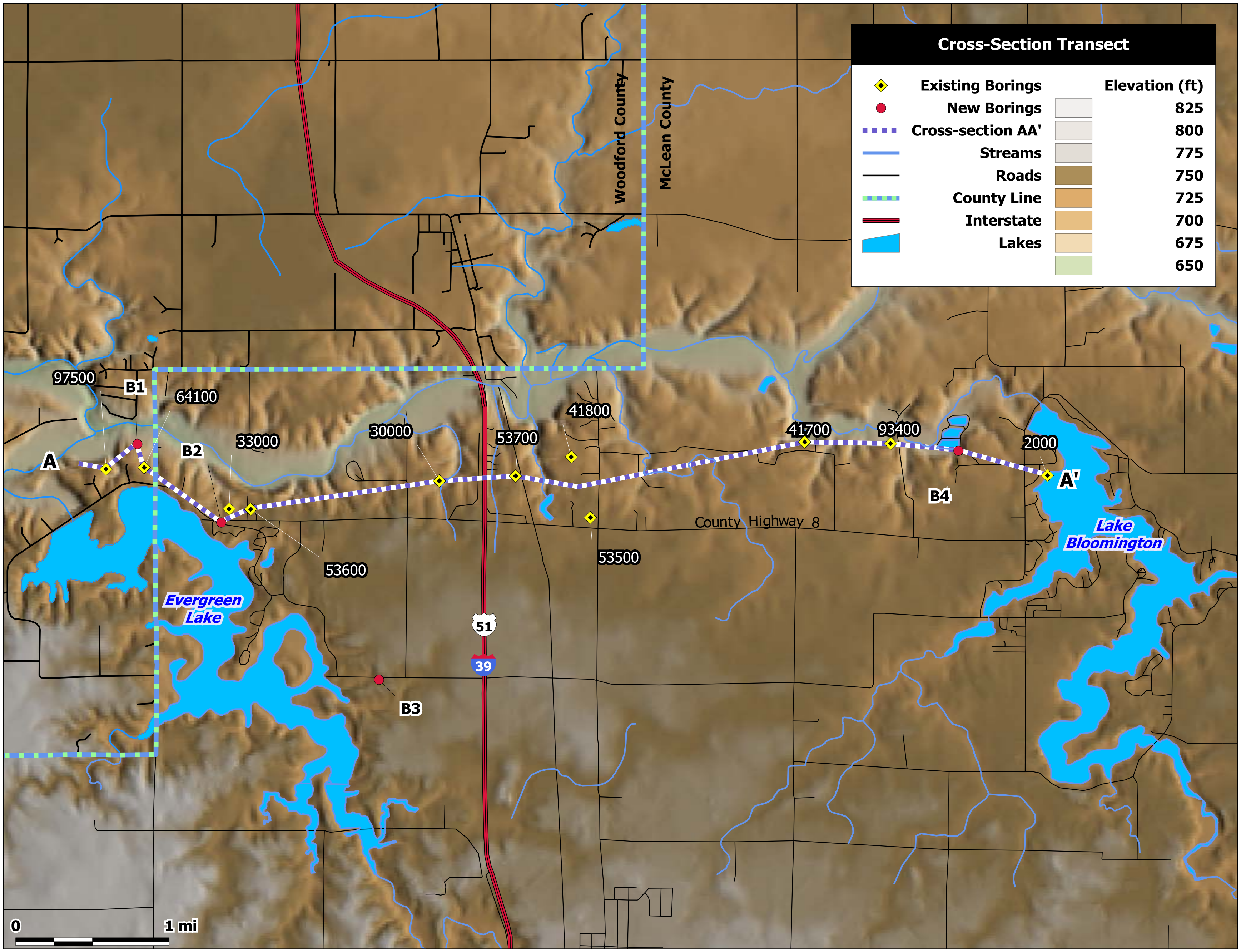


Figure 14: Location of geologic cross-section A-A'.

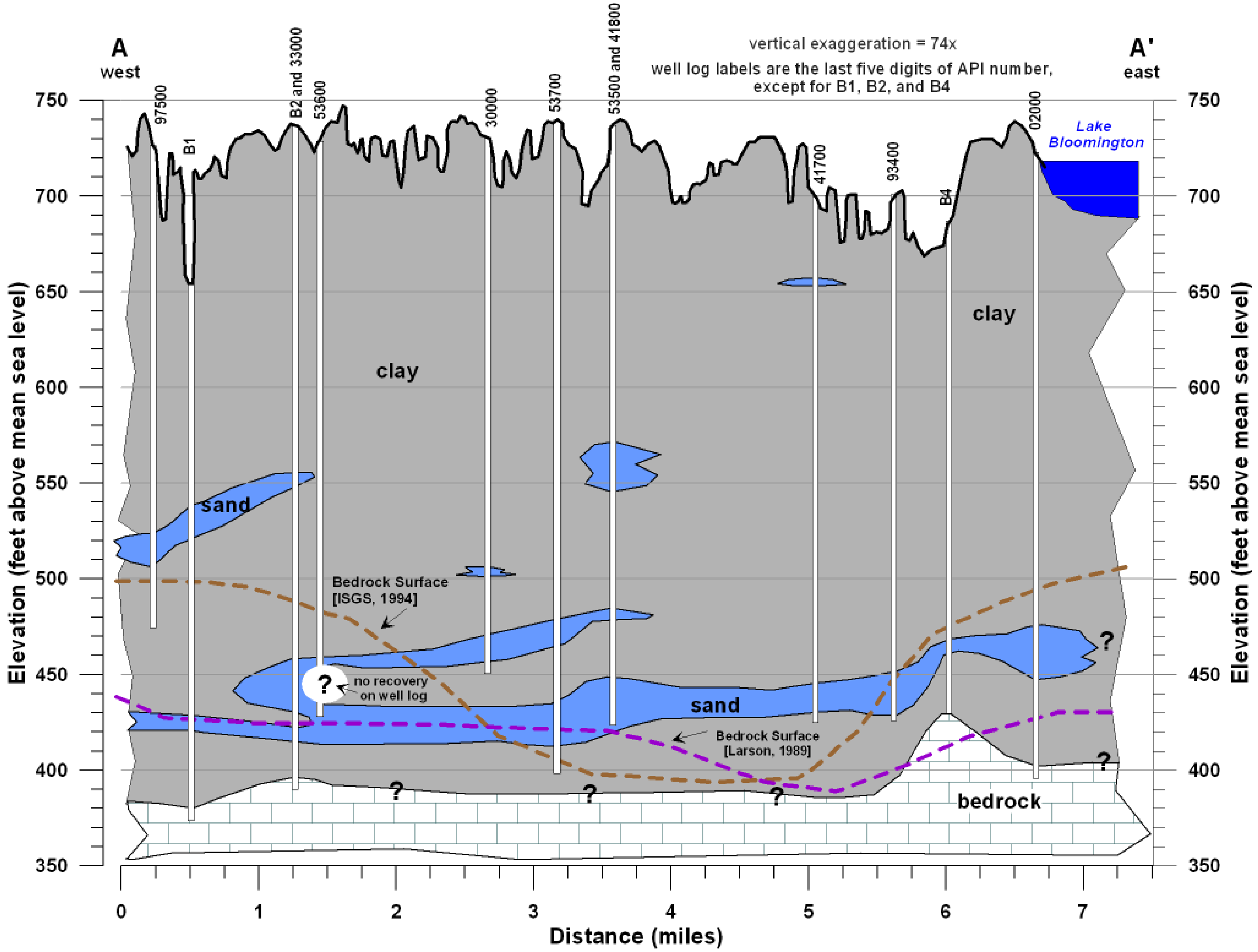


Figure 15: Cross-section A-A’ from Evergreen Lake to Lake Bloomington.

The measured nitrate concentration was very low ($0.02 mg/l as N$), indicating groundwater in the aquifer is suitable for blending with lake water. Because the concentration is so far below the primary standard (MCL), this groundwater could be effective at lowering nitrate levels in the raw water supply for the city. Ammonia was at a higher concentration than the typical lake concentration. Depending on the blending rate this may increase chlorine consumption in the treatment process. All other water-quality parameters were within a range that indicates there will be no additional effects on the existing water treatment process when groundwater is blended with lake water.

Groundwater from the test well is a sodium-bicarbonate type with moderate hardness and a high concentration of sodium. The sodium concentration of $130 mg/l$ is above the guidance level of $20 mg/l$ for individuals on restricted sodium diets [AWWA, 2006]. No MCL was exceeded in the groundwater sample with the exception of thallium, which was detected near the MCL of $0.002 mg/l$. Thallium levels would be reduced significantly by dilution if blended with lake water. No VOCs were detected above the reporting limit (see Appendix C). High arsenic occurs in groundwater in some areas of the Mahomet Aquifer. Arsenic concentrations above the MCL have been measured in Glasford sands in McLean and neighboring counties [Warner, 2001][Holm and Scott, 2004]. Arsenic was detected in the monitoring well, but at a concentration near the reporting limit and well below the MCL (Table 3).

4.2 Groundwater Flow Modeling

We used groundwater flow modeling as a scoping tool to estimate the potential yield of wells in the basal deposits and estimate the spacing that may be required to use multiple wells. The two areas considered for wellfield development include an area east of Evergreen Lake and the area between the lakes where the aquifer is possibly thickest (Figure 16). We developed a simple conceptual model of the aquifer system based on our understanding of the hydrogeologic setting, existing boring logs, and the test borings drilled for this study. The elements of the conceptual model were incorporated into a ModAEM analytic element groundwater flow model [Kelson, 2007] using GMS as a preprocessing tool [Aquaveo, 2009].

4.2.1 Conceptual Model

The conceptual aquifer is shown as a single layer with transmissivity zones to represent the variation in thickness of the sand layer across the valley (Figure 17). The two transmissivity zones are assumed to have similar hydraulic conductivities and are delineated based on aquifer thickness. The conceptual model assumes an average thickness of $40 ft$ in the center of the bedrock valley and an average thickness of $20 ft$ at both edges. The aquifer is bound by the rising bedrock valley walls on both sides and by either bedrock or a clay layer on the bottom. The aquifer is confined with a thick clay layer overlying the sand and gravel formation. Recharge is simulated as areal recharge through the clay layer. Intermediate sand and gravel layers between the aquifer and the ground surface are not included in the conceptual model.

Table 3: Water-quality sampling results for select parameters from monitoring well B2, Danvers Bedrock Valley.

Parameter	**Units**	**MCL (NSDWR)**	**10/01/08**
Iron	mg/l	(0.30)	0.31
Silicon as SiO2	mg/l		7.1
Sodium	mg/l		130
Aluminum	mg/l	(0.050-0.20)	0.18
Antimony	mg/l	0.006	0.004
Arsenic	mg/l	0.010	0.003
Barium	mg/l	2.0	0.3
Beryllium	mg/l	0.004	0.002
Cadmium	mg/l	0.005	0.001
Calcium	mg/l		27
Chromium	mg/l	0.050	0.007
Copper	mg/l	(1.0)	0.006
Lead	mg/l	0.015	0.002
Magnesium	mg/l		13
Manganese	mg/l	(0.050)	0.15
Mercury	mg/l	0.002	<0.0002
Nickel	mg/l		0.03
Selenium	mg/l	0.050	0.01
Thallium	mg/l	0.002	0.003
Zinc	mg/l	(5)	0.019
Nitrate as N	mg/l	10	<0.02
Nitrite as N	mg/l	1	<0.15
Chloride	mg/l	(250)	64
Fluoride	mg/l	4.0 (2.0)	<0.25
Sulfate	mg/l	(250)	26
Cyanide, Total	mg/l		0.01
Alkalinity, Total as CaCO3	mg/l		350
Hardness, Total as CaCO3	mg/l		120
Conductivity	umhos/cm		870
Solids Total Dissolved	mg/l	(500)	480
Solids Total Suspended	mg/l		<4
pH	units	(6.5-8.5)	7.34
Nitrogen, Ammonia as N	mg/l		3.9
Phosphorus, Ortho as P	mg/l		<0.02
Carbon Total Organic	mg/l		5.7

MCL=USEPA Maximum Contaminant Level, NSDWR=National Secondary Drinking Water Regulation

[1] *method hold time exceeded*

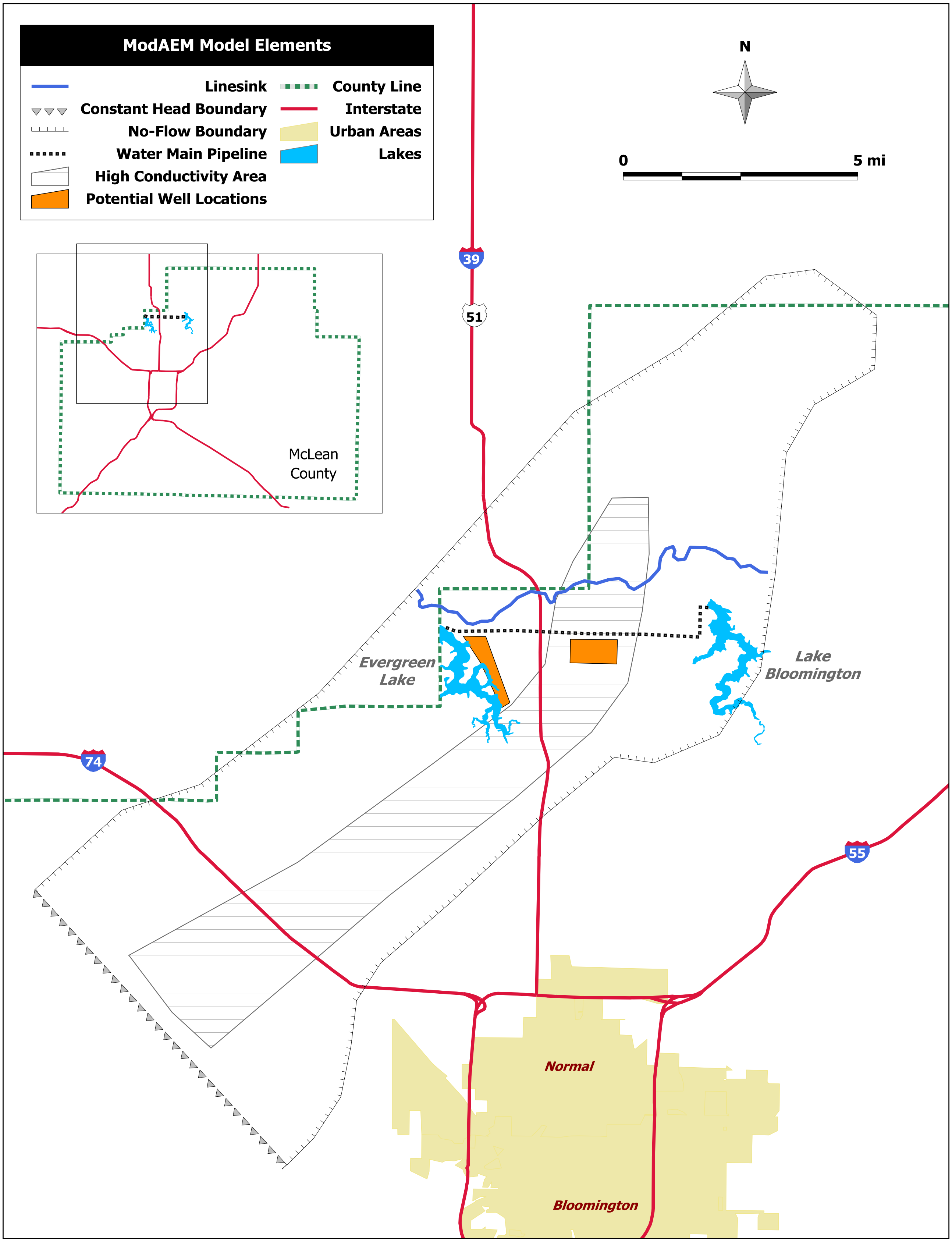


Figure 16: Potential well locations and layout of ModAEM groundwater flow model, Danvers Bedrock Valley.

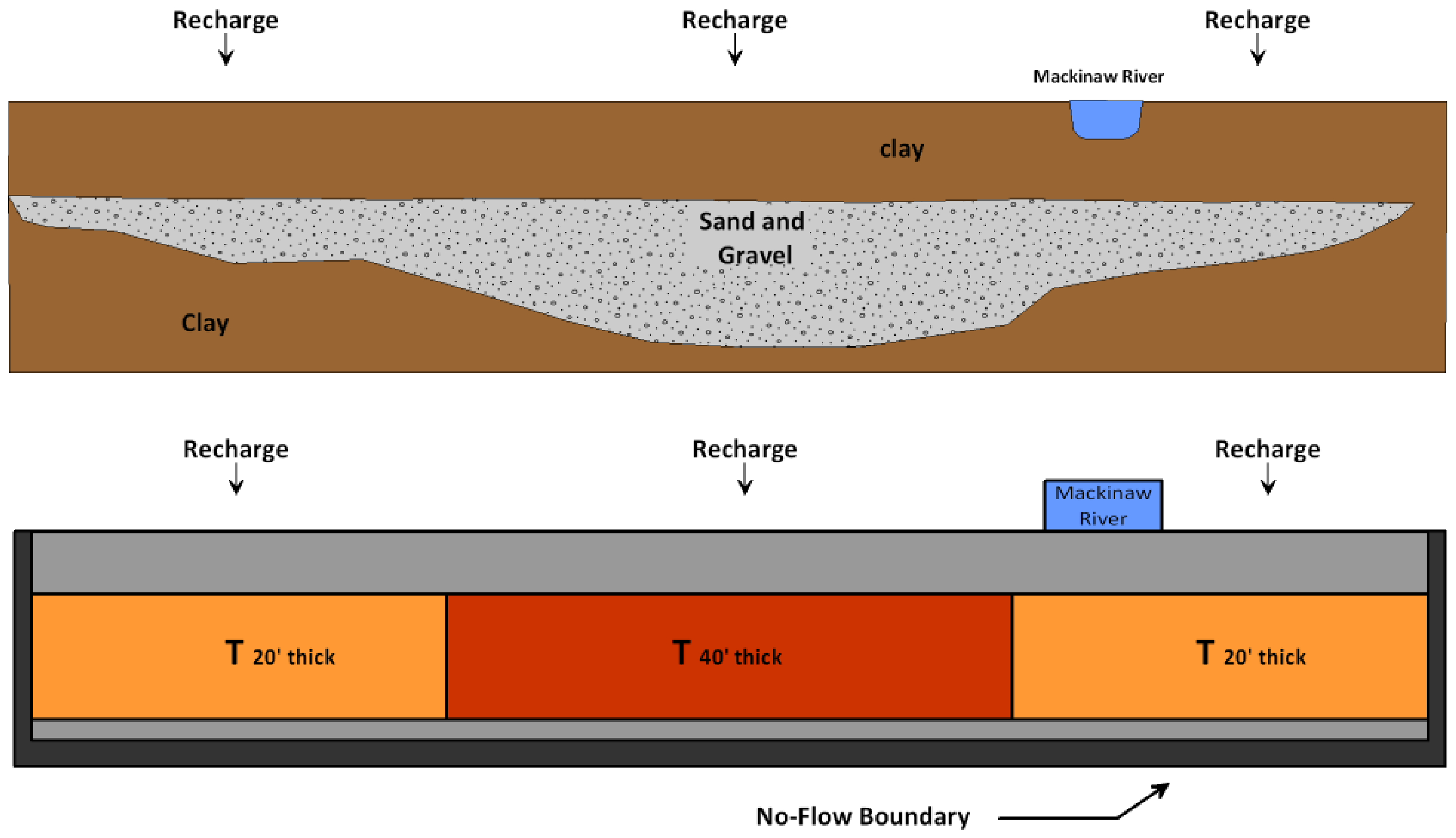


Figure 17: Conceptual model of basal deposits in the Danvers Bedrock Valley.

Table 4: Aquifer properties used in predictive modeling, Danvers Bedrock Valley.

Scenario	**Hydraulic conductivity** (ft/day)	**Recharge** ($in/year$)
Conservative	100	0.4
Best Case	300	1

ft=feet; in=inches

4.2.2 Model Development

The model was developed with no-flow boundaries to represent the termination of the aquifer on the sides and to the north (Figure 16). At the southwest end of the model where the Danvers Valley opens up and the basal deposits are thicker, the model has a constant-head boundary to allow water to move in and out of the modeled area. The water level at this boundary was set based on static water levels reported in boring logs from the area. The static water level was approximately $90\,ft$ lower than the observed groundwater levels near Lake Evergreen, resulting in an approximate $0.0018\,ft/ft$ gradient towards the southeast. A line-sink is used with a very high resistance to flow to represent the Mackinaw River.

The aquifer was modeled as a single layer with an inhomogeneity used to represent the thicker gravel zones in the middle of the bedrock valley. To account for the uncertainty in the aquifer extent and the aquifer properties, the model was bracketed with conservative and best case assumptions (Table 4). The range of values for the hydraulic conductivity were derived from historical values for the Banner formation (see Section 2.2.3, Table 1) and results from grain-size analysis of samples obtained from the test borings. The range for aquifer recharge was selected based on similar deep formations in the area, primarily the Mahomet aquifer where the ISWS used a recharge value of $0.78\,in/yr$ [Wilson et al., 1998]. For our analysis we used a range of $0.4-1.0\,in/yr$ (Table 4).

4.2.3 Model Results

Results from the preliminary modeling analysis indicate that the basal deposits in the Danvers Bedrock Valley between the lakes could supply $1-2\,mgd$, depending on the extent, transmissivity, and amount of recharge available to the deposits. Table 5 shows results from the predictive modeling analysis. Using the best case scenario for the aquifer parameters, the predictive model indicates that either the Lake Evergreen or the Center location may yield $2\,mgd$. The best case results for the center location indicate that the aquifer could support 3-4 wells, spaced at least $1,000\,ft$ apart, pumping a total of $2.5\,mgd$ without excessive drawdown (Table 5). Results from the conservative scenarios indicate that the aquifer may only yield $1\,mgd$ without excessive drawdown. With the conservative assumptions, the well spacing would need to be at least $3,000-4,000\,ft$.

Table 5: Predictive modeling results, Danvers Bedrock Valley.

Location	**Scenario**	**Well Configuration**			**Output**
		No. of Wells	**Rate** (gpm)	**Spacing** (ft)	(mgd)
Lake Evergreen	Conservative	3	250	4,000	1
Center	Conservative	3	250	3,000	1+
Lake Evergreen	Best Case	3	465	2,000	2
Center	Best Case	3	350	1,000	2.5

mgd=million gallons per day, ft=feet, gpm=gallons per minute

4.3 Conclusions and Recommendations

Based on the results of a limited field investigation and simple groundwater modeling of flow in the basal deposits in the Danvers Bedrock Valley, we reach the following conclusions:

- The basal deposits in the Danvers Bedrock Valley may have the potential to supply $1-2mgd$, using 3 vertical wells spaced $1,000-3,000ft$ apart, depending on the transmissivity of the aquifer, and the rate of recharge to the aquifer.
- The most promising location to develop a wellfield is in the center of the Valley, between the lakes.
- The potential source water appears to be suitable for blending with lake water. Because the nitrate concentration is low, this source could be effective at lowering nitrate levels in the raw water supply for the City.

We recommend that the City take additional steps to develop an interim water supply in the basal deposits of the Danvers Bedrock Valley. We recommend that the City pursue development of a wellfield at the center location between the lakes because preliminary results indicate that this area has the highest potential for development. Another advantage of this location is its orientation with the raw water main between the lakes. Regardless of the required spacing, supply wells at the center location could be located very near the main, requiring little additional transmission pipe.

More field work is needed to better understand the potential capacity of the aquifer, the infrastructure needed to develop a wellfield, and the potential impacts of pumping. Exploratory test borings should be drilled between the lakes to better characterize the aquifer extent and thickness. An aquifer test should be performed with a test well between the lakes to improve estimates for aquifer properties and better understand the extent of drawdown and the potential impacts on neighboring wells. We recommend the following additional work :

- A gravity survey between the lakes to map the bedrock surface, identify potential well locations, and help define the extent and shape of the aquifer
- Exploratory borings in the area between the lakes to confirm the aquifer extent and thickness and identify optimal well locations

- An extended aquifer test at a location between the lakes to measure aquifer properties and identify aquifer discontinuities
- Water-quality testing to better characterize the source water
- Model aerial recharge to the basal deposits to refine estimates of recharge
- Update the groundwater flow model to determine firm yield, optimize pumping locations, and estimate potential impacts to neighbors

5 Sugar Creek Valley

This section describes the results of a hydrogeologic investigation of the Sugar Creek Valley, including a field investigation of a parcel of land owned by Stark. The Stark property is located southwest of Bloomington, on the northwest corner of the intersection of E 1000 N Road and N 1025 E Road, or Bloomingdale Road (Figure 18). The property, which sits in Sections 22 and 23 of the Dale Township (T23N R1E), was identified as a prospect based on 1) previously reported sand and gravel deposits in the area, 2) its proximity to Sugar Creek (a potential source of recharge), and 3) its proximity to the City's water distribution infrastructure. The objective of the investigation was to assess the potential of the local groundwater aquifer to supply a new source of water for the City.

5.1 Approach

We used the following approach to assess the aquifer, determine the potential yield of a wellfield at the site, and evaluate the potential impacts. Our approach is described as follows:

1. Drill test borings at the site using a sonic drill rig to characterize the shallow deposits ($<100\,ft$).
2. Conduct an aquifer test at the Fox Creek Golf Course using existing wells, to determine aquifer properties.
3. Install a temporary test well and conduct an aquifer test to determine aquifer properties at the site.
4. Collect water-quality samples from the test well and the creek during the aquifer test to describe the chemical composition of the aquifer and nearby stream.
5. Develop a conceptual model of the aquifer system based on results from steps 1 and 2.
6. Develop a recharge model to estimate recharge to the local aquifer and distribute the recharge throughout the year.
7. Using the recharge estimates from step 5, use a transient groundwater flow model to assess the seasonal effects of recharge on safe yield.
8. Use a steady state groundwater flow model to estimate yield and select an efficient wellfield designs.

5.2 Field Investigation

The field investigation included test borings, installation of monitoring wells and a test production well, aquifer testing, and water-quality sampling at the Stark property. In addition, an aquifer test was performed with an existing City well at the Fox Den Golf Course located approximately 2.5 miles northeast of the Stark property. Results from the field investigation were incorporated into the modeling analysis.

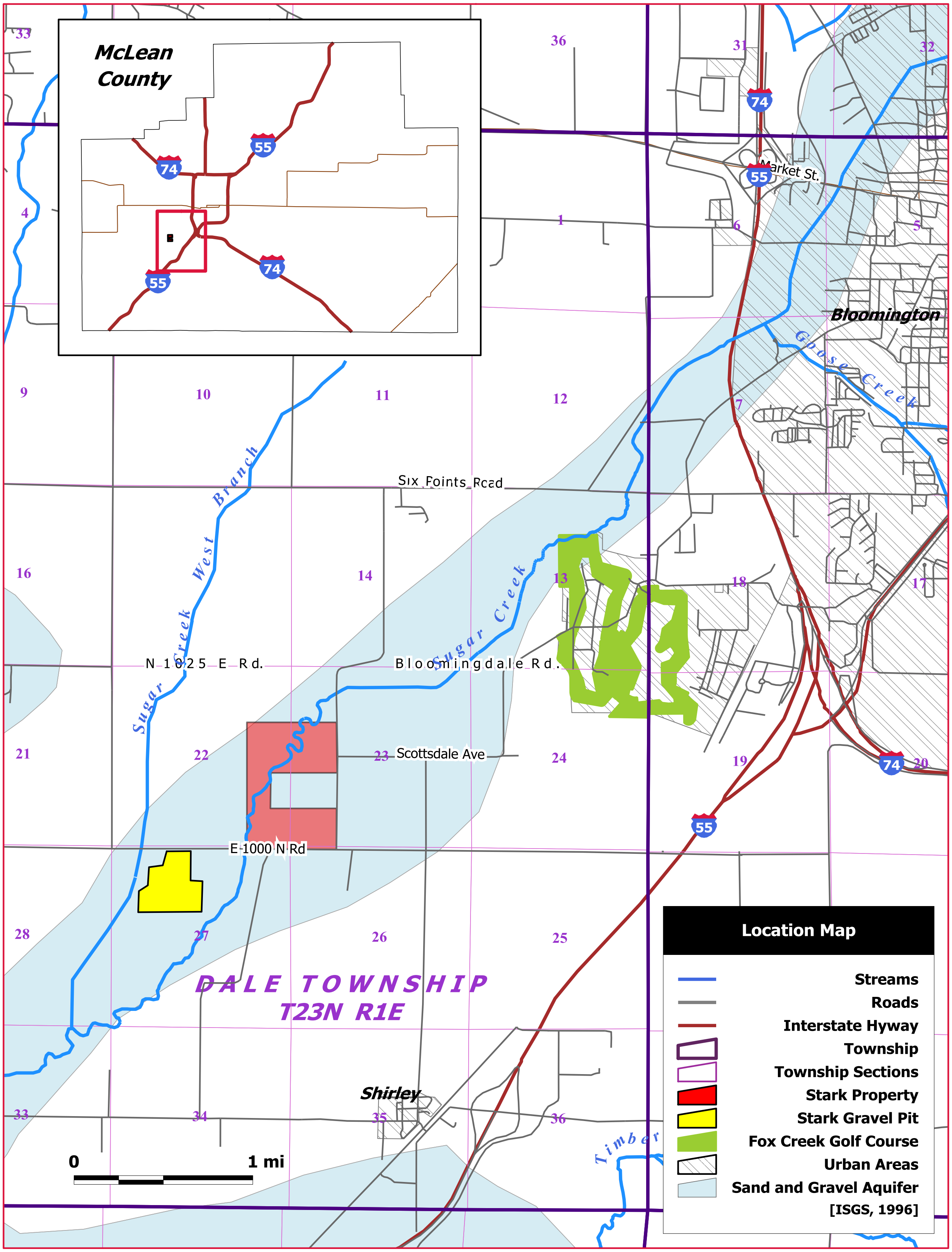


Figure 18: Location of study area in the Sugar Creek Watershed.

5.2.1 Test borings

Test borings were drilled at the site to characterize and map the extent and thickness of the shallow sand and gravel deposits. In June 2009, six test borings were drilled with a rotosonic rig along Sugar Creek (S1, S4, S7, and S8) and along the southern portion of the property (S2 and S3); four of these borings were converted into monitoring wells (MWS1, MWS2, MWS3, and MWS7) for use as measuring points during the aquifer test (Figure 19). In July 2009, two additional monitoring wells and a test well were installed with a reverse air rotary dilling rig (MWS5 and MWS6) (Figure 19). Logs from the test borings and monitoring wells are presented in Appendix A. Representative grab samples collected from three of the sonic cores (S1, S2, and S3) were analyzed for grain-size distribution (Appendix B).

5.2.2 Cross-sections

Results from the exploratory drilling were combined with existing information to build local and regional geologic cross-sections. These cross-sections were then used as the basis for our conceptual model of the aquifer system. The primary source of existing geologic information is from wells logs generated from borings drilled for resources like water and gas exploration. Well logs are submitted by drillers and cataloged and maintained by the ISGS and the ISWS. Figure 19 shows the transects for geologic cross-sections B-B’, C-C’, and D-D’. Cross-section B-B’ cuts east to west roughly along county road E 1000 N (Figure 21). Cross-section C-C’ runs from the eastern terminus of cross-section B-B’ northeast to Fox Creek Golf Course (Figure 22). Cross-section D-D’ runs south to north, from county road E 1000 N to Sugar Creek (Figure 23).

Results from the exploratory drilling confirm previous observations by Vaiden and Kempton (1989). The aquifer is comprised mainly of coarse sand and small to large gravel with some cobbles and boulders. The permeable deposits at the site appear to be two separate units, a deep deposit of sand and gravel resting on basal clay and a thin, predominately gravel deposit present near the land surface. Cross-section B-B’ shows a $40-60\,ft$ layer of sand and gravel with a surface elevation of approximately $690\,ft\,amsl$ at the golf course. Under the Stark property further south, cross-section A-A’ shows a $50-70\,ft$ thick sand and gravel layer with a surface elevation near $700\,ft\,amsl$. Under monitoring well MSW2, the shallow and deep deposits are connected, forming a $70\,ft$ thick, continuous zone of sand and gravel. Under the current location of the Sugar Creek, the deep deposits are not present. Away from the creek, the shallow and deep deposits are separated by glacial till consisting of dry gravelly clay. Above the aquifer there is a laterally extensive layer of soft brown to yellow clayey soil ranging between 5 to $8\,ft$ thick. The base of the aquifer is a $100-200\,ft$ of hard blue clay overlying bedrock. Surface elevation at the site is around 690 to 710 $ft\ amsl$ based on sub-meter GPS data collected in the field. Bedrock in the area is around 450 and $475 ft\ amsl$.

5.2.3 Fox Creek Golf Course Aquifer Test

The City of Bloomington operates three wells at The Den at Fox Creek Golf Course, located in sections 13 and 14 of the Dale Township (Figure 18). These wells are used to maintain water levels in the golf course water features as well as for irrigation. An aquifer test was performed at the golf course between March 14 and 16, 2008 using the existing wells (Figure 24). Well logs from the golf course indicate more than $60\,ft$ of combined

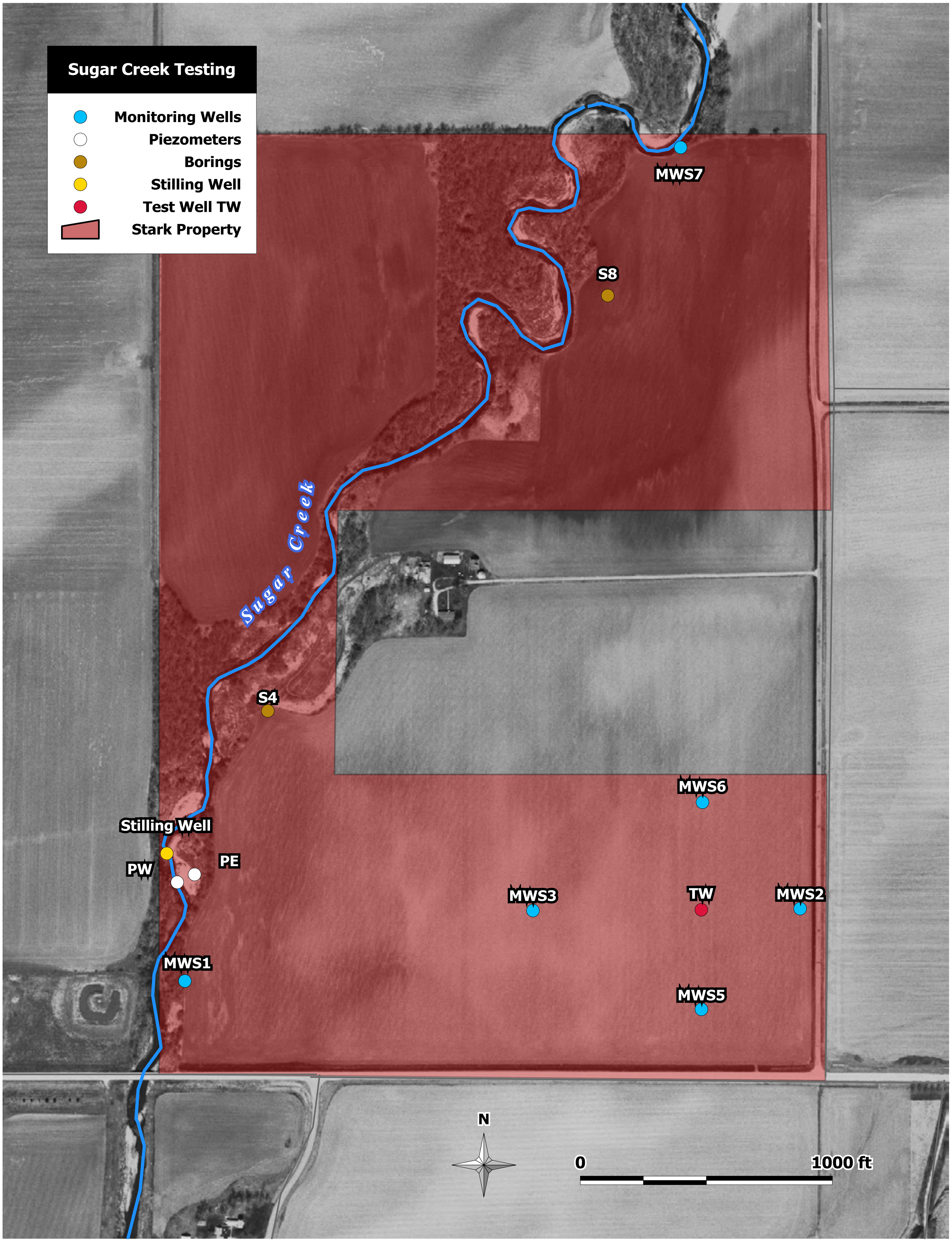


Figure 19: Location of borings and monitoring wells installed on the Stark property site.

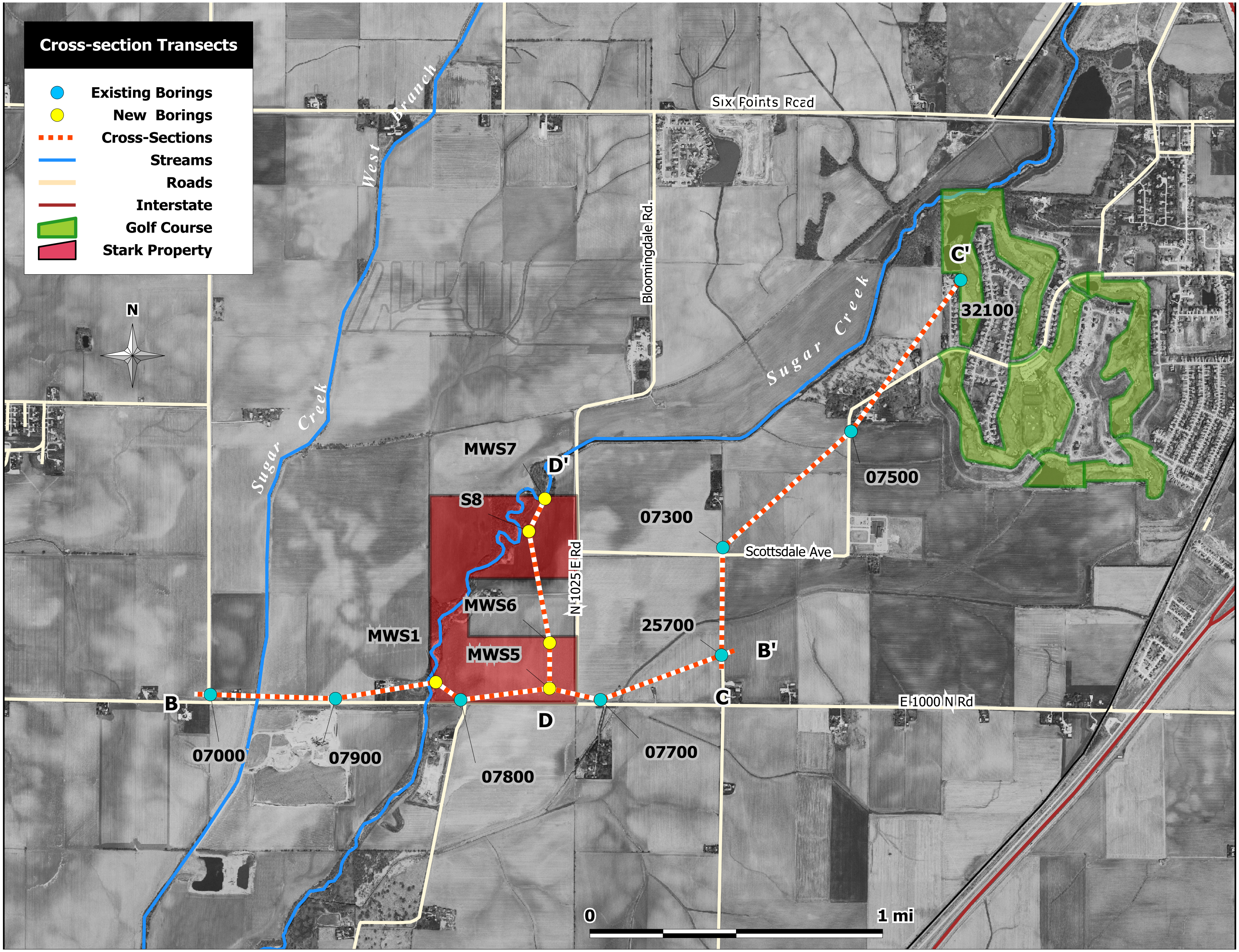


Figure 20: Location of the cross-sections B-B’, C-C’, and D-D’.

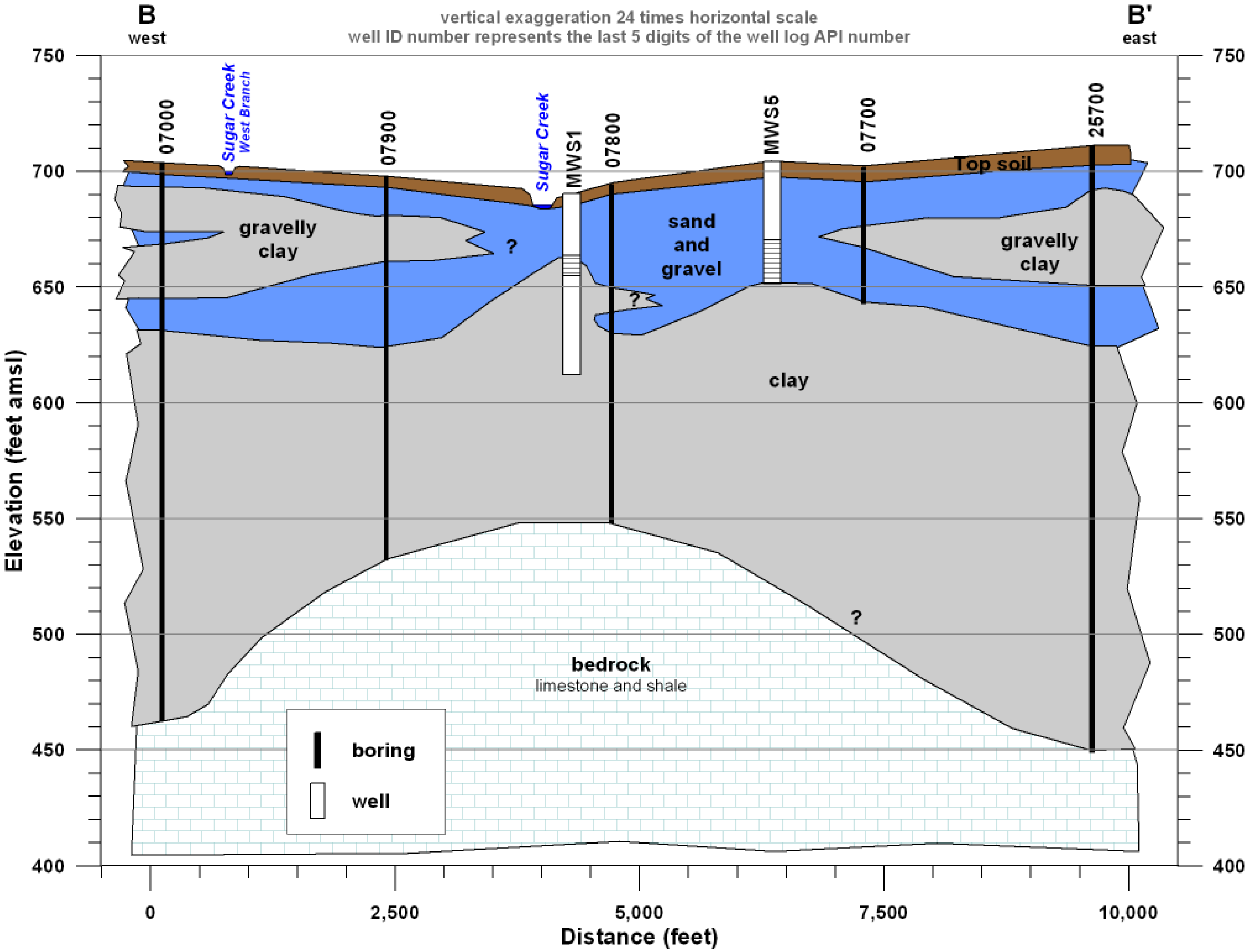


Figure 21: Geologic cross-section B-B'.

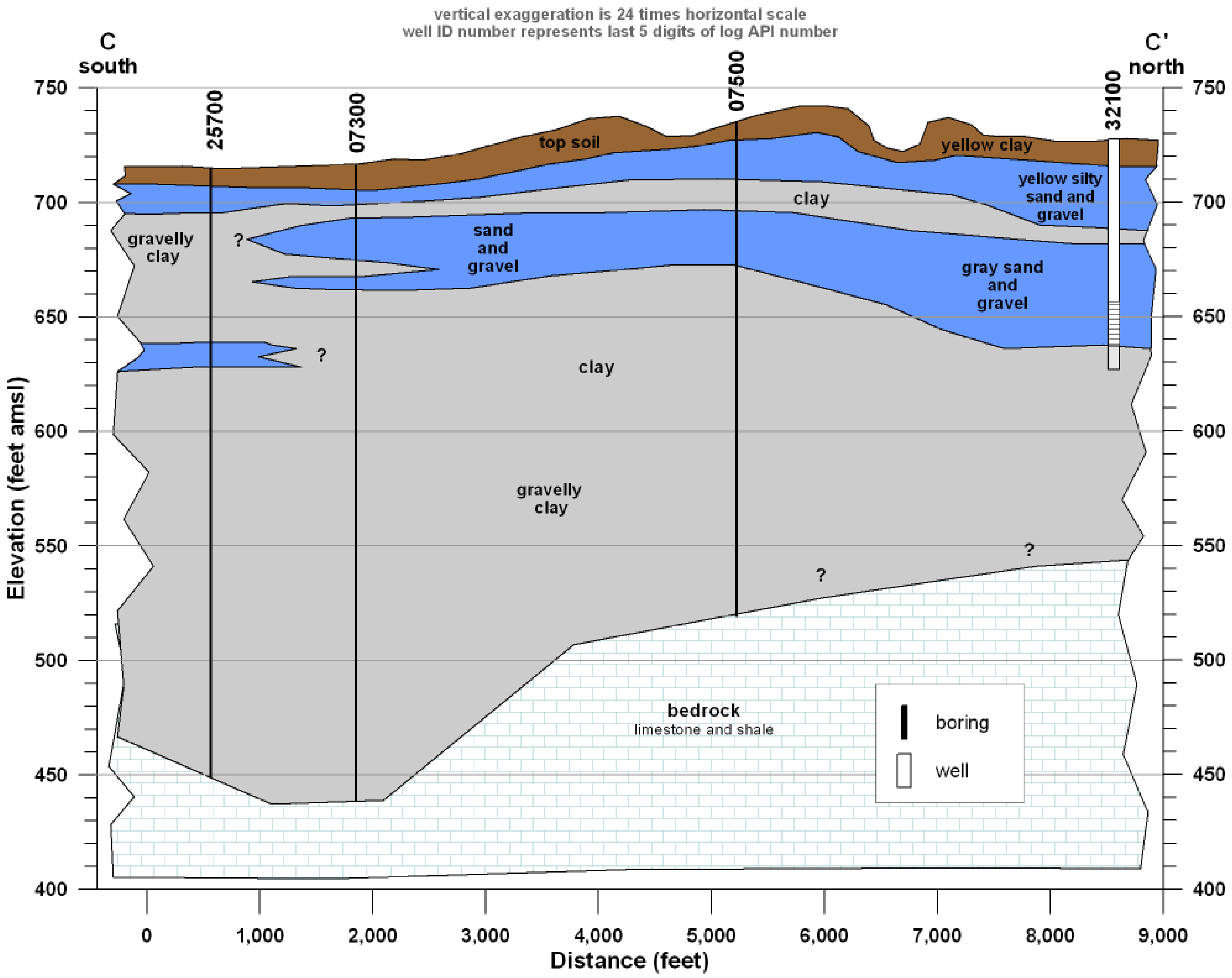


Figure 22: Geologic cross-section C-C'.

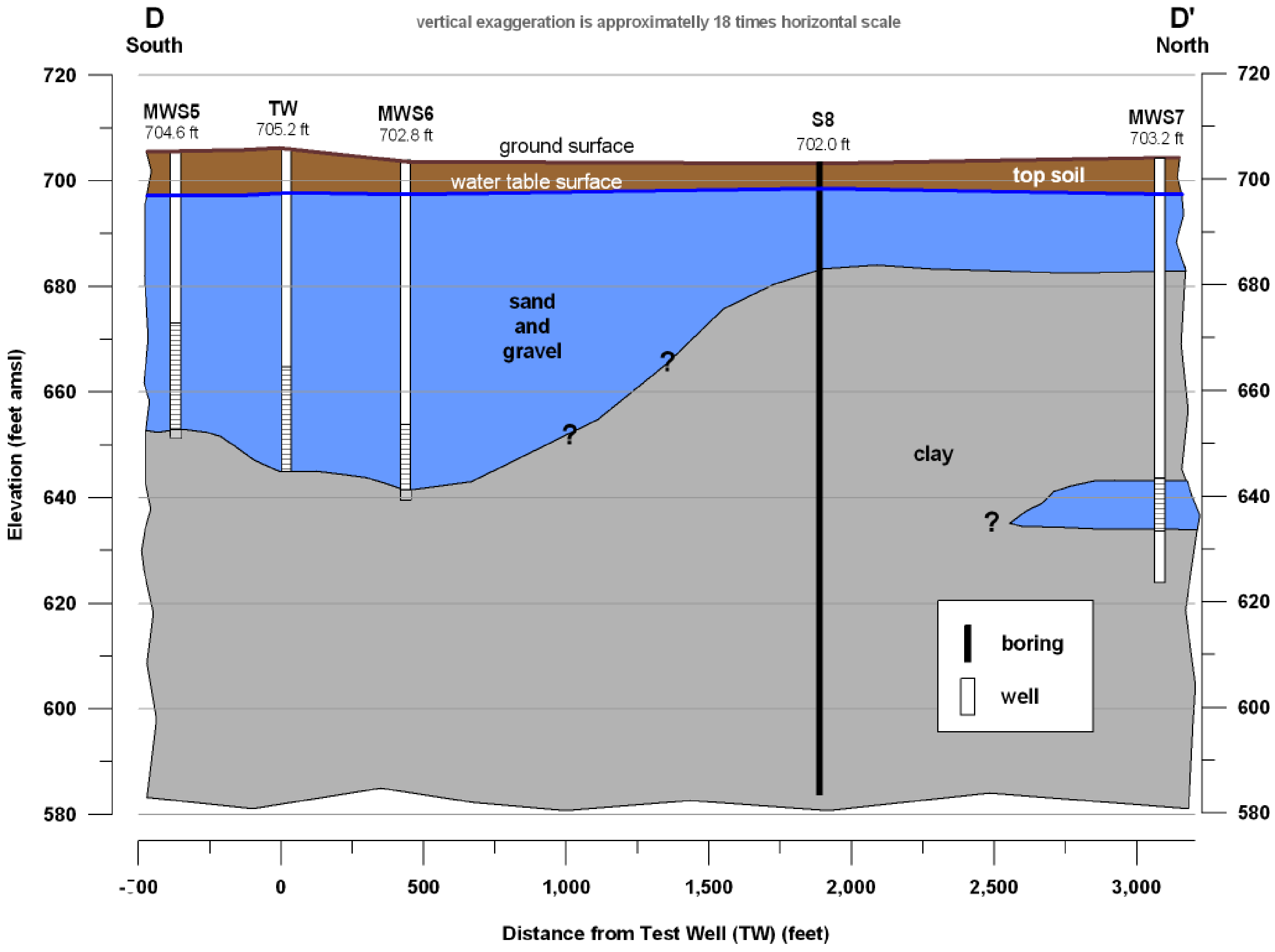


Figure 23: Geologic cross-section D-D'.

sand and gravel (Figure 22).The wells are set at depths around $85\,ft\,bgs$ in $38-40\,ft$ of sand and gravel. This unit of sand and gravel is overlain by a $2-6\,ft$ of clay and approximately $30\,ft$ of silty sand and gravel. Sugar Creek is located $850\,ft$ from pumping well.

During the test the weather was clear with air temperatures reaching the mid 60's ^oF. The test was started at 10:50 am. The flow rate, measured with a flow meter, ranged between $220-225$ gallons per minute (gpm) with an average rate of $222.9\,gpm$. Rain started in the early morning of March 15 and continued throughout the day. The pump test was stopped on March 16, at 10:20 am. The total test time was 47.5 hours and approximately 635,550 total gallons of water were pumped from the test well and discharged at the golf course pond.

By the end of the test, the level in the monitoring well had dropped 4.2 ft. Figure 25 shows the drawdown observed in the monitoring well during the aquifer test. The time-drawdown curves were evaluated using the AQTESOLV software package [Duffield, 2002]. The pond immediately adjacent to the well was not included as a constant-head source in the analysis. The top of the pumped aquifer is approximately 30 ft below the bottom of the pond and static water level in the monitoring well was approximately $9ft$ lower than the level in the pond. In addition, the ponds were constructed with a clay liner to prevent percolation into the underlying sediment [Satterwhite, 2008].

Based on the shape of the time-drawdown curve and the derivative of the time-drawdown curve, the results are indicative of a leaky-confined aquifer. The data fit well to a Hantush-Jacob type-curve with a transmissivity (T) of $4,900\,ft^2/day$, a storage coefficient of 0.00024, and a value of r/B = 0.0563. The average aquifer thickness near the pumping wells was $48\,ft$ and the resulting hydraulic conductivity is $102\,ft/day$. The value of r/B obtained from the analysis is representative of a $10\,ft$ thick clay-confining layer with a hydraulic conductivity of $0.0025\,ft/day$. The AQTESOLV analysis results are included in Appendix E.

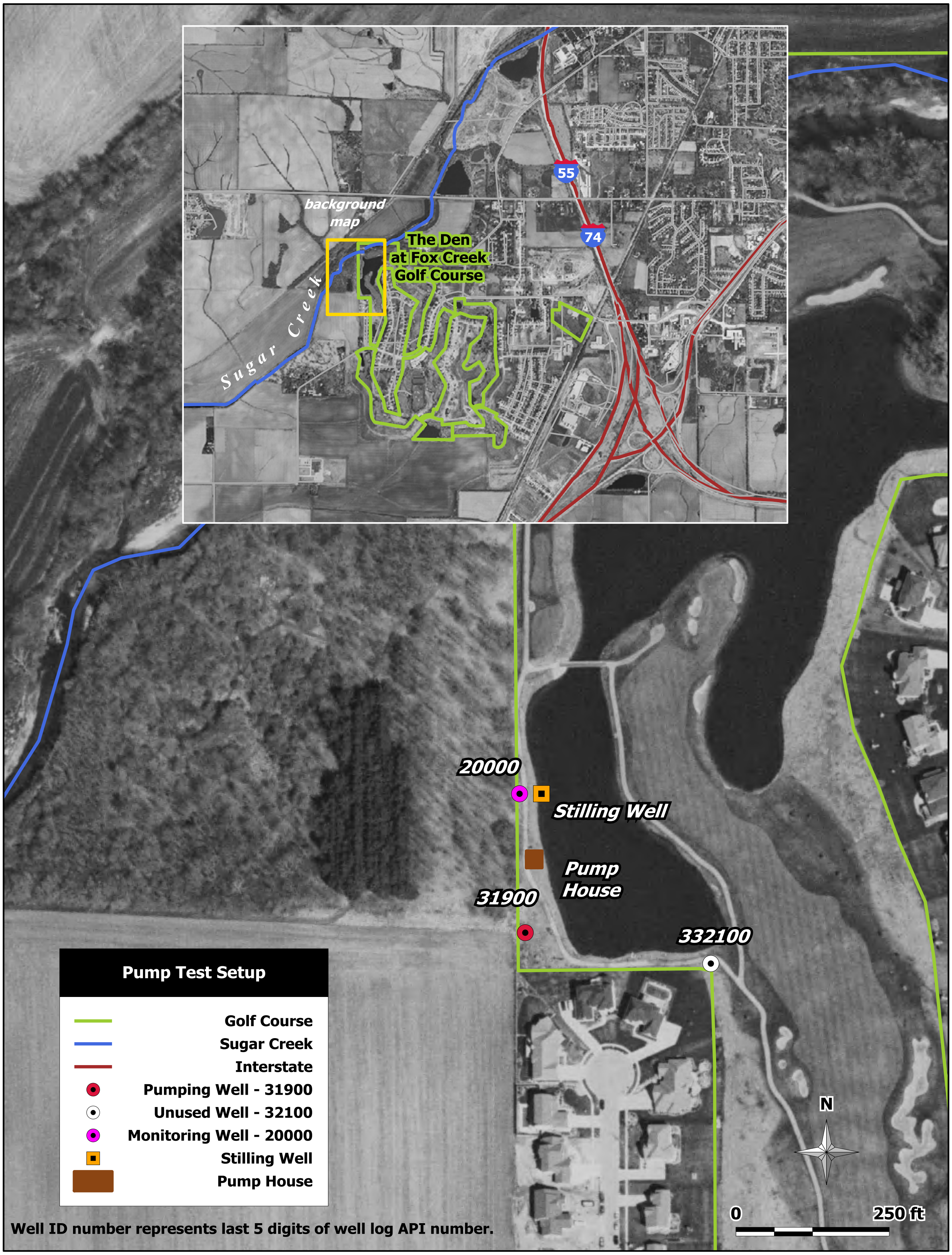


Figure 24: Setup for the aquifer test at Fox Creek Golf Course.

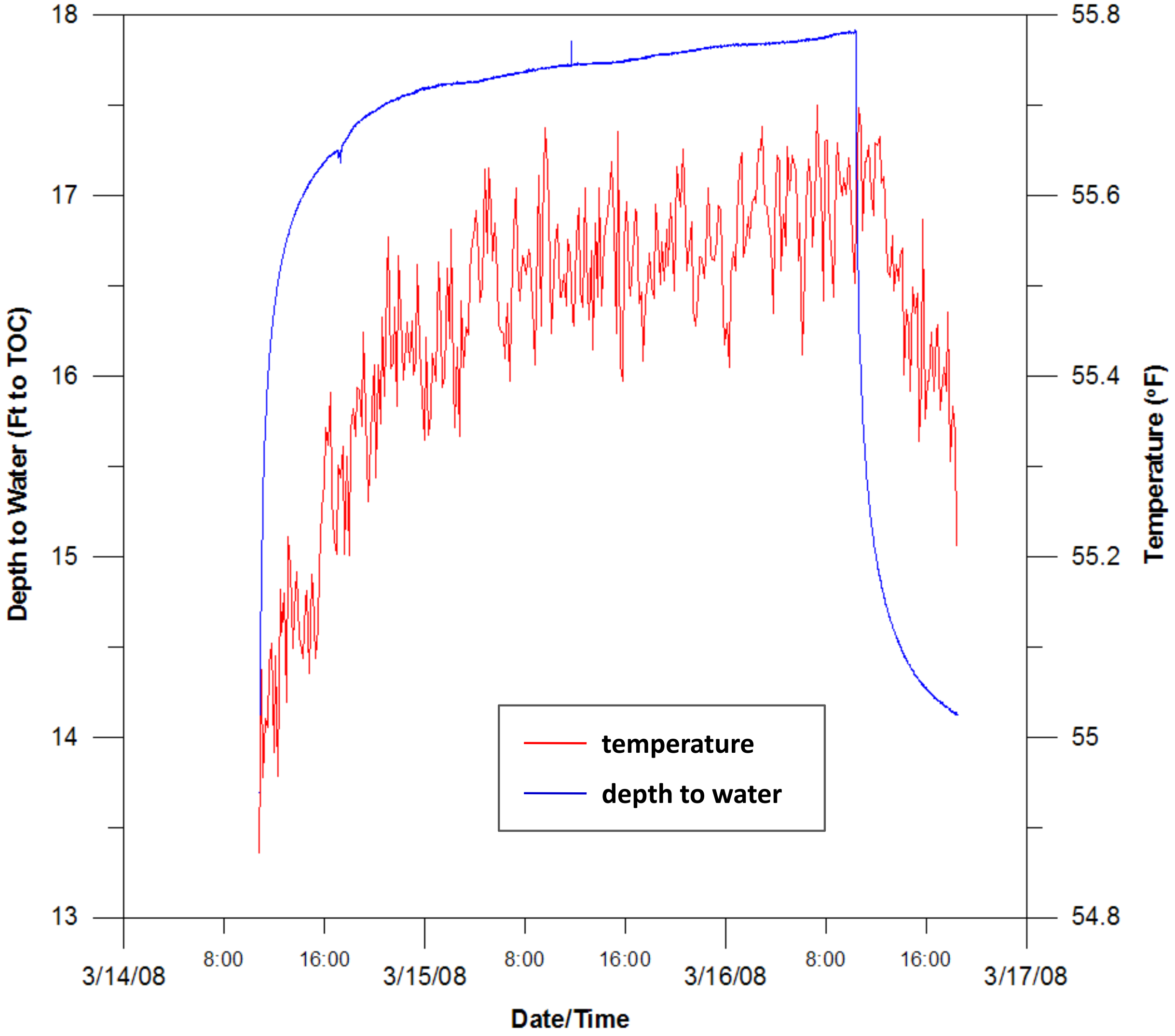


Figure 25: Results of aquifer test at Fox Creek Golf Course: drawdown and temperature recorded at the monitoring well.

Table 6: Location and properties of measuring points used in Stark property aquifer test.

Well ID	Northing	Easting	Ground Elevation $(ft\,amsl)$	Casing Elevation $(ft\,amsl)$	Casing Stickup (ft)	Total Depth $(ft\,bgs)$	Screen Interval $(ft\,bgs)$	Distance from test well (ft)
TW	-89.07345	40.43092	705.2	708.8	3.6	62	39-59	n.a.
MWS1	-89.08078	40.43001	695.1	698.9	3.8	25	20-25	2068.8
MWS2	-89.07204	40.43095	706.0	709.6	3.6	90	60-80	392.2
MWS3	-89.07584	40.43086	701.7	706.5	4.8	60	40-50	668.3
MWS5	-89.07340	40.42980	704.6	708.2	3.6	53	32-52	395.4
MWS6	-89.07347	40.43209	702.8	705.8	3.0	63	52-62	426.7
PE	-89.08092	40.43108	689.3	693.2	3.9	7.8	3.8-7.8	2015.7
PW	-89.08068	40.43117	689.3	694.2	4.9	8.2	4.2-8.2	2064.2
Stilling well	-89.08108	40.43139	685.5	691.1	5.6	NA	NA	2131.9
MWS7	-89.07400	40.43921	703.2	707.2	4.0	80	60.5-70.5	3105.1

Elevations shown based on field survey with Trimble GeoXH GPS unit with sub-foot accuracy
S8 and S4 are location of borings only, no wells installed
ft=feet, amsl=above mean sea level, ags=above ground surface,
bgs=below ground surface, NA=Not Applicable

5.2.4 Stark Property Aquifer Test

Under the terms of an access agreement between the City and Mr. Stark, WHPA performed a hydrogeologic investigation to characterize the underlying stratigraphy, estimate aquifer properties, and define the water quality characteristics of the groundwater. Hydraulic data collected during the aquifer test was used to estimate aquifer properties and parameterize the groundwater flow model.

Aquifer Test Setup

An $8\,in$ diameter temporary test well (TW) was installed at the site in late July 2009 (Figure 19). The test well is 57 ft deep and has 20 ft of screen set at the bottom of the well. A submersible pump was set just above the screen. The aquifer response to pumping was monitored in five monitoring wells; two piezometers driven into the bank of Sugar Creek were also monitored (Figure 19). Characteristics of the measuring points are presented in Table 2. The measuring points, including a stilling well set in the creek (Figure 19), were instrumented with temperature and water-column pressure recording devices. In addition, manual water-level readings were also recorded daily to confirm the automated measurements. A discharge pipe was extended from the test well to Sugar Creek.

Prior to testing, the natural groundwater gradient was toward the creek as shown in Figure 26. The gradient between the test well and the Sugar Creek was approximately $5x10^{-3}\,\frac{ft}{ft}$.

A step test was performed on August 6, 2009 from 8:35 am until 1:05 pm. For the step test, the test well was pumped at 600 gpm for two hours and at 900 gpm for two hours, with 30 minutes of recovery time in between. Results of the step test, shown in Figure 27, were used to choose the pumping rate for the constant-rate test.

The constant-rate test began at 11:30 am on August 10 and terminated at 11:30 am on August 14 (96 hours total). No recordable precipitation was observed during the test. The air temperature was in the high-80s ^oF during the day and the mid-60s ^oF at night. The pumping rate was held constant at 800 gpm throughout the test. Discharge from the test was piped to Sugar Creek. Water samples were collected once a day for the four days of the test, at the wellhead and in Sugar Creek above the test discharge. During the test, the flow in Sugar Creek was measured at the N. 1025 E. bridge, north of the test site and upstream of the test discharge pipe, as well as at the E. 1000 N. Rd. bridge, west of the test site and downstream of the discharge pipe. Results shows a flow of approximately 21.9 cfs (9,855 gpm) at the upstream bridge and 23.9 cfs (10,755 gpm) at the downstream bridge, which included the discharge from the test (1.8 cfs, or 800 gpm).

Aquifer Test Results

Figure 28 shows the observed water-level changes in the five instrumented monitoring wells, two piezometers, and stilling well. Maximum drawdowns were seen in monitoring wells MWS5, MWS2, and MWS6. Monitoring well MWS3 had less drawdown, possibly due in part to infiltration of water from leaks in the discharge pipe and because of the large distance from the test well.

The aquifer test did not generate significant drawdown in MWS1, the monitoring well next to the creek. Note also that the piezometer on the east side of Sugar Creek (PE) did record influence from pumping during the test (Figure 28). This effect is not observed in the piezometer on the opposite side of the creek (PW). Most of the change in water elevation recorded at MWS1 was influence from the creek. The creek stage shows a daily pulse where the highest discharge occurs around noon. This pulse is caused by the discharge of the upstream treatment plant.

The raw data from the aquifer test are included on the CD-ROM found in Appendix D. The drawdown in the test well stabilized at $20 ft$ during the test, resulting in a specific capacity of $40 gpm/ft$. The water-level measurements from the test well during the step test and the constant rate test are in Appendix D.

Stark Property Aquifer test data analysis

We analyzed the the aquifer test data with the AQTESOLV [Duffield, 2002] to estimate values for the aquifer transmissivity (T) and the storage coefficient (S). The AQTESOLV program estimates aquifer properties by obtaining a best fit to a type curve based on a transient aquifer solution *[Duffield, 2002].*

The Theis solution for an unconfined aquifer provided the best fit for this analysis [Theis, 1935] using data from monitoring wells MSW2, MSW3, MWS5, and MWS6. The estimated aquifer transmissivity (T) is $20,370 ft^2/d$ and storativity (S) is 0.059. The data analysis is included in Appendix E. Assuming an average aquifer thickness of $46 ft$ in the area results in an estimated hydraulic conductivity of $436 ft/d$. This value is generally consistent with sieve analysis of the formation from the material samples taken at the monitoring wells, but is high compared to test results from other Glasford wells as listed in Section 2.2.3, Table 1. The storativity is at the low end of the range that typically defines an unconfined aquifer [Batu, 1998]. This is

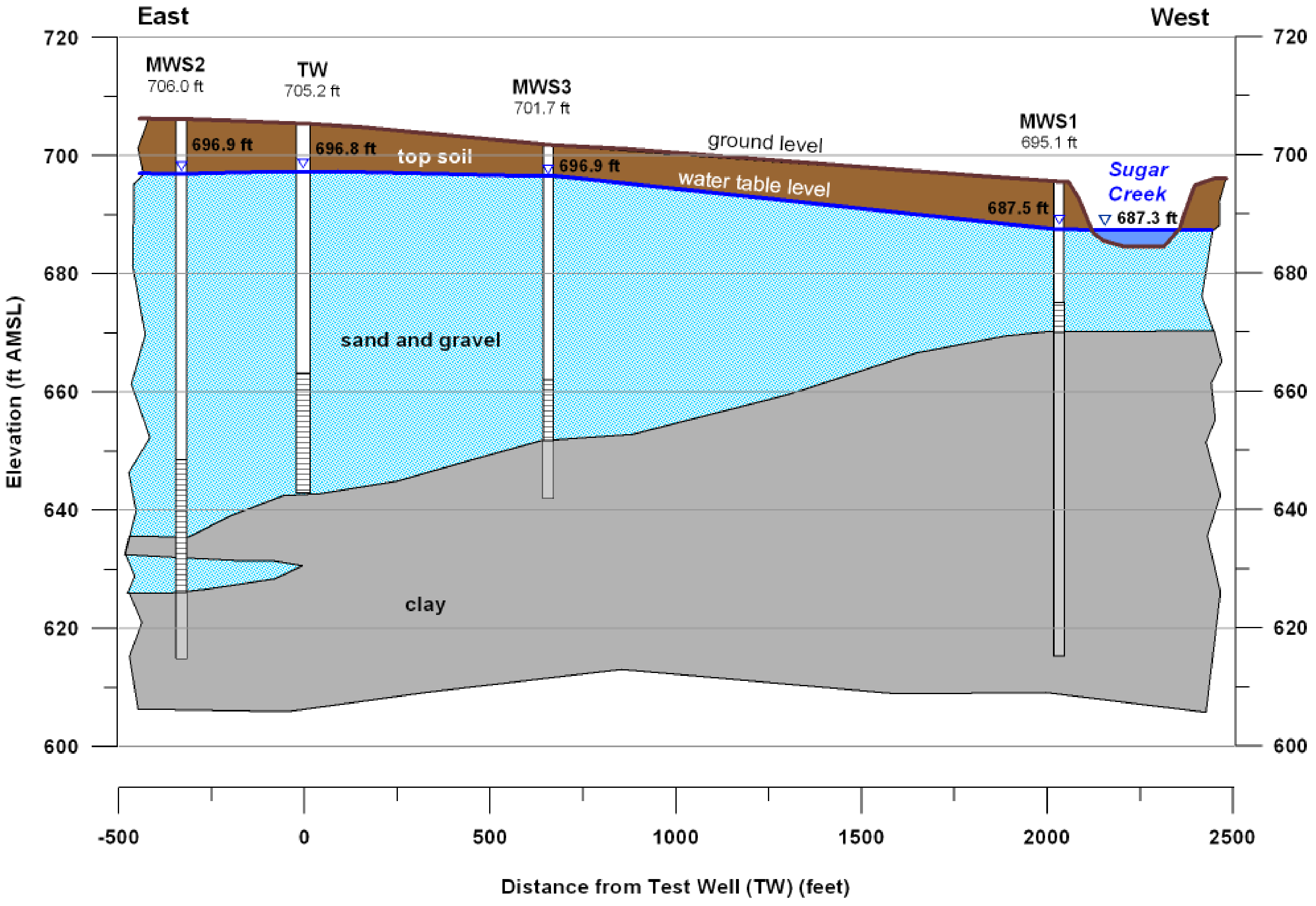


Figure 26: Static water-level elevations measured August 10, 2009, prior to Stark property aquifer test.

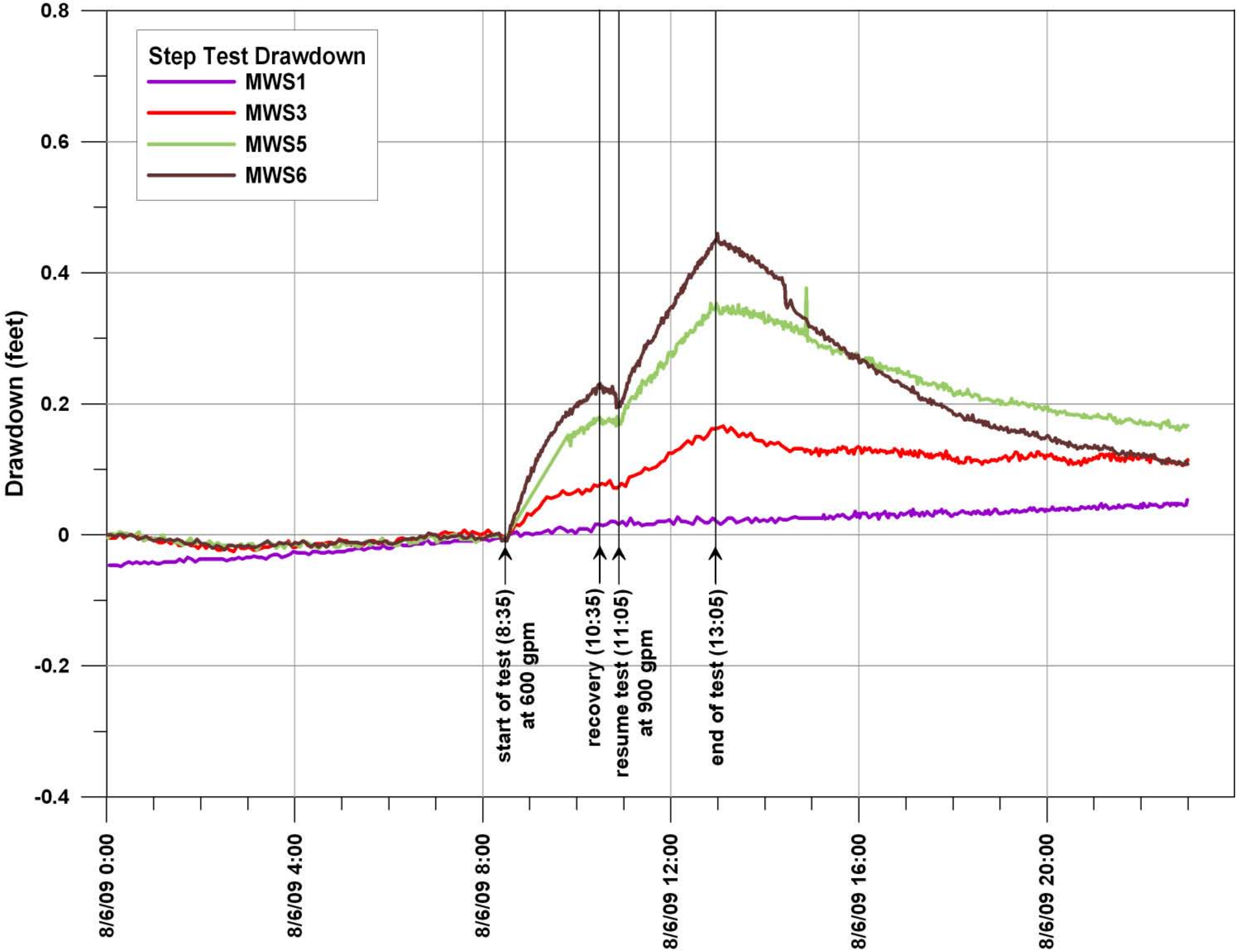


Figure 27: Results of step test prior to Stark property aquifer test.

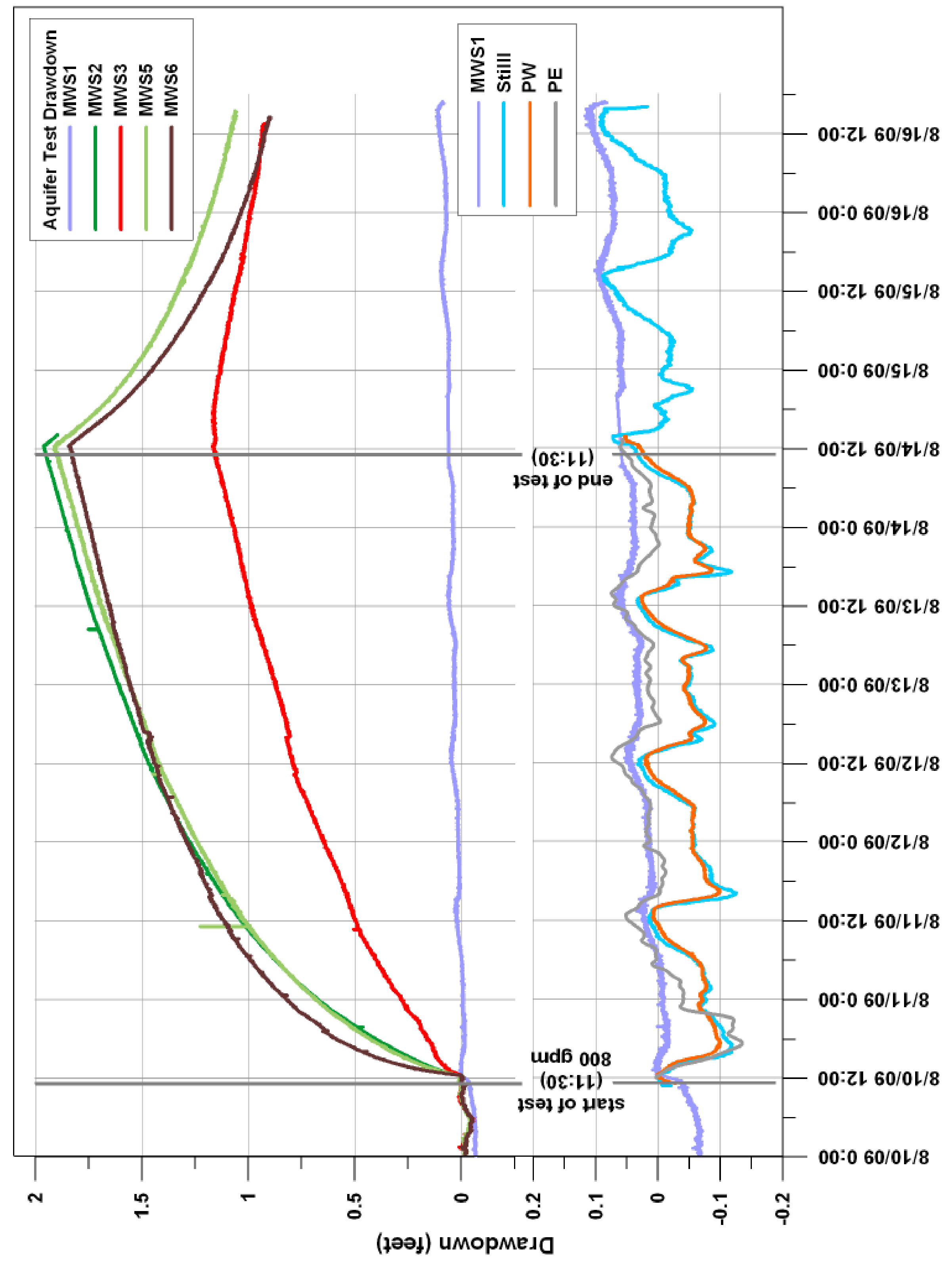


Figure 28: Stark property aquifer test results.

consistent with observations at the site that show the static water level near the bottom of a silty top soil layer (Figure 23).

The drawdown near the creek was insufficient to quantify the hydraulic connection between creek and the aquifer. However, there is some indication of a hydraulic between the aquifer and the creek in the response of the two piezometers on either side of the creek. Before the test, both piezometers responded instantaneously to changes in the creek stage. During the test, the water level in PE, located on the same side as the pumping well, showed a slight drawdown from pumping, whereas the water level in PW on the opposite side of the creek was not effected by pumping (Figure 28).

5.2.5 Water-Quality

Water samples were collected from the test well (TW) to characterize the quality of the groundwater. Water samples were also collected from Sugar Creek as it may be a source of recharge for wells pumping from the aquifer. Results from the aquifer test suggest that the aquifer and the creek are connected.

Samples were collected from the test well and the creek on each of the four days of the aquifer test and analyzed for a suite of parameters of concern for drinking water. All samples were submitted for analysis to PDC Laboratories, Inc., in Peoria, IL. Water-quality results from the test well are reported in Table 7 and results from Sugar Creek are in Table 8. The raw data and results for volatile organic compounds (VOCs) are presented in Appendix C. In Tables 7 and 8, the results are compared to national primary and secondary drinking water standards. Primary standards such as the Maximum Contaminant Level (MCL) are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water. National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines for contaminants that may cause cosmetic or aesthetic effects in drinking water.

The results from the test well indicate that groundwater at the site is suitable for public supply. However, treatment would be necessary to address taste and aesthetic issues associated with iron, manganese, total dissolved solids (TDS), and hardness. Secondary standards were exceeded in each sample for each of these three constituents (Table 7). Iron concentration in the test well was consistently around $3\,mg/l$, an order of magnitude higher than the secondary standard. Manganese concentrations were slightly higher than the secondary standard of $0.05\,mg/l$.

Groundwater from the test well is a calcium-bicarbonate type with high hardness and relatively low concentrations sodium and chloride. No MCL was exceeded in the groundwater samples and no VOCs were detected above the reporting limit (see Appendix C). Arsenic and nitrate were detected in some of the four groundwater samples, but at low concentrations near the respective reporting limits.

Even though nitrate was detected at very low concentrations in the groundwater, this constituent could become a problem in the future for a wellfield in this setting. The shallow aquifer is vulnerable to contamination at the land surface. The predominate land use in the area is row-crop agriculture. Over time, excess nitrogen applied at the land surface could be induced into the deeper zones of the aquifer where the proposed wells would be screened.

The water-quality characteristics of the groundwater is very different from the creek. As shown in Tables 7 and 8 and summarized in Figure 29, the creek is lower in TDS, alkalinity, and dissolved iron. However, the creek is higher in sodium and chloride due to the contribution of the wastewater plant to baseflow in the creek. The creek is apparently also higher in nitrate (Table 8). However, three of the four nitrate samples from the creek are only estimates because the recommended holding time for samples was exceeded. In addition, the nitrate concentration in the creek most likely varies throughout the year. The samples were collected at a time when we would expect nitrate levels to be highest in the creek. The samples were collected in June, after spring application of fertilizer, and after a significant rain event, during which excess nitrate is transported to the creek by runoff.

Table 7: Water-quality results from samples collected from test well TW during the aquifer test.

Parameter	**Units**	**MCL (NSDWR)**	**8/10/09**	**8/11/09**	**8/12/09**	**8/13/09**
Iron	mg/l	(0.30)	3	3	3.2	3.2
Silicon as SiO2	mg/l		14	14	14	13
Sodium	mg/l		17	18	18	17
Aluminum	mg/l	(0.050-0.20)	0.016	<0.01	<0.01	<0.01
Antimony	mg/l	0.006	<0.003	<0.003	<0.003	<0.003
Arsenic	mg/l	0.01	<0.001	0.002	<0.001	0.001
Barium	mg/l	2.0	0.13	0.13	0.14	0.11
Beryllium	mg/l	0.004	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/l	0.005	<0.001	<0.001	<0.001	<0.001
Calcium	mg/l		120	120	120	120
Chromium	mg/l	0.050	<0.004	<0.004	<0.004	<0.004
Copper	mg/l	(1.0)	0.048	0.029	0.22	0.009
Lead	mg/l	0.015	0.002	0.003	0.015	0.002
Magnesium	mg/l		50	45	43	43
Manganese	mg/l	(0.050)	0.072	0.067	0.075	0.064
Mercury	mg/l		<0.0002	<0.0002	<0.0002	<0.0002
Nickel	mg/l		<0.005	<0.005	<0.005	<0.005
Selenium	mg/l	0.050	0.002	0.003	0.002	0.002
Thallium	mg/l	0.002	<0.001	<0.001	<0.001	<0.001
Zinc	mg/l	(5)	0.091	0.058	0.14	0.05
Nitrate as N	mg/l	10	0.045[1]	<0.02[1]	0.25[1]	0.36
Nitrite as N	mg/l	1	<0.15[1]	<0.15[1]	<0.15[1]	<0.15
Chloride	mg/l	(250)	55	57	58	52
Fluoride	mg/l	4.0 (2.0)	0.27	0.25	0.27	0.28
Sulfate	mg/l	(250)	53	52	53	49
Cyanide, Total	mg/l		<0.01	<0.01	0.01	<0.01
Alkalinity, Total as CaCO3	mg/l		390	390	400	390
Hardness, Total as CaCO3	mg/l		480	490	490	460
Conductivity	umhos/cm		910	910	900	900
Solids Total Dissolved	mg/l	(500)	600	600	600	560
Solids Total Suspended	mg/l		6.4	4.4	5.6	<4
pH	units	(6.5-8.5)	8.27[1]	8.08[1]	7.51[1]	7.35[1]
Nitrogen, Ammonia as N	mg/l		<0.05	0.061	0.78	0.72
Phosphorus, Ortho as P	mg/l		0.049[1]	0.094[1]	0.044[1]	0.06
Carbon, Total Organic	mg/l		0.93	0.73	0.94	0.96
Sufide, Total	mg/l		<2	<2[2]	<2[2]	<2

MCL=USEPA Maximum Contaminant Level, NSDWR=National Secondary Drinking Water Regulation

[1] *method hold time exceeded*, [2] *sample never turned clear, rather light purple*

Table 8: Water-quality results from samples collected from Sugar Creek during the aquifer test.

Parameter	**Units**	**MCL (NSDWR)**	**8/10/09**	**8/11/09**	**8/12/09**	**8/13/09**
Iron	mg/l	(0.30)	0.25	0.26	0.23	0.17
Silicon as SiO2	mg/l		3.3	3.4	3.3	3
Sodium	mg/l		75	87	87	92
Aluminum	mg/l	(0.050-0.20)	0.24	0.23	0.12	0.12
Antimony	mg/l	0.006	<0.003	<0.003	<0.003	<0.003
Arsenic	mg/l	0.010	<0.001	<0.001	<0.001	<0.001
Barium	mg/l	2.0	0.046	0.048	0.049	0.047
Beryllium	mg/l	0.004	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/l	0.005	<0.001	<0.001	<0.001	<0.001
Calcium	mg/l		68	80	70	70
Chromium	mg/l	0.050	<0.004	<0.004	<0.004	<0.004
Copper	mg/l	(1.0)	0.007	0.004	0.004	0.007
Lead	mg/l	0.015	<0.001	<0.001	<0.001	<0.001
Magnesium	mg/l		28	33	29	29
Manganese	mg/l	(0.050)	0.051	0.048	0.048	0.045
Mercury	mg/l	0.002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel	mg/l		<0.005	<0.005	<0.005	<0.005
Selenium	mg/l	0.050	<0.001	<0.001	<0.001	0.001
Thallium	mg/l	0.002	<0.001	<0.001	<0.001	<0.001
Zinc	mg/l	(5)	0.019	0.16	0.026	0.025
Nitrate as N	mg/l	10	9.4[1]	14[1]	16[1]	15
Nitrite as N	mg/l	1	<0.15[1]	<0.15[1]	<0.15[1]	<0.15
Chloride	mg/l	(250)	140	150	150	150
Fluoride	mg/l	4.0 (2.0)	0.5	0.67	0.68	0.63
Sulfate	mg/l	(250)	57	65	63	61
Cyanide, Total	mg/l		<0.01	<0.01	<0.01	<0.01
Alkalinity, Total as CaCO3	mg/l		190	160	160	150
Hardness, Total as CaCO3	mg/l		280	290	290	290
Conductivity	umhos/cm		920	970	990	1000
Solids Total Dissolved	mg/l	(500)	540	590	610	580
Solids Total Suspended	mg/l		5.2	<4	<4	<4
pH	units	(6.5-8.5)	8.1[1]	8.35[1]	7.61[1]	7.81[1]
Nitrogen, Ammonia as N	mg/l		0.79	<0.05	0.2	0.065
Phosphorus, Ortho as P	mg/l		1.4[1]	1.7[1]	1.9[1]	2
Carbon Total Organic	mg/l		5	5.8	6	6.2
Sulfide, Total	mg/l		–	<2	5.3	<2

MCL=USEPA Maximum Contaminant Level, NSDWR=National Secondary Drinking Water Regulation

[1] *method hold time exceeded*

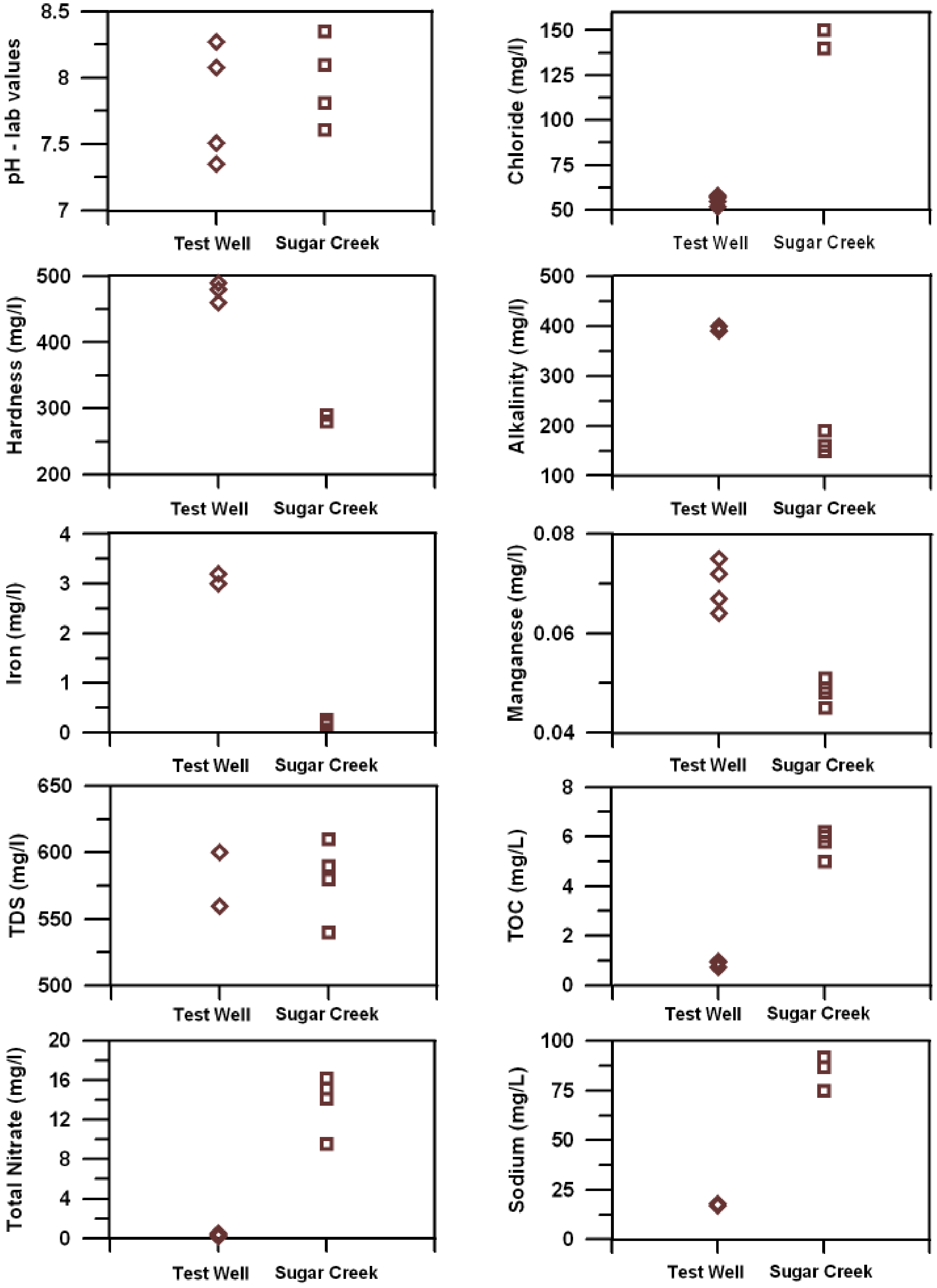


Figure 29: Select water-quality results from the test well and Sugar Creek.

5.3 Recharge Modeling

According to the Illinois State Water Survey's water budget for Illinois, 11 percent of total precipitation in the state becomes groundwater recharge [ISWS, 2006]. Figure 10 shows the distribution of average annual precipitation in Illinois. Average annual precipitation in the study area is about $37.5\,in$ [ISWS, 2002]. Schicht and Walton (1961) analyzed groundwater budgets for small watersheds in central Illinois, including Mason and Tazewell counties located to the west of McLean County. Recharge estimates from that study range from 10 to 28% of precipitation in years of near-normal precipitation. The highest percentage corresponds to $10.5\,in$ of recharge per year [Schicht and Walton, 1961].

In shallow unconfined aquifers like the Sugar Creek Aquifer recharge becomes a driving factor affecting the aquifer yield and has a decisive influence on wellfield management strategy. Because of its importance for wellfield design, we used a USGS recharge model called the Soil-Moisture Water Balance (SWB) Model to quantify aquifer recharge within the study area and to assess the potential impacts of seasonally varying recharge at the site. The SWB model estimates temporal and spatial variations in ground water recharge [Westenbroek and Bradbury, 2009]. Results from the recharge modeling were used as input for the ground water modeling described in Section 5.4.

The SWB model tracks soil-moisture (sources and sinks of water) based on a modified Thornthwaite-Mather soil-moisture balance approach [Westenbroek and Bradbury, 2009]. Sources and sinks are determined based on input climate data and landscape characteristics. Recharge is calculated as the difference between the soil moisture and sources and sinks of water. The data required for the model is widely available and can be manipulated on a geographic information systems (GIS). Outputs of the model can be summarized on a daily, monthly or annual basis.

5.3.1 Conceptual SWB Model

Recharge is calculated as the difference between the change in soil moisture and moisture sources (precipitation, snowmelt, and inflow) and sinks (interception, outflow, and evapotranspiration) as represented on Figure 30 and equation 1.

$$R = (P + S + IN) - (I + OUT + ET) - \triangle SM \tag{1}$$

where :
R= recharge,
P= precipitation,
S =snowmelt,
IN= inflow,
I= interception,
OUT = outflow,
ET = evapotranspiration,
$\triangle SM$= change in soil moisture.
Specific water-balance components of the SWB model are discussed briefly below.

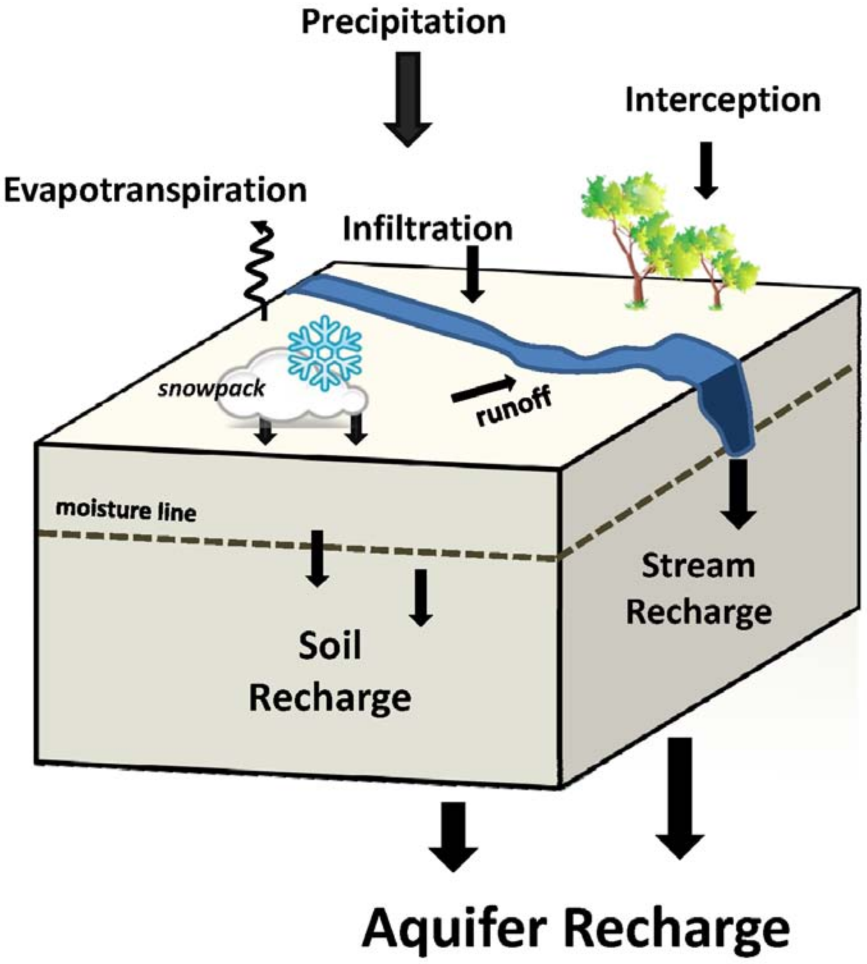


Figure 30: Conceptual model of the soil-water balance.

precipitation Precipitation data are input on a daily basis, in inches.

snowmelt Snow is allowed to accumulate and/or melt on a daily basis. The daily mean, maximum and minimum air temperatures are used to determine whether precipitation takes the form of rain or snow. Precipitation that falls on a day when the mean temperature minus one-third the difference between the daily high and low temperatures is less than or equal to $32\,^{\circ}F$ is considered to fall as snow. Snowmelt takes place based on a temperature-index method. In the SWB code it is assumed that $1.5\,mm$ ($0.059\,in$) of water-equivalent snow melts per day per average degree Celsius that the daily maximum temperature is above the freezing point.

inflow Inflow is calculated using a flow direction grid derived from a digital elevation model to route outflow (surface runoff, see below) to adjacent downslope grid cells. Inflow is considered to be zero if flow routing is turned off.

interception Interception is treated simply using a "bucket" model approach—a specific amount of rainfall (user specified) is assumed to be trapped and used by vegetation and evaporated or transpired from plant surfaces. Daily precipitation values must exceed the specified interception amount before any water is assumed to reach the soil surface. Interception values are specified for each land use type and season (growing and non-growing).

outflow Outflow (or surface runoff) from a cell is calculated using a Soil Conservation Service curve-number rainfall-runoff relationship (Appendix F). This rainfall-runoff relationship relates rainfall to runoff based on four basin properties: soil type, land use, surface condition, and antecedent runoff condition. The curve number method defines runoff in relationship to the difference between precipitation and an "initial abstraction" term. Conceptually, this initial abstraction term represents the summation of all processes that might act to reduce runoff, including interception by plants and fallen leaves, depression storage, and infiltration. Outflow from a cell becomes inflow to the downslope cell as determined from the flow direction grid.

evapotranspiration (ET) The Thornthwaite-Mather method is used to estimate potential evapotranspiration from portions of the soil zone that are not included in the interception calculation.

$\triangle$**soil moisture** In order to track changes in soil moisture, a number of intermediary values are calculated, including precipitation minus potential evapotranspiration ($P-PE$), accumulated potential water loss (APWL), actual evapotranspiration, soil moisture surplus, and soil moisture deficit. These terms are described below. The first step in calculating a new soil moisture value for any given grid cell is to subtract potential evapotranspiration from the daily precipitation (P–PE). Negative values of $P-PE$ represent a potential deficiency of water, while positive $P-PE$ values represent a potential surplus of water.

accumulated potential water loss (APWL) The accumulated potential water loss is calculated as a running total of the daily $P-PE$ values during periods when the $P-PE$ values are negative. This running total represents the total amount of unsatisfied potential evapotranspiration to which the soil has been subjected. Soils typically yield water more easily during the first days in which $P-PE$ is negative. On subsequent days as the APWL grows, soil moisture is less readily given up. The nonlinear relationship between soil moisture and the accumulated potential water loss was described by Thornthwaite and Mather in a series of tables. These tables are incorporated into the SWB code.

soil moisture, $\triangle$soil moisture When $P-PE$ is positive, the new soil moisture value is found by adding this $P-PE$ term directly to the old soil moisture value. If the new soil moisture value is still below the maximum water-holding capacity, the Thornthwaite-Mather soil-moisture tables are consulted to calculate a new, reduced accumulated potential water loss value. If the new soil moisture value exceeds the maximum water-holding capacity, the soil moisture value is capped at the value of the maximum water-holding capacity, the excess moisture is converted to recharge, and the accumulated potential water loss term is reset to zero. When $P-PE$ is negative, the new soil moisture term is calculated using the new accumulated potential water loss value, looking up the resultant soil moisture in the Thornthwaite-Mather tables.

actual ET When $P-PE$ is positive, the actual evapotranspiration equals the potential evapotranspiration. When $P-PE$ is negative, the actual evapotranspiration is equal only to the amount of water that can be extracted from the soil ($\triangle$ soil moisture).

soil moisture SURPLUS If the soil moisture reaches the maximum soil moisture capacity, any excess precipitation is added to the daily soil moisture surplus value. Under most conditions, the soil moisture surplus value is considered as equivalent to the daily groundwater recharge value.

soil moisture DEFICIT The daily soil moisture deficit is the amount by which the actual evapotranspiration differs from the potential evapotranspiration.

5.3.2 SWB Model Input

The input components for the SWB model of the Sugar Creek study area is described below. Figure 31 shows the SWB model boundaries and respective location of the study area within the model domain.

climate data The SWB model requires tabular climate data including daily precipitation (in inches) and average, maximum, and minimum daily temperature (in $^{\circ}F$) for full years. We used climate data from a climate station in Bloomington (ID 110764), located 4 miles north of the study area. The data was obtained from the Northeast Regional Climate Center [CLIMOD, 2009].

look-up table The last required model component is a lookup table used to assign runoff curve numbers, interception values, rooting depths and maximum daily recharge values for each hydrologic soil group and land cover type combinations contained in the grid (see look-up tables on Appendix F).

The model also requires four grids compiled using GIS in cells sized 30 meters by 30 meters:

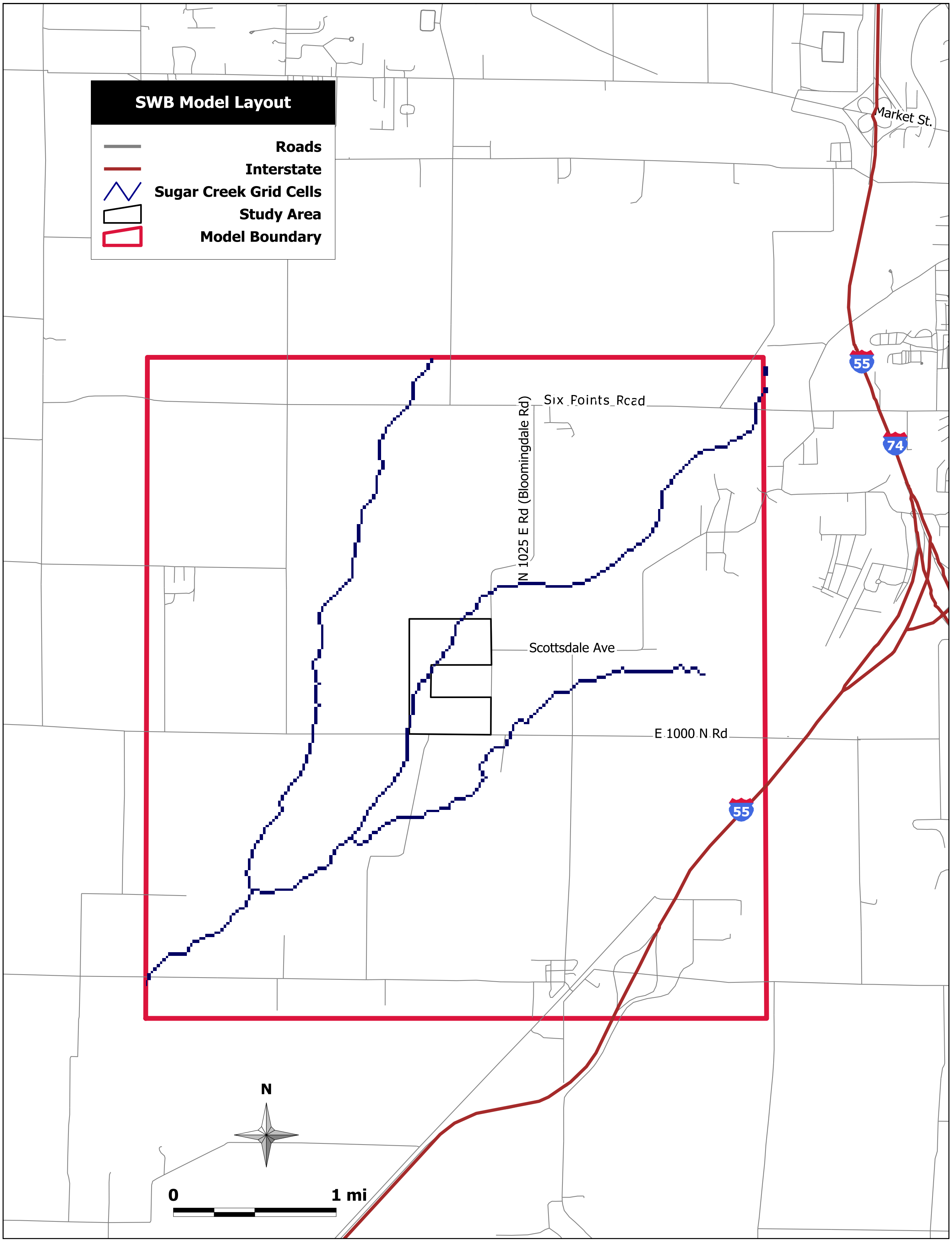


Figure 31: SWB model layout.

land use/land cover The model requires land use/land cover information, together with the soil available water capacity information, to calculate surface runoff and assign a maximum soil moisture holding capacity for each grid cell. Land use/land cover data is classified according to Anderson Level II Land Cover Classification method (Appendix F). The predominate land use/land cover classification within the study area is row crop agriculture (Figure 32) [USDA, 2007].

hydrologic soils group The Soil Conservation Service (SCS) has categorized over 14,000 soil series within the United States into 1 of 4 hydrologic soil groups based on its infiltration capacity (A - D). Soil group information may be input to the model as an ARC ASCII or Surfer ASCII grid with integer values ranging from 1 (soil group A) to 4 (soil group D). The SCS soil hydrologic group "A" soils have a high minimum infiltration capacity and subsequently, a low overland flow potential while, "D" soils have a very low infiltration capacity and subsequently, a high overland flow potential. Figure 33 shows the soils groups within the study area. Hydrologic Soils Group was obtained from the USDA Geospatial Data Gateway website [USDA, 2008].

soil water capacity Available water capacity values were given to each hydrologic soil group as shown in Appendix F.

surface flow direction Flow direction is calculated from an Digital Elevation Model (DEM), available at the USGS National Seamless Map Server [USGS, 2001]. Elevation values are analyzed for eight neighboring cells for each cell; the neighboring cell with the lowest elevation will be the direction to which surface runoff is routed from that cell. Figure 34 shows the flow direction grid used in the model. Table of flow direction values is shown in Appendix F.

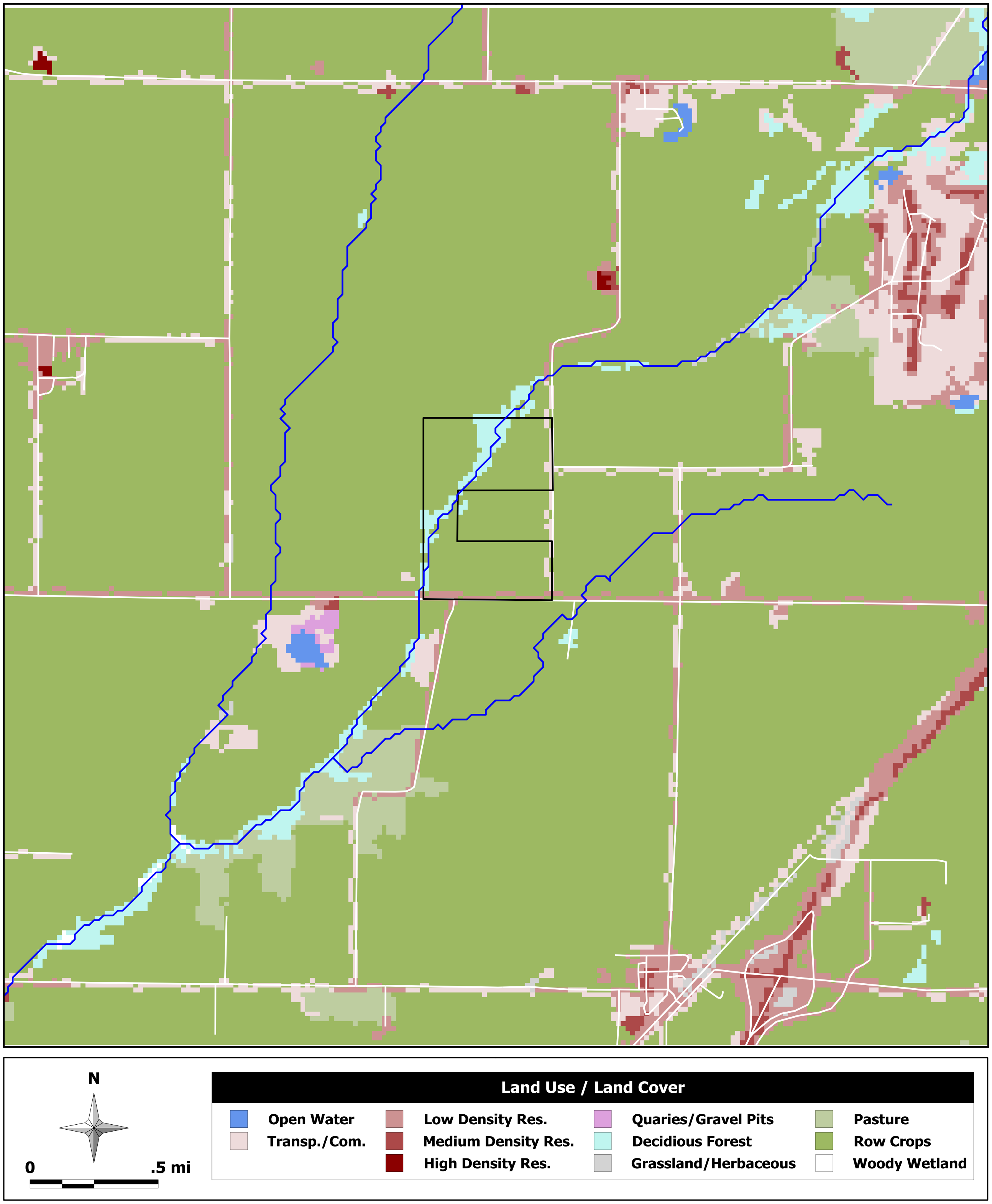


Figure 32: Land use/land cover classification within the model boundary [USDA, 2007].

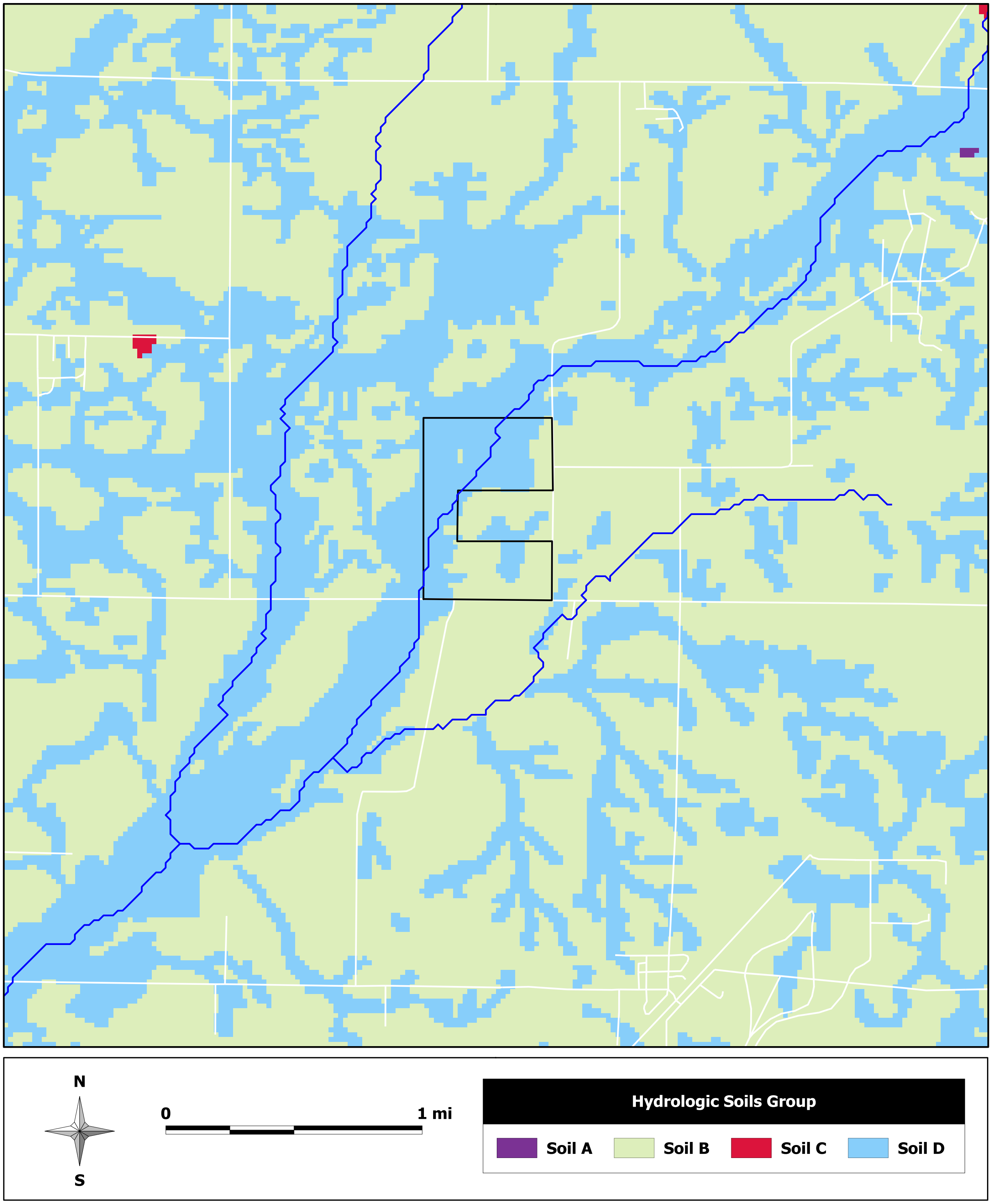


Figure 33: Hydrologic soils group classification within the SWB model boundary [USDA, 2008].

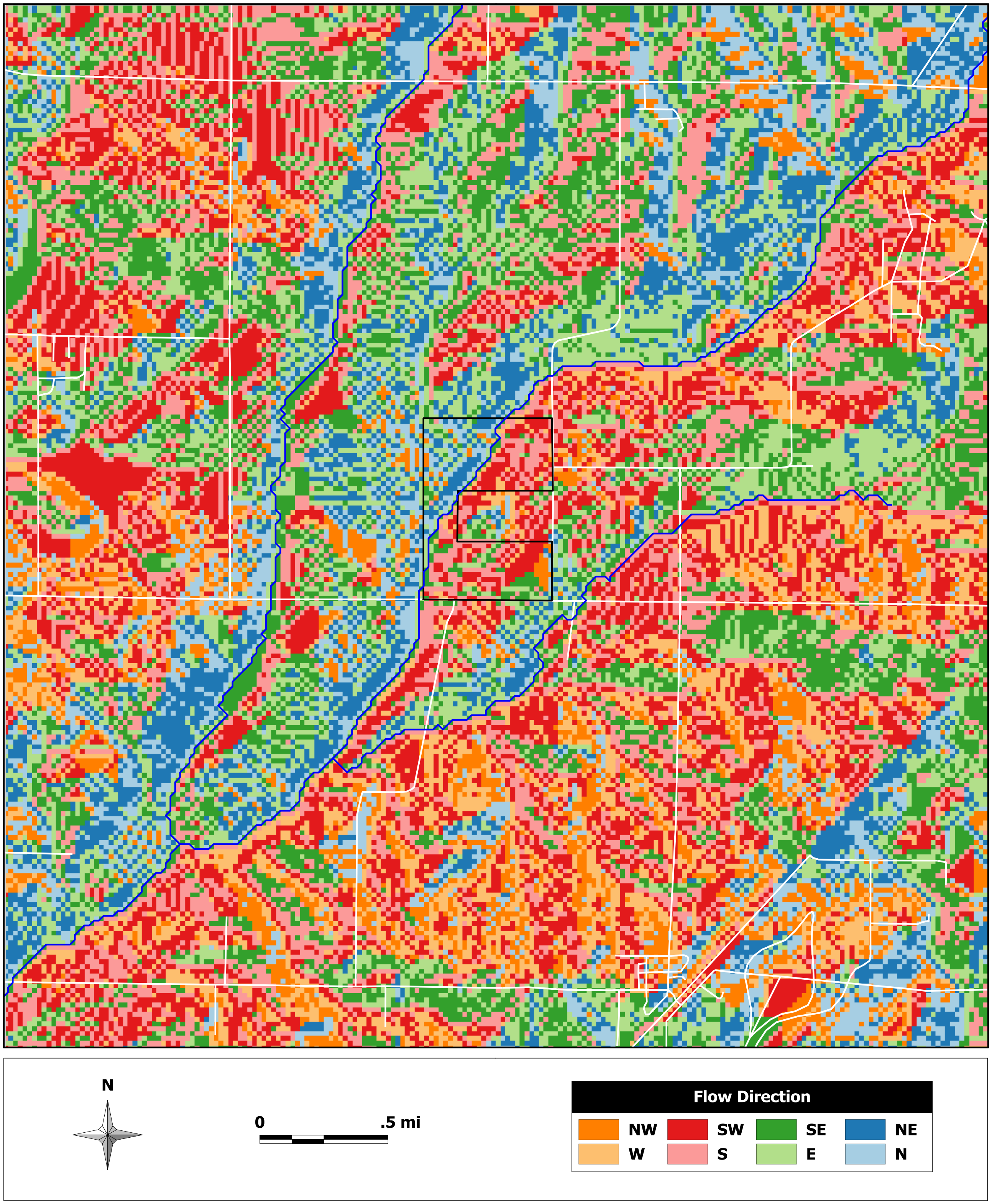


Figure 34: Flow direction of runoff [USGS, 2001].

Table 9: SWB model results- predicted average annual recharge for modeled years 2001-2008.

Year	**Precipitation** (*in*)	**Snowfall** (*in*)	**Recharge** (*in*)	**Percent of Precipitation**
2001	39.8	3.9	9.4	23.6
2002	39.3	3.9	6.3	16.0
2003	37.2	4.8	5.1	13.7
2004	39.7	3.1	7.0	17.6
2005	29.7	3.9	7.2	24.2
2006	40.7	4.4	9.7	23.8
2007	37.5	10.6	10.9	29.1
2008	50.3	10.4	13.6	27.0
average 01-06	37.7	4.1	7.1	18.8
average 01-08	39.1	5.5	8.2	21.0

in=inches

5.3.3 SWB Model Results

Table 9 shows model results for total annual precipitation and snowfall as well as average annual recharge for the modeled period between 2001 and 2008. The last two modeled years (2007 and 2008) had the two largest annual recharge values compared to the prior six years because snowfall for those two years was significantly higher. The highest annual recharge was 13.6*in* for 2008 and the smallest recharge was 5.1*in* for 2003. For the modeled period of 2001 through 2006, the average annual recharge was 7.1*in*. Figure 35 shows average monthly recharge for the 2001 - 2006 modeled period. The calculated percentage of precipitation going to recharged averages 21% over the period 2001-2008. This is approximately twice the value of 11% reported by the ISWS (2006) for the State of Illinois. The value does, however, fall within the range of 10% to 28% reported by Schict and Walton (1961). The monthly recharge values reported in Table 9 were used as input for the transient MODFLOW model, discussed in Section 5.4.2.

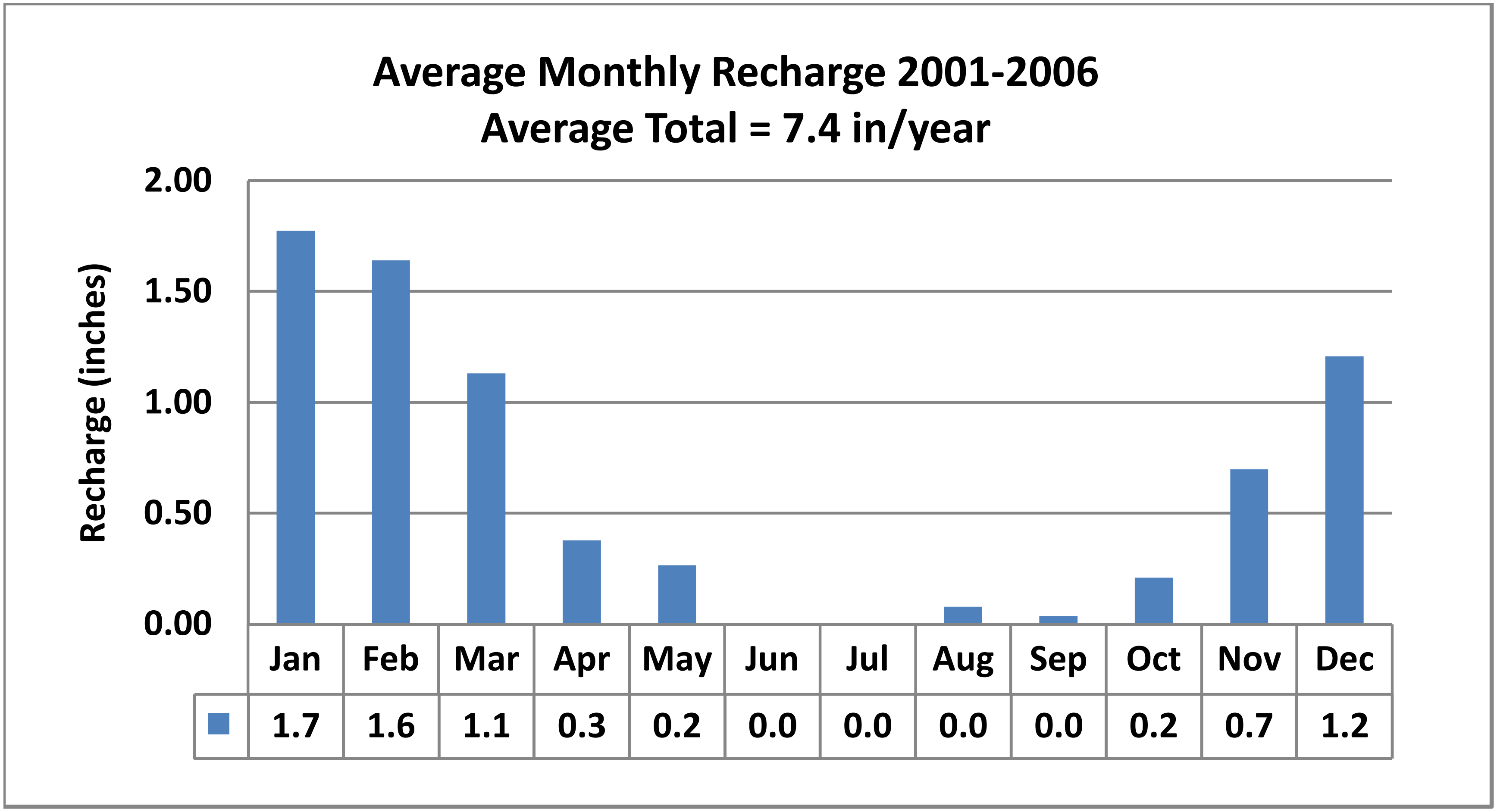


Figure 35: Modeled monthly distribution of recharge to the Sugar Creek Aquifer.

5.4 Groundwater Flow Modeling

We used groundwater flow modeling to examine the importance of seasonal recharge patterns on yield from the Sugar Creek Aquifer, to estimate the yield of the wellfield located on the Stark property, to evaluate the use of vertical wells and collector wells, and to examine the potential impacts of pumping on neighbors. The groundwater flow modeling was conducted in two phases: first, a transient MODFLOW model was used to assess the potential impacts of seasonally varying recharge at the site; second, a steady-state analytic element model (ModAEM), based in part on the MODFLOW results, was used to investigate options for water supply development at the site. The MODFLOW model was developed because the aquifer is of limited spatial extent, which leads to the possibility that little or no recharge during the summer could constrain yields, and making a transient analysis necessary.

First, a conceptual model of the regional groundwater system was developed based on information obtained from existing borings, the test borings drilled for this study, the aquifer tests, and the regional hydrogeology. The significant features of the conceptual model were incorporated into a transient groundwater flow model using the finite difference code MODFLOW-2000 [Banta and Harbaugh, 2000] supported by the GMS user interface [Aquaveo, 2009], and then into a steady-state ModAEM model [Kelson, 2007]. The MODFLOW model provided insight into effects of time-varying recharge while ModAEM was used for predicting well yields and the potential impacts of pumping. In this section, we describe the conceptual model, model development, calibration, and results.

5.4.1 Conceptual model

Our conceptual model of the regional groundwater system was developed based on our understanding of the hydrogeologic setting and results of two aquifer tests. The conceptual model includes the water-bearing zones in the shallow sand and gravel deposits along and near Sugar Creek.

The aquifer is composed mainly of coarse sand and small to large gravel with some cobbles and boulders. The permeable deposits at the site appear to be two separate deposits – a deep deposit of sand and gravel resting on basal clay and a thin, predominately gravel deposit present near the land surface. In our primary area of interest the upper and lower deposits are connected; farther away from the Stark property the two units are separated by glacial till consisting of dry gravelly clay. The top unit varies in thickness, thinning just north of the Stark property and becoming thicker again around the Fox Creek Golf Course. There is a laterally extensive layer of clayey soil $5-8\,ft$ thick above the aquifer . The base of the aquifer is hard blue clay overlying bedrock.

In plan view, the aquifer is a narrow strip of highly permeable alluvium and outwash that lies roughly parallel to Sugar Creek. The lateral extent of the aquifer perpendicular to the creek varies with the widest section extending east of Sugar Creek at the Stark property. The aquifer narrows to the northeast, and although there are only a few boring logs to confirm this, it also appears to narrow towards the southwest.

Previous studies indicate that aquifer properties of the formation vary spatially. This is consistent with our findings; the estimated transmissivity from the pump test at the Stark property was $20,370\,ft^2/day$, whereas the estimated hydraulic conductivity from the pump test at the Fox Creek Golf Course was $4,900\,ft^2/day$. Our conceptual model was simplified into a single layer aquifer of varying thickness and having two zones of hydraulic conductivity. The thickest section is at the Stark property where the two formations are connected.

The two zones of hydraulic conductivity are delineated by a high conductivity zone around the Stark property where we have pump test data to support it, and a lower conductivity zone in areas away from the Stark property where there is no data to support a high conductivity zone. This is a conservative assumption.

The conceptual model, shown in Figure 36, assumes a single, bounded aquifer with an impermeable, horizontal base and sides. The high conductivity zone is in the middle of the aquifer in the location of the wellfield, and the low conductivity zone is the area away from the Stark property. Recharge is applied uniformly across the aquifer and the specified value is based on the monthly averages estimated from the SWB model.

5.4.2 Transient MODFLOW groundwater flow model

The elements of the conceptual model were incorporated into a MODFLOW finite difference groundwater flow model. We used the hydrologic preprocessor code GMS to model the 3-D configuration of the sediments at the site. The aquifer materials were modeled as a single layer aquifer. Boring logs (Appendix A) were used where possible to define the aquifer thickness and boundary. Borehole data was manually edited as necessary to generate the single layer model. Where no boring logs were available, data points were generated based on the mapped boundary of the sand and gravel resources [ISGS, 1996] to define the aquifer boundary. The GMS program provides an inverse distance method to interpolate the aquifer thickness between data points. The lateral dimensions of the model grid were refined around the test well and a point normal to the test well adjacent to the creek. The minimum cell size is $50x50\,ft$ and the largest is $214x695\,ft$.

The layout of the MODFLOW model is shown in Figure 37. As mentioned earlier, the widest and deepest sections of the aquifer are in the area of the Stark property. No-flow boundaries are placed on the western and eastern edges of the aquifer where the sand and gravel sediments are absent. At the upstream (north) and downstream (south) ends of the model, a no-flow boundary oriented roughly normal to the river is used. Inside the model domain, the only important regional boundary is Sugar Creek. The Creek is located as shown in Figure 37 with the streambed conductance estimated during the model calibration process. The elevation of the aquifer bottom in the MODFLOW model is based on an interpolated surface derived locally from elevations found on boring logs and regionally from the mapped distribution of sand and gravel [ISGS, 1996].

MODFLOW Model calibration

The model was calibrated using data from the aquifer test conducted on the Stark property . In this effort, it was necessary to use a sub-region of the regional model, both for performance reasons and because there were no synoptic measurements of water levels off the project site. The local transient model was configured to include fluctuations in the river stage as well as the pumping stress due to the test well. The MODFLOW model described above was configured to run in transient mode as follows:

- Heads in the creek were adjusted in 16 stress periods timed to match a change in direction of stage recorded in the stilling well during the aquifer test. Each stress period had between $4-8$ time steps, depending on the gap between stress periods. The creek bed conductance was initially set at $120\,ft^2/d/ft$.

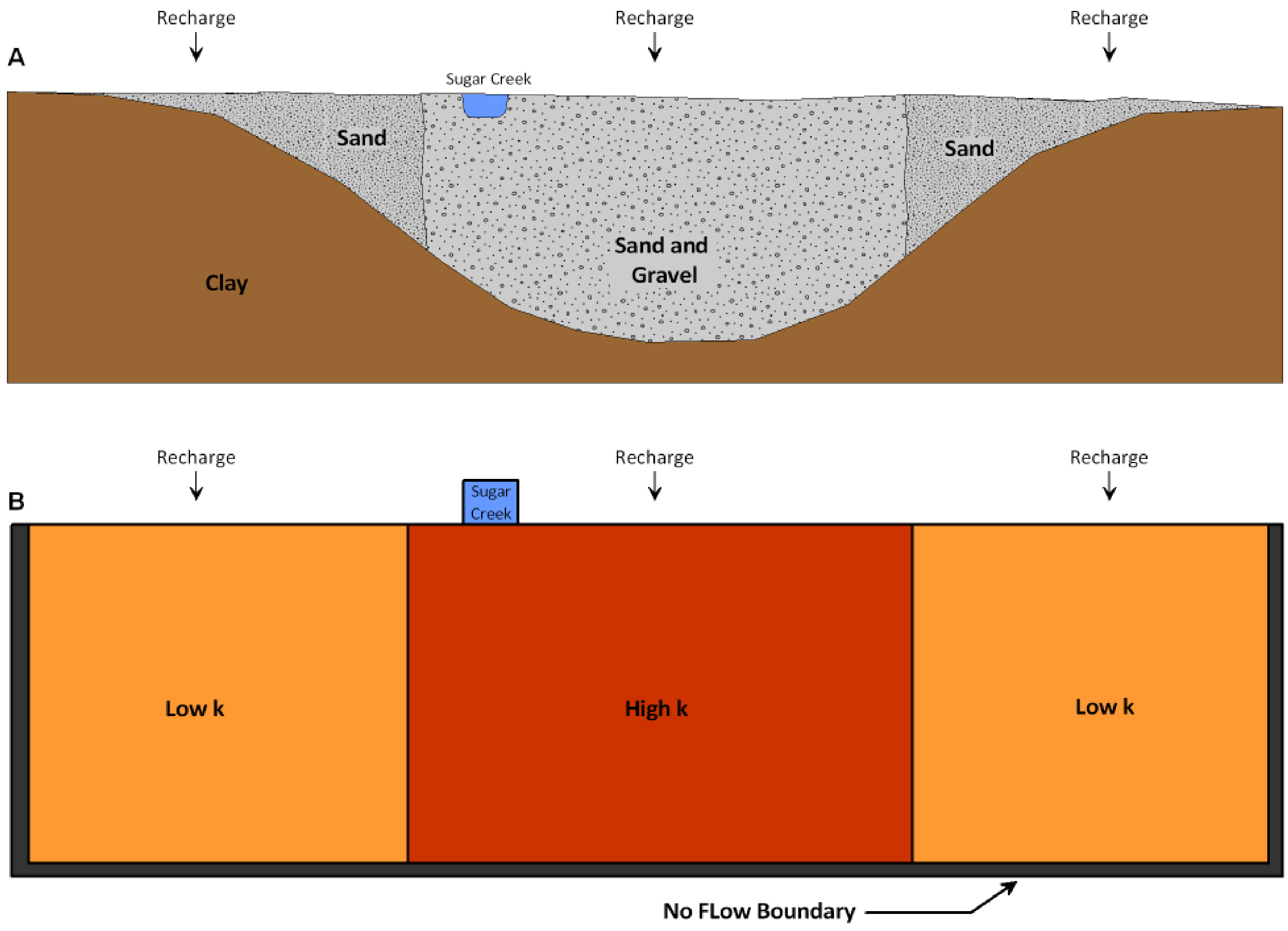


Figure 36: Conceptual model of the Sugar Creek Aquifer for A) transient MODFLOW model and B) steady-state ModAEM model.

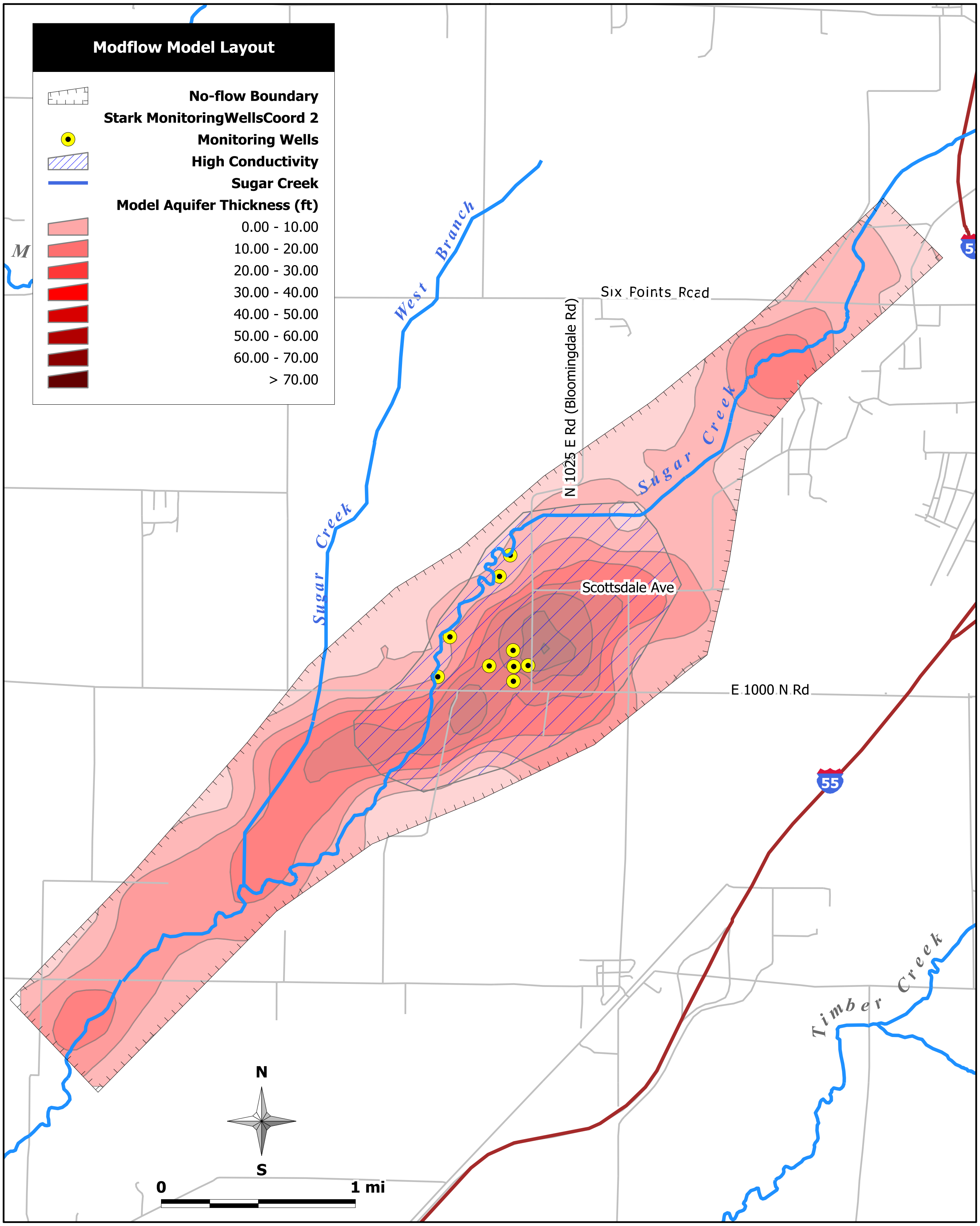


Figure 37: Layout of MODFLOW model of Sugar Creek Aquifer.

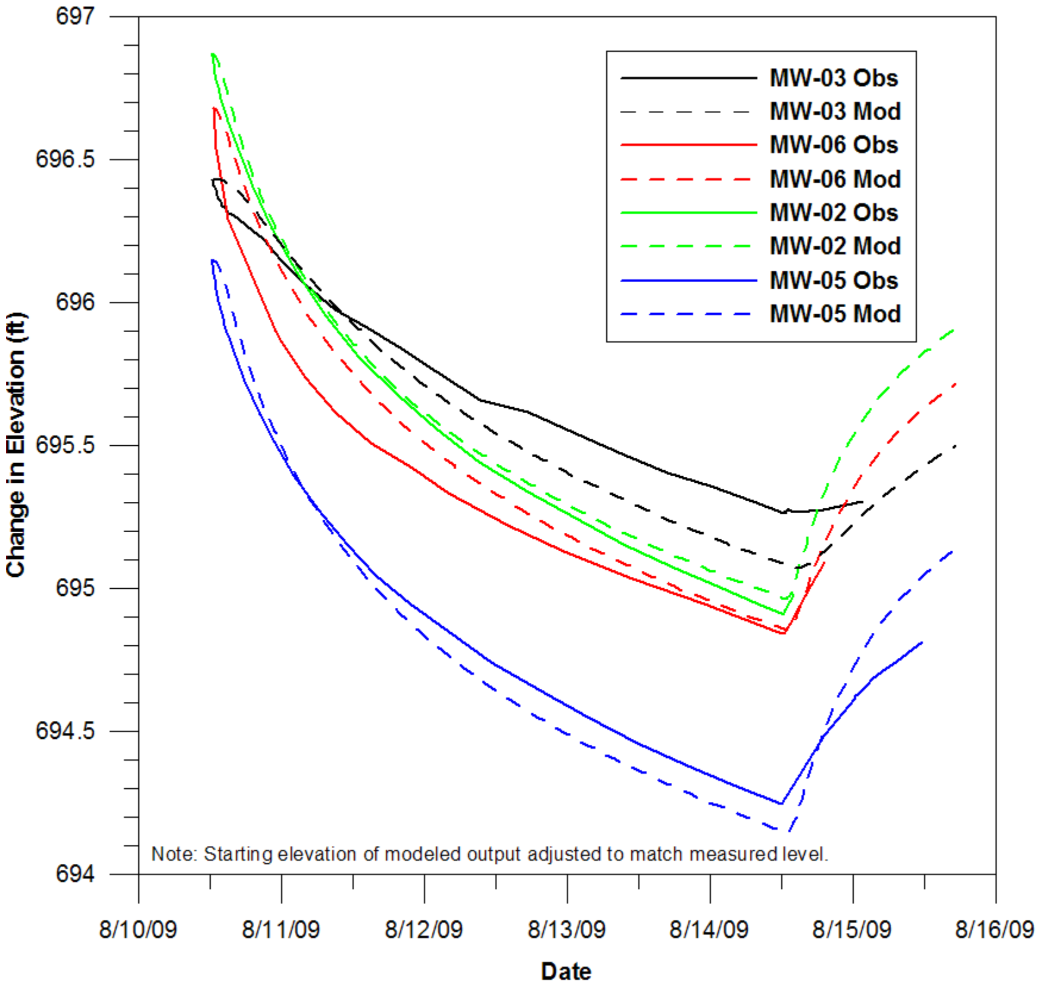


Figure 38: MODFLOW model calibration results.

- The pumping rate for the well was assigned to the appropriate stress periods to match the starting and stopping points in the test.

- Prior to calibration, the initial aquifer properties were assigned based on preliminary test results. The high conductivity zone was assigned a hydraulic conductivity of 436 ft/d, and the rest of the aquifer was assigned a hydraulic conductivity of 100 ft/d. The specific yield was assigned a value of 0.059 based on the aquifer test results. Recharge was set to 5 in/yr (0.00114 ft/d).

The model was calibrated by comparing the modeled to the measured drawdowns in monitoring wells MWS1, MWS2, MWS3, MWS5, and MWS6. The best fit solution for monitoring wells MWS2, MWS5, and MWS6 was obtained with a hydraulic conductivity value of 404 ft/d (Figure 38). The model over-predicts drawdown in MWS3, however we believe this is probably a result of the discharge pipe leaking near that monitoring well during the aquifer test and artificially keeping the measured drawdown low.

Table 10: Calibrated aquifer properties of MODFLOW model.

Parameter	**Units**	**Best-fit Value**
Hydraulic Conductivity - High (K)	$[ft/d]$	404
Hydraulic Conductivity - Low (K)	$[ft/d]$	100
Specific Yield (S_y)	$[-]$	0.059
Riverbed Conductance	$[ft^2/d/ft]$	80

The model was generally insensitive to changes in the hydraulic conductivity of the low K zone. Likewise, changes in the conductance of the creek bed had no effect on modeled drawdowns in MWS2, MWS3, MWS5, and MWS6. However, the modeled water levels in MWS1 (adjacent to the creek) were affected by the creek bed conductance. Keeping the other parameters constant, the creek bed conductance was adjusted until a best fit with MWS1 was achieved at $80\,ft^2/d/ft$. This results in an estimated hydraulic conductivity through the creekbed of $8\,ft/d$. The final calibrated parameters of the MODFLOW model are shown in Table 10.

Effects of seasonally-varying recharge

The purpose of the MODFLOW model was to assess the effects of time-varying recharge at the site. This analysis is informative, because if large-scale seasonal effects exist, there may be a potential for limited yields from the aquifer during the summer, when recharge is low and seasonal demand is high. Figure 39 illustrates the annual variation in head at the location of the test well for the predevelopment case (no well pumpage) , as simulated with the MODFLOW model. For this simulation the monthly recharge rates are based on the results of the SWB model as shown in Figure 35.

The transient model was modified to include the test well pumping at a rate of $1\,mgd$ for a three-month period in the spring and early summer. Figure 39 compares the aquifer response to a three-month pumping period both with and without seasonally varying recharge. The recharge rate in the simulation with constant recharge is specified as teh average annual value of $7.4\,in/yr$ estimated with the SWB model. It is apparent that the effects of seasonal recharge variations are small compared to the stress imposed by the well. We conclude that the seasonal variations in recharge estimated with the SWB model do not limit aquifer yield during summer months. Therefore, a steady-state model may be used to estimate well yields at the site representing average annual conditions for our predictive analysis.

5.4.3 Steady-state ModAEM model

The steady-state modeling was performed using WHPA's customized version of ModAEM. ModAEM makes use of the analytic element method (AEM). The AEM does not make use of a model grid; instead, it is based on the superposition of analytic functions, each of which explicitly represents a hydraulic feature or boundary condition in the model. In general, this offers the advantage that the groundwater velocity is expressed as a

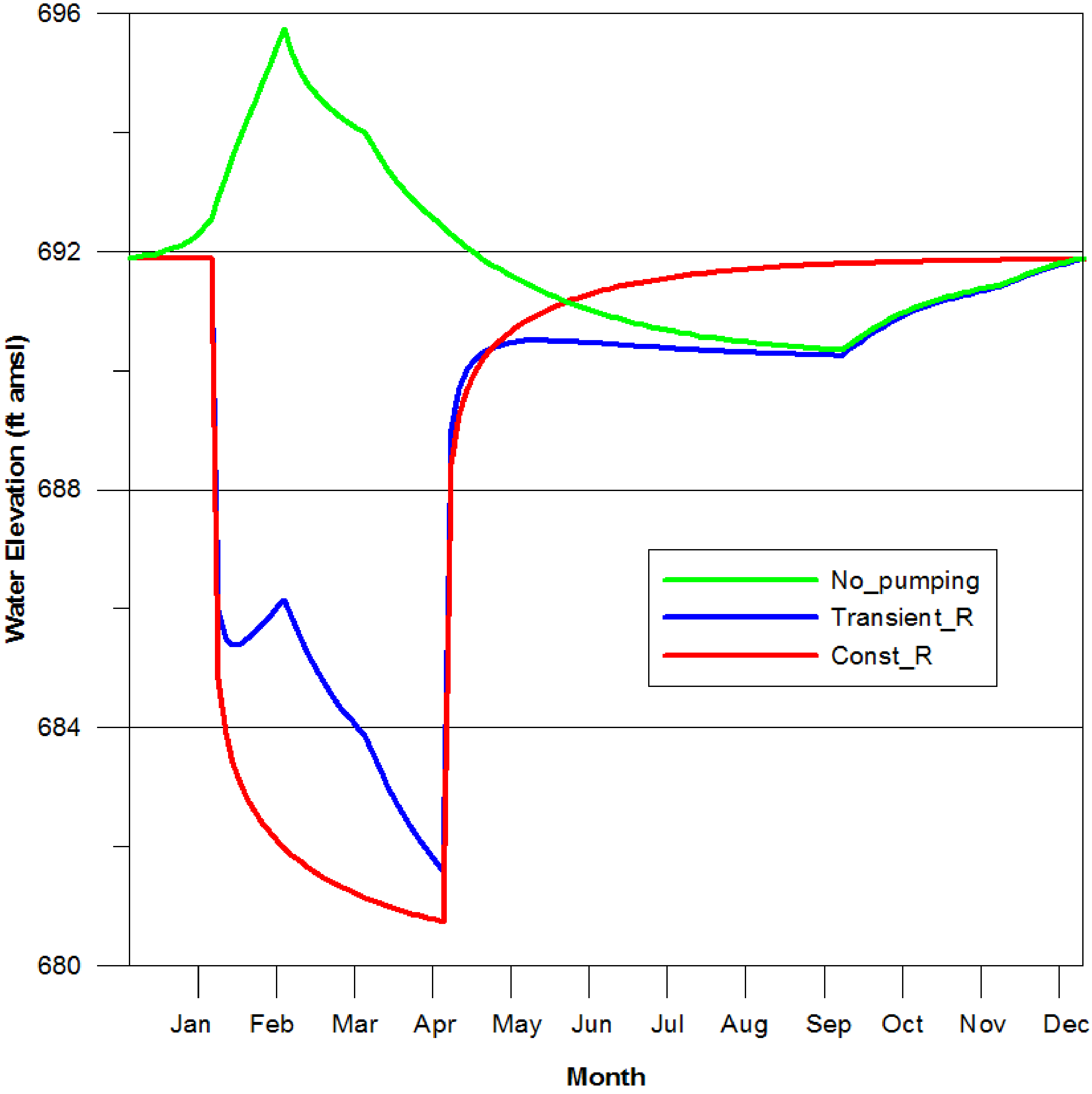


Figure 39: Simulated annual variation in groundwater level at the location of the test well.

continuous function, as opposed to a numerical approximation. This means that a more accurate solution is available, particularly in the vicinity of wells. ModAEM provides the capability of explicitly simulating the performance of a horizontal collector well or to assess the effects of local 3-D flow near vertical wells.

Figure 40 shows the arrangement of analytic elements that were used in the steady state model. The model's extent and the aquifer properties used in the ModAEM model are consistent with those used in the MODFLOW model. As discussed in Section 5.4.1, the model domain is divided into two sections, a regional aquifer that is about $40\,ft$ thick and a zone of higher transmissivity in the near vicinity of the test well. This thicker zone was identified from boring logs at the site and from the regional map, and boring logs indicate that the aquifer in the thicker zone is comprised of coarser sediments. Thus, the highly-transmissive zone indicated in brown in Figure 40 is modeled with a larger hydraulic conductivity as well. The spatial extent of the more-transmissive zone is not well understood, however the regional map [ISGS, 1996] suggests that it might extend southwest of the test site, perhaps up to or beyond Sugar Creek on the far south end of the study region.

Sources and sinks Sugar Creek is represented by a series of head-specified line-sink elements, each of which has an "entry resistance" that represents the degree of hydraulic connection between the creek and the aquifer.. We selected an entry resistance that is consistent with the river cell resistance in the MODFLOW model. Recharge is applied over the entire model domain at a rate of $6\,in/yr$, which is slightly less than the average recharge estimate determined with the SWB model. We believe this represents a conservative choice of recharge rate.

Steady-state model of predevelopment (current) conditions The steady-state model was run with no pumping included and compared to the MODFLOW model. Simulated water levels from this "predevelopment" model were the base conditions used to compute drawdown distributions in the predictive models (see below). We used two predevelopment models to bracket a range of possible entry resistance values for the streambed, one with an entry resistance of $1\,d$ and one with an entry resistance of $5\,d$ along Sugar Creek. Figure 41 shows the simulated predevelopment water levels at the project site

Predictive modeling

In order to assess the potential of the aquifer, we ran a series of predictive scenarios as shown in Table 11. Scenarios 1 and 2 were designed to assess the feasibility of pumping $3\,mgd$ from the Stark property with a set of vertical wells or a single collector well (Table 11). For these simulations, the wells were located away from the creek where the sand and gravel deposits are known to be thickest on Stark property in section 23 (T23N R1E). This thick section of sand and gravel may intercept Sugar Creek farther south in section 27. If so, it may be possible to achieve higher yields at this location by inducing recharge from the creek. Scenarios 3 and 4 were used to assess the potential gain from locating the pumping center closer to the creek (Table 11), assuming that the hydrogeologic conditions are favorable. For these simulations, a single collector well was located adjacent to the creek in section 27. For all scenarios, we used a range of values for stream resistance to account for uncertainty in this parameter.

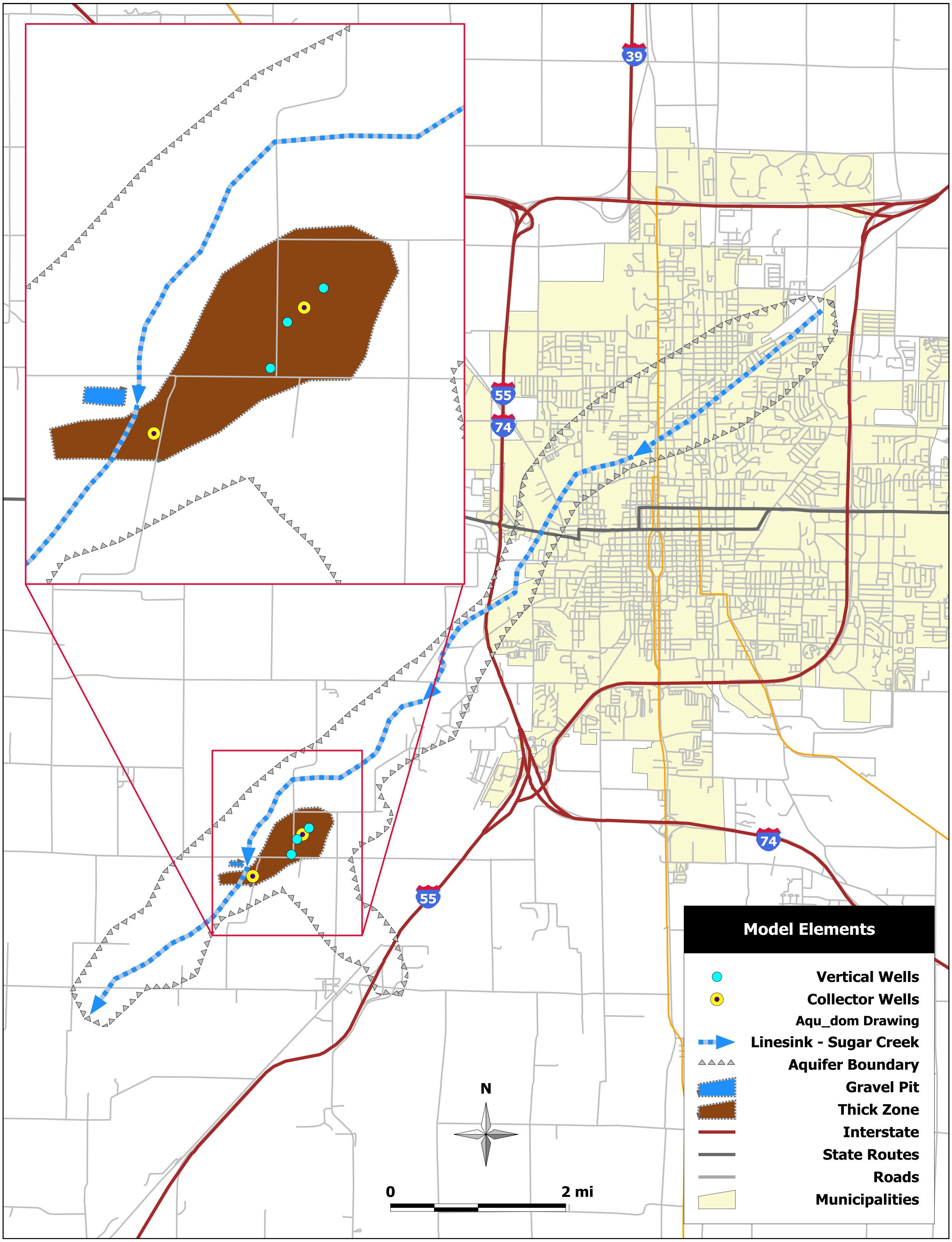


Figure 40: ModAEM model layout.

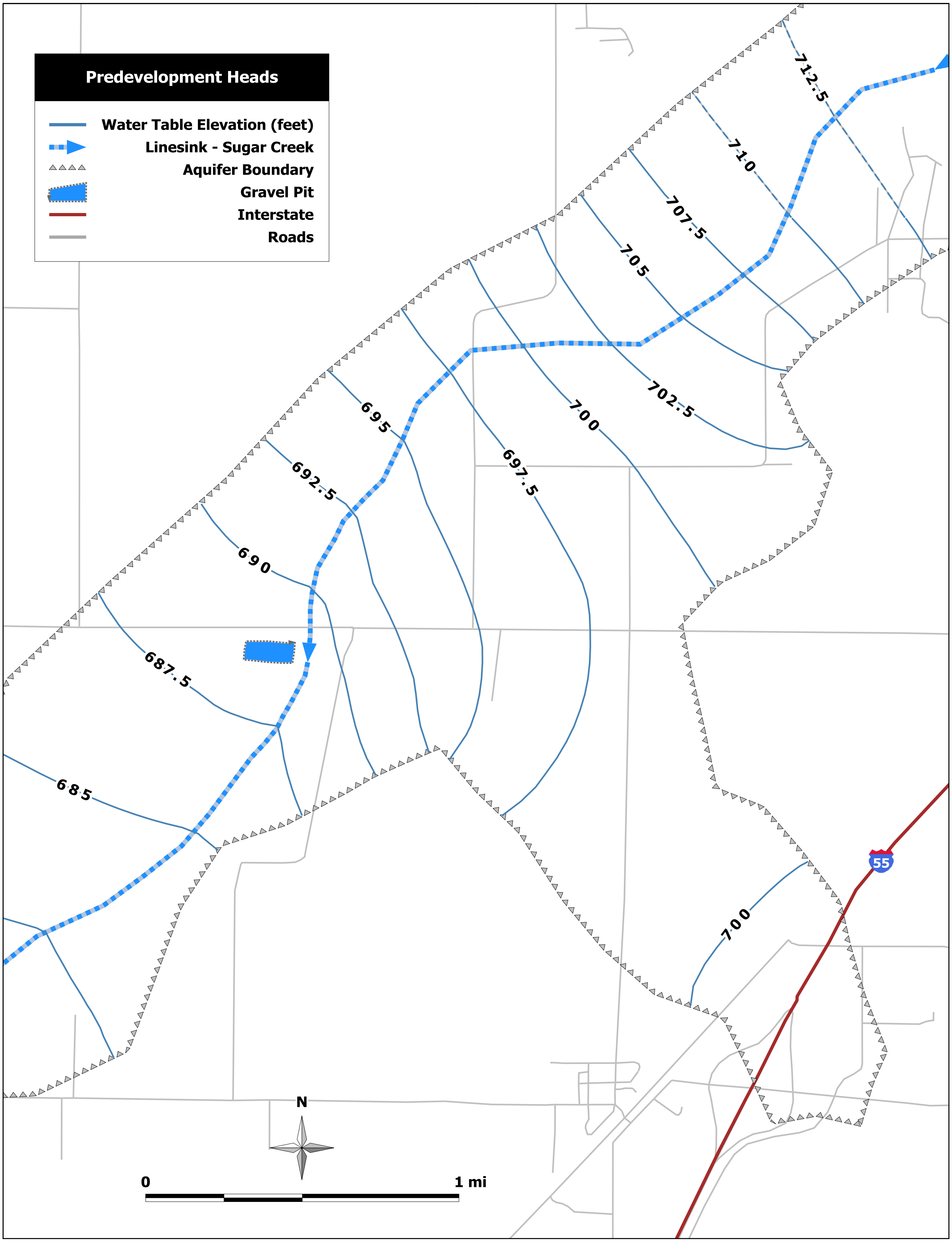


Figure 41: Simulated predevelopment water levels at the Sugar Creek study area.

Table 11: Scenarios used in the predictive modeling.

Scenario Name	**Well Type and Quantity**	**Well Location**	**Total Pumping Rate** (mgd)	**Stream Resistance** (d)
1	vertical (3)	near test well	3	1-5
2	collector (1)	near test well	3	1-5
3	collector (1)	south, near creek	3	1-5
4	collector (1)	south, near creek	5	1-5

MGD=million gallons per day, d=days

In each collector well simulation, the collector well was considered to have laterals $5\,ft$ above the aquifer bottom. In the vertical well runs, the vertical wells were assumed to be screened over the bottom $20\,ft$ of aquifer, and a specialized model formulation was used to estimate the head at the well screen, including the 3-D effects of partial penetration. The partial penetration effects assume that the aquifer is vertically anisotropic; a ratio of horizontal-to-vertical conductivity ($k_h : k_v$) of $10 : 1$ was specified in the model.

Results of the predictive modeling are shown in Table 12. For each scenario, Table 12 includes the modeled head at the well, the drawdown at the well, and the pumping level in the well. The ranges are a result of using a range of values for the stream entry resistance. The pumping level in the well was estimated by assuming a well with 80% screen efficiency and with the specific capacity degraded by 20%. For comparison, a critical pumping level inside the well is included for each scenario in Table 12. The critical pumping level was determined by estimating the likely screen elevation for vertical wells and collector wells at the site and adding a $5\,ft$ buffer. This assumes that the bottom of each well can be installed at or below an elevation of $640\,ft\,amsl$.

The predictive results demonstrate that the aquifer can support $3MGD$ of pumping at the Stark property, with either a collector well or a set of three vertical wells. The predicted drawdown is similar for the vertical well scenario and the collector well scenario (Scenarios 1 and 2, Table 12). However, use of vertical wells will require more land; the modeled spacing between the vertical wells is about $1000\,ft$. This spacing is necessary for the vertical wells to avoid excessive interference between them. The predictive modeling results indicate that higher yields may be obtained with a collector well located near the creek (Scenarios 3 and 4, Table 12). Yield as high as $5MGD$ may be possible, but only if the hydrogeologic conditions are favorable for induced infiltration at this location.

Contour plots of the simulated drawdown value for the predictive scenarios are included in Figures 42-45. In general, drawdown is higher for the model runs using the high end value for stream resistance. With higher stream resistance, less water is available from the boundary condition, causing higher drawdown in the aquifer. For Scenarios 1 and 2, where $3MGD$ is pumped from Stark property, drawdown beyond the property is less than $13\,ft$ (Figures 42 and 43). The simulated drawdown is less for the case where $3MGD$ is pumped closer to the creek (Scenario 3, Figure 44). Increasing the pumping rate to $5MGD$ near the creek (Scenario 4) increases drawdown significantly (Figure 45), particularly near the well.

For a well that pumps near a surface water body, one issue that determines the water quality in the well is the amount of surface water that enters the well over a short period of time. This is due to the fact that the

Table 12: Results of predictive modeling.

Scenario	Description	Modeled Head at Well $(ft\,amsl)$	Drawdown at Well (ft)	Critical Pumping Level in Well $(ft\,amsl)$	Modeled Head in Well* $(ft\,amsl)$
1	3 verticals, 3 mgd total, near test well	678-682	15-17	665	669-674
2	1 collector, 3 mgd total, near test well	677-679	17-22	652	664-675
3	1 collector, 3 mgd total, near creek	673-677	13-19	652	663-670
4	1 collector, 5 mgd total, near creek	656-668	19-36	652	635-660

ft=feet, amsl=above mean sea level

**assumes 80% efficient well and 20% degradation of specific capacity*

chemistry of water that is induced to enter the aquifer from the creek and then enters the well after a short travel time may resemble the stream more than the ambient groundwater. As a surrogate, we delineated the 1-year travel time capture zones for all three well configurations (Scenarios 1-3), pumping at 3 MGD in Figures 46-48. For Scenarios 1 and 2, with the wells located away from the creek, the 1-year capture zone does not reach the river (Figures 46-47), indicating that the source water for this location will be predominately groundwater. With a collector well pumping next to the river, the 1-year capture zone does reach the river (Figure 48), indicating that the source water from a collector well at this location would be a mix of surface water and groundwater.

5.5 Conclusions and Recommendations

Based on the results of a field investigation, including test borings and two aquifer tests, and modeling of the Sugar Creek Aquifer including transient and steady-state groundwater flow modeling, we conclude the following:

- Our results are consistent with previous studies that suggest a production rate of 3 MGD might be achieved at the subject sites along Sugar Creek. A production rate of 3 MGD can be produced from 3 vertical wells or a single collector well constructed at the Stark site.
- The quality of the groundwater at the site is suitable for public supply. However, treatment would be necessary to address taste and aesthetic issues associated with iron, manganese, total dissolved solids (TDS), and hardness.
- Nitrate, though detected at very low concentrations in the groundwater, could become a problem in the future. The shallow aquifer is vulnerable to contamination at the land surface. Excess nitrogen applied

at the land surface could be induced into the deeper zones of the aquifer where the proposed wells would pump.

- The transient effects on yield of seasonal recharge variations are small.
- The more highly-transmissive portion of the aquifer might extend southwest under the creek. If additional exploration confirms this, it may be possible to construct a collector well at that location, specifically for the purpose of inducing recharge from the creek (a process known as "river bank filtration", or RBF). Depending on the degree of hydraulic connection between the creek and the aquifer, a larger pumping rate of $5\,MGD$ or more might be achieved.

We recommend development of the Stark property site. For this site, a collector well may be the best option for development, for the following reasons: 1) The collector well would require less land for its construction because it would require only one wellhead, and 2) By placing the laterals at a lower elevation, the available drawdown at the well is increased.

More capacity from the aquifer is potentially available beyond the Stark property investigated for this project. If the City anticipates needing more than $3\,MGD$ from the Sugar Creek location, we recommend additional exploration and testing in section 27 south of the project site. If the hydrogeologic conditions are favorable for RBF in section 27 and if sufficient recharge can be induced from the creek, a collector well at this location may yield as much as $5\,MGD$.

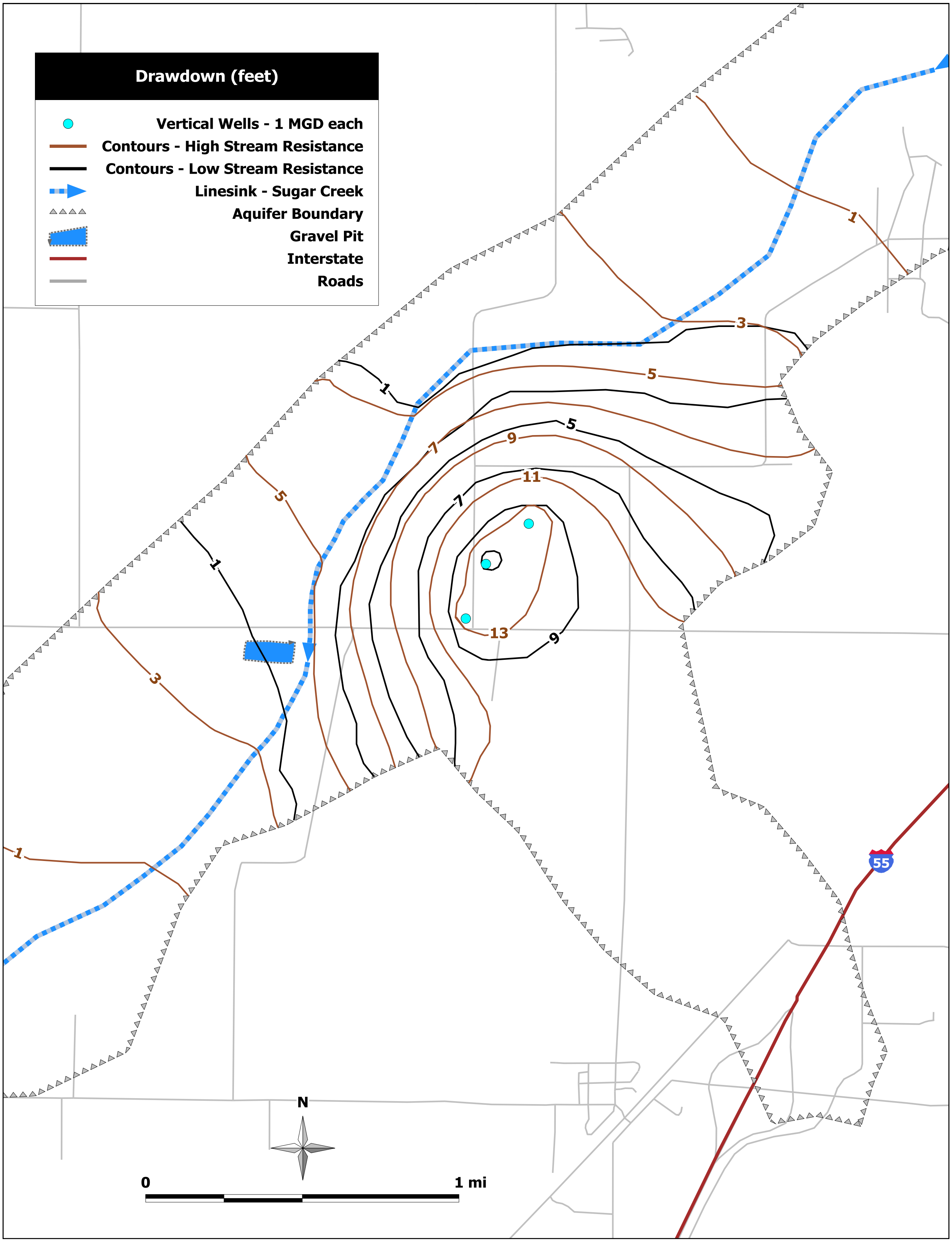


Figure 42: Simulated drawdown distribution for Scenario 1- three vertical wells near the test well, with aggregate pumping rate of $3mgd$. Black contours are for $1d$ stream resistance, Brown contours are for $5d$ stream resistance.

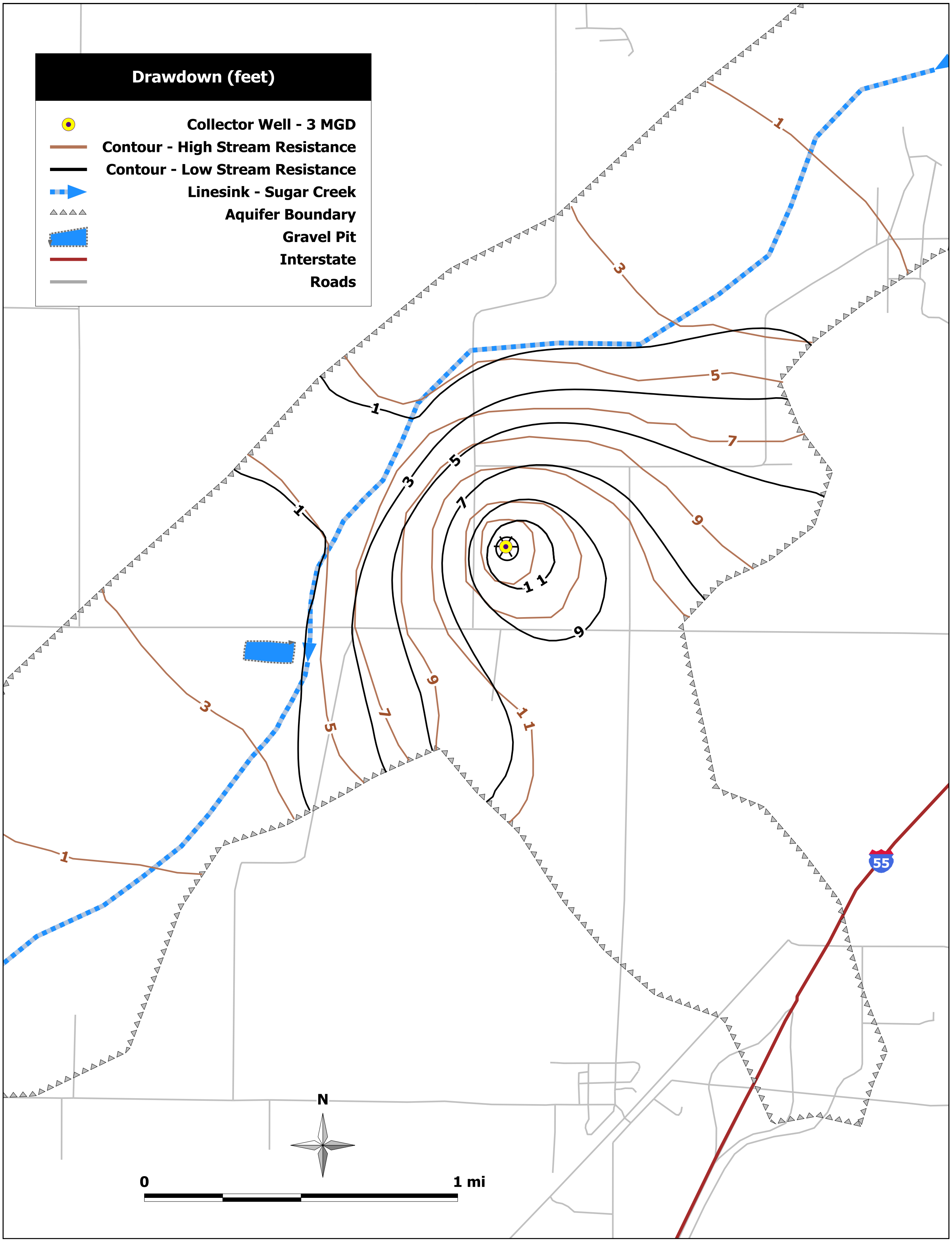


Figure 43: Simulated drawdown distribution for Scenario 2- one collector well near the test well, with a pumping rate of $3\,mgd$. Black contours are for $1\,d$ stream resistance, brown contours are for $5\,d$ stream resistance.

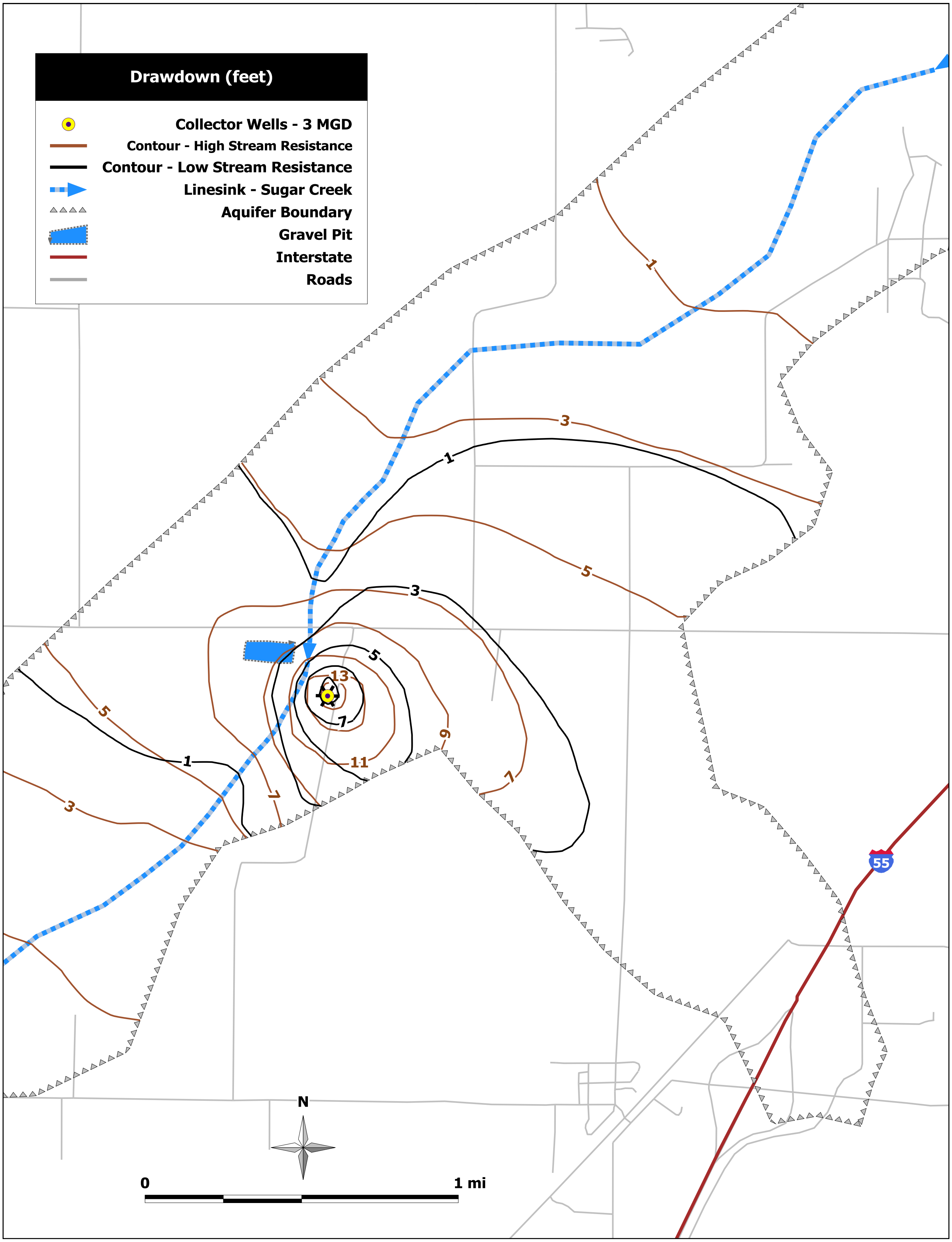


Figure 44: Simulated drawdown distribution for Scenario 3- one collector well south of the test well along Sugar Creek, with a pumping rate of 3 *mgd*. Black contours are for 1 *d* stream resistance, brown contours are for 5 *d* stream resistance.

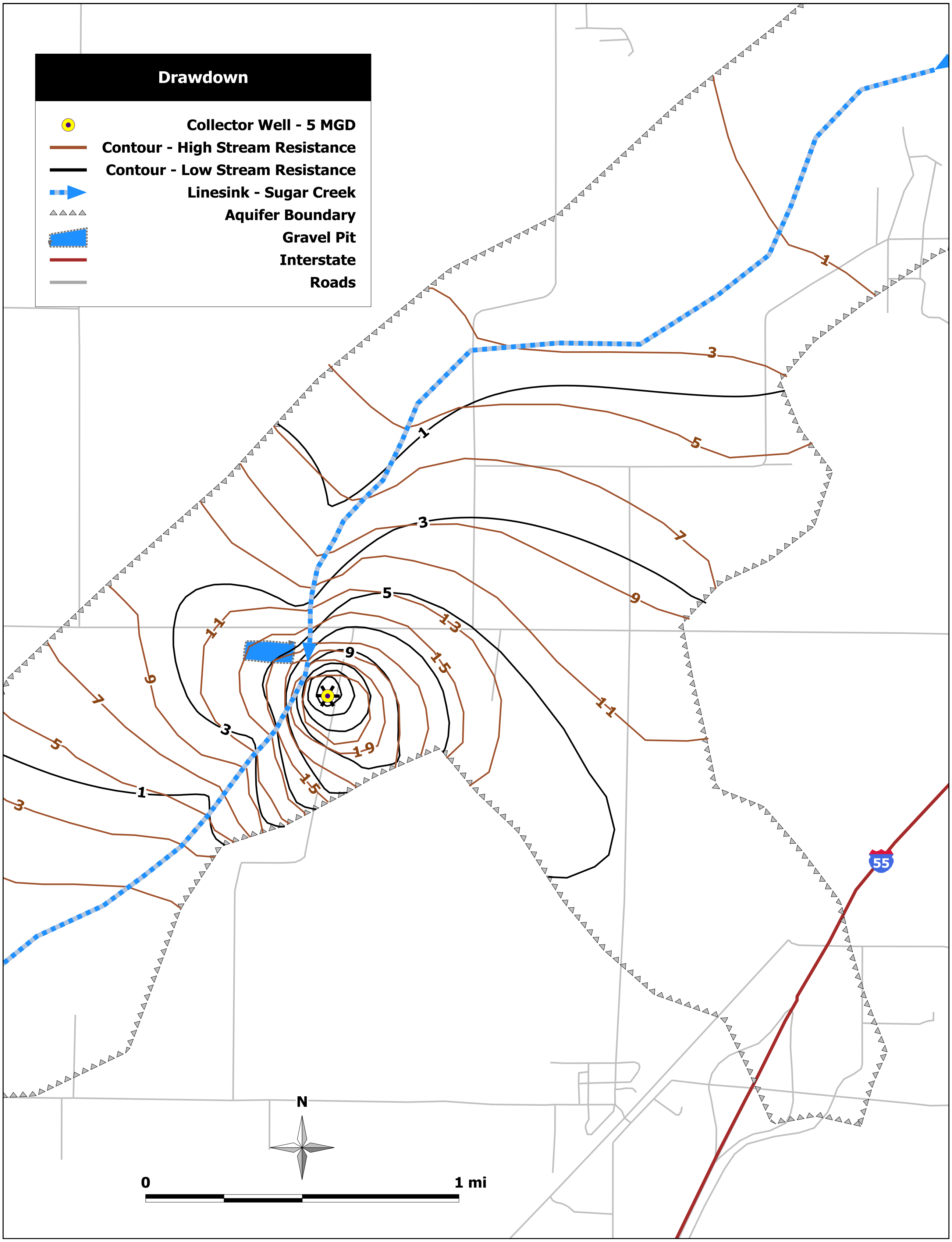


Figure 45: Simulated drawdown distribution for Scenario 4- one collector well south of the test well along Sugar Creek, with a pumping rate of 5 *mgd*. Black contours are for 1 *d* stream resistance, brown contours are for 5 *d* stream resistance.

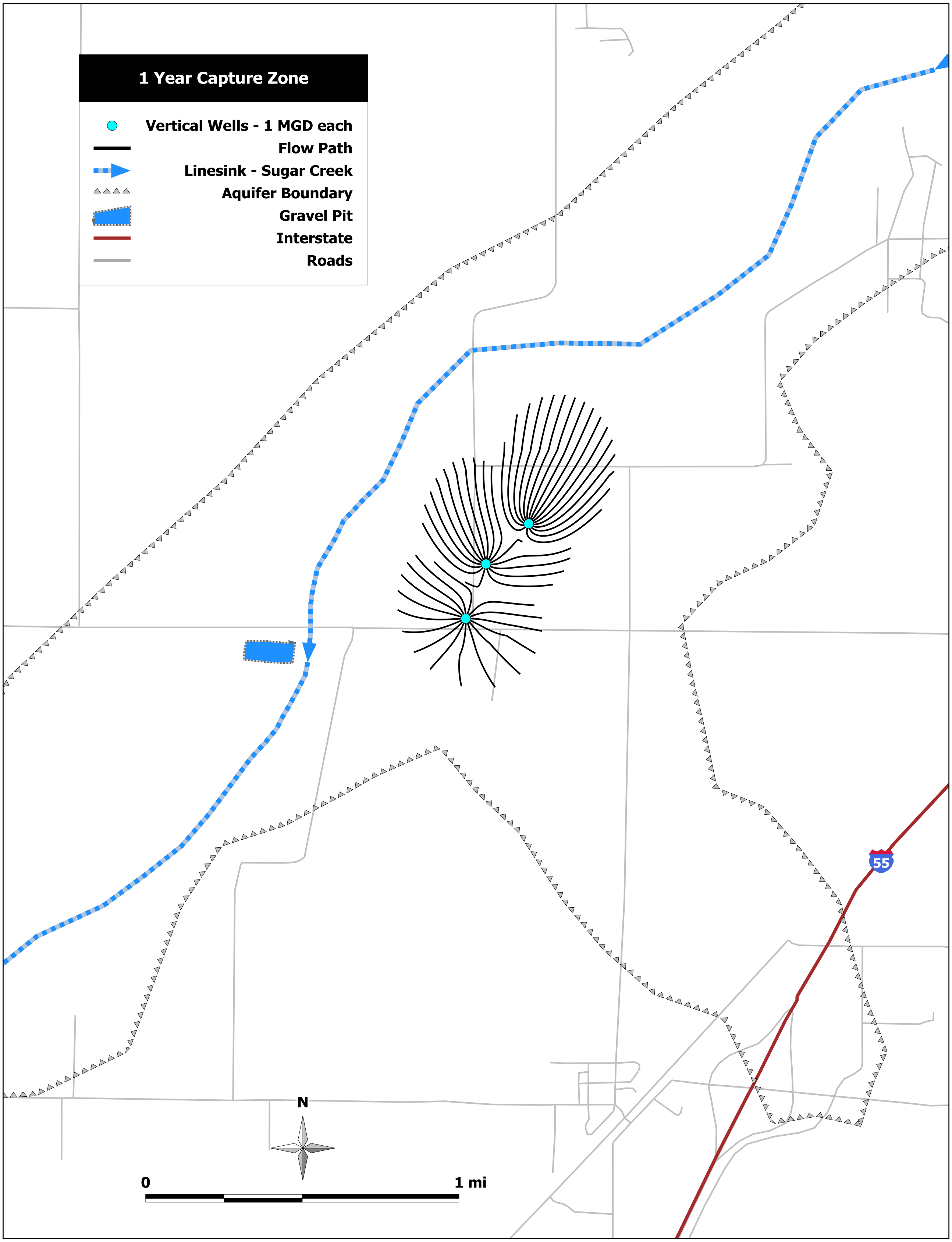


Figure 46: Simulated 1-year capture zone for Scenario 1- three vertical wells near the test well, with aggregate pumping rate of 3 mgd. Stream resistance is 1 d.

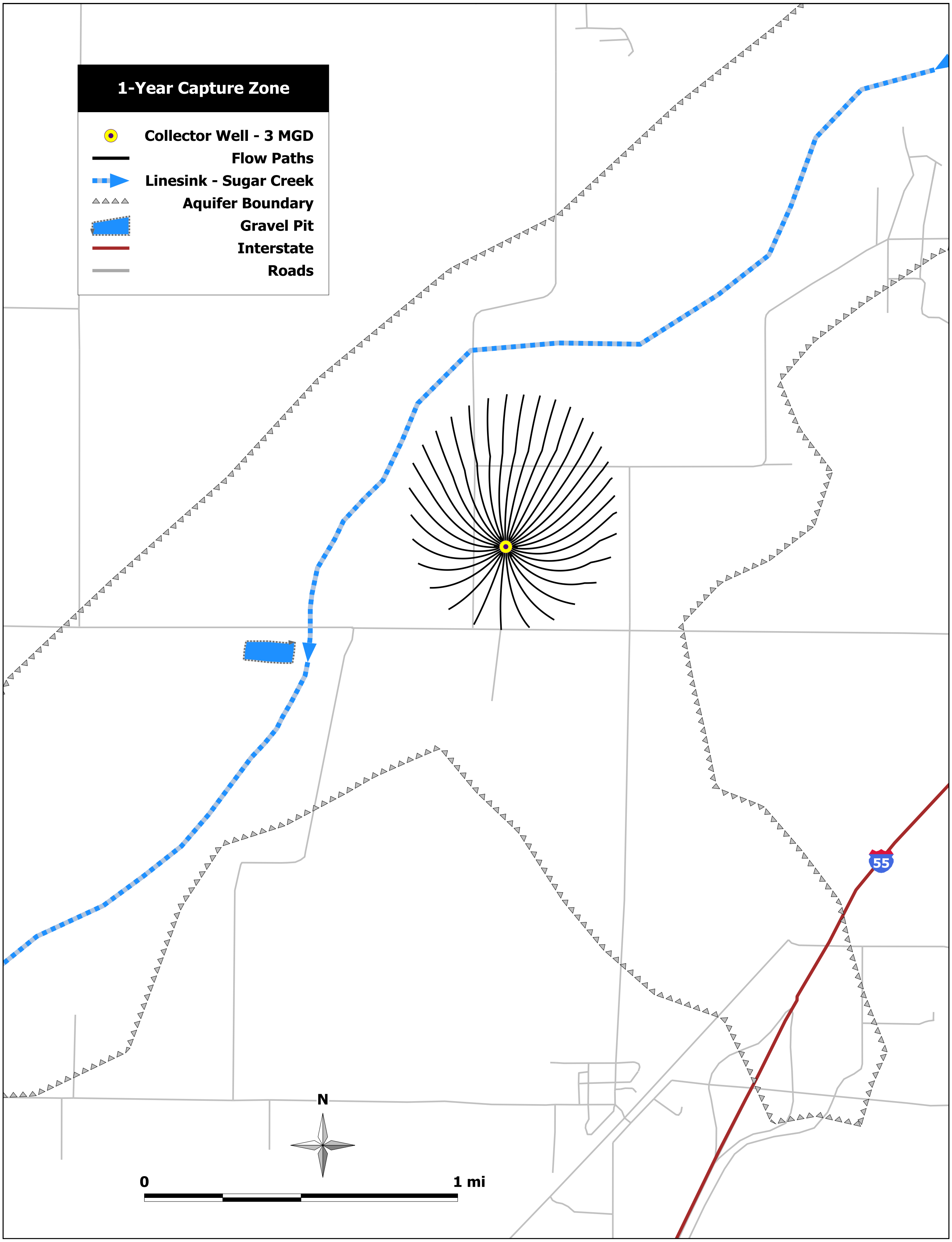


Figure 47: Simulated 1-year capture zone for Scenario 2- one collector well near the test well, with a pumping rate of $3\,mgd$. Stream resistance is $1\,d$.

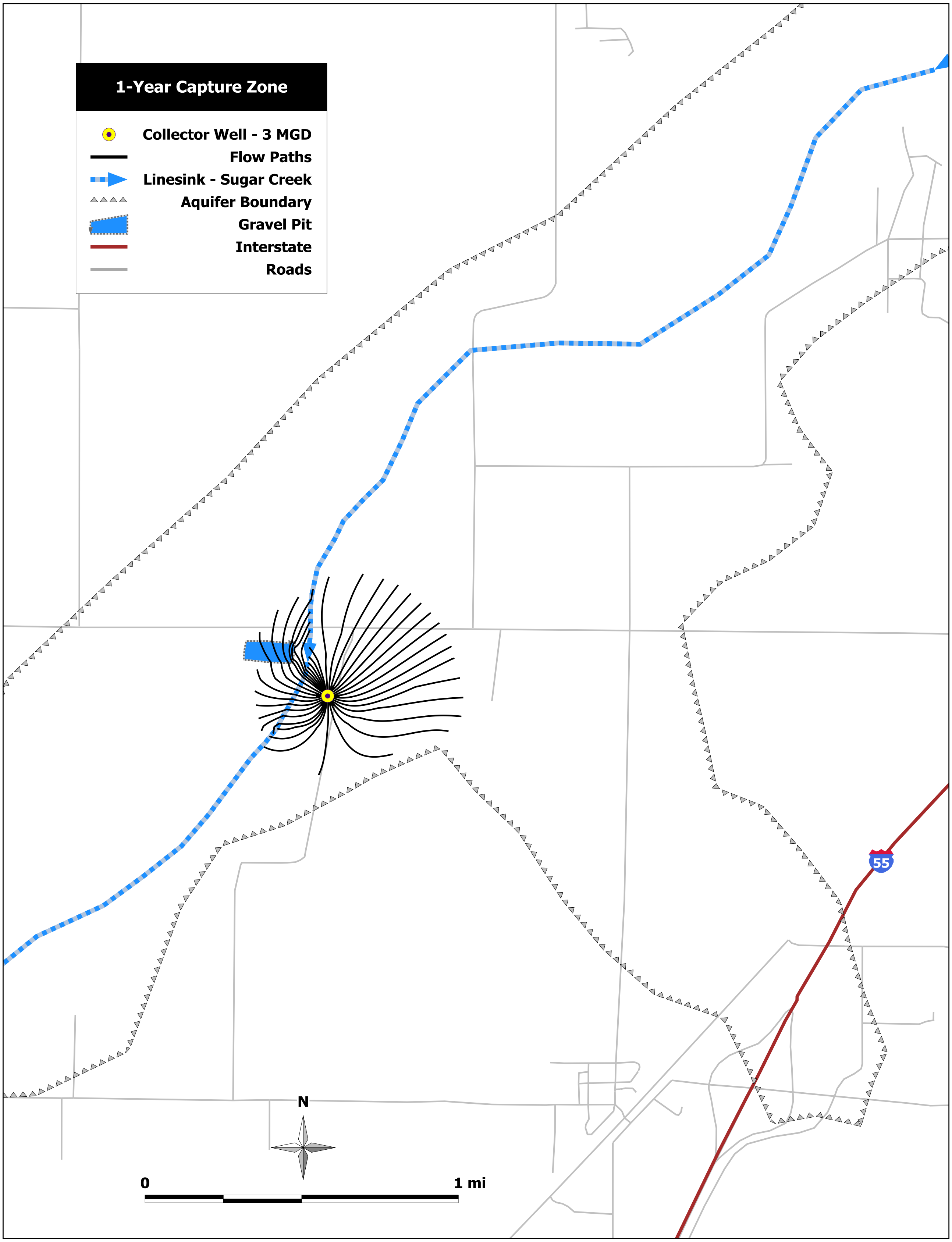


Figure 48: Simulated 1-year capture zone for Scenario 3- one collector well south of the test well along Sugar Creek, with a pumping rate of $3\,mgd$. Stream resistance is $1\,d$.

References

[Aquaveo, 2009] Aquaveo (2009). Groundwater Modeling System Version 6.5. http://www.aquaveo.com. Aquaveo.

[AWWA, 2006] AWWA (2006). Field Guide to SDWA regulations.

[Banta and Harbaugh, 2000] Banta, N. and Harbaugh, A. (2000). MODFLOW-2000, The U.S. Geological Survey Modular three-dimensional finite-difference ground-water Flow Model–2000 updated version. Technical report, U.S. Geological Survey.

[Batu, 1998] Batu, V. (1998). *Aquifer Hydraulics A Comprehensive Guide to Hydrogeologic Data Analysis*. John Wiley and Sons, New York.

[CLIMOD, 2009] CLIMOD (2009). Climate Information for Management and Operational Decisions Database. http://www.nrcc.cornell.edu/.

[Duffield, 2002] Duffield, G. (2002). AQTESOLV for Windows Version 3.50 Professional. Technical report, HydroSOLVE, Inc.

[Herzog et al., 1994] Herzog, B., Stiff, B., Chenoweth, C., Warner, K., Sievering, J., and Avery, C. (1994). Buried Bedrock Surface of Illinois. Technical report, Illinois State Geological Survey.

[Holm,] Holm. Groundwater Quality in the Mahomet Aquifer, Mclean, Logan, and Tazewell Counties. Technical report, Illinois State Water Survey, Chemistry Division.

[Holm and Scott, 2004] Holm, Kelly, W. R. T. and Scott (2004). Arsenic Geochemistry and distribution in the Mahomet Aquifer, Illinois. Technical report, Illinois State Water Survey and Illinois Waste Management and Research Center, WMRC Report- RR-107.

[ISGS, 1996] ISGS (1996). Digital format of Major sand and gravel aquifers. http://www.isgs.uiuc.edu/nsdihome.com. Illinois State Geological Survey.

[ISWS, 1989] ISWS (1989). Properties Database for Sand and Gravel and Bedrock Aquifers in Illinois.

[ISWS, 2002] ISWS (2002). Climate maps for Illinois. http://www.isws.illinois.edu/atmos/statecli. Illinois State Climate Office of the Illinois State Water Survey.

[ISWS, 2006] ISWS (2006). The Water Cycle and Water Budgets in Illinois: a Framework for Drought and Water-Supply Planning. I/EM 2006-02.

[ISWS, 2009] ISWS (2009). Historical Climate Summary- Station 116200 Normal 4NE. http://www.isws.illinois.edu/atmos/statecli/Summary/116200.html. Illinois State Climate Office of the Illinois State Water Survey.

[Kelson, 2007] Kelson, V. (2007). The ModAEM-1.8 User's Guide. Technical report, WHPA Inc.

[Kempton and Visocky, 1992] Kempton, J. and Visocky, A. (1992). Regional Groundwater Resources in Western Mclean and Eastern Tazewell Counties. Technical report, Illinois State Geological Survey and Illinois State Water Survey cooperative report 13.

[NCDC, 2009] NCDC (2009). NNDC Climate Data Online- Station No. 110761, Bloomington Water Works. http://www.cdo.ncdc.noaa.gov. National Climate Data Center, National Oceanic and Atmospheric Administration.

[NRCS, 2009] NRCS (2009). Watershed Boundary Dataset. http://www.ncgc.nrcs.usda.gov.

[Satterwhite, 2008] Satterwhite, K. (2008). Personal communication. discussion March 10, 2008.

[Schicht and Walton, 1961] Schicht and Walton (1961). Hydrologic Budget for three Small Watershed in Illinois. ROI 40.

[Stanley A. Changnon, 1987] Stanley A. Changnon, J. (1987). Detecting Drought Conditions in Illinois. Technical report, Illinois State Water Survey.

[Theis, 1935] Theis, C. (1935). The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. *Am. Geophys. Union Trans.*, 16:519–524.

[USDA, 2007] USDA (2007). National Land Cover Database. http://datagateway.nrcs.usda.gov/.

[USDA, 2008] USDA (2008). Soil Survey Geographic Database. http://SoilDataMart.nrcs.usda.gov/.

[USGS, 2001] USGS (2001). Digital Elevation Model. http://seamless.usgs.gov/.

[USGS, 2009] USGS (2009). National Water Information System. http://waterdata.usgs.gov/il/nwis/. Station-5580950, Sugar Creek near Bloomington, Illinois.

[Vaiden and Kempton, 1989] Vaiden, R. and Kempton, J. (1989). Hydrogeological Investigations for a Supplemental Groundwater Supply for the City of Normal. Technical report, Illinois State Geological Survey.

[Walker, 1966] Walker, W. (1966). Town of Normal, Shallow Sand and Gravel Aquifer Along Suger Creek, letter to G.L. Farnsworth.

[Warner, 2001] Warner (2001). Arsenic in Glacial Drift Aquifers and the Implication for Drinking Water-Lower Illinois River Basin. *Groundwater*, 39:433–442.

[Westenbroek and Bradbury, 2009] Westenbroek, Kelson, D. and Bradbury (2009). A modified Thornthwaite-Mather soil-water-balance code for estimating groundwater recharge. Techniques and Methods 6-A31, 67 pages.

[Wilson et al., 1998] Wilson, S., Roadcap, G., Herzog, B., Larson, D., and Winstanley, D. (1998). Hydrogeology and Groundwater Availability in Southwest Mclean and Southeast Tazewell Counties Part 2: Aquifer Modeling and Final Report. Technical report, Illinois State Geological Survey and Illinois State Water Survey cooperative report 19.

Appendix A- Boring Logs

Layne Well Logs (Danvers Valley and Downs Well Boring Logs)

TEST HOLE
NO. B-1

TEST WELL REPORT

Layne®-Western

a division of Layne Christensen Company

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone 630/897-6941
229 West Indiana Avenue • Beecher, Illinois 60401 • Phone 708/946-2244

1. Owner BLOOMINGTON EXPLORATION TEST HOLES CONTRACT NO. 0205W DATE 11/3/08
2. City BLOOMINGTON STATE IL
3. Driller's Name CHRIS MORGANEGG Helpers TOM LANAN
4. Static Water Level +14 How Obtained Dual Tube
5. Size Mud Pit - Length Width

DRILLERS LOG

TOP FT.	BOTTOM FT.	MUD LOSS INCHES	MUD WEIGHT	DESCRIPTION OF FORMATION	REMARKS
0	2			TOPSOIL	
2	9			BROWN CLAY	
9	19			GRAVEL W/COARSE SAND STREAKS	
19	47			GREY CLAY W/GRAVEL EMBEDDED	
47	52			BLUEISH GREY CLAY	
52	113			GREY GLAY WITH GRAVEL EMBEDDED	
113	130			SAND AND GRAVEL	
130	210			GREY CLAY WITH GRAVEL EMBEDDED	
210	216			REDDISH BROWN CLAY	
216	227			GREY CLAY WITH GRAVEL EMBEDDED	
227	236			GRAVEL	
236	267			GREY CLAY	
267	274			BROWN SAND	
274	282			BLUE SHALE	
				2" PVC 261' UP TO 236'	
				2" 10 SLOT SCREEN 236' TO 226'	
				2" PVC FROM 226' TO 0'	
				18' 2" PVC STAND PIPE	

TEST WELL REPORT

Layne-Western Company, Inc.

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone: 708/897-6941

TEST HOLE
NO. B2

1. Owner Bloomington Exploration Test Hole Contract No. (16020SW) Date ~~[illegible]~~ 9/26/08
2. City Bloomington B-2 State Il.
3. Driller's Name C. Morganegg Helpers T. Lanan
4. Static Water Level 65' DUEL TUBE ~~How Obtained — Washed ( ) Pumped ( )~~
5. ~~Size Mud Pit — Length N/A Width~~

DRILLERS LOG

TOP FT.	BOTTOM FT.	MUD LOSS INCHES	MUD WEIGHT	DESCRIPTION OF FORMATION	REMARKS
0	3			TOPSOIL	
3	13			YELLOWISH CLAY w/ GRAVEL	
13	32			GREY CLAY w/GRAVEL	STATIC AT 320'
32	34			GRAVEL SEAM	70'
34	43			BROWNISH GREY CLAY	
43	71			GREY CLAY w/GRAVEL	
71	74			GRAVEL w/ CLAY	
74	90			DARK GREY CLAY	
90	152			GREY CLAY w/GRAVEL	
152	163			BROWN CLAY w/GRAVEL	
163	183			GREY CLAY	
183	223			GREY CLAY	
223	230			GREEN CLAY	
230	248			GREY CLAY w/GRAVEL	
248	253			HEAVING SAND w/GRAVEL	
253	277			GREY CLAY	
277	296			SAND & GRAVEL	SCREENED
296	299			SILTY FINE SAND	"
299	308			FINE TO COURSE SAND	"
308	315			CLAY	
315	322			SAND GRAVEL	SCREENED
322	344			CLAY	
344	350			LIME	
				322-315 3[illegible]-277	

W-95

(SEE OTHER SIDE)

TEST HOLE
NO. B3

TEST WELL REPORT

Layne®-Western

a division of Layne Christensen Company

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone 630/897-6941
229 West Indiana Avenue • Beecher, Illinois 60401 • Phone 708/946-2244

1. Owner BLOOMINGTON EXPLORATION TEST HOLE CONTRACT NO. 16-0205W DATE 11/9/08
2. City BLOOMINGTON STATE ILLINOIS
3. Driller's Name CHRIS MORGANEGG Helpers TOM LANAN
4. Static Water Level 65' DUAL TUBE
5. Size Mud Pit - Length N/A Width

DRILLERS LOG

TOP FT.	BOTTOM FT.	MUD LOSS INCHES	MUD WEIGHT	DESCRIPTION OF FORMATION	REMARKS
0	2			Topsoil	
2	8			Clay w/Gravel Embedded	
8	12			Gravel	
12	38			Grey Clay w/Gravel	
38	54			Brown Clay w/Gravel	
54	89			Grey Clay w/Gravel Embedded	
89	107			Sand and Gravel	
107	142			Grey Clay w/Gravel	
142	146			Brown Clay	
146	205			Grey Clay w/Trace Gravel	
205	210			Sandy Clay	
210	250			Grey Clay w/Gravel	
250	261			Gravel w/Sand	
261	308			Clay w/Gravel	
308	324			Sand and Gravel	
324	325			Black Sandy Shale	
325	333			Grey Clay w/Gravel	
333	341			Brown and Grey Limestone	
				Screen from 324' – 304'	
				Blank 2" from 341' - 324'	
				2" Flush Joint from 0 – 304'	

TEST WELL REPORT

TEST HOLE
NO. B-4

Layne®-Western
a division of Layne Christensen Company

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone 630/897-6941
229 West Indiana Avenue • Beecher, Illinois 60401 • Phone 708/946-2244

1. Owner BLOOMINGTON EXPLORATION TEST HOLES CONTRACT NO. 0205 DATE 11/19/08

2. City BLOOMINGTON STATE IL

3. Driller's Name CHRIS MORGANEGG Helpers TOM LANAN

4. Static Water Level 81' How Obtained Dual Tube

5. Size Mud Pit - Length N/A Width N/A

DRILLERS LOG

TOP FT.	BOTTOM FT.	MUD LOSS INCHES	MUD WEIGHT	DESCRIPTION OF FORMATION	REMARKS
0	2			TOPSOIL	
2	8			RED CLAY (HARD)	
8	150			GREY CLAY WITH GRAVEL SEAMS	
150	175			BLUEISH GREEN CLAY WITH GRAVEL	
175	219			REDDISH BROWN CLAY WITH GRAVEL	
219	225			SAND AND GRAVEL	
225	258			GREY CLAY WITH GRAVEL EMBEDDED	
258	260			BROWN LIME	
				NO OB WELL AT THIS SITE	
				NOT ENOUGH FORMATION	
				GPS: 40° 39' 29" N, 88° 56' 43" W	

SKETCH SHOWING LOCATION OF TEST WELL

(Tie it into Permanent Structures as much as possible)

x			

County MCLEAN Section 1 Township 25N Range 2E

TEST HOLE NO. B-5

TEST WELL REPORT

Layne®-Western

a division of Layne Christensen Company

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone 630/897-6941
229 West Indiana Avenue • Beecher, Illinois 60401 • Phone 708/946-2244

1. Owner BLOOMINGTON EXPLORATION TEST HOLES CONTRACT NO. 16-0205 DATE 12/1/08

2. City BLOOMINGTON STATE ILLINOIS

3. Driller's Name CHRIS MORGANEGG Helpers TOM LANAN

4. Static Water Level 8' How Obtained DUAL TUBE

5. Size Mud Pit - Length N/A Width N/A

DRILLERS LOG

TOP FT.	BOTTOM FT.	MUD LOSS INCHES	MUD WEIGHT	DESCRIPTION OF FORMATION	REMARKS
0	1			TOPSOIL	
1	4			GREY CLAY WITH GRAVEL EMBEDDED	
4	25			COARSE SAND AND GRAVEL	
25	60			GREY CLAY	
60	65			GRAVEL	
65	95			CLAY WITH GRAVEL	
95	98			BROWNISH GREEN CLAY	
98	103			LIMESTONE	
				SET 2" PVC FROM 103' UP TO 70'	
				70'- 60' 2" PVC SCREEN	
				60' – 0' 2" PVC PIPE	
				FLUSH JOINT 2" PVC	

SKETCH SHOWING LOCATION OF TEST WELL

(Tie it into Permanent Structures as much as possible)

County ____________ Section _________ TWP __________ Range ________

TEST WELL REPORT

TEST HOLE NO. B-6

Layne®-Western

a division of Layne Christensen Company

721 West Illinois Avenue • Aurora, Illinois 60506-2892 • Phone 630/897-6941
229 West Indiana Avenue • Beecher, Illinois 60401 • Phone 708/946-2244

1. Owner BLOOMINGTON EXPLORATION TEST HOLES CONTRACT NO. 16-0205 DATE 12/4/08
2. City BLOOMINGTON STATE ILLINOIS
3. Driller's Name CHRIS MORGANEGG Helpers TOM LANAN
4. Static Water Level How Obtained DUAL TUBE
5. Size Mud Pit - Length N/A Width N/A

DRILLERS LOG

TOP FT.	BOTTOM FT.	MUD LOSS INCHES	MUD WEIGHT	DESCRIPTION OF FORMATION	REMARKS
0	2			TOPSOIL	
2	8			BROWN CLAY WITH GRAVEL	
8	32			GREY CLAY WITH GRAVEL	
32	34			SAND AND GRAVEL (MEDIUM)	
34	40			GREY CLAY WITH GRAVEL	
40	54			GRAVEL (COARSE)	
54	112			GREY CLAY WITH GRAVEL STREAKS	
112	130			GRAVEL	
				130' STILL IN GRAVEL	
				TERMINATED DUE TO INFLUENCE TO POND	

SKETCH SHOWING LOCATION OF TEST WELL

(Tie it into Permanent Structures as much as possible)

County ____________ Section _________ TWP __________ Range ________

Sugar Creek Valley Well Logs

Wittman Hydro Planning Associates
Water Resource Planning Consultants

WELL BORING LOG

Boring: S1

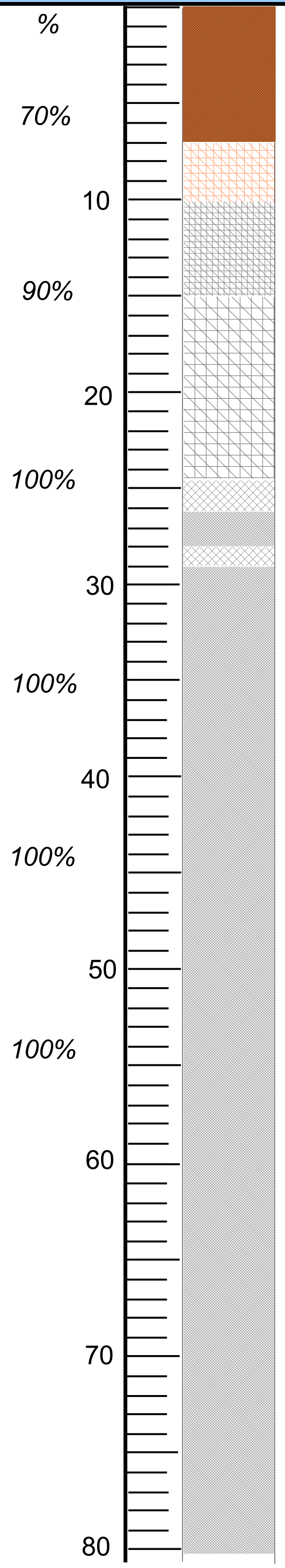
Date: 6/23/2009

Client: City of Bloomington
Driller: Layne – Matt White
Logged by: Sam Lax

Location: SW Bloom- Stark
Latitude: 40.43001 N
Longitude: -89.08080 W

ToC Elevation: 3.8 (ft)
Grade Elevation (GPS): 695.1 (ft)
Boring Diameter: 4 (in)

Recovery Depth | Material Description | Well Construction



SOIL, moist. Top 5 ft of dark brown and 2 ft of yellow clayey sandy soil, gravelly at bottom.

loose, yellow, poorly sorted, rounded GRAVEL w/ f -c sand and silt

loose, medium to dark gray, sorted c- SAND wet, gravelly 12-14 ft bgs

loose small GRAVEL and c-SAND medium gray, 10% large gravel

sandy-CLAY, 10% gravel and cobbles

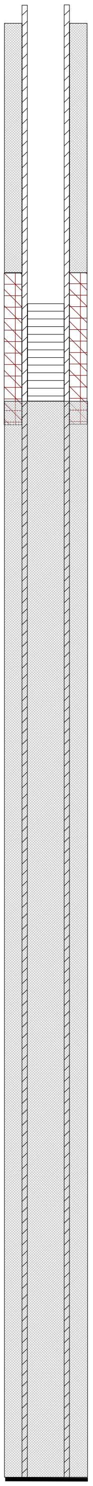
med-gray CLAY (till)

moist fm-sandy clay around 30-35 ft bgs

dry and hard from 35 – 80 ft bgs

End of boring at 80 ft bgs

Monitoring Well: MWS1



Static water level: 7.3 ft bgs

Finished 3.8 ft above grade w/ pvc casing and cap

2 inch ø PVC pipe

w/ 5 ft of screen between 20 – 25 ft bgs

20 ft top of screen

25 ft bottom of screen

Wittman Hydro Planning Associates
Water Resource Planning Consultants

WELL BORING LOG

Boring: S2

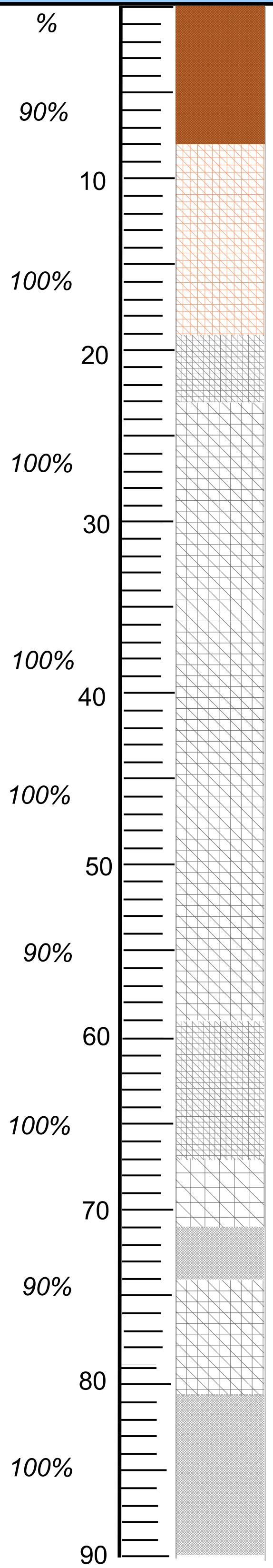
Date: 6/24/2009

Client: City of Bloomington
Driller: Layne – Matt White
Logged by: Sam Lax

Location: SW Bloom- Stark
Latitude: 40.43095 N
Longitude: -89.07204 W

ToC Elevation: 709.5(ft)
Grade Elevation (GPS): 706.0(ft)
Boring Diameter: 4 (in)

Recovery Depth Material Description Well Construction



SOIL, moist. dark brown to yellow
clayey soil, sandy from 7-8

loose, yellow, poorly sorted, s-l GRAVEL
Wet, rounded, with f-c SAND

sandier bottom foot

loose, medium gray, c- SAND
wet, few coal chips

loose wet m-c SAND and l- GRAVEL
70% C- SAND

GRAVEL, less SAND from 33 to 34 ft bgs

grading to s- GRAVEL and c-SAND
from36 to 39 ft bgs

s- GRAVEL from 46 to 48 ft bgs

l- GRAVEL from 52 to 54 ft bgs

m-c SAND 54 to 54.5 ft bgs

loose, medium gray, c- SAND

wet, 20% s- GRAVEL coarsening downwards

wet poorly sorted l- GRAVEL
40% pebble and cobble

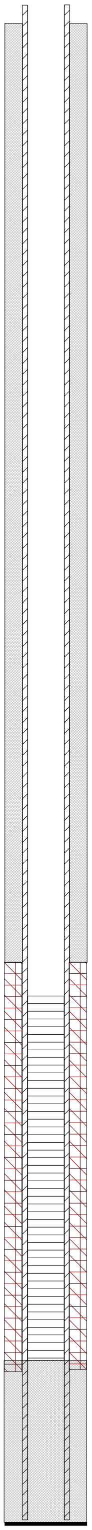
cohesive and soft moist CLAY
sandy in middle

wet, poorly sorted s-l GRAVEL

dense and dry CLAY (till)

End of boring at 90 ft bgs

Monitoring Well: MWS2



*Static water level at
9.0 ft bgs*

*Finished 3.5 ft above
grade
w/ pvc casing and cap*

2 inch ø PVC pipe

w/ 20 ft of screen
between 60 – 80 ft bgs

60 ft top of screen

80 ft bottom of screen

Wittman Hydro Planning Associates
Water Resource Planning Consultants

WELL BORING LOG

Boring: S3

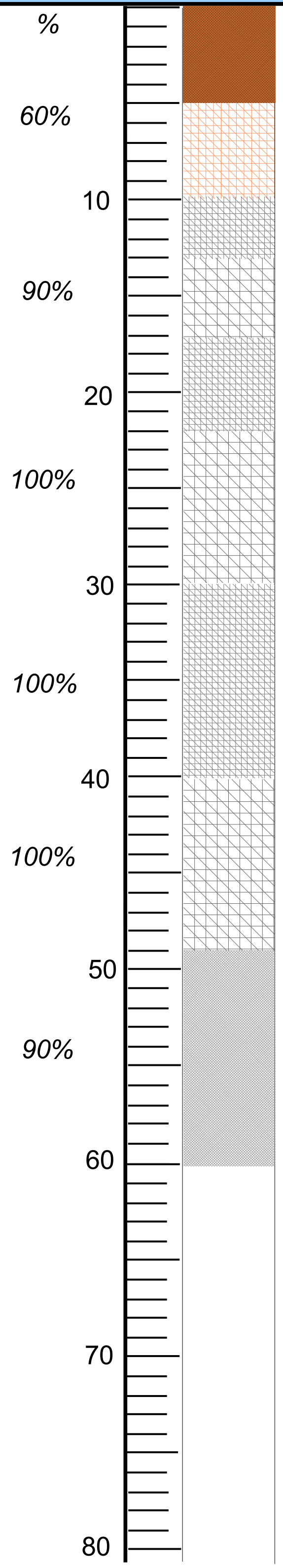
Date: 6/24/2009

Client: City of Bloomington
Driller: Layne – Matt White
Logged by: Sam Lax

Location: SW Bloom- Stark
Latitude: 40.43086 N
Longitude: -89.07584 W

ToC Elevation: 706.5(ft)
Grade Elevation (GPS): 701.7(ft)
Boring Diameter: 4 (in)

Recovery Depth Material Description Well Construction



SOIL, moist. dark brown to yellow clayey sandy soil

loose, yellow, poorly sorted, rounded GRAVEL w/ f -c sand and silt

loose, medium gray, well sorted m- SAND wet, coarsening downwards

loose s-m yellow to gray GRAVEL and c- SAND

loose wet gray c- SAND some 20% gravel

loose wet l- GRAVEL cobbles at 23 ft bgs
grading to s- GRAVEL to 30 ft bgs

loose wet gray f-c SAND
50% s- GRAVEL from 33 to 34 ft bgs
COBBLES from 37 to 39 ft bgs

loose wet c- SAND and s- GRAVEL
grading to l- GRAVEL from 43 to 48 ft bgs
Clayey GRAVEL from 48 to 49 ft bgs

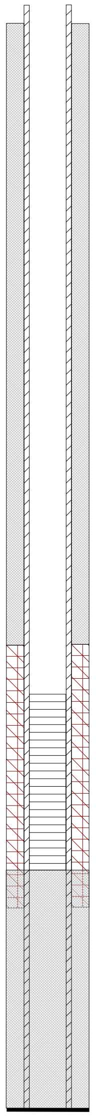
med-gray CLAY (till)

dry and hard CLAY from 49 - 58 ft bgs

dry and gravelly 58 to 60 ft bgs

End of boring at 60 ft bgs

Monitoring Well: MWS3



Finished 4.8 ft above grade
w/ pvc casing and cap
Static 5.3 ft bgs

2 inch ø PVC pipe

w/ 10 ft of screen between 40 – 50 ft bgs

40 ft top of screen

50 ft bottom of screen

Wittman Hydro Planning Associates
Water Resource Planning Consultants

WELL BORING LOG

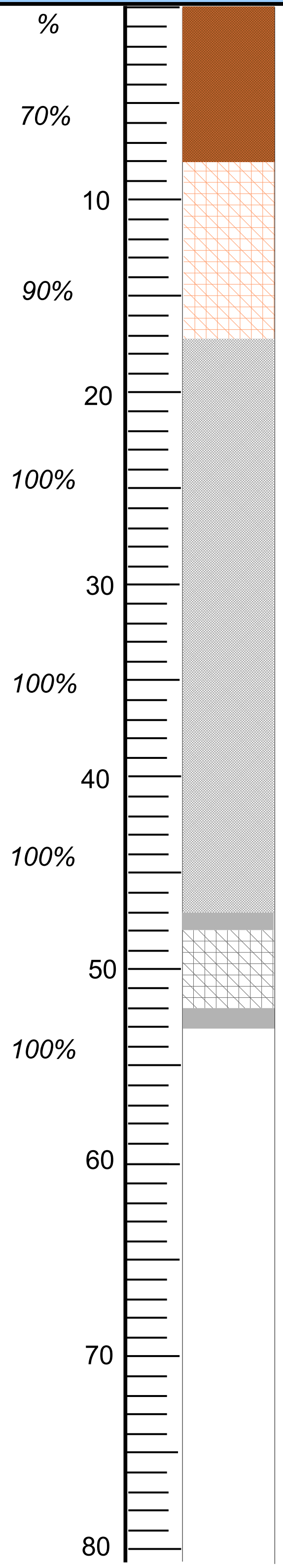
Monitoring Well:MWS5

Client: City of Bloomington
Driller: Layne Christensen
Logged by: Layne

Method: Dual Tube
Location: SW Bloom- Stark
Latitude: 40.42980 N
Longitude: -89.07340 W

Date: 7/25/2009
ToC Elevation: 708.2 (ft)
Grade Elevation (GPS): 704.6(ft)
Boring Diameter: 5 (in)

Recovery Depth | Material Description | Well Construction



TOP SOIL. Top 2 ft of dark brown and 6 ft of gray CLAY.

Coarse SAND and GRAVEL.

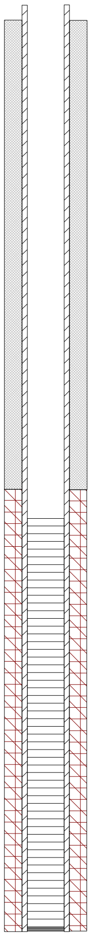
Fine SAND.

Gray CLAY.

SAND and GRAVEL.

Gray CLAY.

End of boring just bellow 52 ft bgs



Static water level: 8 ft bgs

Finished 3.6 ft above grade
With pvc casing and cap

2 inch Ø pvc pipe

w/ 20 ft of screen
between 32 – 52 ft bgs

32 ft top of screen

52 ft bottom of screen

Wittman Hydro Planning Associates
Water Resource Planning Consultants

WELL BORING LOG

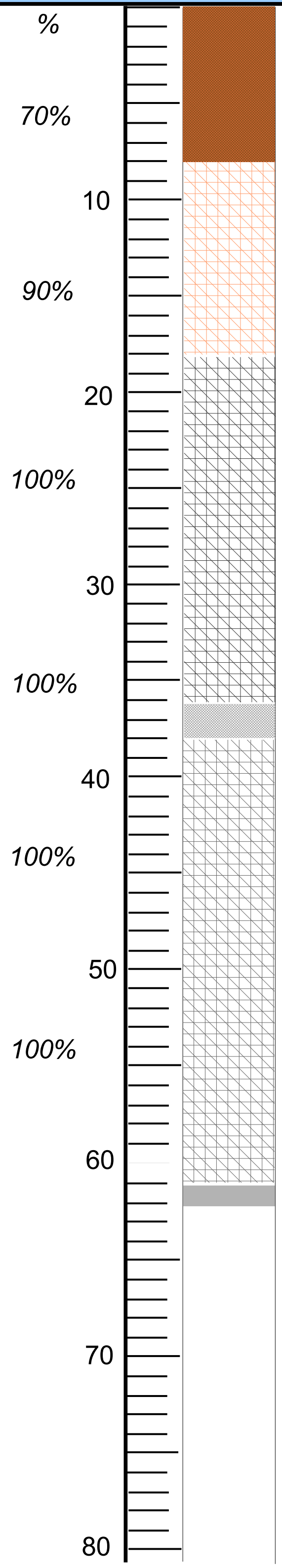
Monitoring Well:MWS6

Client: City of Bloomington
Driller: Layne Christensen
Logged by: Layne

Method: Dual Tube
Location: SW Bloom- Stark
Latitude: 40.4320 N
Longitude: -89.0734 W

Date: 7/30/2009
ToC Elevation: 705.8 (ft)
Grade Elevation (GPS): 702.8(ft)
Boring Diameter: 5 (in)

Recovery	Depth	Material Description	Well Construction



TOP SOIL. Top 2 ft of dark brown and 6 ft of gray CLAY.

Brown SAND and GRAVEL.

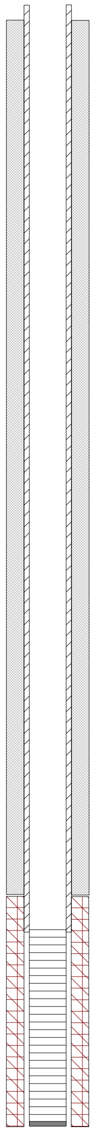
Gray SAND and GRAVEL.

Fine SAND.

Medium SAND and GRAVEL.

Gray CLAY.

End of boring just bellow 62 ft bgs.



Static water level: 8 ft bgs

Finished 3.0 ft above grade
With PVC casing and cap

2 inch Ø PVC pipe

w/ 10 ft of screen
between 52 – 62 ft bgs

52 ft top of screen

62 ft bottom of screen

Wittman Hydro Planning Associates
Water Resource Planning Consultants

WELL BORING LOG

Boring: S7

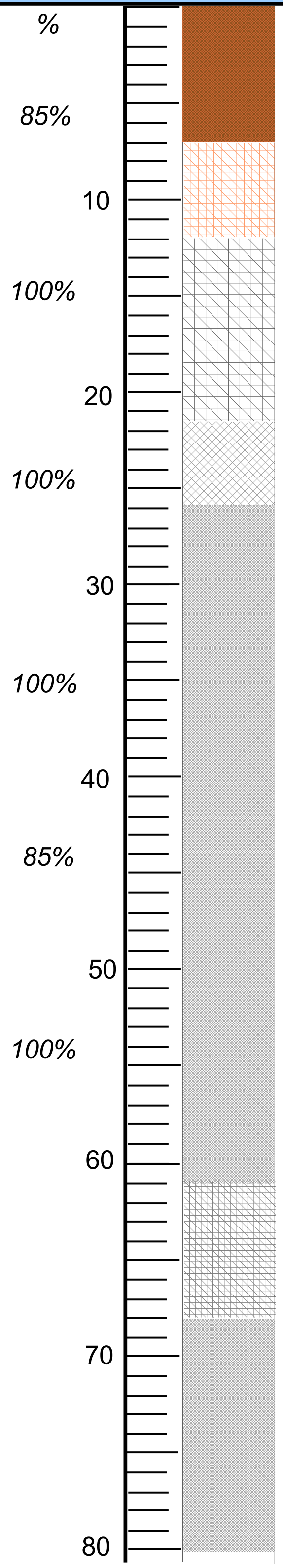
Date: 6/9/2009

Client: City of Bloomington
Driller: Layne – Mat White
Logged by: Sam Lax

Location: SW Bloomington- Stark
Latitude: 40.4392
Longitude: -89.0740

ToC Elevation: 707.2(ft)
Grade Elevation: 703.2(ft)
Boring Diameter: 4 (in)

Recovery Depth | Material Description | Well Construction



SOIL, wet. Top 3 ft of dark brown and 4 ft of yellow clayey sandy soil, gravelly bottom 1 ft.

loose, yellow, poorly sorted, round GRAVEL w/ f -c sand and silt, lens of dark gray c-sand larger gravel at bottom.

loose, gray, poorly sorted, round s- GRAVEL
small gravel to coarse sand on top
coarsening down
6 in dark gray sand at 15 ft bgs.
bottom 4 ft coarser sand, relatively clean.

f-m light gray clayey f-m SAND on top 3-4 ft
(5% c-sand, 55% fine sand)

medium gray dry CLAY
5% small gravel top 3 ft
30% gravel around 29 ft bgs

increased round gray gravel around 35 ft bgs

m-c sandy clay around 38-39 ft bgs

sandy and gravelly, rigid around 45 ft bgs, dry

48 through 55 ft bgs - softer to drill

sandy at 55 ft bgs looser clay

coarsening sand and small gravel bottom 3 ft
denser at 60 ft bgs smooth transition to
sand around 61 ft bgs

loose, medium to dark gray, sorted c- SAND

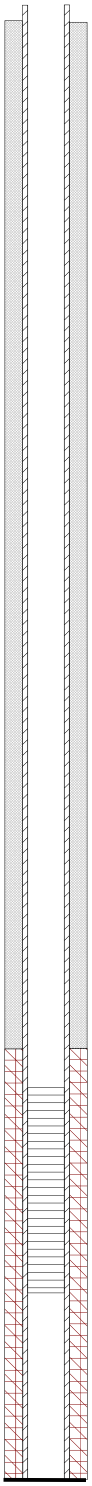
dense medium gray CLAY

dry - 3 in boulder at 68 ft bgs

dense sticky clay to 80 ft bgs

End of boring at 80 ft bgs

Monitoring Well: MWS7



Finished 4 ft above grade
w/ pvc casing and cap

2 inch ø PVC pipe

W/ 10 ft screen

60.5 ft top of
screen

70.5 ft bottom of
screen

Wittman Hydro Planning Associates
Water Resource Planning Consultants

WELL BORING LOG

Boring: S4

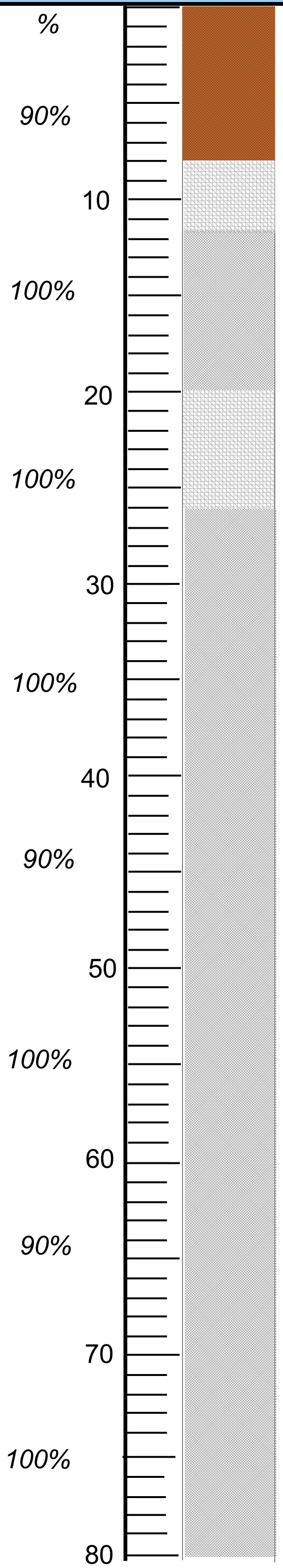
Date: 6/22/2009

Client: City of Bloomington
Driller: Layne – Mat White
Logged by: Sam Lax

Location: SW Bloomington- Stark
Latitude: 40.43297 N
Longitude: -89.07969 W

ToC Elevation:
Grade Elevation: 700(ft)
Boring Diameter: 4 (in)

Recovery Depth Material Description Well Construction



SOIL, moist, dark brown soft
sandy and gravelly from 6 to 8 ft bgs

dark brown silt and m-c SAND, wet with
s-GRAVEL coarser on top

dry, medium gray CLAY
5-10% – GRAVEL hard (till)

wet, brownish m-c SAND
10% GRAVEL top, gravelly downwards

light gray, moist CLAY
gravelly from 29 to 30 ft bgs

5–10% GRAVEL

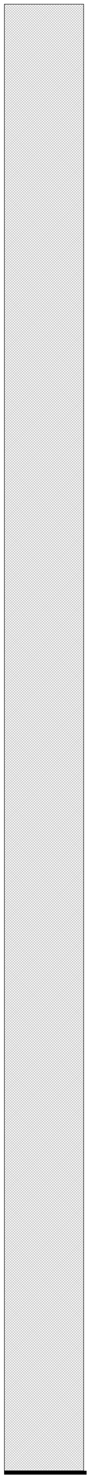
f-m SAND in CLAY from 33 to 40 ft bgs
loose sand around 36 ft bgs

dry, dense from 40 to 47 ft bgs

c- sandy from 48 to 49.5 ft bgs

Dry and hard CLAY
5-10% GRAVEL (till) from 40 to 80 ft bgs

End of boring at 80 ft bgs



No well installed. Plugged with bentonite grout and chips

Wittman Hydro Planning Associates
Water Resource Planning Consultants

WELL BORING LOG

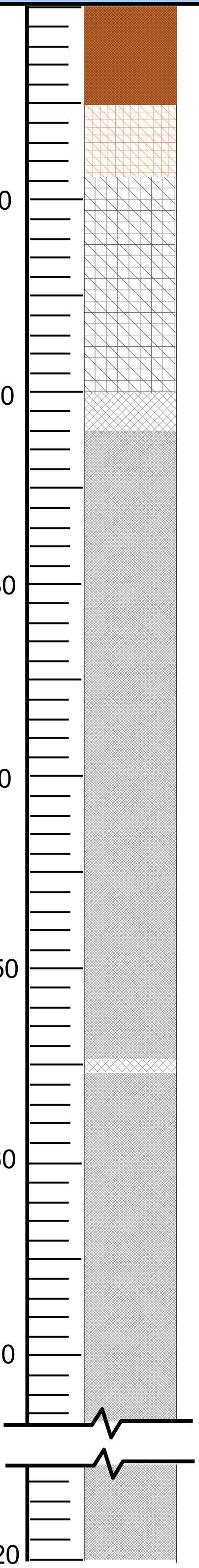
Boring: S8

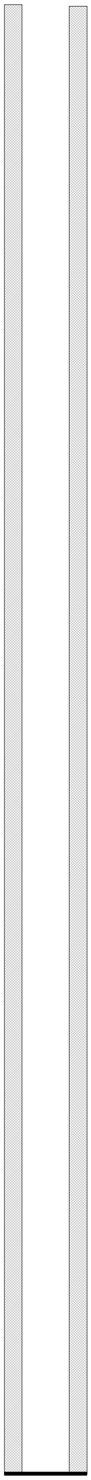
Date: 6/16/2009

Client: City of Bloomington
Driller: Layne – Mat White
Logged by: Sam Lax

Location: SW Bloomington- Stark
Latitude: 40.4394 N
Longitude: -89.0845 W

ToC Elevation:
Grade Elevation: 702 (ft)
Boring Diameter: 4 (in)





Recovery	Depth	Material Description	Well Construction
%		SOIL, moist, dark brown soft to yellow sandy to gravelly around 5 ft bgs.	
80%		loose, yellow, poorly sorted, round s-l GRAVEL w/ f -c sand and silt.	*No well installed. Plugged with bentonite grout and chips*
	10		
40%		loose, gray, poorly sorted, round s- GRAVEL coarse sand little silt and clay, wet, non-cohesive	
	20	light gray clayey f-m SAND cohesive	
100%		6 in loose f-c clayey SAND from 22.5 ft bgs	
		medium gray dry CLAY 5- 10% small gravel to coarse sand grains (till)	
	30		
		5 in m- SAND well sorted med dark gray, around 33 ft bgs	
100%			
	40		
		m-sandy CLAY from 40 to 45, dry, dense	
100%			
	50		
90%			
		6 inches of f-c SAND at 55 ft bgs	
		sandy CLAY (till) to 62 ft bgs	
	60		
100%			
		gravelly till from 68 – 70 ft bgs	
	70		
		same until 120 ft bgs, dry, dense CLAY – till sandy from 106-110 and from 115- 120 ft bgs	
100%			
	120	*end of boring at 120 ft bgs*	

Wittman Hydro Planning Associates
Water Resource Planning Consultants

WELL BORING LOG

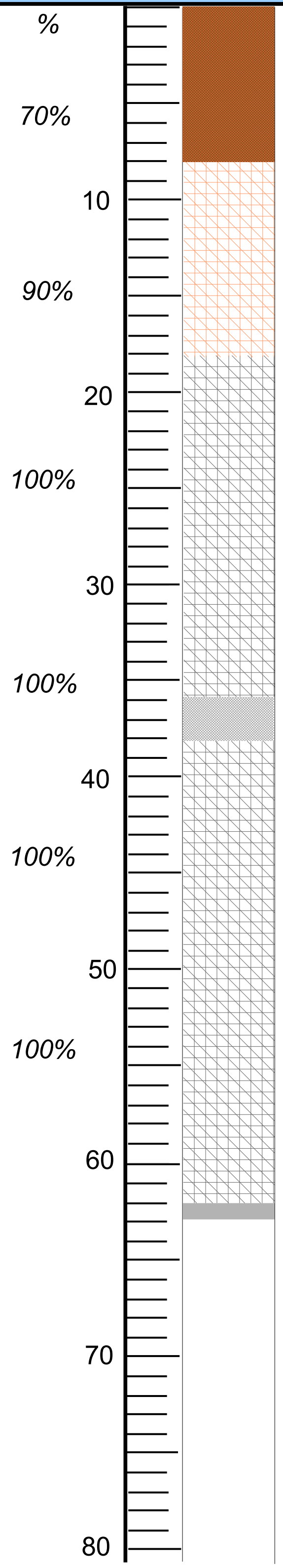
Test Well: S #1 TW

Client: City of Bloomington
Driller: Layne Christensen
Logged by: Layne

Method: Dual Tube
Location: SW Bloom- Stark
Latitude: 40.43090 N
Longitude: -89.07340 W

Date: 7/23/2009
ToC Elevation: 3.6 (ft)
Grade Elevation (GPS): 705.2 (ft)
Boring Diameter: 16 (in)

Recovery Depth | Material Description | Well Construction



TOP SOIL. Top 2 ft of dark brown and 6 ft of gray clayey sandy soil.

Brown SAND and GRAVEL.

Gray SAND and GRAVEL.

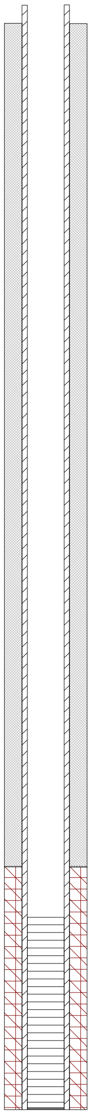
Fine SAND.

Medium SAND and GRAVEL.

Coarse SAND and GRAVEL.

Gray CLAY.

End of boring just bellow 62 ft bgs



Static water level: 8 ft bgs

10 inch steel casing
8 inch stainless screen
screen length 10 ft

52 ft top of screen

62 ft bottom of screen

Existing Well Logs (Danvers Valley Cross-section)

ILLINOIS STATE GEOLOGICAL SURVEY

Private Water Well	**Top**	**Bottom**
yellow clay	0	5
green clay	5	24
gray clay	24	26
green clay	26	39
gray clay with streaks of gravel	39	190
soft clay with sand	190	201
gray clay	201	204
gravel	204	221
gray clay	221	250
Total Depth		250

Casing: 5" PVC from 0' to 250'
Screen: 10' of 5" diameter 20 slot
Grout: DRILL CUTTINGS from 30 to 208.
Grout: BENTONITE from 10 to 30.
Water from gravel at 211' to 221'.
Static level 160' below casing top which is 1' above GL
Pumping level 220' when pumping at 10 gpm for 2 hours

Address of well: Evergreen Lake Rd. R.R. #1
Hudson, IL

Location source: Location from permit

Permit Date: October 27, 1997 **Permit #:** 203-561

COMPANY Cole, Raymond J.
FARM Uphoff, Neal
DATE DRILLED **NO.**
ELEVATION 0 **COUNTY NO.** 21975
LOCATION SE NW SE
LATITUDE 40.654259 **LONGITUDE** -89.051028
COUNTY Woodford **API 122032197500** **1 - 25N - 1E**

ILLINOIS STATE GEOLOGICAL SURVEY

Private Water Well	**Top**	**Bottom**
no record	0	109
sand & gravel	109	111
no record	111	282
sand & gravel	282	283
no record	283	284
sand & gravel	284	285
no record	285	295
sand & gravel	295	300
Total Depth		300

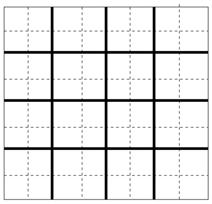
Casing: 5" SDR 21 from -1' to 296'
Screen: 4' of 5" diameter 20 slot
Grout: HOLE PLUG from 0 to 0.
Water from sand & gravel at 295' to 300'.
Static level 72' below casing top which is 1' above GL
Pumping level 80' when pumping at 10 gpm for 0 hours

Permanent pump installed at 100' on May 24, 1989, with a capacity of 10 gpm

Location source: Location from permit

Permit Date: May 11, 1989 **Permit #:** 011276

COMPANY Layten, James
FARM Lampert, Steve
DATE DRILLED May 24, 1989 **NO.** 2
ELEVATION 0 **COUNTY NO.** 22536
LOCATION SW SW SE
LATITUDE 40.650788 **LONGITUDE** -89.032989
COUNTY McLean **API** 121132253600 6 - 25N - 2E



ILLINOIS STATE GEOLOGICAL SURVEY

Water Well	**Top**	**Bottom**
no record	0	48
blue gravel	48	51
no record	51	91
blue gravel	91	94
no record	94	126
sand	126	130
no record	130	230
blue gravel	230	234
no record	234	265
blue gravel	265	280
Total Depth		280

Casing: 4" 11 LBS from 4' to 274'
Screen: 4' of 5" diameter 20 slot
Water from gravel at 265' to 280'.
Static level 60' below casing top which is 1' above GL
Pumping level 60' when pumping at 10 gpm for 2 hours

Permanent pump installed at 84'

Driller's Log filed
Location source: Platbook verified

Permit Date: August 26, 1977 **Permit #:** 66015

COMPANY Layten, James
FARM Dowen, Richard
DATE DRILLED September 3, 1977 **NO.** 1
ELEVATION 0 **COUNTY NO.** 21300
LOCATION NW SW SW
LATITUDE 40.652948 **LONGITUDE** -89.002956
COUNTY **McLean** **API** **121132130000** **4 - 25N - 2E**

ILLINOIS STATE GEOLOGICAL SURVEY

Industrial Water Well	**Top**	**Bottom**
SS #66927 (0'-340')	0	0
yellow clay	0	13
gray clay	13	29
sand	29	30
gray clay	30	52
sand & gravel	52	56
gray clay	56	143
sand	143	144
wood, brown drift	144	148
green clay	148	167
green sand	167	169
green clay	169	215
white soft limestone	215	218
green clay	218	235
gray clay	235	261
sand	261	275
gray clay	275	302
gray clay w/coal & wood	302	307
gray sand w/medium boulders	307	327
sticky gray clay	327	332
green clay	332	343
Total Depth		343

Casing: 4" SDR 21 from -1' to 316'
Screen: 10' of 4" diameter 20 slot
Grout: CUTTINGS from 0 to 300.

Permit Date: March 24, 1989 **Permit #:** 139679

COMPANY David M. Smith
FARM Whitwood Farm Service
DATE DRILLED April 30, 1989 **NO.**
ELEVATION 0 **COUNTY NO.** 22537
LOCATION NW NE NW
LATITUDE 40.649153 **LONGITUDE** -88.998053
COUNTY **McLean** **API** **121132253700** **9 - 25N - 2E**

ILLINOIS STATE GEOLOGICAL SURVEY

Size hole below casing: 6.75"

Water from sand & gravel at 302' to 327'.
Static level 60' below casing top which is 1' above GL
Pumping level 60' when pumping at 0 gpm for 2 hours

Permanent pump installed at 100' on April 30, 1989, with a capacity of 11 gpm

Sample set # 66927 (0' - 340') Received: May 3, 1989

Location source: Location from permit

ILLINOIS STATE GEOLOGICAL SURVEY

Private Water Well	**Top**	**Bottom**
black dirt	0	2
yellow sand	2	17
gray clay	17	64
sand	64	65
gray clay	65	82
sand	82	83
gray clay	83	88
sand	88	90
gray clay	90	131
sand	131	139
green clay	139	148
sand	148	151
clay	151	152
sand	152	155
wood	155	160
green clay	160	165
green sand	165	166
green clay	166	176
gray clay	176	254
sand	254	268
gray clay	268	271
sand	271	277
gray clay	277	285
sand	285	314

Permit Date: March 24, 1989 **Permit #:** 010090

COMPANY David M. Smith

FARM Beck, Charles

DATE DRILLED March 25, 1989 **NO.**

ELEVATION 0 **COUNTY NO.** 22535

LOCATION SE SW SE

LATITUDE 40.650734 **LONGITUDE** -88.990869

COUNTY McLean **API 121132253500** **4 - 25N - 2E**

gray clay	314	325
Total Depth		325

Casing: 4" SDR 21 from -1' to 300'
Screen: 10' of 4" diameter 20 slot
Grout: CUTTINGS from 0 to 295.
Size hole below casing: 6.75"

Water from sand & gravel at 285' to 314'.
Static level 50' below casing top which is 1' above GL
Pumping level 1' when pumping at 50 gpm for 2 hours

Permanent pump installed at 100' on March 26, 1989, with a capacity of 10 gpm

Location source: Location from permit

ILLINOIS STATE GEOLOGICAL SURVEY

Private Water Well	**Top**	**Bottom**
yellow clay	0	13
gray clay	13	35
green clay	35	37
gray clay	37	162
gravel-sand insufficient gravel for gpm	162	167
gravel	167	192
gray clay	192	194
green clay	194	202
gravel	202	204
gray & brown clay soft	204	211
gray clay soft	211	215
greenish gray clay	215	219
gray clay with gravel	219	228
gravel	228	230
tan clay with gravel	230	235
gray clay with gravel	235	238
gravel - insufficient gravel for gpm	238	242
gravel with clay	242	248
gravel - insufficient gravel for gpm	248	253
sand & gravel (no mud loss)	253	260
sand firm - insufficient gravel for gpm	260	265
gravel with clay showing - dirty	265	290
good gravel	290	308
Total Depth		308

Permit Date: July 15, 1997 **Permit #:** 113-059

COMPANY Layten, James
FARM Siegrist, Jeff
DATE DRILLED July 23, 1997 **NO.** 1
ELEVATION 0 **COUNTY NO.** 23418
LOCATION NW NW SE
LATITUDE 40.656423 **LONGITUDE** -88.993407
COUNTY McLean **API 121132341800** **4 - 25N - 2E**

Casing: 5" SDR 21 from -1' to 240'
5" SDR 17 from 240' to 298'

Screen: 6' of 5" diameter 20 slot

Grout: BENTONITE from 0 to 0.

Water from gravel at 0' to 0'.

Static level 62' below casing top which is 1' above GL

Pumping level 67' when pumping at 30 gpm for 0 hours

Permanent pump installed at 100' on August 22, 1997, with a capacity of 30 gpm

Address of well: R.R.
Hudson, IL

Location source: Location from permit

ILLINOIS STATE GEOLOGICAL SURVEY

Private Water Well	**Top**	**Bottom**
yellow clay	0	14
tan clay	14	17
gray clay	17	44
sand & gravel	44	46
gray clay	46	70
peat	70	80
gray clay	80	102
peat with wood	102	111
gray clay	111	165
gray clay - gravel	165	170
gray clay	170	180
green clay	180	185
gray clay	185	194
gravel with clay showing	194	195
gravel	195	197
gray clay	197	205
tan clay	205	250
sand & gravel	250	251
gray clay	251	255
sand & gravel	255	256
gray clay	256	261
sand - gravel - clay	261	265
sand & gravel	265	278
Total Depth		278

Permit Date: August 28, 1997 **Permit #:** 113-079

COMPANY Layten, James

FARM Selby, Robert

DATE DRILLED September 15, 1997 **NO.** 1

ELEVATION 0 **COUNTY NO.** 23417

LOCATION SW SW NW

LATITUDE 40.658773 **LONGITUDE** -88.964237

COUNTY McLean **API 121132341700** **2 - 25N - 2E**

Casing: 5" SDR 21 from -1' to 251'
5" SDR 17 from 251' to 271'

Screen: 4' of 5" diameter 20 slot

Grout: BENTONITE from 0 to 0.

Water from sand & gravel at 265' to 278'.

Static level 51' below casing top which is 1' above GL

Pumping level 52' when pumping at 12 gpm for 0 hours

Permanent pump installed at 80' on September 18, 1997, with a capacity of 12 gpm

Location source: Location from permit

ILLINOIS STATE GEOLOGICAL SURVEY

Private Water Well	**Top**	**Bottom**
yellow clay	0	8
yellow gravel	8	9
yellow clay	9	19
gray clay	19	32
green clay	32	35
gray clay	35	87
peat (wood)	87	90
gravel (sharp angular)	90	95
gray clay	95	108
green clay	108	113
gray clay	113	121
gravel	121	122
gray clay	122	135
gravel	135	136
gray clay	136	150
gravel	150	157
gray clay	157	176
green clay	176	190
gravel	190	191
green clay	191	196
light brown clay	196	213
gray clay	213	223
soft brown clay	223	230
gravel	230	231

Permit Date: June 30, 1993 **Permit #:**

COMPANY Layten, James

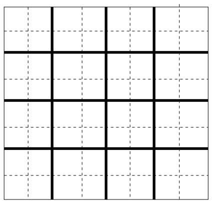
FARM Underwood, Fred

DATE DRILLED July 14, 1993 **NO.** 1

ELEVATION 0 **COUNTY NO.** 22934

LOCATION SE SW NW

LATITUDE 40.658745 **LONGITUDE** -88.961839



COUNTY McLean **API** 121132293400 **2 - 25N - 2E**

gray clay	231	255
gravel	255	276
gray clay	276	280
Total Depth		280

Casing: 5" SDR 21 from -1' to 266'
Screen: 4' of 5" diameter 20 slot
Grout: BENTONITE from 0 to 0.
Water from gravel at 255' to 276'.
Static level 40' below casing top which is 1' above GL
Pumping level 44' when pumping at 0 gpm for 0 hours

Permanent pump installed at 80' on July 15, 1993, with a capacity of 12 gpm

Address of well: R.R.
Hudson, IL

Location source: Location from permit

ILLINOIS STATE GEOLOGICAL SURVEY

Private Water Well	**Top**	**Bottom**
no record	0	19
yellow sand & gravel	19	21
no record	21	45
yellow sand & gravel	45	55
blue sand & gravel	55	60
no record	60	85
sand & gravel	85	86
no record	86	142
sand	142	147
no record	147	177
sand & gravel	177	178
no record	178	179
sand & gravel	179	195
Total Depth		190

Casing: 5" SDR 21 PLASTIC from 0' to 186'
Screen: 4' of 5" diameter 20 slot
Grout: MUD from 0 to 0.
Size hole below casing: 0"

Water from sand & gravel at 179' to 195'.
Static level 44' below casing top which is 1' above GL
Pumping level 46' when pumping at 10 gpm for 1 hour

Permanent pump installed at 60' on , with a capacity of 10 gpm

Location source: Location from permit

Permit Date: August 4, 1986 **Permit #:** 125708

COMPANY Layten, James
FARM Davison, Ray
DATE DRILLED August 19, 1986 **NO.** 2
ELEVATION 728GL **COUNTY NO.** 21102
LOCATION NW NE NE
LATITUDE 40.662958 **LONGITUDE** -89.048931
COUNTY **Woodford** **API** **122032110200** **1 - 25N - 1E**

Existing Well Logs (Sugar Creek Valley Cross-sections)

ILLINOIS STATE GEOLOGICAL SURVEY

Test Hole	**Top**	**Bottom**
SS #52414 (0 - 268')	0	0
topsoil	0	1
yellow clay	1	8
sand & gravel	8	17
gravelly clay, peat, 55-60	17	60
gravelly clay, sand streaks	60	77
sand & gravel	77	88
clay & peat	88	100
soft gravelly clay	100	165
gravelly clay	165	191
clay & gravel, mixed	191	240
dark clay	240	267
broken lime, white shale	267	268
Total Depth		268

Sample set # 52414 (0' - 268') Received: January 3, 1966

Permit Date: **Permit #:**

COMPANY owner

FARM Normal, City of

DATE DRILLED January 1, 1965 **NO.** 14-65

ELEVATION 0 **COUNTY NO.** 22257

LOCATION 800'S line, 1350'E line of SE

LATITUDE 40.431641 **LONGITUDE** -89.062242

COUNTY McLean **API 121132225700** **23 - 23N - 1E**

ILLINOIS STATE GEOLOGICAL SURVEY

Test Hole	Top	Bottom
SS #52326	0	0
top soil	0	5
yellow clay sandy	5	12
sand & gravel	12	17
blue clay	17	23
sand & gravel mud streaks	23	30
sand & gravel mud streaks	30	35
sand & gravel mud	35	40
sand & gravel mud	40	43
clay	43	50
sand & gravel dirty	50	55
sand & gravel	55	56
clay	56	60
clay hard	60	85
clay, boulders at 92	85	92
gravelly clay firm	92	100
soft sticky clay	100	131
gravelly clay hard	131	147
dirty sand & gravel	147	157
gravelly clay	157	210
gravelly clay peat	210	215
gravelly clay	215	265
clay, peat	265	270
clay, dirty sand & gravel	270	283

Permit Date: **Permit #:**

COMPANY owner

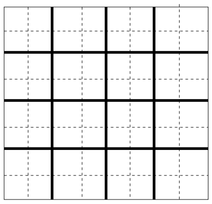
FARM Normal, City of

DATE DRILLED January 1, 1965 **NO.** 8-65

ELEVATION 0 **COUNTY NO.** 22073

LOCATION 2550'N line, 1330'E line of NE

LATITUDE 40.436994 **LONGITUDE** -89.062378



COUNTY **McLean** **API** **121132207300** **23 - 23N - 1E**

Bedrock lime & shale	283	284
Total Depth		284

Sample set # 52326 (0' - 284') Received: December 16, 1965

ILLINOIS STATE GEOLOGICAL SURVEY

Test Hole	Top	Bottom
SS #52330	0	0
top soil	0	4
yellow clay	4	8
yellow sand	8	25
clay	25	37
sand & gravel clay streaks	37	40
sand & gravel clay	40	45
sand & gravel clay	45	50
sand & gravel clay	50	55
sand & gravel clay	55	60
sand & gravel clay	60	63
gravelly clay & boulders	63	100
gravelly clay	100	125
soft sticky clay	125	131
gravelly clay	131	143
dirty sand & clay mixed	143	148
gravelly blue clay	148	216
bedrock, lime, shale at	216	216
Total Depth		216

Sample set # 52330 (0' - 216') Received: December 23, 1965

Permit Date: **Permit #:**

COMPANY owner
FARM Normal, City of
DATE DRILLED January 1, 1965 **NO.** 12-65
ELEVATION 0 **COUNTY NO.** 22075
LOCATION 450'N line, 1000'W line of NW
LATITUDE 40.442866 **LONGITUDE** -89.054189
COUNTY McLean **API 121132207500** **24 - 23N - 1E**

ILLINOIS STATE GEOLOGICAL SURVEY

Irrigation Well	**Top**	**Bottom**
yellow clay	0	12
mixed yellow clay sand gravel	12	40
gray clay	40	46
medium gray sand & gravel	46	93
gray clay	93	100
Total Depth		100

Casing: 6" SDR 21 from -2' to 73'
Screen: 20' of 6" diameter 25 slot
Grout: HOLE PLUG/SLRY from 0 to 71.
Size hole below casing: 10"

Water from sand & gravel at 46' to 93'.
Static level 15' below casing top which is 2' above GL
Pumping level 20' when pumping at 0 gpm for 2 hours
Permanent pump installed at 63' on June 22, 1996, with a capacity of 300 gpm

Additional location info: Lot: Subdivision:
Parks & Recreation

Location source: Location from permit

Permit Date: July 17, 1996 **Permit #:**

COMPANY David M. Smith
FARM Bloomington, City of #3
DATE DRILLED June 20, 1996 **NO.**
ELEVATION 0 **COUNTY NO.** 23321
LOCATION NW NW SE
LATITUDE 40.450511 **LONGITUDE** -89.047372
COUNTY **McLean** **API** **121132332100** **13 - 23N - 1E**

ILLINOIS STATE GEOLOGICAL SURVEY

Test Hole	**Top**	**Bottom**
SS #52310	0	0
top soil	0	1
yellow clay	1	5
yellow clay & sand	5	10
gravelly yellow clay	10	15
clay	15	31
sand	31	35
soft clay & gravel	35	58
sand & gravel	58	60
sand & gravel	60	65
sand & gravel	65	70
sand & gravel	70	73
sand & gravel clay	73	75
gravelly clay	75	80
soft sticky clay	80	120
gravely clay thin sand streak	120	125
hard gravelly clay	125	142
clay	142	143
clay containing gravel	143	145
soft clay sand & gravel mixed	145	168
soft shaly looking clay containing gvl	168	200
sand, gravel, clay, & peat	200	238
soft shaly clay	238	246
shale	246	247

Permit Date: **Permit #:**

COMPANY owner

FARM Normal, City of

DATE DRILLED January 1, 1965 **NO.** 2-65

ELEVATION 0 **COUNTY NO.** 22070

LOCATION 50'S line, 50'W line of SW

LATITUDE 40.429093 **LONGITUDE** -89.0953

COUNTY McLean **API 121132207000** **22 - 23N - 1E**

Total Depth 247

Sample set # 52310 (0' - 247') Received: December 13, 1965

ILLINOIS STATE GEOLOGICAL SURVEY

Test Hole	**Top**	**Bottom**
SS #52311	0	0
top soil	0	1
yellow clay	1	5
yellow sand & gravel	5	15
yellow sand & gravel	15	18
blue clay	18	37
sand & gravel	37	40
sand & gravel	40	45
sand & gravel clay	45	50
sand & gravel dirty	50	55
sand & gravel mud streaks	55	60
sand gravel & boulders	60	65
sand gravel & boulders	65	70
sand gravel & boulders	70	74
clay	74	75
clay & peat	75	90
clay sticky	90	95
gravelly clay	95	135
gravelly clay sticky	135	138
soft clay, peat & gravel mud	138	159
boulders	159	160
soft gravelly clay sticky	160	169
shale & lime bedrock	169	170
Total Depth		170

Permit Date: **Permit #:**

COMPANY owner

FARM Normal, City of

DATE DRILLED January 1, 1965 **NO.** 3-65

ELEVATION 0 **COUNTY NO.** 22079

LOCATION 20'N line, 2300'W line of NW

LATITUDE 40.42904 **LONGITUDE** -89.087176

COUNTY McLean **API 121132207900** **27 - 23N - 1E**

Sample set # 52311 (0' - 170') Received: December 13, 1965

ILLINOIS STATE GEOLOGICAL SURVEY

Test Hole	**Top**	**Bottom**
SS #52309	0	0
sand	0	5
dirty sand & gravel	5	10
sand & gravel cleaner	10	15
sand, some gravel	15	20
sand to small gravel	20	25
sand & gravel coarser	25	30
sand & gravel finer	30	35
sand to small gravel	35	40
sand & gravel	40	45
sand & gravel finer	45	50
sand & gravel coarser (dirty)	50	55
sand, gravel & boulders	55	60
sand, gravel & boulders	60	65
cemented sand & gravel	65	67
muddy sand & gravel	67	70
muddy sand & gravel	70	75
muddy sand & gravel	75	85
shaly looking clay	85	90
soft shaly looking clay gravelly	90	95
soft shaly looking clay gravelly	95	111
muddy gravel	111	115
gravelly clay	115	150
soft shale	150	165

Permit Date: **Permit #:**

COMPANY owner

FARM Normal, City of

DATE DRILLED January 1, 1965 **NO.** 1-65

ELEVATION 0 **COUNTY NO.** 22078

LOCATION 40'N line, 700'E line of NE

LATITUDE 40.429125 **LONGITUDE** -89.079066

COUNTY McLean **API 121132207800** **27 - 23N - 1E**

Total Depth	165

Sample set # 52309 (0' - 165') Received: December 13, 1965

ILLINOIS STATE GEOLOGICAL SURVEY

Test Hole	**Top**	**Bottom**
SS #52313	0	0
top soil & clay	0	7
sand & gravel	7	15
sand & gravel	15	20
sand & gravel	20	25
sand & gravel	25	29
dirty sand & gravel	29	35
sand & gravel	35	40
sand & gravel	40	45
sand & gravel	45	50
sand & gravel	50	55
sand & gravel	55	59
clay	59	60
Total Depth		60

Sample set # 52313 (0' - 60') Received: December 13, 1965

Permit Date: **Permit #:**

COMPANY owner

FARM Normal, City of

DATE DRILLED January 1, 1965 **NO.** 5-65

ELEVATION 0 **COUNTY NO.** 22077

LOCATION 20'N line, 1800'W line of NW

LATITUDE 40.429293 **LONGITUDE** -89.070013

COUNTY **McLean** **API** **121132207700** **26 - 23N - 1E**

Appendix B- Sieve Test Results

Chain of Custody Record

Associated Environmental, Inc
404 Pottawatomie - Manhattan, KS 66502
PH: 785-776-7755 FX: 785-776-0803

Client: WHPA
Project Name: BLOOMINGTON/START
Sampler's Name:
Signature:

SAMPLE INFORMATION

ANALYSIS REQUESTED:

Date	Time	Sample ID	Sample Point ID	Matrix	Number of Containers	Flex Wall Permeameter ASTM 5084	Constant Head Permeameter ASTM 2434	Grain Size & Hydrometer ASTM 422	Moisture Content ASTM 2216	Dry Bulk Density ASTM 2937	Liquid & Plastic Limits ASTM 4318	Proctor-Compaction ASTM 698	Specific Gravity ASTM 854	TOC/FOC Walkley-Black	Porosity	Textural Analysis	Sieve Analysis	Soils PH	AEI Lab #
		S1	MW S1	SOIL	1												X		0907011A
		S21	MW S2														X		B
		S22	MW S2														X		C
		S23	MW S2														X		D
		S31	MW S3														X		E
		S32	MW S3														X		F

#1 Relinquished by: Name: Signature: Time Date
Accepted by: Name: Signature: Time Date

#2 Relinquished by: Name: Signature: Time Date
Accepted by: Name: J. AMAYA Signature: Time 10:00 Date JUL 9-09

Send report to:

Special Instructions:

Page ____ of ____

Updated June 2008

Associated Environmental, Inc.
Soils Testing Laboratory

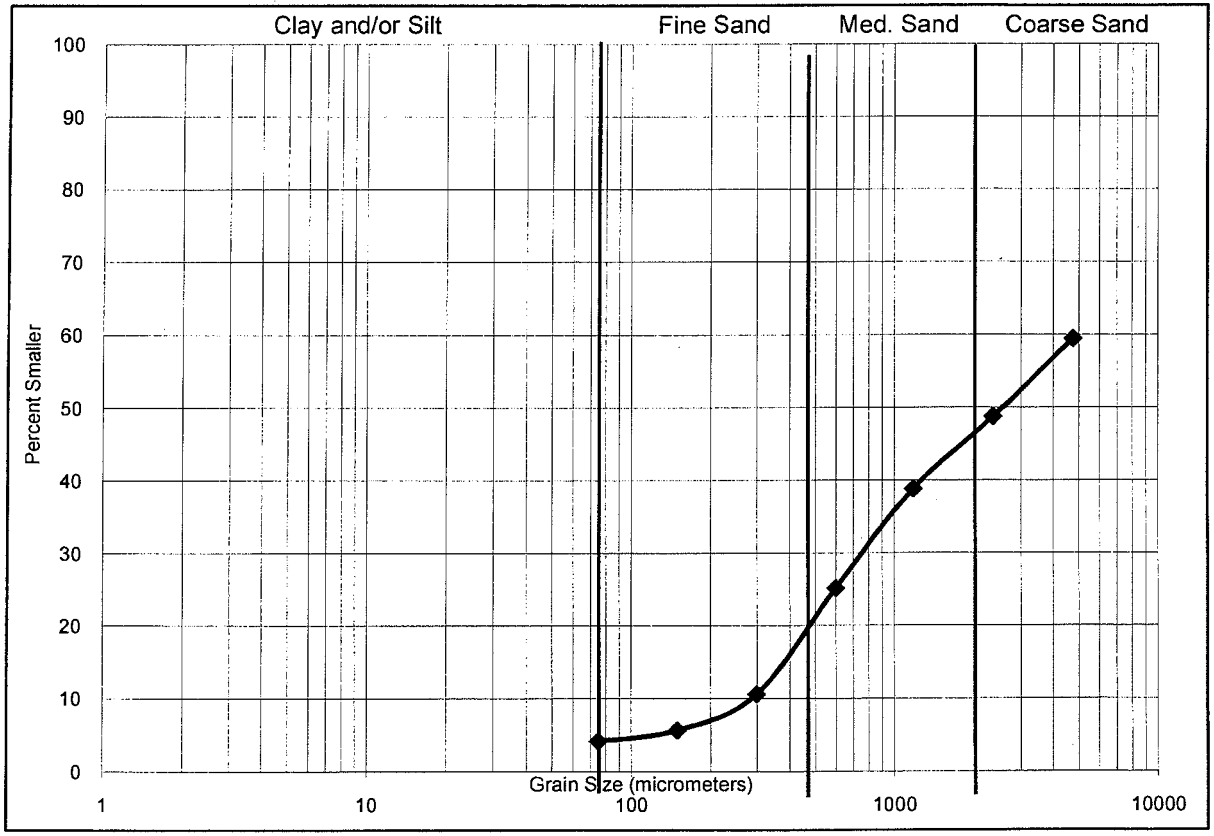
Laboratory Report

Grain Size Determination and Gradation Curve -- ASTM Test Method D 422-63(98)

Sample Identification: **S 1** (15 ft)
Client: **WHPA**

AEI Lab. No. **0907011A**
Client's Project: **Bloomington/Stark**

Sieve Size	Grain Size (micrometers)	Percent Smaller
4	4750	59.5
8	2360	48.8
16	1180	38.8
30	600	25.2
50	300	10.6
100	150	5.7
200	75	4.2



Complete below in accordance with ASTM Method D 422-63

Paragraph 18.1.3 Is sample greater than 5% sand or gravel? Yes X No
Paragraph 18.1.3.1 If yes, is sand or gravel more round than angular ? Yes No X
Paragraph 18.1.3.1 If yes, is sand or gravel: Hard & Durable ? Yes No
Weathered & Friable ? Yes No
Soft ? Yes No

Associated Environmental, Inc.

Soils Testing Laboratory

Calculations Sheet

Client:	**WHPA**
Project:	**Bloomington/Stark**
Sample ID:	**S 1**
AEI Lab. No.	**0907011A**

Grain Size:

Percent Passing:

Sample mass: **100**

Corrected mass: **100** If no hygroscopic moisture, enter sample mass in corrected mass.

Sieve Size	Mass Retained	Percent Passing
4	**40.55**	59.45
8	**51.23**	48.77
16	**61.16**	38.84
30	**74.82**	25.18
50	**89.38**	10.62
100	**94.33**	5.67
200	**95.8**	4.2

Associated Environmental, Inc.
Soils Testing Laboratory

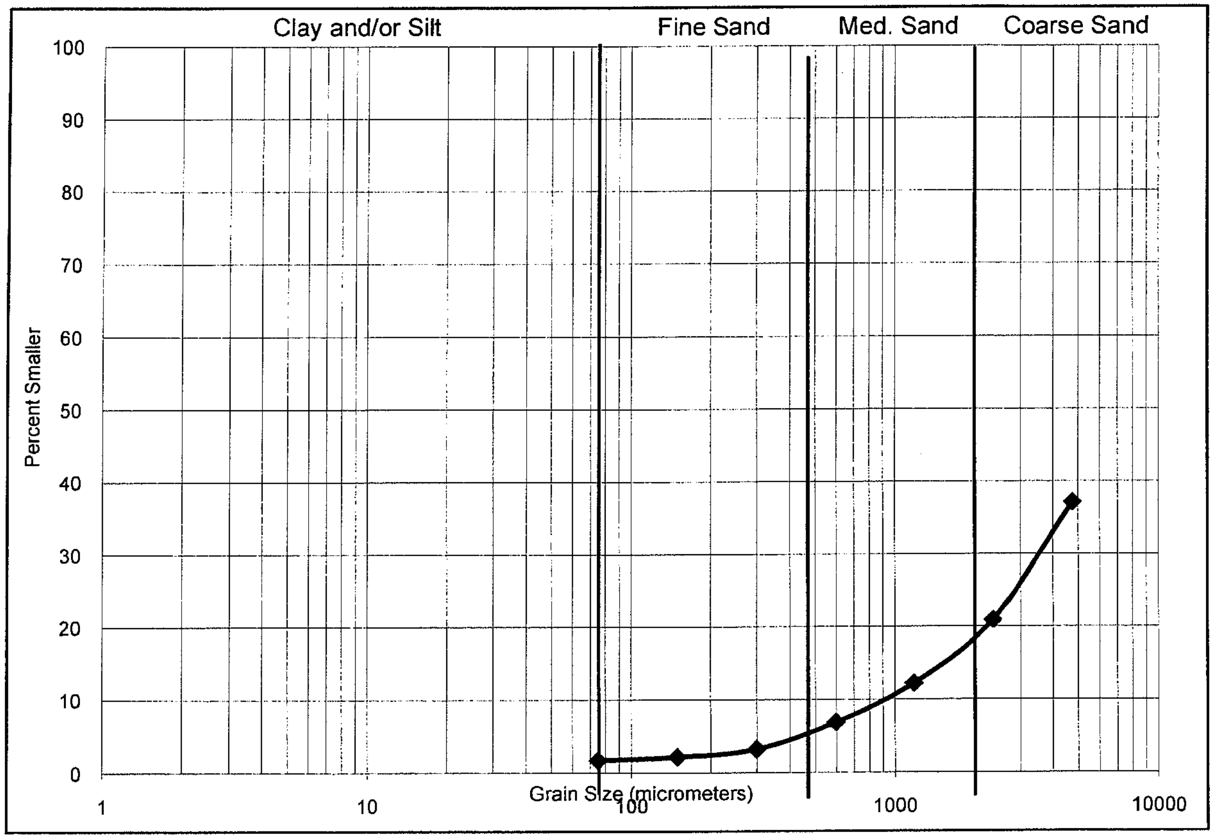
Laboratory Report

Grain Size Determination and Gradation Curve -- ASTM Test Method D 422-63(98)

Sample Identification: **S 21**(50-53 ft)
Client: **WHPA**

AEI Lab. No. **0907011B**
Client's Project: **Bloomington/Stark**

Sieve Size	Grain Size (micrometers)	Percent Smaller
4	4750	37.1
8	2360	20.9
16	1180	12.2
30	600	6.9
50	300	3.2
100	150	2.2
200	75	1.8



Complete below in accordance with ASTM Method D 422-63

Paragraph 18.1.3 Is sample greater than 5% sand or gravel? Yes X No
Paragraph 18.1.3.1 If yes, is sand or gravel more round than angular ? Yes No X
Paragraph 18.1.3.1 If yes, is sand or gravel: Hard & Durable ? Yes No
Weathered & Friable ? Yes No
Soft ? Yes No

Associated Environmental, Inc.

Soils Testing Laboratory

Calculations Sheet

Client: **WHPA**
Project: **Bloomington/Stark**
Sample ID: **S 21**
AEI Lab. No. **0907011B**

Grain Size:

Percent Passing:

Sample mass: **100**
Corrected mass: **100** If no hygroscopic moisture, enter sample mass in corrected mass.

Sieve Size	Mass Retained	Percent Passing
4	**62.87**	37.13
8	**79.06**	20.94
16	**87.78**	12.22
30	**93.09**	6.91
50	**96.78**	3.22
100	**97.82**	2.18
200	**98.24**	1.76

Associated Environmental, Inc.
Soils Testing Laboratory

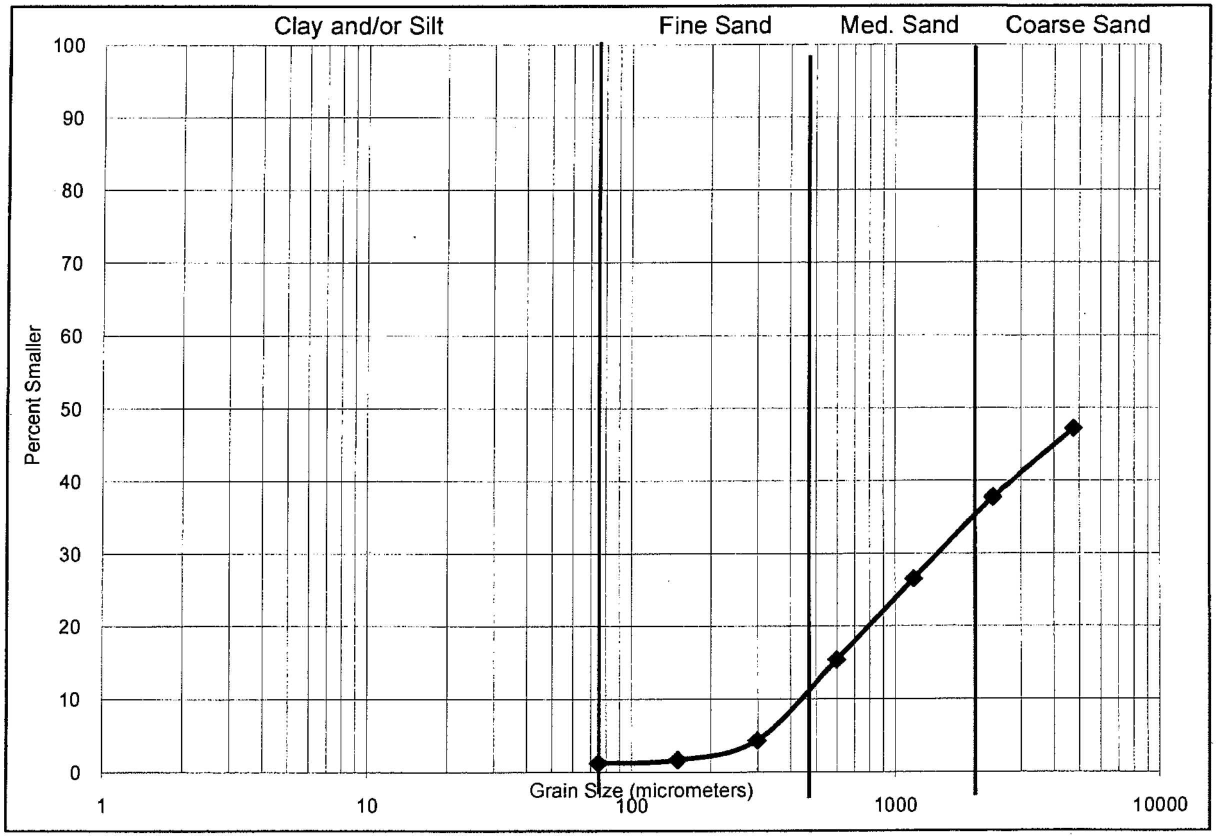
Laboratory Report

Grain Size Determination and Gradation Curve -- ASTM Test Method D 422-63(98)

Sample Identification: **S 22** (60-63 ft)
Client: **WHPA**

AEI Lab. No. **0907011C**
Client's Project: **Bloomington/Stark**

Sieve Size	Grain Size (micrometers)	Percent Smaller
4	4750	47.2
8	2360	37.7
16	1180	26.5
30	600	15.4
50	300	4.4
100	150	1.7
200	75	1.3



Complete below in accordance with ASTM Method D 422-63

Paragraph 18.1.3 Is sample greater than 5% sand or gravel? Yes X No ____
Paragraph 18.1.3.1 If yes, is sand or gravel more round than angular ? Yes ____ No X
Paragraph 18.1.3.1 If yes, is sand or gravel: Hard & Durable ? Yes ____ No ____
Weathered & Friable ? Yes ____ No ____
Soft ? Yes ____ No ____

Associated Environmental, Inc.

Soils Testing Laboratory

Calculations Sheet

Client:	**WHPA**
Project:	**Bloomington/Stark**
Sample ID:	**S 22**
AEI Lab. No.	**0907011C**

Grain Size:

Percent Passing:

Sample mass: **100**

Corrected mass: **100** If no hygroscopic moisture, enter sample mass in corrected mass.

Sieve Size	Mass Retained	Percent Passing
4	**52.78**	47.22
8	**62.26**	37.74
16	**73.49**	26.51
30	**84.62**	15.38
50	**95.61**	4.39
100	**98.3**	1.7
200	**98.73**	1.27

Associated Environmental, Inc.
Soils Testing Laboratory

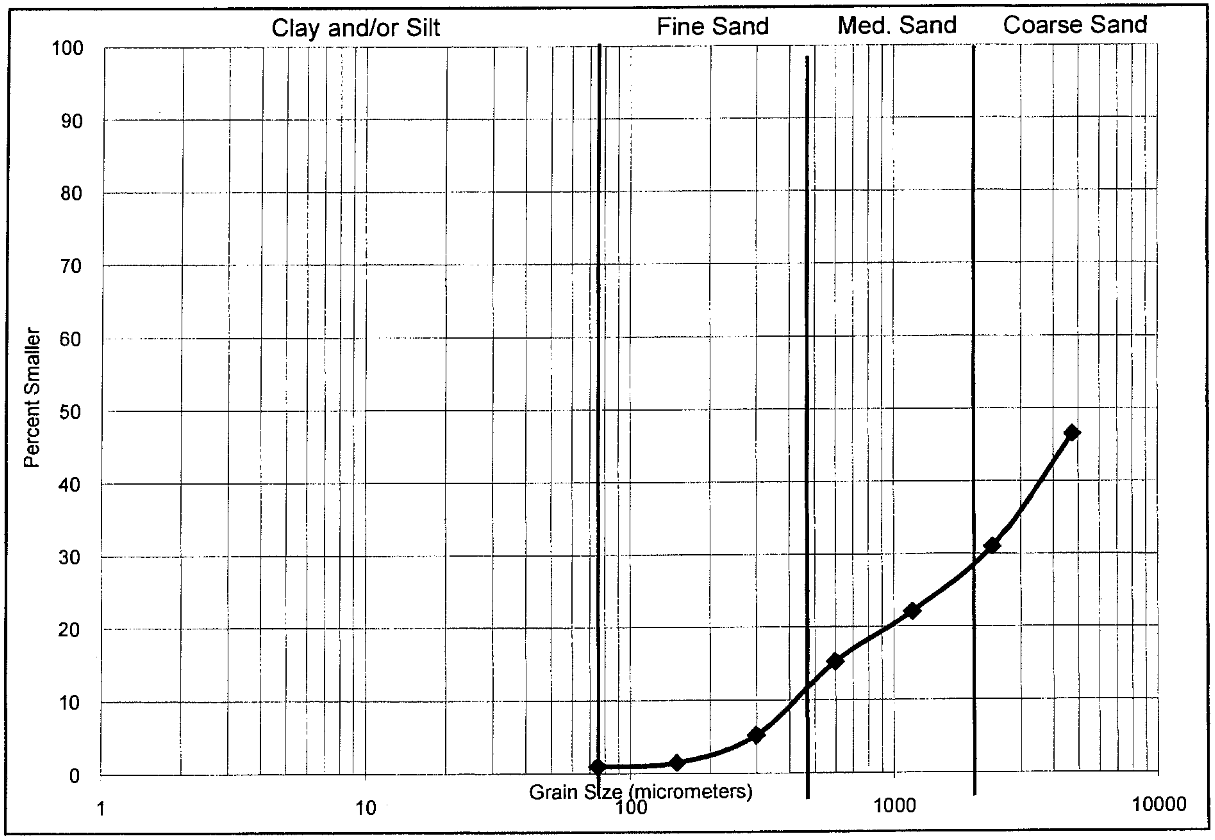
Laboratory Report

Grain Size Determination and Gradation Curve -- ASTM Test Method D 422-63(98)

Sample Identification: **S 23** (35 ft)
Client: **WHPA**

AEI Lab. No. **0907011D**
Client's Project: **Bloomington/Stark**

Sieve Size	Grain Size (micrometers)	Percent Smaller
4	4750	46.6
8	2360	31.0
16	1180	22.1
30	600	15.3
50	300	5.2
100	150	1.5
200	75	1.0



Complete below in accordance with ASTM Method D 422-63

Paragraph 18.1.3 Is sample greater than 5% sand or gravel? Yes X No ____
Paragraph 18.1.3.1 If yes, is sand or gravel more round than angular ? Yes ____ No X
Paragraph 18.1.3.1 If yes, is sand or gravel: Hard & Durable ? Yes ____ No ____
Weathered & Friable ? Yes ____ No ____
Soft ? Yes ____ No ____

Associated Environmental, Inc.

Soils Testing Laboratory

Calculations Sheet

Client:	**WHPA**
Project:	**Bloomington/Stark**
Sample ID:	**S 23**
AEI Lab. No.	**0907011D**

Grain Size:

Percent Passing:

Sample mass: **100**

Corrected mass: **100** If no hygroscopic moisture, enter sample mass in corrected mass.

Sieve Size	Mass Retained	Percent Passing
4	**53.45**	46.55
8	**68.96**	31.04
16	**77.88**	22.12
30	**84.75**	15.25
50	**94.82**	5.18
100	**98.49**	1.51
200	**98.99**	1.01

Associated Environmental, Inc.
Soils Testing Laboratory

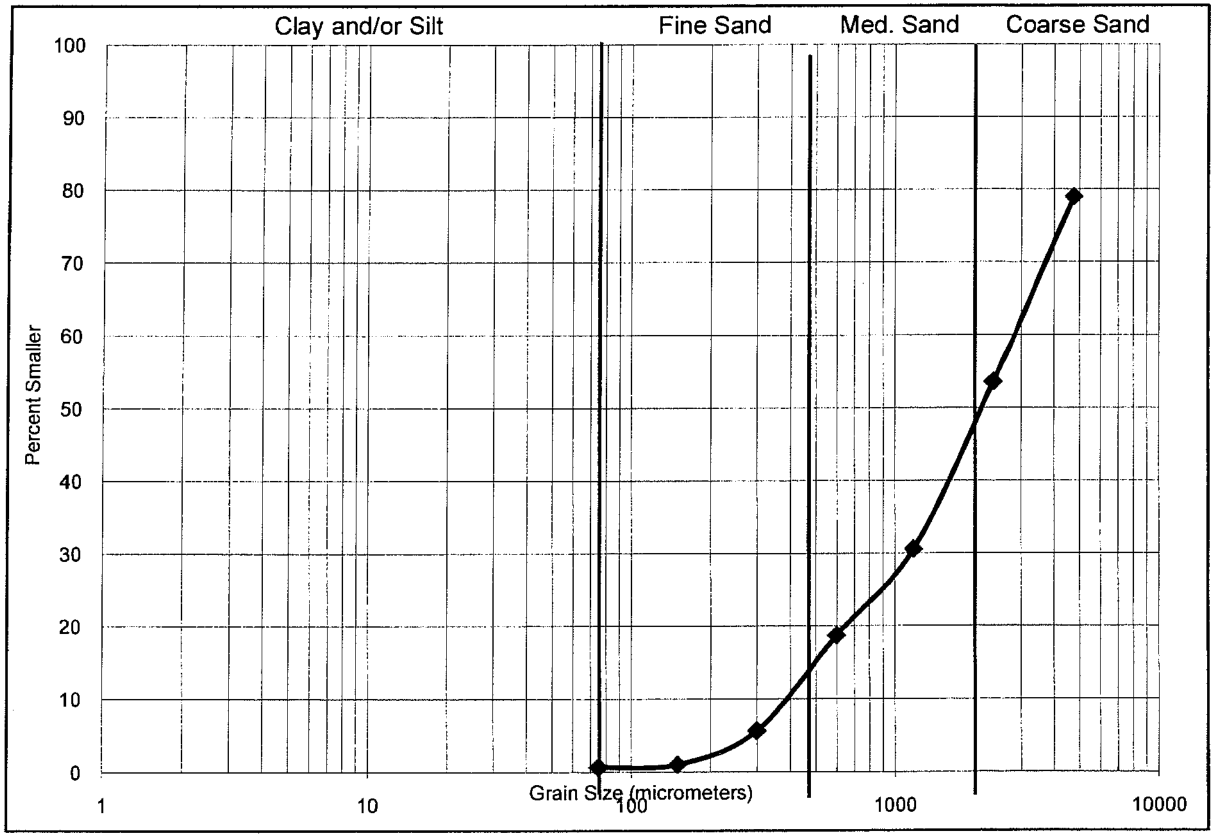
Laboratory Report

Grain Size Determination and Gradation Curve -- ASTM Test Method D 422-63(98)

Sample Identification: **S 31** (35 ft)
Client: **WHPA**

AEI Lab. No. **0907011E**
Client's Project: **Bloomington/Stark**

Sieve Size	Grain Size (micrometers)	Percent Smaller
4	4750	79.0
8	2360	53.6
16	1180	30.6
30	600	18.7
50	300	5.7
100	150	1.1
200	75	0.7



Complete below in accordance with ASTM Method D 422-63

Paragraph 18.1.3 Is sample greater than 5% sand or gravel? Yes X No
Paragraph 18.1.3.1 If yes, is sand or gravel more round than angular ? Yes No X
Paragraph 18.1.3.1 If yes, is sand or gravel: Hard & Durable ? Yes No
Weathered & Friable ? Yes No
Soft ? Yes No

Associated Environmental, Inc.

Soils Testing Laboratory

Calculations Sheet

Client:	**WHPA**
Project:	**Bloomington/Stark**
Sample ID:	**S 31**
AEI Lab. No.	**0907011E**

Grain Size:

Percent Passing:

Sample mass: **100**

Corrected mass: **100** If no hygroscopic moisture, enter sample mass in corrected mass.

Sieve Size	Mass Retained	Percent Passing
4	**21.01**	78.99
8	**46.39**	53.61
16	**69.41**	30.59
30	**81.27**	18.73
50	**94.34**	5.66
100	**98.95**	1.05
200	**99.28**	0.72

Associated Environmental, Inc.
Soils Testing Laboratory

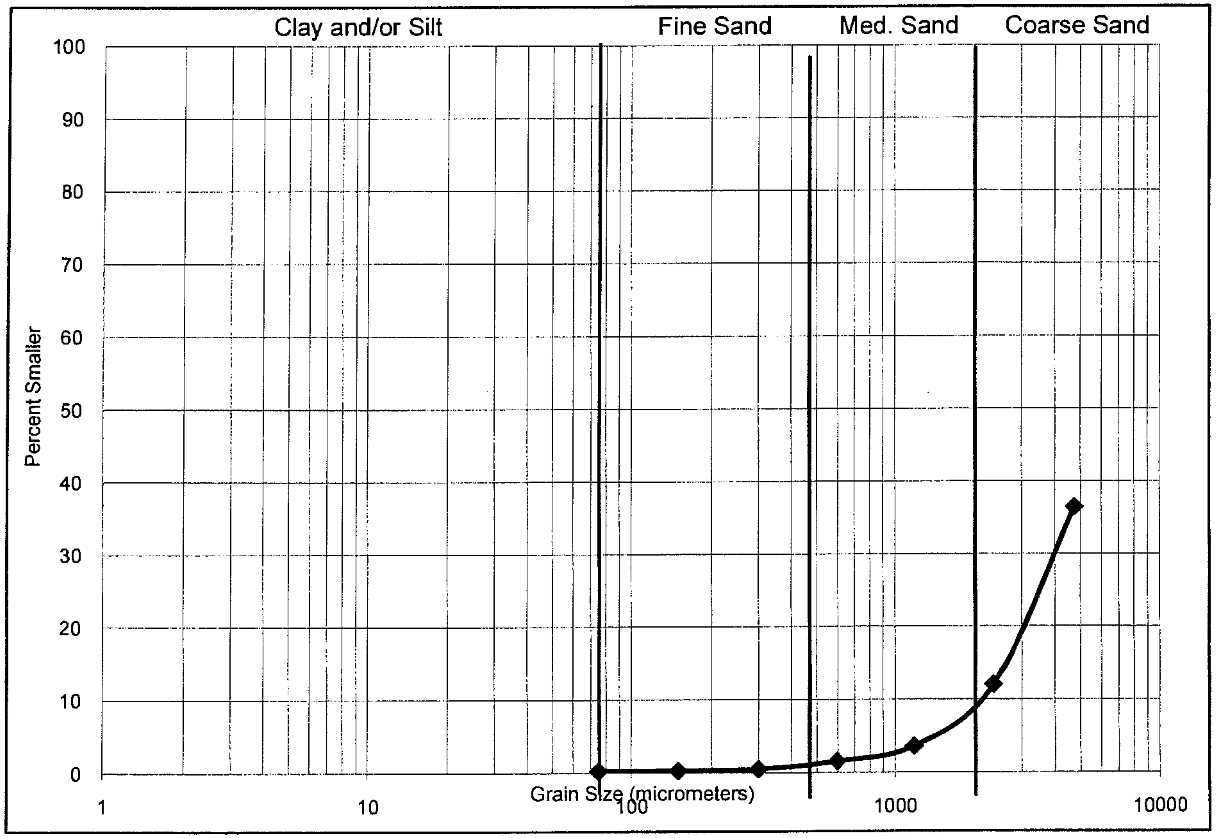
Laboratory Report

Grain Size Determination and Gradation Curve -- ASTM Test Method D 422-63(98)

Sample Identification: **S 32** (43-48 ft)
Client: **WHPA**

AEI Lab. No. **0907011F**
Client's Project: **Bloomington/Stark**

Sieve Size	Grain Size (micrometers)	Percent Smaller
4	4750	36.5
8	2360	12.0
16	1180	3.6
30	600	1.6
50	300	0.5
100	150	0.3
200	75	0.3



Complete below in accordance with ASTM Method D 422-63

Paragraph 18.1.3 Is sample greater than 5% sand or gravel? Yes X No ____
Paragraph 18.1.3.1 If yes, is sand or gravel more round than angular ? Yes ____ No X
Paragraph 18.1.3.1 If yes, is sand or gravel: Hard & Durable ? Yes ____ No ____
Weathered & Friable ? Yes ____ No ____
Soft ? Yes ____ No ____

Associated Environmental, Inc.

Soils Testing Laboratory

Calculations Sheet

Client:	**WHPA**
Project:	**Bloomington/Stark**
Sample ID:	**S 32**
AEI Lab. No.	**0907011F**

Grain Size:

Percent Passing:

Sample mass: **100**

Corrected mass: **100** If no hygroscopic moisture, enter sample mass in corrected mass.

Sieve Size	Mass Retained	Percent Passing
4	**63.51**	36.49
8	**87.98**	12.02
16	**96.37**	3.63
30	**98.44**	1.56
50	**99.47**	0.53
100	**99.69**	0.31
200	**99.71**	0.29

Appendix C- Water-Quality Results

PDC Laboratories, Inc.
P.O. Box 9071 - Peoria, IL 61612-9071
(309) 692-9688 - (800) 752-6651 - FAX (309) 692-6689

Laboratory Results

City of Bloomington
25515 Waterside Way

Hudson, IL 61748
Attn : Mr. Rick Twait

Date Received : 10/02/08 09:00
Report Date 10/23/08
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **08101277-1** Collect Date **10/01/08 10:30**
Client ID : **WELL TEST** Site : **B02** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst
EPA 200.7 R4.4				
Iron		0.31 mg/l	10/20/08 12:00	JFA
Silicon as SiO2		7.1 mg/l	10/16/08 11:00	KJP
Sodium		130 mg/l	10/20/08 12:00	JFA
EPA 200.8				
Aluminum		0.18 mg/l	10/16/08 16:00	KMC
Antimony		0.004 mg/l	10/16/08 16:00	KMC
Arsenic		0.003 mg/l	10/16/08 16:00	KMC
Barium		0.3 mg/l	10/16/08 16:00	KMC
Beryllium		0.002 mg/l	10/16/08 16:00	KMC
Boron		0.24 mg/l	10/16/08 16:00	KMC
Cadmium		0.001 mg/l	10/16/08 16:00	KMC
Calcium		27 mg/l	10/16/08 16:00	KMC
Chromium		0.007 mg/l	10/16/08 16:00	KMC
Cobalt		0.006 mg/l	10/16/08 16:00	KMC
Copper		0.006 mg/l	10/16/08 16:00	KMC
Lead		0.002 mg/l	10/16/08 16:00	KMC
Magnesium		13 mg/l	10/16/08 16:00	KMC
Manganese		0.15 mg/l	10/16/08 16:00	KMC
Mercury	<	0.0002 mg/l	10/16/08 16:00	KMC
Molybdenum		0.022 mg/l	10/16/08 16:00	KMC
Nickel		0.03 mg/l	10/16/08 16:00	KMC
Phosphorus	<	0.05 mg/l	10/16/08 16:00	KMC
Potassium		3.1 mg/l	10/16/08 16:00	KMC
Selenium		0.01 mg/l	10/16/08 16:00	KMC
Silver	<	0.005 mg/l	10/16/08 16:00	KMC
Sodium		150 mg/l	10/16/08 16:00	KMC
Thallium		0.003 mg/l	10/16/08 16:00	KMC
Vanadium	<	0.005 mg/l	10/16/08 16:00	KMC
Zinc		0.019 mg/l	10/16/08 16:00	KMC
EPA 200.8 R5.4				
Aluminum		0.18 mg/l	10/16/08 13:00	KMC
Antimony		0.004 mg/l	10/16/08 13:00	KMC
Arsenic		0.003 mg/l	10/16/08 13:00	KMC
Barium		0.3 mg/l	10/16/08 13:00	KMC

Laboratory Results

City of Bloomington
25515 Waterside Way

Hudson, IL 61748
Attn : Mr. Rick Twait

Date Received : 10/02/08 09:00
Report Date 10/23/08
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **08101277-1** Collect Date **10/01/08 10:30**
Client ID : **WELL TEST** Site : **B02** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst
EPA 200.8 R5.4				
Beryllium		0.002 mg/l	10/16/08 13:00	KMC
Cadmium		0.001 mg/l	10/16/08 13:00	KMC
Calcium		27 mg/l	10/16/08 11:00	KMC
Chromium		0.007 mg/l	10/16/08 13:00	KMC
Copper		0.006 mg/l	10/16/08 13:00	KMC
Lead		0.002 mg/l	10/16/08 13:00	KMC
Magnesium		13 mg/l	10/16/08 11:00	KMC
Manganese		0.15 mg/l	10/16/08 13:00	KMC
Mercury	<	0.0002 mg/l	10/16/08 13:00	KMC
Nickel		0.03 mg/l	10/16/08 13:00	KMC
Selenium		0.01 mg/l	10/16/08 13:00	KMC
Thallium		0.003 mg/l	10/16/08 13:00	KMC
Zinc		0.019 mg/l	10/16/08 13:00	KMC
EPA 300.0 R2.1				
Chloride		64 mg/l	10/03/08 09:13	Igarg
Fluoride	<	0.25 mg/l	10/02/08 17:33	Igarg
Nitrate as N	<	0.02 mg/l	10/03/08 08:55	Igarg
Nitrite as N	<	0.15 mg/l	10/03/08 08:55	Igarg
Sulfate		26 mg/l	10/03/08 09:13	Igarg
EPA 335.4				
Cyanide, Total	<	0.01 mg/l	10/06/08 08:32	Igalr
EPA 524.2 R4.0				
1,1,1-Trichloroethane	<	0.5 ug/l	10/06/08 19:41	MWS
1,1,2-Trichloroethane	<	0.5 ug/l	10/06/08 19:41	MWS
1,1-Dichloroethene	<	0.5 ug/l	10/06/08 19:41	MWS
1,2,4-Trichlorobenzene	<	0.5 ug/l	10/06/08 19:41	MWS
1,2-Dichlorobenzene	<	0.5 ug/l	10/06/08 19:41	MWS
1,2-Dichloroethane	<	0.5 ug/l	10/06/08 19:41	MWS
1,2-Dichloropropane	<	0.5 ug/l	10/06/08 19:41	MWS
1,4-Dichlorobenzene	<	0.5 ug/l	10/06/08 19:41	MWS
Benzene	<	0.5 ug/l	10/06/08 19:41	MWS
Carbon Tetrachloride	<	0.5 ug/l	10/06/08 19:41	MWS
Chlorobenzene	<	0.5 ug/l	10/06/08 19:41	MWS
Ethylbenzene	<	0.5 ug/l	10/06/08 19:41	MWS

Laboratory Results

City of Bloomington
25515 Waterside Way

Hudson, IL 61748
Attn : Mr. Rick Twait

Date Received : 10/02/08 09:00
Report Date 10/23/08
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **08101277-1** Collect Date **10/01/08 10:30**
Client ID : **WELL TEST** Site : **B02** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst
EPA 524.2 R4.0				
Methyl tert-butyl ether	<	0.5 ug/l	10/06/08 19:41	MWS
Methylene Chloride	<	0.5 ug/l	10/06/08 19:41	MWS
Styrene	<	0.5 ug/l	10/06/08 19:41	MWS
Tetrachloroethene	<	0.5 ug/l	10/06/08 19:41	MWS
Toluene	<	0.5 ug/l	10/06/08 19:41	MWS
Total xylenes	<	0.5 ug/l	10/06/08 19:41	MWS
Trichloroethene	<	0.5 ug/l	10/06/08 19:41	MWS
Vinyl Chloride	<	0.5 ug/l	10/06/08 19:41	MWS
cis-1,2-Dichloroethene	<	0.5 ug/l	10/06/08 19:41	MWS
mp-Xylene	<	0.5 ug/l	10/06/08 19:41	MWS
o-Xylene	<	0.5 ug/l	10/06/08 19:41	MWS
trans-1,2-Dichloroethene	<	0.5 ug/l	10/06/08 19:41	MWS
SM (18) 2130B				
Turbidity Check		2.4 NTU	10/03/08 10:07	MBB
SM (18) 2320B				
Alkalinity, Total as CaCO3		350 mg/l	10/06/08 10:50	GDM
SM (18) 2340C				
Hardness, Total as CaCO3		120 mg/l	10/03/08 07:26	GDM
SM (18) 2510B				
Conductivity		870 umhos/cm	10/03/08 14:25	MBB
SM (18) 2540C				
Solids, Total Dissolved		480 mg/l	10/03/08 11:02	GDM
SM (18) 2540D				
Solids, Total Suspended	<	4 mg/l	10/02/08 13:44	acb
SM (18) 4500 H B				
pH	H	7.34 units	10/02/08 14:53	WRW
H - Method Hold Time Exceeded				
SM (18) 4500 NH3 B,H				
Nitrogen, Ammonia as N		3.9 mg/l	10/06/08 16:55	lgtth
SM (18) 4500 NH3 H				

Laboratory Results

City of Bloomington
25515 Waterside Way

Hudson, IL 61748
Attn : Mr. Rick Twait

Date Received : 10/02/08 09:00
Report Date 10/23/08
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **08101277-1** Collect Date **10/01/08 10:30**
Client ID : **WELL TEST** Site : **B02** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst
SM (18) 4500 NH3 H				
Nitrogen, Total Kjeldahl as N	P	4.6 mg/l	10/16/08 11:07	lgtth
SM (18) 4500 P B,E				
Phosphorus, Ortho as P	<	0.02 mg/l	10/03/08 09:16	JRB
SM (18) 5310D				
Carbon, Total Organic		5.7 mg/l	10/06/08 17:48	pli
SW-846 3015				
Sample Preparation			10/06/08 05:30	JEM

Sample No: **08101277-2** Collect Date **10/01/08 00:00**
Client ID : **WELL TEST** Site : **TRIP BLANK** Locator :

Parameter	Qualifier	Result	Analysis Date	Analyst

Trip blank not analyzed due to no sample detects.

PDC Laboratories participates in the following laboratory accreditation/certification and proficiency programs. Endorsement by the Federal or State Government or their agencies is not implied.

NELAC Accreditation for Drinking Water, Wastewater, Hazardous and Solid Wastes Fields of Testing through IL EPA Lab No. 100230
State of Illinois Bacteriological Analysis in Drinking Water Certified Lab Registry No. 17533
Drinking Water Certifications: Indiana (C-IL-040); Kansas (E-10338); Kentucky (90058); Missouri (00870); Wisconsin (998294430)
Wastewater Certifications: Arkansas; Iowa (240); Kansas (E-10338); Wisconsin (99829443)
Hazardous/Solid Waste Certifications: Arkansas; Kansas (E-10338); Wisconsin (998294430)
UST Certification: Iowa (240)

Certified by:
Lori L. Stenzel, Project Manager

This report shall not be reproduced, except in full, without the written approval of the laboratory.

PDC Laboratories, Inc.

2231 W. Altorfer Drive - Peoria, IL 61615
(309) 692-9688 - (800) 752-6651 - FAX (309) 692-9689

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/09/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082770-1**
Collect Date : **08/12/09 11:25**
Client ID : **DRINKING WATER**
Site : **TEST WELL**
Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	Lab
EPA 200.7 R4.4					PIA
Iron		3.2 mg/l	09/04/09 15:00	BAB	
Silicon as SiO2		14 mg/l	08/17/09 12:00	JFA	
Sodium		18 mg/l	08/26/09 10:00	JFA	
EPA 200.8 R5.4					PIA
Aluminum	<	0.01 mg/l	08/21/09 11:00	KMC	
Antimony	<	0.003 mg/l	08/21/09 11:00	KMC	
Arsenic	<	0.001 mg/l	08/21/09 11:00	KMC	
Barium		0.14 mg/l	08/21/09 11:00	KMC	
Beryllium	<	0.001 mg/l	08/21/09 11:00	KMC	
Cadmium	<	0.001 mg/l	08/21/09 11:00	KMC	
Calcium		120 mg/l	08/21/09 16:34	JMW	
Chromium	<	0.004 mg/l	08/21/09 11:00	KMC	
Copper		0.22 mg/l	08/21/09 11:00	KMC	
Lead		0.015 mg/l	08/21/09 11:00	KMC	
Magnesium		43 mg/l	08/21/09 16:34	JMW	
Manganese		0.075 mg/l	08/21/09 11:00	KMC	
Mercury	<	0.0002 mg/l	08/21/09 11:00	KMC	
Nickel	<	0.005 mg/l	08/21/09 11:00	KMC	
Selenium		0.002 mg/l	08/21/09 11:00	KMC	
Thallium	<	0.001 mg/l	08/21/09 11:00	KMC	
Zinc		0.14 mg/l	08/21/09 11:00	KMC	
EPA 300.0 R2.1					PIA
Nitrate as N	H	0.25 mg/l	08/18/09 20:01	Ignay	
Nitrite as N	H<	0.15 mg/l	08/18/09 20:01	Ignay	
H - Method Hold Time Exceeded					
EPA 300.0 R2.1					PIA
Chloride		58 mg/l	08/18/09 20:16	Ignay	
Fluoride		0.27 mg/l	08/18/09 20:01	Ignay	
Sulfate		53 mg/l	08/18/09 20:16	Ignay	
EPA 335.4					PIA
Cyanide, Total	<	0.01 mg/l	08/20/09 10:56	lgarg	
EPA 524.2					PIA
1,1,1-Trichloroethane	<	0.5 ug/l	08/17/09 19:48	MWS	
1,1,2-Trichloroethane	<	0.5 ug/l	08/17/09 19:48	MWS	
1,1-Dichloroethene	<	0.5 ug/l	08/17/09 19:48	MWS	
1,2,4-Trichlorobenzene	<	0.5 ug/l	08/17/09 19:48	MWS	
1,2-Dichlorobenzene	<	0.5 ug/l	08/17/09 19:48	MWS	
1,2-Dichloroethane	<	0.5 ug/l	08/17/09 19:48	MWS	
1,2-Dichloropropane	<	0.5 ug/l	08/17/09 19:48	MWS	
1,4-Dichlorobenzene	<	0.5 ug/l	08/17/09 19:48	MWS	
Benzene	<	0.5 ug/l	08/17/09 19:48	MWS	
Carbon Tetrachloride	<	0.5 ug/l	08/17/09 19:48	MWS	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/09/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082770-1**
Collect Date : **08/12/09 11:25**
Client ID : **DRINKING WATER**
Site : **TEST WELL**
Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	
EPA 524.2					
Chlorobenzene	<	0.5 ug/l	08/17/09 19:48	MWS	
cis-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 19:48	MWS	
Ethylbenzene	<	0.5 ug/l	08/17/09 19:48	MWS	
Methyl tert-butyl ether	<	0.5 ug/l	08/17/09 19:48	MWS	
Methylene Chloride	<	0.5 ug/l	08/17/09 19:48	MWS	
mp-Xylene	<	0.5 ug/l	08/17/09 19:48	MWS	
o-Xylene	<	0.5 ug/l	08/17/09 19:48	MWS	
Styrene	<	0.5 ug/l	08/17/09 19:48	MWS	
Tetrachloroethene	<	0.5 ug/l	08/17/09 19:48	MWS	
Toluene	<	0.5 ug/l	08/17/09 19:48	MWS	
Total xylenes	<	0.5 ug/l	08/17/09 19:48	MWS	
trans-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 19:48	MWS	
Trichloroethene	<	0.5 ug/l	08/17/09 19:48	MWS	
Vinyl Chloride	<	0.5 ug/l	08/17/09 19:48	MWS	
SM (18) 2130B					PIA
Turbidity Check		1.3 NTU	08/19/09 09:00	ECK	
SM (18) 2320B					PIA
Alkalinity, Total as CaCO3		400 mg/l	08/20/09 08:20	PLI	
SM (18) 2340C					PIA
Hardness, Total as CaCO3		490 mg/l	08/21/09 07:10	PLI	
SM (18) 2510B					PIA
Conductivity		900 umhos/cm	08/19/09 13:59	ARG	
SM (18) 2540C					PIA
Solids, Total Dissolved		600 mg/l	08/17/09 14:04	acb	
SM (18) 2540D					PIA
Solids, Total Suspended		5.6 mg/l	08/17/09 12:23	acb	
SM (18) 4500 H B					PIA
pH	H	7.51 units	08/18/09 13:18	WRW	
H - Method Hold Time Exceeded					
SM (18) 4500 NH3 B,H					PIA
Nitrogen, Ammonia as N		0.78 mg/l	08/25/09 09:01	lgtth	
SM (18) 4500 P B,E					PIA
Phosphorus, Ortho as P	H	0.044 mg/l	08/14/09 15:44	GDM	
H - Method Hold Time Exceeded					
SM (18) 5310D					PIA
Carbon, Total Organic		0.94 mg/l	08/19/09 00:19	nay	
SM 4500 S2 E, 376.1					PIA
Sulfide, Total	X,<	2 mg/l	08/17/09 09:22	PLI	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/09/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082770-1**
Collect Date : **08/12/09 11:25**
Client ID : **DRINKING WATER**
Site : **TEST WELL**
Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst
SM 4500 S2 E, 376.1				

X=never turned clear, rather light purple

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/09/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082770-2** Collect Date : **08/12/09 10:25**
Client ID : **DRINKING WATER** Site : **SUGAR CREEK** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	Lab
EPA 200.7 R4.4					PIA
Iron		0.23 mg/l	09/08/09 13:01	jfa	
Silicon as SiO2		3.3 mg/l	09/08/09 09:00	JFA	
Sodium		87 mg/l	08/26/09 12:00	JFA	
EPA 200.8 R5.4					PIA
Aluminum		0.12 mg/l	08/25/09 16:00	KMC	
Antimony	<	0.003 mg/l	08/25/09 16:00	KMC	
Arsenic	<	0.001 mg/l	08/25/09 16:00	KMC	
Barium		0.049 mg/l	08/25/09 16:00	KMC	
Beryllium	<	0.001 mg/l	08/25/09 16:00	KMC	
Cadmium	<	0.001 mg/l	08/25/09 16:00	KMC	
Calcium		70 mg/l	08/21/09 17:50	JMW	
Chromium	<	0.004 mg/l	08/25/09 16:00	KMC	
Copper		0.004 mg/l	08/25/09 16:00	KMC	
Lead	<	0.001 mg/l	08/25/09 16:00	KMC	
Magnesium		29 mg/l	08/21/09 17:50	JMW	
Manganese		0.048 mg/l	08/25/09 16:00	KMC	
Mercury	<	0.0002 mg/l	08/25/09 16:00	KMC	
Nickel	<	0.005 mg/l	08/25/09 16:00	KMC	
Selenium	<	0.001 mg/l	08/25/09 16:00	KMC	
Thallium	<	0.001 mg/l	08/25/09 16:00	KMC	
Zinc		0.026 mg/l	08/25/09 16:00	KMC	
EPA 300.0 R2.1					PIA
Nitrate as N	H	16 mg/l	08/18/09 21:18	lgnay	
Nitrite as N	H<	0.15 mg/l	08/18/09 20:32	lgnay	
H - Method Hold Time Exceeded					
EPA 300.0 R2.1					PIA
Chloride		150 mg/l	08/20/09 17:28	lgnay	
Fluoride		0.68 mg/l	08/18/09 20:32	lgnay	
Sulfate		63 mg/l	08/18/09 21:18	lgnay	
EPA 335.4					PIA
Cyanide, Total	<	0.01 mg/l	08/20/09 10:57	lgarg	
EPA 524.2					PIA
1,1,1-Trichloroethane	<	0.5 ug/l	08/17/09 20:28	MWS	
1,1,2-Trichloroethane	<	0.5 ug/l	08/17/09 20:28	MWS	
1,1-Dichloroethene	<	0.5 ug/l	08/17/09 20:28	MWS	
1,2,4-Trichlorobenzene	<	0.5 ug/l	08/17/09 20:28	MWS	
1,2-Dichlorobenzene	<	0.5 ug/l	08/17/09 20:28	MWS	
1,2-Dichloroethane	<	0.5 ug/l	08/17/09 20:28	MWS	
1,2-Dichloropropane	<	0.5 ug/l	08/17/09 20:28	MWS	
1,4-Dichlorobenzene	<	0.5 ug/l	08/17/09 20:28	MWS	
Benzene	<	0.5 ug/l	08/17/09 20:28	MWS	
Carbon Tetrachloride	<	0.5 ug/l	08/17/09 20:28	MWS	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/09/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082770-2**
Collect Date : **08/12/09 10:25**
Client ID : **DRINKING WATER**
Site : **SUGAR CREEK**
Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	
EPA 524.2					
Chlorobenzene	<	0.5 ug/l	08/17/09 20:28	MWS	
cis-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 20:28	MWS	
Ethylbenzene	<	0.5 ug/l	08/17/09 20:28	MWS	
Methyl tert-butyl ether	<	0.5 ug/l	08/17/09 20:28	MWS	
Methylene Chloride	<	0.5 ug/l	08/17/09 20:28	MWS	
mp-Xylene	<	0.5 ug/l	08/17/09 20:28	MWS	
o-Xylene	<	0.5 ug/l	08/17/09 20:28	MWS	
Styrene	<	0.5 ug/l	08/17/09 20:28	MWS	
Tetrachloroethene	<	0.5 ug/l	08/17/09 20:28	MWS	
Toluene	<	0.5 ug/l	08/17/09 20:28	MWS	
Total xylenes	<	0.5 ug/l	08/17/09 20:28	MWS	
trans-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 20:28	MWS	
Trichloroethene	<	0.5 ug/l	08/17/09 20:28	MWS	
Vinyl Chloride	<	0.5 ug/l	08/17/09 20:28	MWS	
SM (18) 2130B					PIA
Turbidity Check	<	1 NTU	08/19/09 09:00	ECK	
SM (18) 2320B					PIA
Alkalinity, Total as CaCO3		160 mg/l	08/20/09 08:20	PLI	
SM (18) 2340C					PIA
Hardness, Total as CaCO3		290 mg/l	08/26/09 12:38	GDM	
SM (18) 2510B					PIA
Conductivity		990 umhos/cm	08/19/09 14:01	ARG	
SM (18) 2540C					PIA
Solids, Total Dissolved		610 mg/l	08/17/09 14:05	acb	
SM (18) 2540D					PIA
Solids, Total Suspended	<	4 mg/l	08/17/09 12:23	acb	
SM (18) 4500 H B					PIA
pH	H	7.61 units	08/18/09 13:20	WRW	
H - Method Hold Time Exceeded					
SM (18) 4500 NH3 B,H					PIA
Nitrogen, Ammonia as N		0.2 mg/l	08/25/09 09:02	lgtth	
SM (18) 4500 P B,E					PIA
Phosphorus, Ortho as P	H	1.9 mg/l	08/14/09 15:44	GDM	
H - Method Hold Time Exceeded					
SM (18) 5310D					PIA
Carbon, Total Organic		6 mg/l	08/19/09 00:30	nay	
SM 4500 S2 E, 376.1					PIA
Sulfide, Total	P	5.3 mg/l	08/17/09 09:22	PLI	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/09/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082770-2** Collect Date : **08/12/09 10:25**
Client ID : **DRINKING WATER** Site : **SUGAR CREEK** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	
SW-846 3015					PIA
Sample Preparation			08/31/09 05:30	JEM	
Sample Preparation			08/21/09 05:45	ECK	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/09/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082770-3** Collect Date : **08/13/09 12:05**
Client ID : **DRINKING WATER** Site : **TEST WELL** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	Lab
EPA 200.7 R4.4					PIA
Iron		3.2 mg/l	09/04/09 15:00	BAB	
Silicon as SiO2		13 mg/l	08/17/09 12:00	JFA	
Sodium		17 mg/l	08/26/09 10:00	JFA	
EPA 200.8 R5.4					PIA
Aluminum	<	0.01 mg/l	08/21/09 11:00	KMC	
Antimony	<	0.003 mg/l	08/21/09 11:00	KMC	
Arsenic		0.001 mg/l	08/21/09 11:00	KMC	
Barium		0.11 mg/l	08/21/09 11:00	KMC	
Beryllium	<	0.001 mg/l	08/21/09 11:00	KMC	
Cadmium	<	0.001 mg/l	08/21/09 11:00	KMC	
Calcium		120 mg/l	08/21/09 16:38	JMW	
Chromium	<	0.004 mg/l	08/21/09 11:00	KMC	
Copper		0.009 mg/l	08/21/09 11:00	KMC	
Lead		0.002 mg/l	08/21/09 11:00	KMC	
Magnesium		43 mg/l	08/21/09 16:38	JMW	
Manganese		0.064 mg/l	08/21/09 11:00	KMC	
Mercury	<	0.0002 mg/l	08/21/09 11:00	KMC	
Nickel	<	0.005 mg/l	08/21/09 11:00	KMC	
Selenium		0.002 mg/l	08/21/09 11:00	KMC	
Thallium	<	0.001 mg/l	08/21/09 11:00	KMC	
Zinc		0.05 mg/l	08/21/09 11:00	KMC	
EPA 300.0 R2.1					PIA
Chloride		52 mg/l	08/15/09 02:24	Ignay	
Fluoride		0.28 mg/l	08/15/09 01:38	Ignay	
Nitrate as N		0.36 mg/l	08/15/09 01:38	Ignay	
Nitrite as N	<	0.15 mg/l	08/15/09 01:38	Ignay	
Sulfate		49 mg/l	08/15/09 02:24	Ignay	
EPA 335.4					PIA
Cyanide, Total	<	0.01 mg/l	08/20/09 10:58	Igarg	
EPA 524.2					PIA
1,1,1-Trichloroethane	<	0.5 ug/l	08/17/09 21:08	MWS	
1,1,2-Trichloroethane	<	0.5 ug/l	08/17/09 21:08	MWS	
1,1-Dichloroethene	<	0.5 ug/l	08/17/09 21:08	MWS	
1,2,4-Trichlorobenzene	<	0.5 ug/l	08/17/09 21:08	MWS	
1,2-Dichlorobenzene	<	0.5 ug/l	08/17/09 21:08	MWS	
1,2-Dichloroethane	<	0.5 ug/l	08/17/09 21:08	MWS	
1,2-Dichloropropane	<	0.5 ug/l	08/17/09 21:08	MWS	
1,4-Dichlorobenzene	<	0.5 ug/l	08/17/09 21:08	MWS	
Benzene	<	0.5 ug/l	08/17/09 21:08	MWS	
Carbon Tetrachloride	<	0.5 ug/l	08/17/09 21:08	MWS	
Chlorobenzene	<	0.5 ug/l	08/17/09 21:08	MWS	
cis-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 21:08	MWS	
Ethylbenzene	<	0.5 ug/l	08/17/09 21:08	MWS	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/09/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082770-3**
Collect Date : **08/13/09 12:05**
Client ID : **DRINKING WATER**
Site : **TEST WELL**
Locator : **GRAB**

Parameter	**Qualifier**	**Result**	**Analysis Date**	**Analyst**	
EPA 524.2					
Methyl tert-butyl ether	<	0.5 ug/l	08/17/09 21:08	MWS	
Methylene Chloride	<	0.5 ug/l	08/17/09 21:08	MWS	
mp-Xylene	<	0.5 ug/l	08/17/09 21:08	MWS	
o-Xylene	<	0.5 ug/l	08/17/09 21:08	MWS	
Styrene	<	0.5 ug/l	08/17/09 21:08	MWS	
Tetrachloroethene	<	0.5 ug/l	08/17/09 21:08	MWS	
Toluene	<	0.5 ug/l	08/17/09 21:08	MWS	
Total xylenes	<	0.5 ug/l	08/17/09 21:08	MWS	
trans-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 21:08	MWS	
Trichloroethene	<	0.5 ug/l	08/17/09 21:08	MWS	
Vinyl Chloride	<	0.5 ug/l	08/17/09 21:08	MWS	
SM (18) 2130B					PIA
Turbidity Check	<	1 NTU	08/19/09 09:00	ECK	
SM (18) 2320B					PIA
Alkalinity, Total as CaCO3		390 mg/l	08/20/09 08:20	PLI	
SM (18) 2340C					PIA
Hardness, Total as CaCO3		460 mg/l	08/21/09 07:10	PLI	
SM (18) 2510B					PIA
Conductivity		900 umhos/cm	08/19/09 14:03	ARG	
SM (18) 2540C					PIA
Solids, Total Dissolved		560 mg/l	08/17/09 14:05	acb	
SM (18) 2540D					PIA
Solids, Total Suspended	<	4 mg/l	08/17/09 12:23	acb	
SM (18) 4500 H B					PIA
pH	H	7.35 units	08/18/09 13:22	WRW	
H - Method Hold Time Exceeded					
SM (18) 4500 NH3 B,H					PIA
Nitrogen, Ammonia as N		0.72 mg/l	08/25/09 09:03	lgtth	
SM (18) 4500 P B,E					PIA
Phosphorus, Ortho as P		0.06 mg/l	08/14/09 15:44	GDM	
SM (18) 5310D					PIA
Carbon, Total Organic		0.96 mg/l	08/19/09 00:41	nay	
SM 4500 S2 E, 376.1					PIA
Sulfide, Total	<	2 mg/l	08/17/09 09:22	PLI	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/09/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082770-4**
Collect Date : **08/13/09 12:00**
Client ID : **DRINKING WATER**
Site : **SUGAR CREEK**
Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	Lab
EPA 200.7 R4.4					PIA
Iron		0.17 mg/l	09/08/09 13:03	jfa	
Silicon as SiO2		3 mg/l	09/08/09 08:00	JFA	
Sodium		92 mg/l	08/26/09 12:00	JFA	
EPA 200.8 R5.4					PIA
Aluminum		0.12 mg/l	08/25/09 16:00	KMC	
Antimony	<	0.003 mg/l	08/25/09 16:00	KMC	
Arsenic	<	0.001 mg/l	08/25/09 16:00	KMC	
Barium		0.047 mg/l	08/25/09 16:00	KMC	
Beryllium	<	0.001 mg/l	08/25/09 16:00	KMC	
Cadmium	<	0.001 mg/l	08/25/09 16:00	KMC	
Calcium		70 mg/l	08/21/09 18:03	JMW	
Chromium	<	0.004 mg/l	08/25/09 16:00	KMC	
Copper		0.007 mg/l	08/25/09 16:00	KMC	
Lead	<	0.001 mg/l	08/25/09 16:00	KMC	
Magnesium		29 mg/l	08/21/09 18:03	JMW	
Manganese		0.045 mg/l	08/25/09 16:00	KMC	
Mercury	<	0.0002 mg/l	08/25/09 16:00	KMC	
Nickel	<	0.005 mg/l	08/25/09 16:00	KMC	
Selenium		0.001 mg/l	08/25/09 16:00	KMC	
Thallium	<	0.001 mg/l	08/25/09 16:00	KMC	
Zinc		0.025 mg/l	08/25/09 16:00	KMC	
EPA 300.0 R2.1					PIA
Chloride		150 mg/l	08/20/09 17:43	lgnay	
Fluoride		0.63 mg/l	08/15/09 02:39	lgnay	
Nitrate as N		15 mg/l	08/15/09 02:55	lgnay	
Nitrite as N	<	0.15 mg/l	08/15/09 02:39	lgnay	
Sulfate		61 mg/l	08/15/09 02:55	lgnay	
EPA 335.4					PIA
Cyanide, Total	<	0.01 mg/l	08/20/09 10:59	lgarg	
EPA 524.2					PIA
1,1,1-Trichloroethane	<	0.5 ug/l	08/17/09 21:48	MWS	
1,1,2-Trichloroethane	<	0.5 ug/l	08/17/09 21:48	MWS	
1,1-Dichloroethene	<	0.5 ug/l	08/17/09 21:48	MWS	
1,2,4-Trichlorobenzene	<	0.5 ug/l	08/17/09 21:48	MWS	
1,2-Dichlorobenzene	<	0.5 ug/l	08/17/09 21:48	MWS	
1,2-Dichloroethane	<	0.5 ug/l	08/17/09 21:48	MWS	
1,2-Dichloropropane	<	0.5 ug/l	08/17/09 21:48	MWS	
1,4-Dichlorobenzene	<	0.5 ug/l	08/17/09 21:48	MWS	
Benzene	<	0.5 ug/l	08/17/09 21:48	MWS	
Carbon Tetrachloride	<	0.5 ug/l	08/17/09 21:48	MWS	
Chlorobenzene	<	0.5 ug/l	08/17/09 21:48	MWS	
cis-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 21:48	MWS	
Ethylbenzene	<	0.5 ug/l	08/17/09 21:48	MWS	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/09/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082770-4**
Collect Date : **08/13/09 12:00**
Client ID : **DRINKING WATER**
Site : **SUGAR CREEK**
Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	
EPA 524.2					
Methyl tert-butyl ether	<	0.5 ug/l	08/17/09 21:48	MWS	
Methylene Chloride	<	0.5 ug/l	08/17/09 21:48	MWS	
mp-Xylene	<	0.5 ug/l	08/17/09 21:48	MWS	
o-Xylene	<	0.5 ug/l	08/17/09 21:48	MWS	
Styrene	<	0.5 ug/l	08/17/09 21:48	MWS	
Tetrachloroethene	<	0.5 ug/l	08/17/09 21:48	MWS	
Toluene	<	0.5 ug/l	08/17/09 21:48	MWS	
Total xylenes	<	0.5 ug/l	08/17/09 21:48	MWS	
trans-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 21:48	MWS	
Trichloroethene	<	0.5 ug/l	08/17/09 21:48	MWS	
Vinyl Chloride	<	0.5 ug/l	08/17/09 21:48	MWS	
SM (18) 2130B					PIA
Turbidity Check		1.1 NTU	08/19/09 09:00	ECK	
SM (18) 2320B					PIA
Alkalinity, Total as CaCO3		150 mg/l	08/20/09 08:20	PLI	
SM (18) 2340C					PIA
Hardness, Total as CaCO3		290 mg/l	08/26/09 12:38	GDM	
SM (18) 2510B					PIA
Conductivity		1000 umhos/cm	08/19/09 14:05	ARG	
SM (18) 2540C					PIA
Solids, Total Dissolved		580 mg/l	08/17/09 14:05	acb	
SM (18) 2540D					PIA
Solids, Total Suspended	<	4 mg/l	08/17/09 12:24	acb	
SM (18) 4500 H B					PIA
pH	H	7.81 units	08/18/09 13:24	WRW	
H - Method Hold Time Exceeded					
SM (18) 4500 NH3 B,H					PIA
Nitrogen, Ammonia as N		0.065 mg/l	08/25/09 09:03	lgtth	
SM (18) 4500 P B,E					PIA
Phosphorus, Ortho as P		2 mg/l	08/14/09 15:44	GDM	
SM (18) 5310D					PIA
Carbon, Total Organic		6.2 mg/l	08/19/09 00:52	nay	
SM 4500 S2 E, 376.1					PIA
Sulfide, Total	P,<	2 mg/l	08/17/09 09:22	PLI	
SW-846 3015					PIA
Sample Preparation			08/31/09 05:30	JEM	
Sample Preparation			08/21/09 05:45	ECK	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/09/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082770-5**
Collect Date : **08/13/09 00:00**
Client ID : **DRINKING WATER**
Site : **TRIP BLANK**
Locator :

Parameter	Qualifier	Result	Analysis Date	Analyst	Lab

This report shall not be reproduced, except in full, without the written approval of the laboratory.

PDC Laboratories participates in the following accreditation/certification and proficiency programs at the following locations.
Endorsement by the Federal or State Government or their agencies is not implied.

PIA	PDC Laboratories - Peoria, IL NELAC Accreditation for Drinking Water, Wastewater, Hazardous and Solid Wastes Fields of Testing through IL EPA Lab No. 100230 State of Illinois Bacteriological Analysis in Drinking Water Certified Lab Registry No. 17553 Drinking Water Certifications: Indiana (C-IL-040); Kansas (E-10338); Kentucky (90058); Missouri (00870); Wisconsin (998294430) Wastewater Certifications: Arkansas; Iowa (240); Kansas (E-10338); Wisconsin (998294430) Hazardous/Solid Waste Certifications: Arkansas; Kansas (E-10338); Wisconsin(998294430) UST Certification: Iowa (240)
SPMO	PDC Laboratories - Springfield, MO EPA DMR-QA Program
STL	PDC Laboratories - St. Louis, MO NELAC Accreditation for Wastewater, Hazardous and Solid Wastes Fields of Testing through IL EPA Lab No. 100253.

Certified by:
Lori L. Stenzel, Project Manager

PDC LABORATORIES, INC.
2231 WEST ALTORFER DRIVE
PEORIA, IL 61615

PHONE # 800-752-6651
FAX # 309-692-9689

CHAIN OF CUSTODY RECORD

State where samples collected IL

*ALL HIGHLIGHTED AREAS MUST BE COMPLETED BY CLIENT (PLEASE PRINT) - **(SAMPLE ACCEPTANCE POLICY ON REVERSE)***

① CLIENT: City of Bloomington
ADDRESS: 25515 Waterside Way
CITY STATE ZIP: Hudson, IL 61748
CONTACT PERSON: Jill Mayes

PROJECT NUMBER: Stark-BLM Well
P.O. NUMBER:
MEANS SHIPPED: PDC Courier
PHONE NUMBER: 434-2153
FAX NUMBER: 434-2159
DATE SHIPPED: 8/14/09
SAMPLER (PLEASE PRINT): Rick Twait
SAMPLER'S SIGNATURE:

MATRIX TYPES:
WW-WASTEWATER
DW-DRINKING WATER
GW-GROUND WATER
WWSL-SLUDGE
NAS-SOLID
LCHT-LEACHATE
OTHER: ____

④ (FOR LAB USE ONLY)
LOGIN # 09082770-4
LOGGED BY: TLB
LAB PROJ. #
TEMPLATE:
PROJ. MGR.:

③ ANALYSIS REQUESTED

② SAMPLE DESCRIPTION AS YOU WANT ON REPORT	DATE COLLECTED	TIME COLLECTED	SAMPLE TYPE GRAB	SAMPLE TYPE COMP	MATRIX TYPE	BOTTLE COUNT	IOC+VOC+TOC	Alkalinity Hardness	pH, Spec Con, TDS TSS	Chloride, NH3-N, NO3-N	NO2-N, Ortho Phosphate	Al, Ca, Cu, Pb, Mg	Silica sulfide	REMARKS
Test well	8/12/09	11:25a.m.	X		GW	10	X	X	X	X	X	X	X	
Sugar Creek	8/12/09	10:25a.m.	X		GW	9	X	X	X	X	X	X	X	
Test well	8/13/09	12:05p.m.	X		GW	10	X	X	X	X	X	X	X	
Sugar Creek	8/13/09	12:00p.m.	X		GW	9	X	X	X	X	X	X	X	

⑤ TURNAROUND TIME REQUESTED (PLEASE CIRCLE) [✓ NORMAL] RUSH
(RUSH TAT IS SUBJECT TO PDC LABS APPROVAL AND SURCHARGE)
DATE RESULTS NEEDED
RUSH RESULTS VIA (PLEASE CIRCLE) FAX PHONE E-MAIL
FAX # PHONE # EMAIL ADDRESS

⑥ *The sample temperature will be measured upon receipt at the lab. By initialing this area you request that the lab notify you, before proceeding with analysis, if the sample temperature is outside of the range of 0.1-6.0°C. By not initialing this area you allow the lab to proceed with analytical testing regardless of the sample temperature.* ____

⑦ RELINQUISHED BY: (SIGNATURE) Tony Hurwood DATE 8/14/09 TIME
RECEIVED BY: (SIGNATURE) DATE TIME
RELINQUISHED BY: (SIGNATURE) DATE TIME
RECEIVED BY: (SIGNATURE) DATE TIME
RELINQUISHED BY: (SIGNATURE) DATE TIME
RECEIVED AT LAB BY: (SIGNATURE) DATE 8/14/09 TIME 1430

⑧ COMMENTS: (FOR LAB USE ONLY)
*No sulfide bottles received for Creek samples TLB

SAMPLE TEMPERATURE UPON RECEIPT 14 °C
CHILL PROCESS STARTED PRIOR TO RECEIPT [✓ Y] OR N
SAMPLE(S) RECEIVED ON ICE [✓ Y] OR N
PROPER BOTTLES RECEIVED IN GOOD CONDITION ~~Y~~ OR [✓ N]
BOTTLES FILLED WITH ADEQUATE VOLUME [✓ Y] OR N
SAMPLES RECEIVED WITHIN HOLD TIME(S) [✓ Y] OR N
(EXCLUDES TYPICAL FIELD PARAMETERS)
DATE AND TIME TAKEN FROM SAMPLE BOTTLE ____

Copies: white should accompany samples to PDC Labs. **Yellow copy to be retained by the client.**

PAGE 1 OF 1

PDC Laboratories, Inc.
2231 W. Altorfer Drive - Peoria, IL 61615
(309) 692-9688 - (800) 752-6651 - FAX (309) 692-9689

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/11/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082776-1**
Collect Date : **08/10/09 12:05**
Client ID : **DRINKING WATER**
Site : **TEST WELL**
Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	Lab
EPA 200.7 R4.4					PIA
Iron		3 mg/l	09/08/09 13:36	jfa	
Silicon as SiO2		14 mg/l	08/19/09 07:00	JFA	
Sodium		17 mg/l	08/26/09 10:00	JFA	
EPA 200.8 R5.4					PIA
Aluminum		0.016 mg/l	08/21/09 11:00	KMC	
Antimony	<	0.003 mg/l	08/21/09 11:00	KMC	
Arsenic	<	0.001 mg/l	08/21/09 11:00	KMC	
Barium		0.13 mg/l	08/21/09 11:00	KMC	
Beryllium	<	0.001 mg/l	08/21/09 11:00	KMC	
Cadmium	<	0.001 mg/l	08/21/09 11:00	KMC	
Calcium		120 mg/l	08/21/09 16:47	JMW	
Chromium	<	0.004 mg/l	08/21/09 11:00	KMC	
Copper		0.048 mg/l	08/21/09 11:00	KMC	
Lead		0.002 mg/l	08/21/09 11:00	KMC	
Magnesium		50 mg/l	08/21/09 16:47	JMW	
Manganese		0.072 mg/l	08/21/09 11:00	KMC	
Mercury	<	0.0002 mg/l	08/21/09 11:00	KMC	
Nickel	<	0.005 mg/l	08/21/09 11:00	KMC	
Selenium		0.002 mg/l	08/21/09 11:00	KMC	
Thallium	<	0.001 mg/l	08/21/09 11:00	KMC	
Zinc		0.091 mg/l	08/21/09 11:00	KMC	
EPA 300.0 R2.1					PIA
Nitrate as N	H	0.045 mg/l	08/20/09 18:29	Ignay	
Nitrite as N	H<	0.15 mg/l	08/20/09 18:29	Ignay	

H - Method Hold Time Exceeded

Parameter	Qualifier	Result	Analysis Date	Analyst	Lab
EPA 300.0 R2.1					PIA
Chloride		55 mg/l	08/20/09 18:45	Ignay	
Fluoride		0.27 mg/l	08/20/09 18:29	Ignay	
Sulfate		53 mg/l	08/20/09 18:45	Ignay	
EPA 335.4					PIA
Cyanide, Total	<	0.01 mg/l	08/20/09 10:59	Igarg	
EPA 524.2					PIA
1,1,1-Trichloroethane	<	0.5 ug/l	08/17/09 22:27	MWS	
1,1,2-Trichloroethane	<	0.5 ug/l	08/17/09 22:27	MWS	
1,1-Dichloroethene	<	0.5 ug/l	08/17/09 22:27	MWS	
1,2,4-Trichlorobenzene	<	0.5 ug/l	08/17/09 22:27	MWS	
1,2-Dichlorobenzene	<	0.5 ug/l	08/17/09 22:27	MWS	
1,2-Dichloroethane	<	0.5 ug/l	08/17/09 22:27	MWS	
1,2-Dichloropropane	<	0.5 ug/l	08/17/09 22:27	MWS	
1,4-Dichlorobenzene	<	0.5 ug/l	08/17/09 22:27	MWS	
Benzene	<	0.5 ug/l	08/17/09 22:27	MWS	
Carbon Tetrachloride	<	0.5 ug/l	08/17/09 22:27	MWS	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/11/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082776-1**
Collect Date : **08/10/09 12:05**
Client ID : **DRINKING WATER**
Site : **TEST WELL**
Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	
EPA 524.2					
Chlorobenzene	<	0.5 ug/l	08/17/09 22:27	MWS	
cis-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 22:27	MWS	
Ethylbenzene	<	0.5 ug/l	08/17/09 22:27	MWS	
Methyl tert-butyl ether	<	0.5 ug/l	08/17/09 22:27	MWS	
Methylene Chloride	<	0.5 ug/l	08/17/09 22:27	MWS	
mp-Xylene	<	0.5 ug/l	08/17/09 22:27	MWS	
o-Xylene	<	0.5 ug/l	08/17/09 22:27	MWS	
Styrene	<	0.5 ug/l	08/17/09 22:27	MWS	
Tetrachloroethene	<	0.5 ug/l	08/17/09 22:27	MWS	
Toluene	<	0.5 ug/l	08/17/09 22:27	MWS	
Total xylenes	<	0.5 ug/l	08/17/09 22:27	MWS	
trans-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 22:27	MWS	
Trichloroethene	<	0.5 ug/l	08/17/09 22:27	MWS	
Vinyl Chloride	<	0.5 ug/l	08/17/09 22:27	MWS	
SM (18) 2130B					PIA
Turbidity Check	<	1 NTU	08/19/09 09:00	ECK	
SM (18) 2320B					PIA
Alkalinity, Total as CaCO3		390 mg/l	08/20/09 08:20	PLI	
SM (18) 2340C					PIA
Hardness, Total as CaCO3		480 mg/l	08/21/09 07:10	PLI	
SM (18) 2510B					PIA
Conductivity		910 umhos/cm	08/19/09 14:07	ARG	
SM (18) 2540C					PIA
Solids, Total Dissolved		600 mg/l	08/17/09 14:05	acb	
SM (18) 2540D					PIA
Solids, Total Suspended		6.4 mg/l	08/17/09 12:25	acb	
SM (18) 4500 H B					PIA
pH	H	8.27 units	08/18/09 14:20	WRW	
H - Method Hold Time Exceeded					
SM (18) 4500 NH3 B,H					PIA
Nitrogen, Ammonia as N	<	0.05 mg/l	08/25/09 09:16	lgtth	
SM (18) 4500 P B,E					PIA
Phosphorus, Ortho as P	H	0.049 mg/l	08/14/09 15:44	GDM	
H - Method Hold Time Exceeded					
SM (18) 5310D					PIA
Carbon, Total Organic		0.93 mg/l	08/19/09 01:03	nay	
SM 4500 S2 E, 376.1					PIA
Sulfide, Total	<	2 mg/l	08/17/09 09:22	PLI	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/11/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082776-2** Collect Date : **08/10/09 12:49**
Client ID : **DRINKING WATER** Site : **SUGAR CREEK** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	Lab
EPA 200.7 R4.4					PIA
Iron		0.25 mg/l	09/08/09 13:05	jfa	
Silicon as SiO2		3.3 mg/l	09/09/09 08:00	JFA	
Sodium		75 mg/l	08/26/09 12:00	JFA	
EPA 200.8 R5.4					PIA
Aluminum		0.24 mg/l	08/25/09 16:00	KMC	
Antimony	<	0.003 mg/l	08/25/09 16:00	KMC	
Arsenic	<	0.001 mg/l	08/25/09 16:00	KMC	
Barium		0.046 mg/l	08/25/09 16:00	KMC	
Beryllium	<	0.001 mg/l	08/25/09 16:00	KMC	
Cadmium	<	0.001 mg/l	08/25/09 16:00	KMC	
Calcium		68 mg/l	08/21/09 18:06	JMW	
Chromium	<	0.004 mg/l	08/25/09 16:00	KMC	
Copper		0.007 mg/l	08/25/09 16:00	KMC	
Lead	<	0.001 mg/l	08/25/09 16:00	KMC	
Magnesium		28 mg/l	08/21/09 18:06	JMW	
Manganese		0.051 mg/l	08/25/09 16:00	KMC	
Mercury	<	0.0002 mg/l	08/25/09 16:00	KMC	
Nickel	<	0.005 mg/l	08/25/09 16:00	KMC	
Selenium	<	0.001 mg/l	08/25/09 16:00	KMC	
Thallium	<	0.001 mg/l	08/25/09 16:00	KMC	
Zinc		0.019 mg/l	08/25/09 16:00	KMC	
EPA 300.0 R2.1					PIA
Nitrate as N	H	9.4 mg/l	08/20/09 19:31	lgnay	
Nitrite as N	H<	0.15 mg/l	08/20/09 19:16	lgnay	
H - Method Hold Time Exceeded					
EPA 300.0 R2.1					PIA
Chloride		140 mg/l	08/20/09 19:46	lgnay	
Fluoride		0.5 mg/l	08/20/09 19:16	lgnay	
Sulfate		57 mg/l	08/20/09 19:31	lgnay	
EPA 335.4					PIA
Cyanide, Total	<	0.01 mg/l	08/20/09 11:02	lgarg	
EPA 524.2					PIA
1,1,1-Trichloroethane	<	0.5 ug/l	08/17/09 23:07	MWS	
1,1,2-Trichloroethane	<	0.5 ug/l	08/17/09 23:07	MWS	
1,1-Dichloroethene	<	0.5 ug/l	08/17/09 23:07	MWS	
1,2,4-Trichlorobenzene	<	0.5 ug/l	08/17/09 23:07	MWS	
1,2-Dichlorobenzene	<	0.5 ug/l	08/17/09 23:07	MWS	
1,2-Dichloroethane	<	0.5 ug/l	08/17/09 23:07	MWS	
1,2-Dichloropropane	<	0.5 ug/l	08/17/09 23:07	MWS	
1,4-Dichlorobenzene	<	0.5 ug/l	08/17/09 23:07	MWS	
Benzene	<	0.5 ug/l	08/17/09 23:07	MWS	
Carbon Tetrachloride	<	0.5 ug/l	08/17/09 23:07	MWS	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/11/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082776-2**
Collect Date : **08/10/09 12:49**
Client ID : **DRINKING WATER**
Site : **SUGAR CREEK**
Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	
EPA 524.2					
Chlorobenzene	<	0.5 ug/l	08/17/09 23:07	MWS	
cis-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 23:07	MWS	
Ethylbenzene	<	0.5 ug/l	08/17/09 23:07	MWS	
Methyl tert-butyl ether	<	0.5 ug/l	08/17/09 23:07	MWS	
Methylene Chloride	<	0.5 ug/l	08/17/09 23:07	MWS	
mp-Xylene	<	0.5 ug/l	08/17/09 23:07	MWS	
o-Xylene	<	0.5 ug/l	08/17/09 23:07	MWS	
Styrene	<	0.5 ug/l	08/17/09 23:07	MWS	
Tetrachloroethene	<	0.5 ug/l	08/17/09 23:07	MWS	
Toluene	<	0.5 ug/l	08/17/09 23:07	MWS	
Total xylenes	<	0.5 ug/l	08/17/09 23:07	MWS	
trans-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 23:07	MWS	
Trichloroethene	<	0.5 ug/l	08/17/09 23:07	MWS	
Vinyl Chloride	<	0.5 ug/l	08/17/09 23:07	MWS	
SM (18) 2130B					PIA
Turbidity Check		1.4 NTU	08/19/09 09:00	ECK	
SM (18) 2320B					PIA
Alkalinity, Total as CaCO3		190 mg/l	08/20/09 08:20	PLI	
SM (18) 2340C					PIA
Hardness, Total as CaCO3		280 mg/l	08/26/09 12:38	GDM	
SM (18) 2510B					PIA
Conductivity		920 umhos/cm	08/19/09 14:09	ARG	
SM (18) 2540C					PIA
Solids, Total Dissolved		540 mg/l	08/17/09 14:06	acb	
SM (18) 2540D					PIA
Solids, Total Suspended		5.2 mg/l	08/17/09 12:25	acb	
SM (18) 4500 H B					PIA
pH	H	8.1 units	08/18/09 14:24	WRW	
H - Method Hold Time Exceeded					
SM (18) 4500 NH3 B,H					PIA
Nitrogen, Ammonia as N		0.79 mg/l	08/25/09 09:17	lgtth	
SM (18) 4500 P B,E					PIA
Phosphorus, Ortho as P	H	1.4 mg/l	08/14/09 15:44	GDM	
H - Method Hold Time Exceeded					
SM (18) 5310D					PIA
Carbon, Total Organic		5.5 mg/l	08/19/09 01:14	nay	
SW-846 3015					PIA
Sample Preparation			08/31/09 05:30	JEM	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/11/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082776-2** Collect Date : **08/10/09 12:49**
Client ID : **DRINKING WATER** Site : **SUGAR CREEK** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst
SW-846 3015				
Sample Preparation			08/21/09 05:45	ECK

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/11/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082776-3**
Collect Date : **08/11/09 11:33**
Client ID : **DRINKING WATER**
Site : **TEST WELL**
Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	Lab
EPA 200.7 R4.4					PIA
Iron		3 mg/l	09/08/09 13:44	jfa	
Silicon as SiO2		14 mg/l	08/19/09 07:00	JFA	
Sodium		18 mg/l	08/26/09 10:00	JFA	
EPA 200.8 R5.4					PIA
Aluminum	<	0.01 mg/l	08/21/09 11:00	KMC	
Antimony	<	0.003 mg/l	08/21/09 11:00	KMC	
Arsenic		0.002 mg/l	08/21/09 11:00	KMC	
Barium		0.13 mg/l	08/21/09 11:00	KMC	
Beryllium	<	0.001 mg/l	08/21/09 11:00	KMC	
Cadmium	<	0.001 mg/l	08/21/09 11:00	KMC	
Calcium		120 mg/l	08/21/09 17:06	JMW	
Chromium	<	0.004 mg/l	08/21/09 11:00	KMC	
Copper		0.029 mg/l	08/21/09 11:00	KMC	
Lead		0.003 mg/l	08/21/09 11:00	KMC	
Magnesium		45 mg/l	08/21/09 17:06	JMW	
Manganese		0.067 mg/l	08/21/09 11:00	KMC	
Mercury	<	0.0002 mg/l	08/21/09 11:00	KMC	
Nickel	<	0.005 mg/l	08/21/09 11:00	KMC	
Selenium		0.003 mg/l	08/21/09 11:00	KMC	
Thallium	<	0.001 mg/l	08/21/09 11:00	KMC	
Zinc		0.058 mg/l	08/21/09 11:00	KMC	
EPA 300.0 R2.1					PIA
Nitrate as N	H<	0.02 mg/l	08/21/09 13:53	lgnay	
Nitrite as N	H<	0.15 mg/l	08/21/09 13:53	lgnay	
H - Method Hold Time Exceeded					
EPA 300.0 R2.1					PIA
Chloride		57 mg/l	08/21/09 14:08	lgnay	
Fluoride	<	0.25 mg/l	08/21/09 13:53	lgnay	
Sulfate		52 mg/l	08/21/09 14:08	lgnay	
EPA 335.4					PIA
Cyanide, Total	<	0.01 mg/l	08/20/09 11:07	lgarg	
EPA 524.2					PIA
1,1,1-Trichloroethane	<	0.5 ug/l	08/17/09 23:47	MWS	
1,1,2-Trichloroethane	<	0.5 ug/l	08/17/09 23:47	MWS	
1,1-Dichloroethene	<	0.5 ug/l	08/17/09 23:47	MWS	
1,2,4-Trichlorobenzene	<	0.5 ug/l	08/17/09 23:47	MWS	
1,2-Dichlorobenzene	<	0.5 ug/l	08/17/09 23:47	MWS	
1,2-Dichloroethane	<	0.5 ug/l	08/17/09 23:47	MWS	
1,2-Dichloropropane	<	0.5 ug/l	08/17/09 23:47	MWS	
1,4-Dichlorobenzene	<	0.5 ug/l	08/17/09 23:47	MWS	
Benzene	<	0.5 ug/l	08/17/09 23:47	MWS	
Carbon Tetrachloride	<	0.5 ug/l	08/17/09 23:47	MWS	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/11/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082776-3**
Collect Date : **08/11/09 11:33**
Client ID : **DRINKING WATER**
Site : **TEST WELL**
Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	
EPA 524.2					
Chlorobenzene	<	0.5 ug/l	08/17/09 23:47	MWS	
cis-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 23:47	MWS	
Ethylbenzene	<	0.5 ug/l	08/17/09 23:47	MWS	
Methyl tert-butyl ether	<	0.5 ug/l	08/17/09 23:47	MWS	
Methylene Chloride	<	0.5 ug/l	08/17/09 23:47	MWS	
mp-Xylene	<	0.5 ug/l	08/17/09 23:47	MWS	
o-Xylene	<	0.5 ug/l	08/17/09 23:47	MWS	
Styrene	<	0.5 ug/l	08/17/09 23:47	MWS	
Tetrachloroethene	<	0.5 ug/l	08/17/09 23:47	MWS	
Toluene	<	0.5 ug/l	08/17/09 23:47	MWS	
Total xylenes	<	0.5 ug/l	08/17/09 23:47	MWS	
trans-1,2-Dichloroethene	<	0.5 ug/l	08/17/09 23:47	MWS	
Trichloroethene	<	0.5 ug/l	08/17/09 23:47	MWS	
Vinyl Chloride	<	0.5 ug/l	08/17/09 23:47	MWS	
SM (18) 2130B					PIA
Turbidity Check	<	1 NTU	08/19/09 09:00	ECK	
SM (18) 2320B					PIA
Alkalinity, Total as CaCO3		390 mg/l	08/20/09 08:20	PLI	
SM (18) 2340C					PIA
Hardness, Total as CaCO3		490 mg/l	08/21/09 07:10	PLI	
SM (18) 2510B					PIA
Conductivity		910 umhos/cm	08/19/09 14:13	ARG	
SM (18) 2540C					PIA
Solids, Total Dissolved		600 mg/l	08/17/09 14:06	acb	
SM (18) 2540D					PIA
Solids, Total Suspended		4.4 mg/l	08/17/09 12:25	acb	
SM (18) 4500 H B					PIA
pH	H	8.08 units	08/18/09 14:27	WRW	
H - Method Hold Time Exceeded					
SM (18) 4500 NH3 B,H					PIA
Nitrogen, Ammonia as N		0.061 mg/l	08/25/09 09:17	lgtth	
SM (18) 4500 P B,E					PIA
Phosphorus, Ortho as P	H	0.094 mg/l	08/14/09 15:44	GDM	
H - Method Hold Time Exceeded					
SM (18) 5310D					PIA
Carbon, Total Organic		0.73 mg/l	08/19/09 18:40	nay	
SM 4500 S2 E, 376.1					PIA
Sulfide, Total	X,<	2 mg/l	08/17/09 09:22	PLI	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/11/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082776-3** Collect Date : **08/11/09 11:33**
Client ID : **DRINKING WATER** Site : **TEST WELL** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst

SM 4500 S2 E, 376.1

X=never turned clear, rather light purple

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/11/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082776-4** Collect Date : **08/11/09 11:30**
Client ID : **DRINKING WATER** Site : **SUGAR CREEK** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	Lab
EPA 200.7 R4.4					PIA
Iron		0.26 mg/l	09/08/09 13:07	jfa	
Silicon as SiO2		3.4 mg/l	09/08/09 08:00	JFA	
Sodium		87 mg/l	08/26/09 12:00	JFA	
EPA 200.8 R5.4					PIA
Aluminum		0.23 mg/l	08/25/09 16:00	KMC	
Antimony	<	0.003 mg/l	08/25/09 16:00	KMC	
Arsenic	<	0.001 mg/l	08/25/09 16:00	KMC	
Barium		0.048 mg/l	08/25/09 16:00	KMC	
Beryllium	<	0.001 mg/l	08/25/09 16:00	KMC	
Cadmium	<	0.001 mg/l	08/25/09 16:00	KMC	
Calcium		80 mg/l	08/21/09 18:10	JMW	
Chromium	<	0.004 mg/l	08/25/09 16:00	KMC	
Copper		0.004 mg/l	08/25/09 16:00	KMC	
Lead	<	0.001 mg/l	08/25/09 16:00	KMC	
Magnesium		33 mg/l	08/21/09 18:10	JMW	
Manganese		0.048 mg/l	08/25/09 16:00	KMC	
Mercury	<	0.0002 mg/l	08/25/09 16:00	KMC	
Nickel	<	0.005 mg/l	08/25/09 16:00	KMC	
Selenium	<	0.001 mg/l	08/25/09 16:00	KMC	
Thallium	<	0.001 mg/l	08/25/09 16:00	KMC	
Zinc		0.16 mg/l	08/25/09 16:00	KMC	
EPA 300.0 R2.1					PIA
Nitrate as N	H	14 mg/l	08/21/09 15:25	lgnay	
Nitrite as N	H<	0.15 mg/l	08/21/09 15:10	lgnay	
H - Method Hold Time Exceeded					
EPA 300.0 R2.1					PIA
Chloride		150 mg/l	08/21/09 15:40	lgnay	
Fluoride		0.67 mg/l	08/21/09 15:10	lgnay	
Sulfate		65 mg/l	08/21/09 15:25	lgnay	
EPA 335.4					PIA
Cyanide, Total	<	0.01 mg/l	08/20/09 11:07	lgarg	
SM (18) 2130B					PIA
Turbidity Check		1.2 NTU	08/19/09 09:00	ECK	
SM (18) 2320B					PIA
Alkalinity, Total as CaCO3		160 mg/l	08/20/09 08:20	PLI	
SM (18) 2340C					PIA
Hardness, Total as CaCO3		290 mg/l	08/26/09 12:38	GDM	
SM (18) 2510B					PIA
Conductivity		970 umhos/cm	08/19/09 14:16	ARG	
SM (18) 2540C					PIA

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/11/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

Sample No: **09082776-4** Collect Date : **08/11/09 11:30**
Client ID : **DRINKING WATER** Site : **SUGAR CREEK** Locator : **GRAB**

Parameter	Qualifier	Result	Analysis Date	Analyst	
SM (18) 2540C					
Solids, Total Dissolved		590 mg/l	08/17/09 14:06	acb	PIA
SM (18) 2540D					
Solids, Total Suspended	<	4 mg/l	08/17/09 12:25	acb	PIA
SM (18) 4500 H B					
pH	H	8.35 units	08/18/09 14:30	WRW	PIA
H - Method Hold Time Exceeded					
SM (18) 4500 NH3 B,H					
Nitrogen, Ammonia as N	<	0.05 mg/l	08/25/09 09:18	lgtth	PIA
SM (18) 4500 P B,E					
Phosphorus, Ortho as P	H	1.7 mg/l	08/14/09 15:44	GDM	PIA
H - Method Hold Time Exceeded					
SM (18) 5310D					
Carbon, Total Organic		5.8 mg/l	08/20/09 02:58	nay	PIA
SM 4500 S2 E, 376.1					
Sulfide, Total	<	2 mg/l	08/17/09 09:22	PLI	PIA
SW-846 3015					
Sample Preparation			08/21/09 05:45	ECK	
Sample Preparation			08/31/09 05:30	JEM	

Laboratory Results

City of Bloomington
WATER TREATMENT PLANT
25515 WATERSIDE WAY
Hudson, IL 61748
Attn : Ms Jill Mayes

Date Received : 08/14/09 14:30
Report Date 09/11/09
Customer # : 275096
P.O. Number : 17379
Facility : IL1130200

This report shall not be reproduced, except in full, without the written approval of the laboratory.

PDC Laboratories participates in the following accreditation/certification and proficiency programs at the following locations.
Endorsement by the Federal or State Government or their agencies is not implied.

PIA	PDC Laboratories - Peoria, IL NELAC Accreditation for Drinking Water, Wastewater, Hazardous and Solid Wastes Fields of Testing through IL EPA Lab No. 100230 State of Illinois Bacteriological Analysis in Drinking Water Certified Lab Registry No. 17553 Drinking Water Certifications: Indiana (C-IL-040); Kansas (E-10338); Kentucky (90058); Missouri (00870); Wisconsin (998294430) Wastewater Certifications: Arkansas; Iowa (240); Kansas (E-10338); Wisconsin (998294430) Hazardous/Solid Waste Certifications: Arkansas; Kansas (E-10338); Wisconsin(998294430) UST Certification: Iowa (240)
SPMO	PDC Laboratories - Springfield, MO EPA DMR-QA Program
STL	PDC Laboratories - St. Louis, MO NELAC Accreditation for Wastewater, Hazardous and Solid Wastes Fields of Testing through IL EPA Lab No. 100253.

Certified by: Lori L. Stenzel
Lori L. Stenzel, Project Manager

COLIFORM ANALYSIS REPORT

BLOOMINGTON WATER TREATMENT PLANT

25515 WATERSIDE WAY, HUDSON IL 61748

CONTACT: Richard M Twait, Director of Water Purification at 309.434.2150

Facility No.: 1130200 Name: Bloomington
Sampling Period: N/A
Surface Supply: Yes
Chlorine Exempt: No

Date & Time Received: 8/11/09 2:30 p.m.
Received by: T. Alwood
Date & Time Analyzed: 8/11/09 2:35 p.m.
Analyzed by: T. Alwood

Date Collected: 8/10/09
Sample collector: Rick Twait

Sample Purpose: __Routine __Replacement
__Invalid Replacement __Repeat
Original Lab Sample No(s).:
X Other Test Well and Stream
__New Construction Permit No.______FY____

Lab Control 1 ✓Pass __Fail

Bottle#	Sample Type	Residual Chlorine (mg/l)	Lab Sample No.	IEPA Site No. and/or Sample Address	Time Collected _AM_[✓ PM]	Vol analyzed (ml)	Col Read	Total Coli	Ecoli ~~Fecal Coli~~	Opin
1	R	0	01-081109	Test Well	12:00	100	N/A	~~>200.5~~ P	N	u
2	R	0	02-081109	Stream	12:50	100	N/A	>200.5	91.0	u

Lab Control 2 ✓ Pass __Fail

Method *(circle one)*: Membrane Filter /[✓ Colilert]/Colilert 18 Person Notified: ____________
Laboratory Cert No: 17576 Name: Bloomington Date: __/__/__ Time: ______
Reported by: Jill Mayes Date: 8/12/09

COLIFORM ANALYSIS REPORT

BLOOMINGTON WATER TREATMENT PLANT

25515 WATERSIDE WAY, HUDSON IL 61748

CONTACT: Richard M Twait, Director of Water Purification at 309.434.2150

Facility No.: 1130200 Name: Bloomington
Sampling Period: N/A
Surface Supply: Yes
Chlorine Exempt: No

Date & Time Received: 8/11/09 2:30 p.m.
Received by: T. Alwood
Date & Time Analyzed: 8/11/09 2:40 p.m.
Analyzed by: T. Alwood

Date Collected: 8/11/09
Sample collector: Rick Twait

Sample Purpose: __Routine __Replacement
__Invalid Replacement __Repeat
Original Lab Sample No(s).:
X Other Test Well and Stream
__New Construction Permit No.______FY____

Lab Control 1 ✓Pass __Fail

Bottle#	Sample Type	Residual Chlorine (mg/l)	Lab Sample No.	IEPA Site No. and/or Sample Address	Time Collected _AM_PM	Vol analyzed (ml)	Col Read	Total Coli	Ecoli ~~Fecal Coli~~	Opin
3	R	0	03-081109	Stream	11:40a.m.	100	N/A	>200.5	86.0	u
4	R	0	04-081109	Test Well	12:15p.m.	100	N/A	N	N	S

Lab Control 2 ✓Pass __Fail

Method *(circle one)*: Membrane Filter /[✓ Colilert]/Colilert 18 Person Notified: ____________
Laboratory Cert No: 17576 Name: Bloomington Date: __/__/__ Time: ______
Reported by: Jill Mayes Date: 8/12/09

For explanation of symbols used on this form, see back page.

COLIFORM ANALYSIS REPORT
BLOOMINGTON WATER TREATMENT PLANT

25515 WATERSIDE WAY, HUDSON IL 61748
CONTACT: Richard M Twait, Director of Water Purification at 309.434.2150

Facility No.: 1130200 Name: Bloomington
Sampling Period: n/a
Surface Supply: Yes
Chlorine Exempt: No
Date & Time Received: 8/13/09 10:00am
Received by: T. Alwood
Date & Time Analyzed: 8/13/09 10:00a.m.
Analyzed by: T. Alwood

Date Collected: 8 /12 /09
Sample collector: Rick Twait
Sample Purpose: __Routine __Replacement
__Invalid Replacement __Repeat
Original Lab Sample No(s).:________
X Other Well and Stream
__New Construction Permit No.______FY____

Lab Control 1 ✓ Pass __Fail

Bottle#	Sample Type	Residual Chlorine (mg/l)	Lab Sample No.	IEPA Site No. and/or Sample Address	Time Collected [✓ AM] PM	Vol analyzed (ml)	Col Read	Total Coli	Fecal Coli	Opin
1	R	0	01-081309	Test Well	11:25	100	N/A	P	N	u
2	R	0	02-081309	Sugar Creek	10:25	100	N/A	>200.5	96.0	u

Lab Control 2 ✓ Pass __ Fail

Method *(circle one)*: Membrane Filter / [✓ Colilert] / Colilert 18 Person Notified: ________
Laboratory Cert No: 17576 Name: Bloomington Date: __/__/__ Time: ________
Reported by: Jules Mayes Date: 8/14/09

COLIFORM ANALYSIS REPORT
BLOOMINGTON WATER TREATMENT PLANT

25515 WATERSIDE WAY, HUDSON IL 61748
CONTACT: Richard M Twait, Director of Water Purification at 309.434.2150

Facility No.: 1130200 Name: Bloomington
Sampling Period: ________
Surface Supply: Yes
Chlorine Exempt: No
Date & Time Received: ________
Received by: ________
Date & Time Analyzed: ________
Analyzed by: ________

Date Collected: ___/___/___
Sample collector: ________
Sample Purpose: __Routine __Replacement
__Invalid Replacement __Repeat
Original Lab Sample No(s).:________
__Other ________
__New Construction Permit No.______FY____

Lab Control 1 __ Pass __Fail

Bottle#	Sample Type	Residual Chlorine (mg/l)	Lab Sample No.	IEPA Site No. and/or Sample Address	Time Collected AM PM	Vol analyzed (ml)	Col Read	Total Coli	Fecal Coli	Opin

Lab Control 2 __Pass __ Fail

Method *(circle one)*: Membrane Filter / Colilert / Colilert 18 Person Notified: ________
Laboratory Cert No: 17576 Name: Bloomington Date: __/__/__ Time: ________
Reported by: ________ Date: ________

For explanation of symbols used on this form, see back page.

COLIFORM ANALYSIS REPORT
BLOOMINGTON WATER TREATMENT PLANT
25515 WATERSIDE WAY, HUDSON IL 61748
CONTACT: Richard M Twait, Director of Water Purification at 309.434.2150

Facility No.: 1130200 Name: Bloomington
Sampling Period: n/a
Surface Supply: Yes
Chlorine Exempt: No

Date & Time Received: 8/14/09 7:30 a.m.
Received by: T. Alwood
Date & Time Analyzed: 8/14/09 7:30 a.m.
Analyzed by: T. Alwood

Date Collected: 8 /13 /09

Sample collector: Rick Twait

Sample Purpose: __Routine __Replacement
__Invalid Replacement __Repeat
Original Lab Sample No(s).: ____
X Other Well and Stream
__New Construction Permit No.____FY____

Lab Control 1 __ Pass __Fail

Bottle#	Sample Type	Residual Chlorine (mg/l)	Lab Sample No.	IEPA Site No. and/or Sample Address	Time Collected AM [✓ PM]	Vol analyzed (ml)	Col Read	Total Coli	Fecal Coli	Opin
1	R	0	01-081409	Test Well	12:05	100	N/A	N	N	S
2	R	0	02-081409	Sugar Creek	7:15	100	N/A	> 2005	144.5	U

Lab Control 2 __Pass __ Fail

Method *(circle one)*: Membrane Filter / [✓ Colilert] / Colilert 18 Person Notified: ____
Laboratory Cert No: 17576 Name: Bloomington Date: __/__/__ Time: ____
Reported by: RLS Date: 8/15/09

COLIFORM ANALYSIS REPORT
BLOOMINGTON WATER TREATMENT PLANT
25515 WATERSIDE WAY, HUDSON IL 61748
CONTACT: Richard M Twait, Director of Water Purification at 309.434.2150

Facility No.: 1130200 Name: Bloomington
Sampling Period: ____
Surface Supply: Yes
Chlorine Exempt: No

Date & Time Received: ____
Received by: ____
Date & Time Analyzed: ____
Analyzed by: ____

Date Collected: ___/___/___

Sample collector: ____

Sample Purpose: __Routine __Replacement
__Invalid Replacement __Repeat
Original Lab Sample No(s).: ____
__Other ____
__New Construction Permit No.____FY____

Lab Control 1 __ Pass __Fail

Bottle#	Sample Type	Residual Chlorine (mg/l)	Lab Sample No.	IEPA Site No. and/or Sample Address	Time Collected AM PM	Vol analyzed (ml)	Col Read	Total Coli	Fecal Coli	Opin

Lab Control 2 __Pass __ Fail

Method *(circle one)*: Membrane Filter / Colilert / Colilert 18 Person Notified: ____
Laboratory Cert No: 17576 Name: Bloomington Date: __/__/__ Time: ____
Reported by: ____ Date: ____

For explanation of symbols used on this form, see back page.

EXPLANATIONS OF SYMBOLS ON THE COLIFORM ANALYSIS REPORT

SAMPLE PURPOSE: Check the appropriate box to indicate the following:
Routine – Mark this box if these are your regular monthly samples.
Replacement – Mark this box for samples submitted to replace samples previously submitted but not analyzed.
Boil Order – Mark this box for a sample taken following the issuance of a boil order.
Other - Mark this box for samples submitted for any other reason (such as complaints). Indicate reason for sample.
Repeat Sample – Mark this box for samples submitted following a contaminated sample. Laboratory Number of the contaminated routine sample must be given.
Invalid Sample - Mark this box for samples submitted to replace a sample(s) invalidated due to excessive bacterial growth. Laboratory Number of the invalidated routine sample must be given.

WATER TYPE:
D = Distribution sample taken at a representative point in the distribution system.
F = Sample of the finished water taken at the treatment plant.
R = Raw sample (before any treatment from well or surface water intake.

COLONIES READ: Number of colonies found in the sample analyzed.
TNTC: Too Numerous To Count; >200 colonies found in the sample analyzed.

Total Coli: P = indicates that total Coliform bacteria were present.
N = indicates that no Coliform bacteria were present.
G- = indicates that excess bacteriological growth was present but was negative for Coliform bacteria. A G- sample is invalid and a replacement sample must be collected.

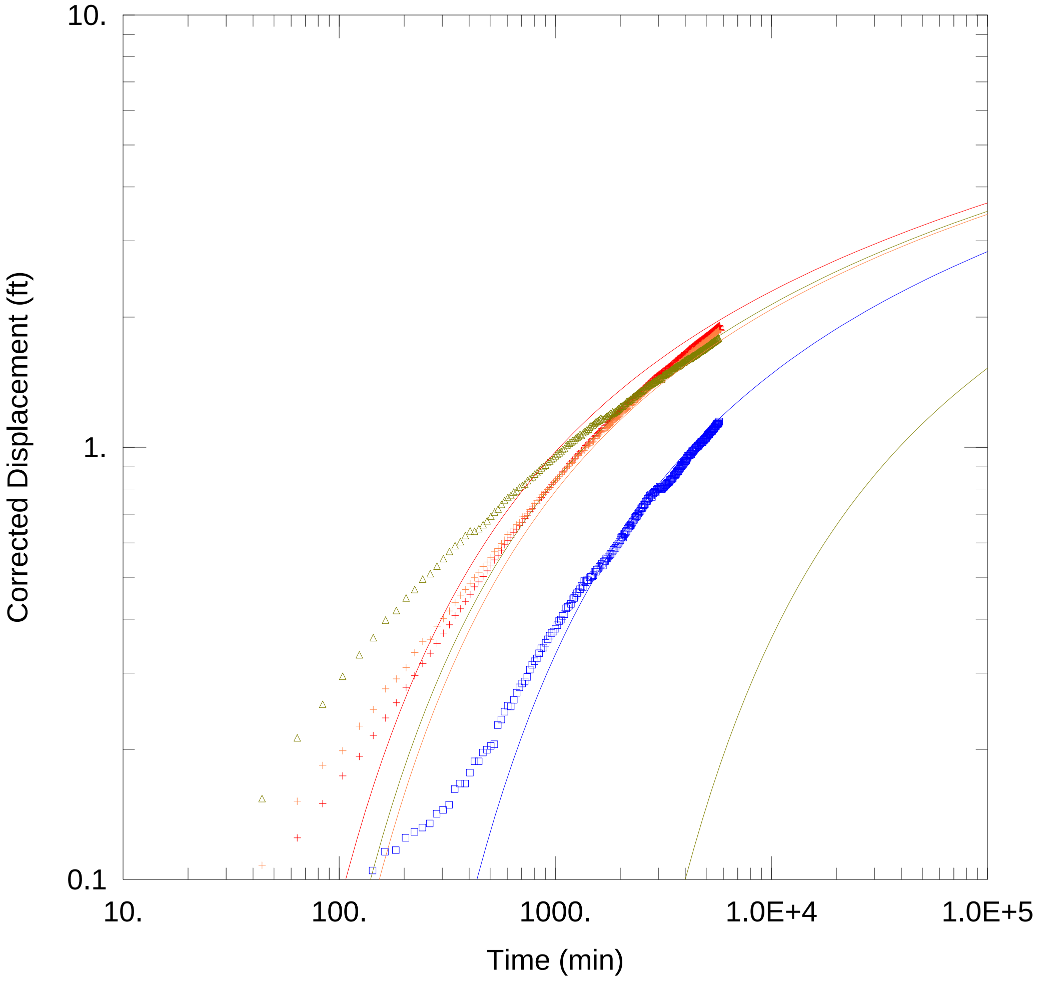
Fecal Coli: Analysis will be done only on samples that are Coliform positive and will be indicated as follows:
P = indicates that Fecal or Escherichia Coliform were present.
N = indicates that no Fecal or Escherichia Coliform were detected.

Opin: An opinion of the bacteriological quality of the water will be indicated using S, U, or I as follows:
S = Satisfactory – no Coliform detected
U = Unsatisfactory – indicates that total Coliform or fecal or Escherichia Coliform bacteria were detected.
I = Sample was invalid because of significant non-coliform growth.

For explanation of symbols used on this form, see back page.

Appendix D- Aquifer Test Data

Appendix E- Aquifer Test Analysis



WELL TEST ANALYSIS

Data Set: Z:\...\final_2_tst.aqt
Date: 01/04/10 Time: 13:50:51

PROJECT INFORMATION

Company: WHPA
Client: Bloomington II
Location: Sugar Creek
Test Well: TW1
Test Date: 7/2/2009

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TW01	0	0
MWS2	347	0
Image	-4500	0

Observation Wells

Well Name	X (ft)	Y (ft)
○ MWS1	-2103	-256
□ MWS3	-698	0
+ MWS2	347	0
+ MWS5	0	-415
△ MWS6	0	396

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 2.037E+4 ft^2/day
S = 0.059
Kz/Kr = 0.5012
b = 40. ft

Appendix F- SWB Model Tables

Table 1: Land use classification within the study area, based on Anderson Level II land use classification.

Class name	Class value	Class name	Class value
Water		**Herbaceous upland natural/semi-natural vegetation**	
Open water	11	Grassland/herbaceous	71
Perennial ice/snow	12	Sedge/Herbaceous	72
Developed		Lichens	73
Open spaces	21	Moss	74
Low intensity	22	**Herbaceous planted/cultivated**	
Medium intensity	23	Pasture/hay	81
High intensity	24	Cultivated crops	82
Barren		**Wetlands**	
Barren land (rock/sand/clay)	31	Woody wetlands	90
Unconsolidated shore	32	Palustrine forested wetland	91
Vegetated: natural forested upland		Palustrine scrub/shrub wetland	92
Deciduous forest	41	Estuarine forested wetland	93
Evergreen forest	42	Estuarine scrub/shrub wetland	94
Vegetated: natural shrubland		Emergent Herbaceous wetlands	95
Dwarf scrub	51	Palustrine emergent wetland (persistent)	96
Shrub/scrub	52	Estuarine emergent wetland	97
		Palustrine aquatic bed	98
		Estuarine aquatic bed	99

Table 2: Available water capacity values for each hydrologic soil group.

Hydrologic soil group	available water capacity (in/ft)
A	1.2
B	2.0
C	2.8
D	3.6

Table 3: Flow direction values depending on direction of runoff flow.

32	64	128
16	center	1
8	4	2

Table 4: Look-up table for land use curve numbers and maximum recharge used in the SWB model.

	Curve numbers					Max Recharge (in/day)				
	Soil 1 (A)	Soil 2 (B)	Soil 3 (C)	Soil 4 (D)	Soil 5	Soil 1 (A)	Soil 2 (B)	Soil 3 (C)	Soil 4 (D)	Soil 5
LU code	Medium	Fine	Loamy Till	Clay Till	Fractures	Medium	Fine	Loamy Till	Clay Till	Fractures
11	100	100	100	100	100	2	0.6	0.24	0.12	5
12	5	5	5	5	100	2	0.6	0.24	0.12	5
21	89	94.5	94	95	100	2	0.6	0.24	0.12	5
22	54	82.5	80	85	100	2	0.6	0.24	0.12	5
23	61	85	83	87	100	2	0.6	0.24	0.12	5
24	77	91	90	92	100	2	0.6	0.24	0.12	5
31	5	5	5	5	100	2	0.6	0.24	0.12	5
32	5	5	5	5	100	2	0.6	0.24	0.12	5
41	42	82	79	85	100	2	0.6	0.24	0.12	5
42	34	76	73	79	100	2	0.6	0.24	0.12	5
51	39	77	74	80	100	2	0.6	0.24	0.12	5
52	39	77	74	80	100	2	0.6	0.24	0.12	5
71	39	77	74	80	100	2	0.6	0.24	0.12	5
72	39	77	74	80	100	2	0.6	0.24	0.12	5
73	39	77	74	80	100	2	0.6	0.24	0.12	5
74	39	77	74	80	100	2	0.6	0.24	0.12	5
81	39	77	74	80	100	2	0.6	0.24	0.12	5
82	67	87	85	89	100	2	0.6	0.24	0.12	5
90	34	76	73	79	100	2	0.6	0.24	0.12	5
91	34	76	73	79	100	2	0.6	0.24	0.12	5
92	100	100	100	100	100	2	0.6	0.24	0.12	5
93	100	100	100	100	100	2	0.6	0.24	0.12	5
94	100	100	100	100	100	2	0.6	0.24	0.12	5
95	100	100	100	100	100	2	0.6	0.24	0.12	5
96	100	100	100	100	100	2	0.6	0.24	0.12	5
97	100	100	100	100	100	2	0.6	0.24	0.12	5
98	100	100	100	100	100	2	0.6	0.24	0.12	5
99	100	100	100	100	100	2	0.6	0.24	0.12	5

Table 5: Look-up table for land use and root zone depth used in the SWB model.

	Root zone depth (ft)			
	Soil 1 (A)	Soil 2 (B)	Soil 3 (C)	Soil 4 (D)
LU code	Medium	Fine	Loamy Till	Clay Till
11	0	0	0	0
12	0	0	0	0
21	1	1	1	1
22	1	1	1	1
23	1	1	1	1
24	1	1	1	1
31	0.5	0.5	0.5	0.5
32	0.5	0.5	0.5	0.5
41	1	0.9	1	0.9
42	1	0.9	1	0.9
51	1.7	1.7	1.8	1.3
52	1.7	1.7	1.8	1.3
71	1.7	1.7	1.8	1.1
72	1.7	1.7	1.8	1.1
73	1.7	1.7	1.8	1.1
74	1.7	1.7	1.8	1.1
81	1.7	1.7	1.8	1.1
82	0.8	0.8	1	0.3
90	2.3	2.3	2.3	2.3
91	2.3	2.3	2.3	2.3
92	2.3	2.3	2.3	2.3
93	2.3	2.3	2.3	2.3
94	2.3	2.3	2.3	2.3
95	2.3	2.3	2.3	2.3
96	2.3	2.3	2.3	2.3
97	2.3	2.3	2.3	2.3
98	2.3	2.3	2.3	2.3
99	2.3	2.3	2.3	2.3

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK

Appendix D

2008 Conservation Plan

WATER CONSERVATION PLAN

CITY OF BLOOMINGTON, ILLINOIS, WATER DEPARTMENT

December, 2008

Wittman Hydro Planning Associates
Water resource planning consultant

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK

Contents

List of Tables

1. Introduction

Historically, water conservation has been a response to local drought conditions or to emergency water shortages. This is no longer the case. Water use efficiency and conservation are now considered part of a long-term strategy to meet water demands, extend the life of existing supplies, protect water quality, and demonstrate good stewardship of a finite resource.

As utilities redefine water conservation from a short-term response to a viable long-term management practice, communities and water utilities are developing and implementing water conservation plans. A conservation plan evaluates current and projected water demands, assesses infrastructure and water supplies, and describes the actions a utility will take to reduce water loss, strategically decrease consumption, and increase the efficiency of their water system.

Conservation planning is a developing concept for the Midwest. Due to the natural abundance of available drinking water and relatively low populations, the Midwest generally has been able to meet customer demands without degrading water sources. However, as water becomes scarce, as consumers and/or regulators require a conservation perspective, and/or as economics necessitate better water management, Midwest utilities are adding conservation planning to their repertoire of tools to address water supply concerns.

Conservation is particularly important when considering surface water sources because of the impact of drought on supply and water-quality concerns. Bloomington, Illinois has experienced both drought and water-quality problems over the last 20 years. As the population continues to grow and water demands increase, Bloomington must find additional means of sustaining their water supply. Conservation planning is one aspect of overall planning that can help the City have a long-term reliable water source.

1.1. City of Bloomington Water Supply

The City of Bloomington, Illinois relies on Evergreen Lake and Lake Bloomington for their community drinking water supply. Together these two reservoirs have an estimated capacity of 22,900 acre-feet. Since the drought of the late 1980's, the City has taken the following steps to increase the reliability of the water supply.

- Intensive watershed management is used to reduce sediment and nutrient loading into the lakes and to improve water quality.
- Evergreen Lake spillway was increased by 5 feet to increase capacity.

- Permits were obtained to pump Mackinaw River water into the Evergreen Lake when there is adequate streamflow and lake levels are low.

Together, at an average water use of 11.5 million gallons per day (MGD), these two lakes could theoretically supply the City with 1-2 years of drinking water. With the added flexibility provided by improvements made in the last several years, the Water Department has moved towards a more stable water supply.

However, the 1988 and 2005 droughts illustrated that any surface water supply in this part of the State is potentially vulnerable to water shortages. Public water supply systems that use reservoirs as their sole source of supply need to have storage far beyond their average needs in order to be resilient to prolonged, multi-year drought.

In addition to drought, the City of Bloomington continues to grow. With growth comes increased average and peak demands for which the City must be able to supply water. Using reservoirs as the sole source of water for a growing community is problematic because sedimentation decreases the volume of water available over time. Therefore, the water supply is decreasing while demands are increasing. Due to activities in the watersheds, both Lake Bloomington and Evergreen Lake experience high sedimentation rates. While watershed management is addressing sediment erosion and raising the Evergreen Lake spillway increased supply, additional ways of ensuring adequate supply need to be evaluated.

Water quality in the reservoirs has also been unreliable. While the City has been able to meet water-quality standards since 1992, Lake Bloomington has nitrate concentrations that exceed the Environmental Protection Agency's (EPA) maximum contaminant level (MCL) of 10 mg/l on a seasonal basis. Evergreen Lake has lower nitrate levels so the water-quality standard for nitrate has been met by using Evergreen Lake water during periods of high nitrates. However, during drought there may be insufficient water available from Evergreen Lake or its nitrate concentration may be too high to deliver water below the MCL.

As drought and growth coincide, the Bloomington water supply will likely be stressed and water-quality problems may become more prevalent. The City has recognized the need to increase supply and manage demand so that they are able to provide reliable and safe drinking water. Although managing both supply and demand is complex, the City has embarked on addressing both sides of the issue.

The City is currently exploring additional water supplies to address both water quality and growth. It is expected that the new groundwater sources will supply additional water during periods of water shortage, provide a source of low nitrate water to ensure high-quality finished water for consumers, and support long-term growth. Additionally, the City continues to work with local and state agencies to improve water quality and decrease sedimentation through watershed management and stream bank and lake shore stabilization.

However, the City understands that in order to protect the water sources currently in place, they must also address demands. The primary way to address demand is to develop a conservation plan. Conservation planning includes management of both supply and demand. Conservation planning is complex due to the many aspects required to develop and implement a comprehensive plan but this report is the first step in developing a comprehensive plan.

1.2. Organization of Report

This report lays out the framework to begin conservation planning. WHPA has included the different components necessary in preparing a water conservation plan and discusses different conservation measures the City of Bloomington can employ to meet conservation goals. Recommendations are given for taking the first steps in conservation planning for the City of Bloomington, Illinois.

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK

2. Conservation Planning

Because the City of Bloomington is facing water-quality problems, continued growth, and drought, conservation planning must be included as part of the overall long-term planning efforts. The Bloomington Water Utility will be able to directly impact water-supply management (e.g., losses, metering) while demand management may take more time due to behavioral changes that need to be made within the customer base.

A conservation plan evaluates current and projected water demands, assesses infrastructure and water supplies, and describes the actions a utility will take to reduce water loss and consumption and increase efficiency. The plan should be goal oriented and practical in design and implementation. Developing a comprehensive conservation plan involves six steps:

1. completing a water audit;
2. developing a water system profile;
3. forecasting demands;
4. setting specific, measurable, and relevant goals;
5. evaluating conservation measures; and
6. determining an implementation strategy.

Each of the six steps is described in more detail below.

Several cities throughout the United States have implemented some or all of the conservation steps outlined above. WHPA has examined several of the plans and compiled general information about the city and their conservation plans (Table 1). This matrix provides Bloomington with a quick look at how other municipalities are implementing conservation.

2.1.Water Audit

A water audit is an accounting procedure that tracks raw, treated, and sold water throughout a system. All utilities, irrespective of size or age, should regularly perform a water audit because it helps identify areas within a water system that need improvement. As part of a conservation plan, a water audit provides a baseline measurement of water use and can be used to track progress made towards meeting conservation goals that address reducing non-revenue water.

Table 1. Matrix of conservation plan components for select cities.

Conservation Plans

			Water Source		Conservation Plan						Conservation Measures			
Utility	Location	Population Served	Surface water	Ground water	Measurable Goals / Objectives	Water Audit	Water Profile	Demand Forecasts	Evaluation of Conservation Measures	Implementation Strategy	Public Education	Water Management	Government Regulation	Economic Incentives
		The Midwest												
Valparaiso City Utilities	Valparaiso, IN	13,000		X	In progress						X			
Waukesha Water Utility	Waukesha, WI	67,700		X	X	X	X	X	X	X	X	X	X	X
Wichita Water Utilities and Environmental Services	Wichita, KS	300,000	X			X				X	X	X	X	X
		The South												
Cary Public Works & Utilities	Cary, NC	130,000	X		X	X	X	X	X	X	X	X	X	X
Metropolitan North Georgia Water Planning District	Metro Atlanta Area	4 million	X		X			X	X	X	X	X	X	X
		The West												
California American Water	Monterey Peninsula, CA	630,000	X	X		X		X	X	X	X	X	X	X
Denver Water	Denver Metro Area	1.24 million	X		X	X		X	X	X	X	X	X	X
		The Northeast												
Salem Water and Sewer	Salem, MA	177,000	X			X					X	X		X
Massachusetts Water Resources Authority	Boston, MA	2.5 million	X		X	X		X	X		X	X	X	X

The International Water Association (IWA) and the American Water Works Association (AWWA) developed an auditing procedure that uses a water balance to calculate water loss volume. Water loss volume is calculated by comparing production (raw water meter output) to authorized billed and unbilled consumption. Water that is not accounted for by authorized consumption, referred to as lost water or non-revenue water, is divided into apparent losses and real losses. The water balance accounts for all water by using measured or estimated quantities of the components listed in Table 2. A cost is calculated for each component in order to assess its financial impact to the water utility (AWWA, 2008b). Table 3 depicts the water balance concept.

Table 2: Components and definitions of the IWA/AWWA Water Balance (AWWA, 2008b)

System Input Volume	*The annual volume input to the water supply system*
Authorized Consumption	***The annual volume of metered and/or unmetered water taken by registered customers, the water supplier, and others who are authorized to do so***
Water Losses	***The difference between System Input Volume and Authorized Consumption, consisting of Apparent Losses plus Real Losses***
Apparent Losses	***Unauthorized Consumption, all types of metering inaccuracies and data handling errors***
Real Losses	***The annual volumes lost through all types of leaks, breaks, and overflows on mains, service reservoirs and service connections, up to the point of customer metering.***
Revenue Water	***Those components of System Input Volume which are billed and produce revenue***
Non-Revenue Water (NRW)	***The difference between System Input Volume and Billed Authorized Consumption***

Water audits require significant amounts of data in order to be useful and the City of Bloomington is moving towards being able to complete a water audit. In the past, Bloomington has performed basic mass balance by looking at water level fluctuations in the reservoirs and comparing those to the meters which were properly working. However, since the raw-water meters and some meters in the system have been unreliable, the City should ensure properly working meters in order to gain true insight into the system. The City has been working towards improved metering by replacing turbine meters with compound meters for customers who have large fluctuations in water use. Compound meters are better able to measure a large range of flows rather than just high flows. Leak detection is another important piece of reducing water loss and the City currently performs leak detection for one-quarter of the entire system every year. While the City may be unable to fully complete a water audit with measured data, they can begin with the data available and use estimates where needed. The City can complete a water audit using AWWA's free water audit software (AWWA, 2008a).

Table 3. The International Water Association (IWA) and American Water Works Association (AWWA) water balance (data in volume for period of reference) (AWWA, 2008).

System input volume (corrected for known errors)	Authorized consumption	Bill authorized consumption	Billed metered consumption (including water exported)	Revenue Water
			Billed unmetered consumption	
		Unbilled authorized consumption	Unbilled metered consumption	Non-Revenue Water (NRW)
			Unbilled unmetered consumption	
	Water losses	Apparent losses	Unauthorized consumption	
			Customer metering inaccuracies	
			Data handling errors	
		Real losses	Leakage on transmission and distribution mains	
			Leakage and overflow at utility's storage tanks	
			Leakage on service connections up to point of customer metering	

2.2. Water-Use Profile

A water-use profile is an inventory of existing supplies and operations, production characteristics, customer water use, and other factors that may affect a water conservation plan (U.S. EPA, 1998). Completing a water-use profile compels a utility to collect new data and to organize data it already maintains in a format that is useful for conservation planning. Once compiled, the utility can use the profile to prioritize conservation goals.

While many of the water-use profile data are known or collected already, Bloomington can organize the data to more readily see the entire water system and determine how conservation can be used to impact demands. An example of the water-use profile used by the EPA is provided in Appendix A. The water-use profile is a holistic view of the system rather than just focusing on the utility as does the water audit.

2.3. Demand Forecast

A demand forecast estimates future water use. The forecast can be a simple projection based on population growth or it can be more complex with several variables (price, income, lot size, etc.); the size of the utility dictates the complexity of the projection (U.S. EPA, 1998). Forecast projections are made at 5-year, 10-year, and 20-year intervals; however, forecast uncertainty increases as interval length increases.

A demand forecast should be made for each user group (residential, industrial, commercial, and institutional) and for non-revenue water, rather than for the water system as a whole. The more commonly used forecasts by utilities include the following (AWWA, 2008a):

- annual per capita water demands;
- annual water demand by major customer class;
- peak day;
- monthly system water demand;
- daily water demand; and/or
- revenue forecasts linked with water demand.

Demand, in many settings, has been shown to be driven by population, weather, climate, water price rates, and current conservation efforts. Linking demand to these drivers would require a more sophisticated regression modeling effort.

The City of Bloomington projected future water demands in 2002 as part of the regional water supply preliminary infrastructure plan. Water demand projections for 2000 to 2050 were based upon existing per capita usage (168 gpcd) and an annual compound growth rate for population of 1.2% (Farnsworth, 2002). This basic demand projection is well suited for infrastructure planning and to gain basic insight into demand but a more complete demand forecast could be completed for conservation planning. The demand forecasts should include forecasts for different customer classes and an analysis of peak day demands. Depending upon the water audit data and system profile, other forecasts may be applicable.

2.4. Measurable Goals

Comprehensive conservation plans are customized for the local operation and water supply. Operations experiencing future infrastructure expansion due to rising peak summer demand would develop goals aimed at reducing peak demand. Conversely, an operation experiencing water supply shortages will develop goals for reducing overall water demand. Operations that have adequate facilities and a plentiful water supply may pursue conservation goals that address using water efficiently for purposes of sustainability and protecting a finite resource for future generations.

Articulating specific goals for a conservation plan provides direction for reducing water use. By stating goals of the plan, the utility makes a commitment to reaching an objective that can relieve pressure on the system when and where it is most needed. The U.S. EPA Water Conservation Plan Guidelines lists common goals for conservation programs.

- Improve reliability and margins of safe and dependable yields.
- Protect and preserve environmental resources.
- Improve drought or emergency preparedness.
- Lower variable operating costs.
- Avoid new source development costs.
- Eliminate, downsize, or postpone the need for capital projects.
- Improve the utilization and extend the life of existing facilities.
- Educate customers about the value of water.

Stating specific objectives, such as specifying a volume or percent reduction in water use, further defines the conservation goal. Additionally, when a goal is measurable, progress can be objectively evaluated.

Since the City of Bloomington is experiencing growth, water-quality problems, and drought, several different goals will need to be set. Once the City has completed the water audit and water system profile they will be better able to set goals that are customized to their operation and community. Goals may be set by the Bloomington Water Department or in cooperation with local citizens. All goals set by Bloomington should include a measurable objective. Measurable goals will allow the City to evaluate the conservation program with objectivity and more precisely than if goals are more generic.

2.5. Conservation Measures

Conservation measures are the practical actions taken to achieve the water conservation goals. Conservation measures can be separated into four broad conservation strategies: water supply management, public education, government regulation, and economic incentives. An effective conservation plan employs a combination of conservation measures from each strategy.

Conservation measures that could achieve the goals of a conservation plan must be identified and then evaluated using cost-benefit analysis. Conservation measures save water or promote water efficiency by use of hardware devices, technologies, behavior and management practices, and/or incentives. When identifying possible measures, it is necessary to consider potential water savings, market saturation of a particular measure, obstacles to implementation, and factors that might cause customer apathy towards conservation, such as decreasing rate structures, customer affluence, and low water and wastewater costs (Vickers, 2001). A simple, initial screening that evaluates each conservation measure against criteria such as expense and effectiveness eliminates inappropriate measures and identifies measures suitable for further analysis.

The cost-effectiveness of each identified measure is then determined by analyzing its benefits, costs, and water savings. Costs include implementation costs, possible initial fluctuations in utility revenues, and customer costs. Benefits include utility cost savings, customer benefits, and environmental preservation. Each conservation measure is approved or rejected based on the results of the analysis. Most conservation programs utilize multiple measures (Table 4) and the cost-effectiveness of each combination of measures must be assessed. The results of the analysis can be presented to decision makers and the public to justify the conservation program. Outlined below is a discussion of the four water conservation strategies with examples of specific conservation measures encompassed by each strategy.

2.5.1. Water Supply Management Programs

The objective of a water supply management program, with respect to water conservation, is to address the efficient delivery of water within the water system. Two primary goals of supply-side management are to better account for all water use and to reduce unnecessary water withdrawals. Better accounting of water involves a water audit and differentiating between real losses and apparent losses of water. Real losses are a result of system leaks that require water utilities to extract, treat, and transport greater volumes of water and use more energy than what is needed (AWWA, 2008a). System leaks are not only wasted water but also wasted money. Apparent losses include meter inaccuracies, unmetered uses, data

Table 4. Matrix of conservation measures used in select cities.

		Conservation Measures																									
		Water conservation tips on website	Public education brochures	Mass media advertising campaigns	Promotional campaigns and events	School programs	Xeriscape garden demonstration	Outreach program	Donations and grants to community organizations	Leak detection and repair program	Meter testing and replacement program	Municipal water use audit	Water conservation administrator	Landscape regulations	Irrigation meters ordinance	Rain sensor ordinance	Water waste ordinance	Summer water use restrictions	Year round water use restrictions	Indoor hardware Rebates	Outdoor hardware rebates	Irrigation rebates	Water conservation pricing	Summer surcharges	Irrigation Audits	Residential and commercial audits	Retrofit devices (free of cost)
Utility	**Location**	**Public Education**								**Water Supply Management**				**Government Regulation**						**Economic Incentives**							
		The Midwest																									
River Falls Municipal Utilities	River Falls, WI		X															X			X						
City of Chanhassen Planning	Chanhassen, MN	X			X			X				X	X	X**				X		X			X		X	X	
Waukesha Water Utility	Waukesha, WI	X	X		X	X				X		X	X					X		X	X		X				
Wichita Water Utilities and Environmental Services	Wichita, KS	X	X	X		X	X	X		X	X			X									X				
Illinois American Water	Chicago & Champaign		X		X					X								X									
Metropolitan Council	Twin Cities Region, MN	X	X																								
City of Cleveland Division of Water	Cleveland, OH																										X
		The South																									
Cary Public Works & Utilities	Cary, NC	X	X		X	X							X	X**	X	X	X	X	X	X	X	X	X			X	X
Newport News Waterworks	Newport News, VA	X	X	X	X					X	X							X						X			
Kentucky American Water	Lexington, KY		X	X					X	X								X									
Metropolitan North Georgia Water Planning District	Metro Atlanta Area	X	X	X		X				X	X					X							X			X	X
		The West																									
Arizona American Water	Statewide		X	X	X	X				X	X															X	X
California American Water	Monterey Peninsula, CA		X	X	X		X	X		X		X					X	X	X	X	X	X	X			X	X
Denver Water	Denver Metro Area	X			X		X	X		X	X	X	X			X		X		XΦ	X	X	X				
		The Northeast																									
Salem Water and Sewer	Salem, MA					X				X	X	X									X		X			X	X
Massachusetts Water Resources Authority	Boston, MA		X			X		X+		X	X	X++								X*			X				
Dept. of Environmental Protection	Pennsylvania	X	X		X																						

*Municipal buildings only; **Commercial only; + For large water users; ++ Pilot program; Φ For commercial, industrial, institutional, and residential management errors, and unauthorized use. Apparent losses result in a financial loss to the supplier because payment is not recovered for water service and the cost occurs at the retail rate charged to customers. Quantifying and controlling real and apparent losses is necessary for reducing water loss and is a natural first step in a water conservation plan.

Another important part of a water management plan is accounting for all city water use. This includes metering schools, cemeteries, parks, athletic fields, and any other municipal use. The New England Water Works Association (NEWWA) and Massachusetts Water Works Association (MWWA) suggest using portable meters to meter water from hydrants and maintaining logs on duration and flow rates of water used in fire fighting, main and hydrant flushing, and tank overflows.

Finally, depending on the extent of the conservation program, having a staff member who manages day-to-day activities is valuable for implementing and measuring the success of the conservation program.

Leak detection and repair program

Leaks in a water system are physical losses that produce needless water loss without satisfying a demand. Furthermore, they inflate production and raise energy costs, and with severe leaks, expedite infrastructure expansion. Lost revenue from system leaks can be measured in terms of production and treatment costs (USEPA, 1998). Leakage control involves efficient identification of leaks and timely, lasting repairs (AWWA, 2008), especially of small leaks at joints and fittings. Typically small leaks go undetected yet are responsible for a large volume of water loss. A successful leak detection and repair program saves on up-front costs of lost water and can defer costs associated with infrastructure maintenance and expansion. The American Water Works Association (AWWA) recommends that utilities target economic levels of leakage. Economic levels of leakage vary among water suppliers and a target level is the point where the cost of reducing leaks is equal to the cost of water saved through leak reduction (AWWA, 2008).

Meter testing and replacement program

Updating and repairing water meters are an important supply side management practice that reduces apparent water losses. Addressing metering issues will not result in immediate reductions in withdrawal as does repairing leaks but does allow water providers to appropriately charge users.

Proper metering ensures that water users are appropriately charged for the water they use, and thus provides an incentive to conserve water. Furthermore, properly metered water allows for distinguishing between water consumption and real loss volumes, which is necessary for accurate decision making (AWWA, 2008).

Municipal water use audit

A city water audit demonstrates to residents the city's interest in conserving limited water resources. An audit identifies excess water usage, prompting the city to reduce usage by implementing appropriate measures. Measures may address irrigation methods for parks and sport fields, retrofitting older (pre-1992) municipal buildings, and redesigning city plantings to include more native, drought tolerant plants.

A city taking an active role in water conservation sets an example to residents demonstrating that the city is willing to make changes to save water. At the same time, an audit identifies wasteful use and, in the long-run, saves the city unnecessary expense.

Water conservation administrator

A water conservation administrator oversees all conservation related activities. Typically this position is a component of an active conservation program. Utilities that offer a limited range of conservation programming or that partner with national organizations such as Water Use it Wisely (discussed below) typically do not have staff dedicated to water conservation.

Water conservation administrators, whether an individual or group of people, are a useful component to a comprehensive conservation plan. Administrators create and distribute bill stuffers, answer questions, track retrofit kits and rebates, and organize residential and commercial audits. For utilities with extensive programs, having a person specialized in water conservation is more useful than burdening staff busy with other demands and responsibilities.

2.5.2. Public Education

Public education (grade school students to adults) is a popular strategy for encouraging water users to adopt water saving practices into their daily activities. Informing all water users about the importance of water conservation is effective and less controversial than increasing water prices and mandating changes (Dziegielewski, 2003). Also, when prices must increase or enacting watering restrictions is necessary, educated water users are better equipped to understand and accept such decisions.

During droughts or water emergency conditions, water users generally are willing to modify their behavior because there is a perceived water shortage. However, after the return to normal weather, users do not maintain their same level of water savings and revert back to previous behavior. The primary role of education is to change the common mentality of water being an unlimited resource to one of water being a limited resource. As the public's outlook changes, so will their behavior.

Water conservation tips on website

As paying for water bills online becomes more common, a utility's website becomes an important source for water conservation information. Links to indoor and outdoor conservation tips, watering restriction reminders, and upcoming conservation programming can be posted on the website.

Public education brochures

For customers without access to the Internet or who do not visit a utility's website, public education brochures are an important source of information that can reach many people. Information can be disseminated through direct mail, bill inserts, and/or handed out during community events.

Mass media advertising campaigns

Dissemination of information is also accomplished through mass media such as television, radio, newspapers, and billboards. These outlets provide an opportunity to present reminders of steps people can do to conserve water each day and update residents on water supply conditions and water restrictions. One example is to publish the drought index in the newspaper to raise people's awareness about the condition of the water supply.

Promotional campaigns and events

Promotional campaigns bring awareness to water conservation issues while engaging the public. Campaigns for water providers to join and adapt to their community include Water Use It Wisely and WaterSense. Water Use it Wisely is a nation-wide campaign aimed at promoting consumer awareness of water use and promoting efficient new indoor and outdoor technology. WaterSense is a U.S. EPA labeling program similar to Energy Star but focused on water efficient products. Utilities can also create campaigns tailored to their customers. The campaign's website provides visitors with water conservation tips, information on water supply technologies, a month by month calendar on good water use, games, and resource links.

Primary and secondary school programs

School programs teach students of all ages about the importance of water conservation. These programs are hands-on, engaging students to track their water usage and that of their family's. Several resources provide curriculum for water conservation. Project WET (Water Education for Teachers) is a nonprofit water education program. Its mission is to promote awareness and stewardship of water resources through the dissemination of classroom-ready teaching aids.

The effectiveness of school programs is difficult to measure because of the complexity of measuring how students apply the information they learn in class to their every day water use habits. However, educating children when they are young and continuing water conservation programs throughout their primary and secondary education can be important in instilling a conservation ethic. Some children may never be exposed to water conservation if it were not taught in school.

Xeriscape Garden Demonstration

The term Xeriscape is derived from the Greek word Xeros meaning dry, and scape comes from landscape. Xeriscape is a type of landscaping that does not require extensive irrigation. It is commonly associated with landscaping in the arid western states; however, it can be practiced in any type of climate.

A Xeriscape garden demonstration on either the utility's property or on city property, such as at a local school, is a good way to promote gardening that uses less water and chemicals, and has lower maintenance costs. A study in the East Bay Municipal Utility District in Oakland, California found that single-family homes with water-efficient landscapes used 42 percent less water than homes with conventional landscapes (Vickers, 2001). The common association of Xeriscape with western states may cause some people to mistakenly believe that it involves turning their yard into a desert-like landscape. It is up to the utility to accurately promote Xeriscape, and to avoid confusion, using the term water-wise landscaping may be more appropriate (Vickers, 2001).

Outreach programs to educate water users

Outreach programs are seminars for the public on a variety of water conservation issues. The cost of the seminar is either free or minimal. Just as students learn about water issues in school, outreach programs typically target adults and cover outdoor related water topics.

Planning a seminar can be time consuming and requires extensive research into a topic. If necessary, the utility could sponsor the seminar and ask knowledgeable community members to host seminars. These programs are an opportunity for demonstrations, such as showing people how to install hardware or how to choose native plant species for gardening. As a result, people may be more inclined to create their own water-efficient garden or install efficient hardware in their home. However, because attending seminars requires people to make time in their schedules, attendance may be limited, and as a consequence, seminars may not be as effective at reaching a large portion of the community. Adequate advertising and proper scheduling (weekend afternoons) are important for having successful turnout.

2.5.3. Government Regulation

Governments are important in creating a regulatory environment with respect to water conservation. Few national policies exist that focus on conservation practices

(Dziegielewski, 2003) so it is important for local governments and utilities to create water policy appropriate to the city's water situation. Ordinances are necessary for city wide adoption of certain measures and the reasoning for ordinances should be explained to the public. However, to be effective, the ordinances must be enforced.

Water use restrictions

It is not uncommon for homeowners and businesses to overwater their lawns and landscapes, especially during the summer months and droughts, when demand is highest and precipitation is lowest. Summer watering contributes to peak demand, the highest total water use experienced by a water supply system. Furthermore, overwatering wastes water, increases runoff into stormwater systems, and raises water bills. Many cities and utilities have enacted watering ordinances restricting watering to a limited number of days per week and during certain hours.

The most common water regulation of the utilities surveyed is watering restrictions during the summer months. Some municipalities restrict water to even and odd days; odd numbered addresses may water on odd numbered days and even addresses water on even days. Other municipalities allow for watering only two or three days a week. Typically these restrictions are from May to September. Other cities use drought ordinances to restrict water usage during shortages. Drought ordinances are effective because people can easily connect the need to conserve water to a drought. Implementing a drought ordinance can be any easy first step in water conservation without implementing mandatory restrictions when precipitation is plentiful.

The effectiveness of odd/even irrigation schedules is debatable because some cities have found that instead of discouraging watering, the schedule leads to overwatering because, with the schedule, people are more inclined to water every other day even though it is not necessary (Vickers, 2001). Lawns do not need to be watered regularly and a schedule of watering once every four to seven days is more effective, especially in areas that receive adequate rainfall. Also, restricting watering to specific hours is important because of evaporation that occurs while watering during the middle of the day when the temperature is hottest. Another important note is that less watered grass survives better during droughts than overwatered lawns because the grass develops deeper roots (Vickers, 2001).

Other restrictions

While watering ordinances are the most common type of regulation among the utilities, some utilities also require the use of particular irrigation equipment, plantings, and hardware devices.

Separate irrigation meters ordinance

The Town of Cary is the only municipality surveyed that requires every new irrigation system installed after 2000 to be separately connected to an irrigation meter. The ordinance applies to residential and commercial accounts. Separating outdoor water use from indoor water use has allowed the Town of Cary to bill water used for irrigation at a tiered rate structure designed specifically for irrigation use. Also, they can monitor the watering behavior of their customers, providing useful information for future planning.

Rain sensor ordinance

A rain sensor is an electric shut-off device that measures rainfall and turns off an irrigation system when a predetermined amount of rain has fallen. A properly working sensor eliminates unnecessary watering in the rain. The Town of Cary enacted its ordinance in 1997 requiring that all sensors be set to turn off after a quarter inch of precipitation. Denver, Colorado and the MNGWPD enacted sensors ordinances in 2003 and 2004, respectively.

In an evaluation of water conservation programs, the Town of Cary discussed the difficulty in evaluating the effectiveness of the rain sensors; to do so would require more detailed billing. However, the ordinance is considered an important part of irrigation management because it reduces unnecessary watering.

New customer/construction regulations

New customer/construction ordinances typically require that newly built structures or remodeled structures meet certain plumbing requirements with respect to high efficiency hardware. The requirements for hardware surpass the federal requirements mandated by the U.S. EPAs U.S. Energy Policy Act of 1992.

Water waste regulation

A water waste regulation prevents overwatering of landscapes. The Town of Cary is the only municipality surveyed that has a water waste regulation. The ordinance prevents watering directly on impervious surfaces and overwatering soil to the extent it no longer absorbs water and becomes runoff. Conservation technicians inspect regularly for violators. The effectiveness of reducing water waste is not easily teased apart from other irrigation ordinances. The Town of Cary believes it is a necessary ordinance because it addresses managing unnecessary water use.

Land development ordinance

A landscape ordinance generally is passed to enhance the attractiveness of a city. However, it can also be used to reduce water used for irrigation and promote drought tolerant native species. The use of non-native ornamental species is prevalent on most commercial landscapes. Non-native species require more maintenance and more water because they are not adapted to the local climate. Native species use less water and require less maintenance.

Typically these ordinances target large area landscapes where there is a potential for large volume water use. Whether this ordinance is effective is yet to be quantified. However, it should reduce turf acreage, which usually receives substantial irrigation (cool season grasses such as fescue or Kentucky blue grass use more water than warm season grasses), and it should require native-drought tolerant plantings that do not require regular watering. An alternative to the landscape development ordinance is to require that commercial sector irrigation systems meet specific requirements such as having rain sensors and certain settings. However, a landscape ordinance also addresses issues of aesthetics and promotes regional biodiversity by using native plants.

2.5.4. Economic Incentives

Incentives for conservation include water pricing, rebates, penalties, tradable water rights, and tax credits (Dziegielewski, 2003). Economic incentives encourage water conservation investments and behavior changes. Rebates, free audits and retrofit kits create an incentive to conserve water whereas changes in water prices create a disincentive to use water.

Water pricing

Water pricing is an important component of conservation programs because, when water is correctly priced, it signals to users the true value of water. Bloomington's rate structures are declining meaning that as consumption increases, the price per unit decreases. A declining rate structure does not encourage conservation or provide the true value of the resource. However, conservation rates must be carefully designed and implemented to ensure revenue stability for Bloomington's Water Utility. Maintaining revenues is essential to providing safe and reliable drinking water. Without revenue stability, the City will be unable to maintain infrastructure, preserve water quality or develop new supplies when needed.

Three common conservation rate structures are uniform rates, seasonal rates, and increasing block rates. Uniform rates are conservation neutral and assign a single rate per unit of water used. Seasonal rates vary throughout the year and typically are highest during the summer months when outdoor water usage is greatest. Increasing (or inverted) block rates assign a single rate per unit of water and as consumption increases, so does the cost per unit. The increasing block structure is widely accepted as the most effective conservation structure; however, demand is relatively inelastic with respect to water price, meaning that as price increases, demand remains the same. Consequently, a rate structure must contain strong incentives to conserve water (Dziegielewski, 2003) and must be designed to ensure revenue stability for the Utility.

All utilities surveyed by WHPA with a conservation plan or conservation program use an increasing block rate - as consumption increase so does price. This price structure covers the service cost of providing water and encourages customers to reduce unnecessary use. The number of tiers (or blocks) and volumes where increased rates are applied within in the pricing structure varies (Table 5).

Table 5. The volume of water (in gallons) where increased rates are applied.

Utility	***State***	***Tier 1***	***Tier 2***	***Tier 3***	***Tier 4***
Cleveland Division of Water	OH	0-7,500	>7,500	--	--
Waukesha Water Utility	WI	0-30,000	30,000-40,000	>40,000	--
Wichita Water Utilities	KS	0-110% AWC	110-310% AWC	>310% AWC	--
City of Chanhassen	MN	0-5,000	5,000-25,000	25,000-50,000	>50,000
Denver Water	CO	0-11,000	12,000-30,000	31,000-40,000	>40,000
Cary Public Works & Utility	NC	0-5,000	5,001-8,000	8,001-23,000	>23,000
California American Water	CA	0-6,000	6,000-18,000	18,000-30,000	>30,000

AWC = average winter consumption

Estimating the price at which water allocation is economically efficient is difficult and resource-consuming. Water use varies through time seasonally and annually making the right price a moving target (PRI, 2004). Furthermore, it is important to estimate how user populations will respond to water price changes. A study of Aurora, Colorado’s water demand management strategies found that high volume water users were more responsive to price changes than low volume water users and that the effect of pricing varied between drought and pre-drought periods (Kenney et al, 2008). The study also found that households consumed five percent less under an increasing block rate than they would have under a uniform rate. However, in the Town of Cary, water rate increases did not have a discernible effect on water consumption. This lack of response underscores the importance of strong incentives to conserve within the rate structure and the importance of understanding population demographics. Ninety-five percent of residential consumption falls within the first three tiers of the four tier block in the Town of Cary and prices within these three tiers only increased three to four percent over a five-year period. This minimal price increase coupled with the affluent make-up of the community (median household income is approximately $75,000) diminishes the impact of the increasing rate structure.

An increasing rate structure may not be the optimal strategy for reducing consumption and certainly should not be the only strategy used, however it does send a signal to users that excess consumption will result in additional cost. The other forms of conservation pricing should also be considered. Conservation pricing should not negatively impact utility revenues and a water pricing consultant could help ensure that prices are set both to encourage conservation and maintain revenues.

Residential and commercial audits

A water audit is an assessment of how much water is used and how much water can be saved within a household or business. A water auditor identifies leaks, suggests simple water-efficient measures and improvements, and may provide information on water conservation programs. This service reduces water bills and wasteful water use. Most utilities offer free audits as an incentive to encourage participation.

Residential water audits are a good way to alert homeowners of leaks and wasteful water practices. The one-on-one attention the homeowner receives may be more effective at changing behaviors than just offering rebates and retrofit kits since there is no guarantee that the hardware will be installed. However, this service may be requested by people already concerned about conserving water and not reach people who are most in need of the consultation. Also, carrying out individual audits is time consuming for the utility.

Rebates

A rebate is a reduction from a charged amount, and with respect to water conservation, can be classified into two categories: indoor hardware and outdoor hardware. Rebates are designed to encourage the replacement of inefficient hardware, such as older model toilets, washing machines, dishwashers, etc., with more water efficient hardware. Also, when presented with a reduction in price, people are more willing to purchase a product that they might not otherwise, such as rain sensors, toilet flappers, and rain barrels. Typically, utilities offer rebates for a selected number of brands and models that carry the Energy Star or WaterSense seal.

Rebates are funded either by state grants or by the water supplier. For example, California American Water (CAW) is in charge of funding rebates and its regulator, Monterey Peninsula Water Management District, administers the rebates.

One drawback to rebates is that they are only effective if people use them and install the hardware. If people just purchase the hardware but never use it, the water supplier looses on its investment.

Retrofit Kits

A retrofit kit is a package of water saving devices for homes and businesses. Generally, the kits include a low-flow showerhead, kitchen aerator, low-flow faucet aerator, leak detection dye tablets, and a flow meter bag for measuring flow from a showerhead or faucet. These kits are especially important in homes built prior to 1992. In 1992, the U.S. Energy Policy Act was enacted establishing maximum water-use levels for toilets, urinals, showerheads, and faucets. The standards apply to plumbing fixtures in all homes built after 1992 and renovated residential and nonresidential facilities (Vickers, 2001). Homes built prior to 1993 may contain inefficient fixtures.

2.5.5. Additional Conservation Measures

The following is a list of conservation measure not discussed above but that can be part of a comprehensive water conservation plan. The list of measures was developed using the U.S. EPAs Water Conservation Guidelines. The description for each of these measures is taken directly from the Water Conservation Guidelines (1998).

Water Accounting and Loss Control

Loss-prevention program: This may include pipe inspection, cleaning, lining, and other maintenance efforts to improve the distribution system and prevent leaks and ruptures from occurring. Utilities might also consider methods for minimizing water used in routine water system maintenance procedures in accordance with other applicable standards.

Costing and Pricing

Cost analysis: Systems should conduct a cost analysis to understand what types of usage drive system costs. For example, systems should analyze patterns of usage by season and class of service.

Information and Education

Understandable water bill: Customers should be able to read and understand their water bills. An understandable water bill should identify volume of usage, rates and charges, and other relevant information.

Informative water bill: An informative water bill goes beyond the basic information used to calculate the bill based on usage and rates. Comparisons to previous bills and tips on water conservation can help consumers make informed choices about water use.

Pressure Management

System wide pressure management: For residential areas, pressures exceeding 80 psi should be assessed for reduction. Pressure management and reduction strategies must be consistent with state and local regulations and standards, as well as take into account system conditions and needs. Obviously, reductions in pressure should not compromise the integrity of the water system or service quality for customers.

Pressure-reducing valves: A more aggressive plan may include the purchase and installation of pressure-reducing valves in street mains, as well as individual buildings. Utilities might also insert flow restrictors on services at the meter. Restrictors can be sized to allow for service length, system pressure, and site elevation. Utilities can consider providing technical assistance to customers to address their pressure problems and install pressure-reducing valves to lower the customers' water pressure. This may be especially beneficial for large-use customers.

Reuse and Recycling

Industrial applications: An alternative water source for some systems is "graywater," or treated wastewater for nonpotable water uses. Water reuse and recycling practices reduce production demands on the water system. Water utilities should work with their nonresidential customers to identify potential areas for reuse or recycling. Some industries can substantially reduce water demand through water reuse (or multiple uses) in manufacturing processes. Recycled wastewater can be used for some industrial purposes, agricultural purposes, groundwater recharge, and direct reuse.

Large-volume irrigation applications: Reuse and recycling can be encouraged for large-volume irrigation.

Selective residential applications: In some areas, reuse and recycling can be used in residential applications. Water systems will need to check with local plumbing codes and ordinances for possible conditions and restrictions.

Hardware

Point use hot water heaters: Compact water heaters that produce hot water instantly. They install directly under a sink or wherever appropriate and do not lose heat as it travels through pipes. Price ranges from $139 and up.

Air-cooled ice machine: Replaces water-cooled units.

2.6. Implementation

An implementation strategy is a plan of action designed to achieve the goals of the conservation plan and put into action specific conservation measures. Implementation begins once the plan has been approved by all parties involved in the development process. Successful implementation of a conservation plan requires garnering public support for the plan and the programs, identifying obstacles to implementation early on and mitigating them, and maximizing benefits at the lowest cost to the utility (AWWA, 2006).

Factors governing implementation of conservation measures are ease of implementation, cost of implementation, customer willingness to participate, and perceived water shortage. A utility may choose to implement less costly programs in the beginning followed by more expensive measures in the future. However, a utility that is experiencing an acute water shortage is more interested in starting programs that produce the greatest level of water savings.

2.7. Conclusion

While this report is a first step in water conservation planning, the City of Bloomington will need to outline a more comprehensive and specific plan for the City. By completing a water audit, a water system profile, and a more detailed demand forecast, the City of Bloomington will gain insight into the most effective means of reducing water use. Implementation will only be able to begin after goals are set, conservation measures are evaluated, and specific conservation measures that are relevant for their community and system are determined.

3. Recommendations

While conservation planning is just beginning in Bloomington, Illinois, the City can begin some conservation measures immediately. Given that the City of Bloomington's surface water supplies are vulnerable to water shortages and that water conservation is a viable long-term management practice, WHPA recommends seven initial steps towards using water supplies efficiently and developing a comprehensive conservation plan and program.

1. *Adopt the drought response ordinance.*

The ordinance will authorize the City of Bloomington, Illinois Water Department to restrict non-essential water use during drought conditions, which is critical for preserving the city's water supply for human consumption, sanitation, and fire protection. The drought ordinance allows the City to maintain control of the water sources when shortages occur yet allows the citizens to choose their use level when water is plentiful. Adopting the drought ordinance is also very important to the City of Bloomington since water-quality problems are exacerbated by drought.

2. *Include a drought index in the Pantagraph and on the City website.*

Adding a drought index to the local newspaper and city website brings awareness to the issue of drought and it becomes are regular reminder to the public of existing drought conditions. People can understand the need to conserve water when they understand that a drought is occurring. This is particularly important to the City of Bloomington because the reservoirs are susceptible to drought and water-quality issues are compounded by drought.

3. *Conduct business water audits through Illinois Sustainable Technology Center program.*

The Illinois Sustainable Technology Center (ISTC) provides businesses with up to eight (8) hours of free consultation to help improve water and energy efficiencies. The City of Bloomington could partner with ISTC to target large water users. These audits would benefit both the business, through decreased operating costs, and the City through reduced usage. It is recommended that the City promote the ISTC and their partnership to encourage participation from local businesses.

4. *Provide water conservation kits to residential customers.*

Residential water conservation kits would be distributed to interested customers. These kits could include low-flow showerheads, showerheads with “lather valve”, low-flow kitchen and bathroom faucet aerators, toilet dams, toilet bowl diverters, dye tablets to help identify leaks, showerhead flow meter, drip gauge for detecting faucet leaks, and/or flush volume calculator. Educational materials should also be included to provide: general understanding of water conservation; a guide to water efficient plants and landscaping specific to Bloomington; installation guides for hardware devices included in the kit; and other sources and products to help conserve water.

5. ***Perform a water audit.***

   The water audit is an essential first water management step that will identify water losses within the delivery system. Water losses in the delivery system are one of the most straight forward conservation measures and can have an impact immediately. However, without knowing where those losses are, the Bloomington Water Department will be unable to address losses.

6. ***Complete a water system profile.***

   A water system profile provides a holistic view of the water system and community. The data required for the water system profile is probably already collected in various forms. By completing the profile, the Bloomington Water Department will be able to view the data and system in light of conservation.

7. ***Develop conservation goals.***

   Once the water audit and system profile have been completed, the City of Bloomington will be ready to set specific, measurable goals for conservation. The basic water demand projections performed in 2002 can be used to help understand the potential impacts of conservation and develop realistic goals. The goals developed at this point could lead directly into determining the conservation measures that will help achieve these goals and to an implementation strategy for the conservation program.

The seven recommendations outlined above should be implemented in the order they appear. Because the water supply is susceptible to drought and water-quality problems are exacerbated by drought, passing the drought ordinance should be a high priority for the City. Creating awareness in the community is also important and is relatively easy to implement. Providing water audits and leak detection kits to interested businesses and residents are relatively inexpensive and could be implemented quickly. The final three recommendations will put the City on a path to a formal conservation program that allows Bloomington to effectively and efficiently use its existing water supplies.

References

AWWA Water Loss Control Committee (2003). Applying Worldwide BMPs in Water Loss Control. Journal AWWA, 95(8):65 – 79.

American Water Works Association, 2008a. Water Audit Methodology http://www.awwa.org/Resources/content.cfm?ItemNumber=588 (Accessed 8/27/2008).

American Water Works Association, 2008b. Water Audit Software http://www.awwa.org/Resources/Content.cfm?ItemNumber=590 (Accessed 8/27/2008).

Dziegielewski, B. 2003. Strategies for managing water demand. Water Resources Update, 126: 29-39.

Edstrom, Jeffrey and Bill Ward (2006). Water Conservation & Protection Plan. Technical report, GeoSyntec Consultants for Waukesha Water Utility. Source: http://www.ci.waukesha.wi.us/WaterUtility/waterConservationAndProtectionPlan.html,accessed June, 2008.

Farnsworth Group (2002). Regional water supply preliminary infrastructure plan. Project report for Long-Range Water Plan Steering Committee.

Jordan Jones & Goulding (2003). Water Supply and Water Conservation Management Plan. Technical report, Metropolitan North Georgia Water Planning District. Source: http://www.northgeorgiawater.com/html/88.htm, accessed June, 2008.

Kenney, D. S., Goemans, C., Klein, R., Lowrey, J., and Reidy, K. (2008). Residential Water Demand Management: Lessons from Aurora, Colorado. Journal of the American Water Resources Association, 44(1):192 – 207.

Mayer, P.W., Towler, E., DeOreo, W. B., Caldwell, E., Miller, T., Osann, E. R., Brown, E., Bickel, P., and Fisher, S. (2004). National Multiple Family Submetering and Allocation Billing Program Study. Technical report, United States Environmental Protection Agency, National Apartment Association, National Multi Housing Council, City of Austin, City of Phoenix, City of Portland, City of Tucson, Denver Water Department, East Bay Municipal Utility District, San Antonio Water System, San Diego County Water Authority, Seattle Public Utilities, and Southern Nevada Water Authority. Source: http://www.nmhc.org/Content/ServeFile.cfm?FileID=4272, accessed June 2008.

Monterey Peninsula Water Management District and California-American Water Company (2008). Summary: Expanded Water Conservation & Standby Rationing Plan. Received June 18, 2008.

MWRA (2006). Water System Master Plan. Technical report, Massachusetts Water Resources Authority. Source: http://www.mwraadvisoryboard.com/Presentation/WaterSystemMasterplan.pdf, accessed June, 2008.

New England Water Works Association and Massachusetts Water Works Association (2008). Toolbox of BMPs for Water Resource Management. Personal communication on June 23, 2008 with Carl Leone, Senior Program Manager of Massachusetts Water Resources Authority.

PRI (2004). Economic Instruments for Water Demand Management in an Integrated Water Resources Management Framework. Synthesis Report ISBN: 0-662-39330-9, Policy Research Initiative for the Government of Canada. PRI Sustainable Development Project. Source: http://www.policyresearch.gc.ca/doclib/PG_SD_EconomicInstruments_200406_e.pdf, accessed June 2008.

USEPA (1998). Water Conservation Plan Guidelines. http://www.epa.gov/watersense/pubs/guide.htm. Accessed June, 2008.

USEPA (2002). Cases in Water Conservation: How Efficiency Programs Help Water Utilities Save Water and Avoid Costs. Online publication 832B02003, United States Environmental Protection Agency. Source: http://www.epa.gov/watersense/docs/utilityconservation_508.pdf, accessed June 2008.

Vickers, A. (2001). Water Use and Conservation. Waterplow Press, Amherst Massachusetts.

Appendix A - Water System Profile

Worksheet 4-1: Water System Profile

A	**SERVICE CHARACTERISTICS**	**Number**
1	Estimated service population	
2	Estimated service area (square miles)	
3	Miles of mains	
4	Number of treatment plants	
5	Number of separate water systems	
6	Interconnection with other systems	

B	**ANNUAL WATER SUPPLY**	**Annual volume**	**Number of intakes or source points**	**Percent metered**
7	Groundwater			%
8	Surface water			%
9	Purchases: raw			%
10	Purchases: treated			%
11	Total annual water supply			%

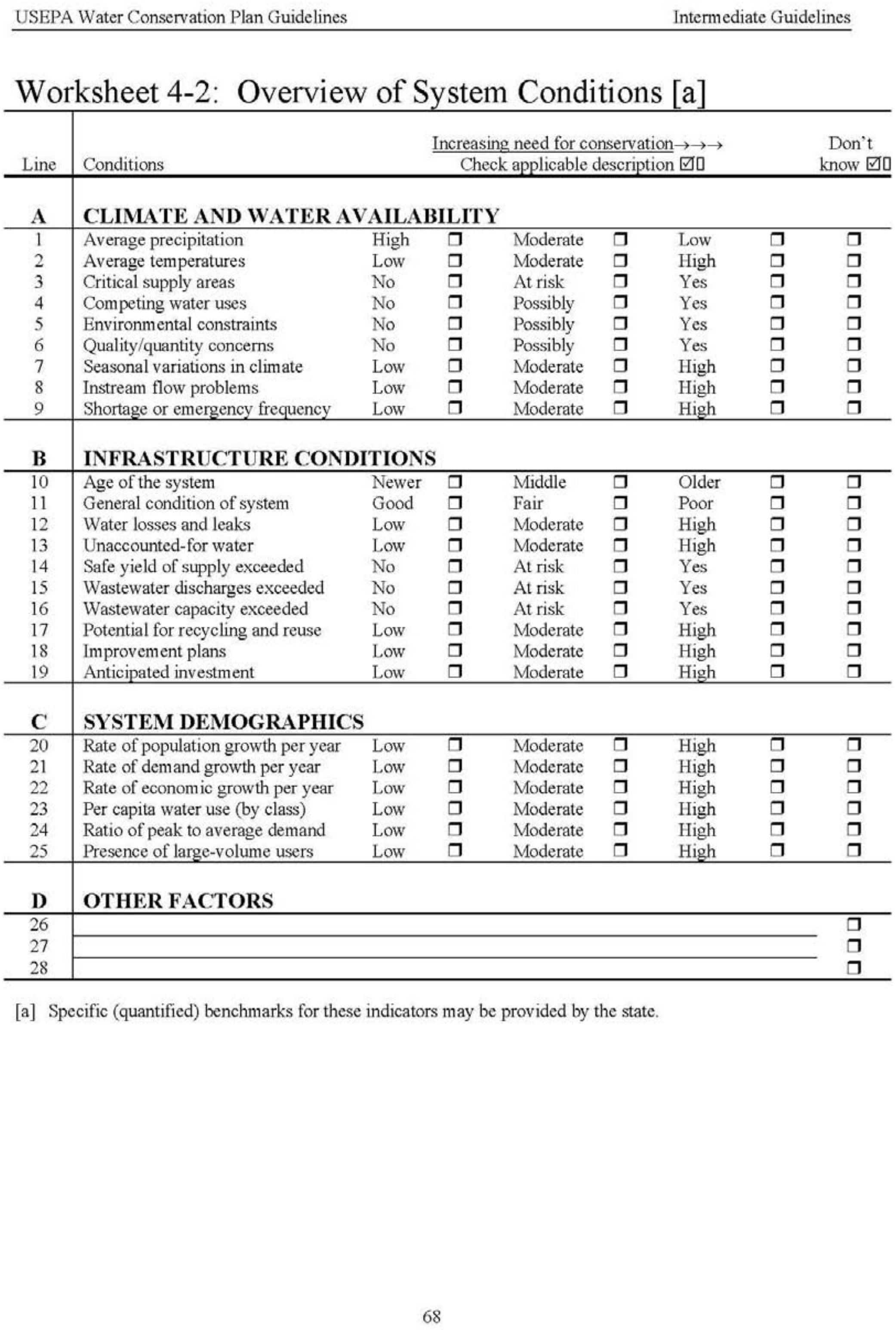
C	**SERVICE CONNECTIONS**	**Connections**	**Water sales**	**Percent metered**
12	Residential, single-family			%
13	Residential, multi-family			%
14	Commercial			%
15	Industrial			%
16	Public or governmental			%
17	Wholesale			%
18	Other			%
19	Total connections			%

D	**WATER DEMAND**	**Annual volume**	**Percent of total**	**Per connection**
20	Residential sales			
21	Nonresidential sales			
22	Wholesale sales			
23	Other sales			
24	Nonaccount water: authorized uses			
25	Nonaccount water: unauthorized uses			
26	Total system demand (total use)			

E	**AVERAGE & PEAK DEMAND**	**Volume**	**Total supply capacity**	**Percent of total capacity**
27	Average-day demand			%
28	Maximum-day demand			%
29	Maximum-hour demand			%

F	**PRICING**	**Rate structure**	**Metering frequency**	**Billing frequency**
30	Residential rate			
31	Nonresidential rate			
32	Other rate			

G	**PLANNING**	**Prepared a plan ☑☐**	**Date**	**Filed with state ☑☐**
33	Capital, facility, or supply plan			
34	Drought or emergency plan			
35	Water conservation plan			



Worksheet 4-2: Overview of System Conditions [a]

Line	Conditions	Increasing need for conservation→→→ Check applicable description ☑☐						Don't know ☑☐
A	**CLIMATE AND WATER AVAILABILITY**							
1	Average precipitation	High	☐	Moderate	☐	Low	☐	☐
2	Average temperatures	Low	☐	Moderate	☐	High	☐	☐
3	Critical supply areas	No	☐	At risk	☐	Yes	☐	☐
4	Competing water uses	No	☐	Possibly	☐	Yes	☐	☐
5	Environmental constraints	No	☐	Possibly	☐	Yes	☐	☐
6	Quality/quantity concerns	No	☐	Possibly	☐	Yes	☐	☐
7	Seasonal variations in climate	Low	☐	Moderate	☐	High	☐	☐
8	Instream flow problems	Low	☐	Moderate	☐	High	☐	☐
9	Shortage or emergency frequency	Low	☐	Moderate	☐	High	☐	☐
B	**INFRASTRUCTURE CONDITIONS**							
10	Age of the system	Newer	☐	Middle	☐	Older	☐	☐
11	General condition of system	Good	☐	Fair	☐	Poor	☐	☐
12	Water losses and leaks	Low	☐	Moderate	☐	High	☐	☐
13	Unaccounted-for water	Low	☐	Moderate	☐	High	☐	☐
14	Safe yield of supply exceeded	No	☐	At risk	☐	Yes	☐	☐
15	Wastewater discharges exceeded	No	☐	At risk	☐	Yes	☐	☐
16	Wastewater capacity exceeded	No	☐	At risk	☐	Yes	☐	☐
17	Potential for recycling and reuse	Low	☐	Moderate	☐	High	☐	☐
18	Improvement plans	Low	☐	Moderate	☐	High	☐	☐
19	Anticipated investment	Low	☐	Moderate	☐	High	☐	☐
C	**SYSTEM DEMOGRAPHICS**							
20	Rate of population growth per year	Low	☐	Moderate	☐	High	☐	☐
21	Rate of demand growth per year	Low	☐	Moderate	☐	High	☐	☐
22	Rate of economic growth per year	Low	☐	Moderate	☐	High	☐	☐
23	Per capita water use (by class)	Low	☐	Moderate	☐	High	☐	☐
24	Ratio of peak to average demand	Low	☐	Moderate	☐	High	☐	☐
25	Presence of large-volume users	Low	☐	Moderate	☐	High	☐	☐
D	**OTHER FACTORS**							
26								☐
27								☐
28								☐

[a] Specific (quantified) benchmarks for these indicators may be provided by the state.

Worksheet 4-3: Current Water Conservation Activities

Summarize the system's current water conservation activities/programs: ____________

Water conservation measures	*Approximate* annual water savings [if known]	Implemented since (date)	Is continued implementation planned?

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK

Appendix E

Drought Response Plan and Ordinance

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK

Drought Response Plan
City of Bloomington, Illinois Water Department

July, 2006

Wittman Hydro Planning Associates, Inc.
320 West Eighth Street, Suite 201, Bloomington, Indiana 47404
phone: (812) 333-9399 **fax: (812) 333-3080** *www.wittmanhydro.com*

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK

Table of Contents

Introduction

The State of Illinois, like most of its Midwestern neighbors, has no constitutional guidance and little statutory language to describe the responsibilities of utilities or local governments for water supply planning. The two most important water management laws in the state are the 1951 Water Authorities Act and the 1983 Water Use Act (as amended).

Section 5 of this law deals with the problem of water conflict resolution:

> *In the event that a land occupier or person proposes to develop a new point of withdrawal, and withdrawals from the new point can reasonably be expected to occur in excess of 100,000 gallons on any day, the land occupier or person shall notify the District before construction of the well begins. The District shall in turn notify other local units of government with water systems who may be impacted by the proposed withdrawal. The District shall then review with the assistance of the Illinois State Water Survey and the State Geological Survey the proposed point of withdrawal's effect upon other users of the water. The review shall be completed within 30 days of receipt of the notice. The findings of such reviews shall be made public. (Source: P.A. 85-1330.) The long history of hydrologic analysis in the state is generally associated with the work done by the State Water Survey (ISWS) and is a legacy of their leadership in the field. However, the ISWS has primarily been a research organization rather than a water manager.*

Other than the indirect reference to their role in the Water Use Act, the ISWS has no statutory authority to manage water use from aquifers or surface water supplies. Annual water use is voluntarily reported to the ISWS by all high capacity users and, unless a neighbor notices a problem with their supply well there are no regulations of water withdrawals. In-stream flow requirements are indicated by the limits imposed by the low-flow requirements of individual NPDES discharge permits and the restrictions built into federal permits for power plant cooling water from surface waters.

For the past 50 years only the local water utilities have done planning for water use by planning for expansion. Local declines in water levels in the deep aquifer and pollution of the shallow aquifers in the more populated areas created new boundary conditions for community planning. Only the ISWS has done any large scale technical analysis to support water supply planning (ISWS, 1995). Other than an executive order from the governor, at this time there is no legislative consensus about the need for, or approach to state-wide water supply planning. There are a number of reasons for the relatively immature water supply planning and policy in Illinois:

- History of Shortage – The state has a relatively moist climate and a limited history of severe drought.
- Relinquishing Local Control – Shortages are likely in areas where there is competition for a scarce resource and water supply planning is not simple when there are neighbors.

- Agriculture is Politically Strong – Like other areas of the country, there is a legacy of incentives that favor agricultural uses of land and water. Some of these incentives conflict with the principles of modern water management.
- Chicago – Like many other issues in the state, the water supply interests and options available to Chicago (the state's largest city on the shores of a huge freshwater lake) diverge from those of the small town populations that make up the rural landscape.
- Shortages Are Often Local – The state covers a large area in a humid part of the continent. In the recent past there have been sub-regional, sub-decadal water shortages that have caused regional concerns but not since the 1960s has any drought been extended or severe. To complicate matters, the City of Chicago has access to Lake Michigan.

In 2001, the state water survey published their plan for "scientific assessment of water supplies" that documents the activities and programs in the state that together estimate the dimensions of the resource and the records that are available for water use in evaluating conditions. The plan for scientific assessment of water supplies describes how the work that is being done now by regulatory agencies in the state are working to protect water quality as they maintain data and technical skills. Illinois has recently found that state laws provide for a strong water research mission but there is no statutory water management authority. Given this policy vacuum, it is incumbent on local governments that are located in areas of the state that may be vulnerable to shortages (especially those already experiencing both rapid growth and limited supplies) to begin or continue the planning process. This Drought Action Plan is an important part of the planning process for the City of Bloomington, Illinois. The plan outlines the nature of the problem, places the issue of drought preparedness into an historical context, offers strategies for dealing with drought with the current water supply system, and provides recommendations for diversifying the portfolio of water sources for the City of Bloomington's drinking water.

City of Bloomington, Illinois Water Supply

The City of Bloomington, Illinois relies on two reservoirs for their community drinking water supply. Since the drought of the late 1980's, the City has taken steps to increase the reliability of the water supply by intensive watershed management to protect water quality (Rutherford and Twait, 2005). The objective of the management effort was to reduce sediment and nutrient loading into the lakes and to improve water quality for treatment. In 1992, the water level in Evergreen Lake Reservoir was increased by 5 feet to bring its capacity to 15,480 acre-feet at normal pool elevation. Lake Bloomington Reservoir can hold 8,760 acre-feet at normal pool elevation. Together, at an average water use of 15 million gallons per day (MGD), these two lakes could theoretically supply the city with 1-2 years of drinking water for their system. With the added flexibility provided by improvements made in the last several years, including permits to pump into the reservoirs from the Mackinaw River during adequate stream flows, the Water Department has moved towards a more stable water supply.

The 1988 and 2005 droughts illustrated that any surface water supply in this part of the state is potentially vulnerable to water shortages. What is troubling is that in 2003 the GAO found that, despite local experience in Illinois, shortages were not considered to be likely (see Figure 1). Public water supply systems that use reservoirs as their sole source of supply need to have storage far beyond their average needs in order to be resilient to prolonged, multi-year drought. While the City of Bloomington, Illinois Water Department has experience with the operational problems of water supply management during shortages, more analysis needs to be done to consider the dimensions of the problem and to create a more stable network of water sources for the city to use when the inevitable dry periods occur.

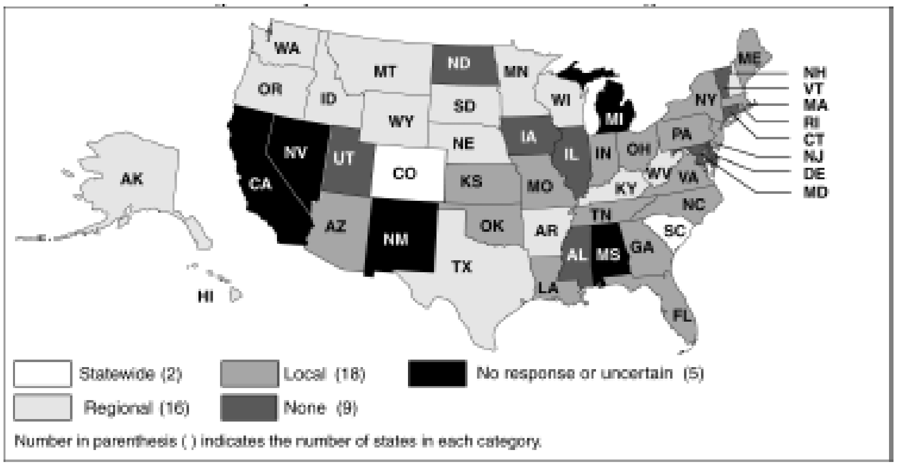


Figure 1: Extent of state shortages likely over the next decade under average water conditions. (GAO, 2003)

Historic Drought

The 1988-1989 drought was a shock to many water supplies throughout the Midwest. During the 37-month drought, water levels dropped far below the spillway elevations in the two Bloomington reservoirs. Restrictions were imposed on watering lawns and serving tap water in restaurants. The city also installed a pumping pool to divert water from the Mackinaw River into Evergreen Lake Reservoir. Water quality deteriorated both during and after the drought and many residents began to purchase bottled water to avoid the taste of the city water. For a short-time, the City purchased water from Normal, where the groundwater-based supply was less affected by the reduction in aquifer recharge. This solution was not sustainable because of problems caused by the differences between the Normal and Bloomington supply systems.

As a result of the drought, many studies were launched across the state. McLean County commissioned a long-term water study in 1990 by Farnsworth & Wylie Engineering that was used to consider options for storage and supply. The study concluded with several recommendations, including supplementing the Bloomington water supply with groundwater. In 1992 the City of Bloomington raised the level of Evergreen Lake

Reservoir by five feet, increasing storage capacity by 36%. Additional projects were executed at the watershed level in an effort to improve the quality of water entering the lakes. These projects were primarily focused on improving agricultural practices, installing buffer zones such as wetlands and filter strips, and identifying the main sources of agricultural pollutants, especially nitrates. The Soil Conservation District recommended sediment structures for Lake Bloomington Reservoir, which were designed and planned for 1991 but never constructed.

Since 1989, the public and the media have been more attuned to local weather conditions, with articles regularly appearing in the local newspaper. Another, less serious drought period occurred in 1991-1992, which led to the City of Bloomington obtaining a permit to use the pumping pool in Mackinaw River based on flow conditions in the river. While the permit was obtained, it was not used until the drought of 2000-2001. This was the first time that the pumping pool was used since the 1989 drought.

Drought again occurred in 2005-2006 and has sparked additional interest in water resources for the state. Governor Blagojevich issued an Executive Order on January 9, 2006 to develop a comprehensive, statewide water supply planning and management strategy. Several studies were already underway at the state level, primarily under the direction of the Illinois State Water Survey. These include numerous reports evaluating the water supply in Illinois and suggesting guidelines for supply planning at both the state and local level.

Drought is not an uncommon phenomenon in the Midwest. While the drought of 1988-1989 is frequently cited as one of the worst in Illinois, several more significant droughts occurred earlier in the 20th Century. According to the recently published report, “Drought Planning for Small Community Water Systems” published by the Illinois State Water Survey (2006), the worst droughts in the Midwest were in 1931-1934, 1953-1958, and 1963-1964. These droughts had the lowest average flows for a period of six months, at levels that were not seen after the 1960’s. The study suggests that Illinois and other Midwestern states should be prepared for one-year to five-year drought scenarios that are much more extreme than those that have occurred in the late 1980s.

Recent investigations have suggested that climate change may increase both the frequency and severity of drought in this area (Xie and Eheart, 2004). The analysis, based on General Circulation Models (GCMs), from the Canadian Climate Centre, these studies suggest that the future drought patterns may be significantly different than historic. The study suggested irrigation will increase in agricultural areas and there will be consequences to water supplies that rely on stream flow. Specifically the study found that:

> *“Climate change in and of itself will affect the vulnerability of regional fresh water resources, by altering the low flow frequencies of stream at reference gauging stations. Moreover, the threats of droughts may motivate farmers to introduce irrigation in this traditionally rain-fed area to maintain high and stable yields. Such irrigations, if any, could exacerbate the effects of the changes in climatic factors.”*

A Practical Definition of Drought

There are many definitions of drought that are used to capture the causes and effects of water shortage. The most common distinction found in the literature is the difference between meteorological drought and agricultural drought. Meteorological drought is generally defined as a period of lower than average precipitation. Agricultural drought occurs when the timing and duration of the dry spell is long enough to have economic implication to the agricultural sector of the economy.

These distinctions may often be useful but they may not address the water shortage issues that arise for a water utility. For a municipal water system a practical definition for drought may be as follows:

> ***A reduction in precipitation or aquifer recharge that affects the ability of the public water system to meet the demands of the customers or causes regulatory or aesthetic reductions in water quality.***

This definition of drought is characterized by the impacts of the shortage on a municipal water system. If the water utility has an oversized storage capacity or has very low demands relative to their supplies, such a drought may be rare. However, in areas where the demands nearly match supplies and growth is occurring in water use, municipal water shortages can occur more frequently. In effect, the surface water system used by the City of Bloomington requires that the average annual inflow into the two lakes is in the range of 3 – 4 inches. More importantly, with only the buffer of the 1-2 year storage, the timing of the inflows need to match the timing of the demands and use. This means that the timing of any drought affects the severity of the shortage from a water supply perspective.

Another important factor that is often considered in engineering analysis and utility planning is the duration of drought. As a general rule, in the Midwest short-term droughts occur over a period of a months and are often described as seasonal “dry spells.” Long-term droughts, however, occur over periods of several seasons or years and may cause changes in lake levels, stream flows and aquifer water levels. These long-term drought are often referred to as hydrological droughts (they affect the hydrologic conditions in an area) and in the past 100 years multiple-year droughts have occurred at least two times (Winstanley and others, 2006). From a planning perspective, the dimensions and consequences of municipal water supply droughts are important to consider when investing in new infrastructure.

The City of Bloomington's water supply is also susceptible to water quality problems that can a cause water-supply shortage. The EPA standard for a safe level of nitrates in drinking water is a maximum of 10 milligrams per liter (mg/L). The City of Bloomington reservoirs, particularly Lake Bloomington Reservoir, often have high nitrate concentrations. Most of the time, even when one lake has a concentration above 10 mg/L, the concentration in the combined water is well below the standard. However, there are short periods of time when even combined, the water supply has concentrations very close the safe drinking water limit. Although, the city has never had a nitrate violation, it is possible that in drought conditions when source options are limited that violations could occur. Currently, the city does not have the ability to remove nitrates and/or dilute the water with a clean source. In effect, if combined nitrate concentrations get too high (over 10 mg/L) the city will have a water quality induced water shortage.

Drought Indexes and Declaration

One of the most important indicators of drought for any utility that uses surface water reservoirs, is the difference between the inflow rates into the reservoirs and the average extraction rate at the treatment plant. This simple measure is another way to understand the increases and decreases in water levels in the reservoirs and can be used to chart the beginning and end of any drought period. For the two reservoirs used by Bloomington, the surface water storage system requires that the average annual flow into the two lakes is in the range of 3 – 4 inches of surface runoff. During normal climatic periods with sufficient precipitation the storage volume in the reservoirs is used to make up the difference between the timing of the inflows and the timing of the demands and use. However during drought, reduced flow into the reservoir and continued demand can cause a water supply shortage.

Custom indicators of drought have been developed for Bloomington's reservoir system based upon reservoir levels. The drought levels have been divided into three categories; moderate, severe, and extreme. These drought levels and their implications will be defined and discussed in more detail in the “Defining Drought” Section of this document.

Purpose of the Drought Response Plan

The purpose of the Drought Response Plan is to protect the water quality and water quantity of the City of Bloomington, Illinois' water supply during drought and/or periods of water shortage. The plan helps minimize the detrimental impacts on water-use customers that can be caused by drought and intentional or unintentional water-supply shortages.

The timely response and actions of the Water Department and it's customers is the key to ensuring a sustainable water-supply during times of duress. The cooperation of residents, commercial, industrial, and other community water users will determine the success of the Drought Response Plan.

Defining Drought Triggers

A Drought Response Plan must be based upon a discrete definition of drought with threshold levels defined that trigger varying responses. The City of Bloomington, Illinois Water Department has defined three levels of drought, each with unique triggers and responses. The reservoirs will be, at all times, in exactly one water-level category: normal (no drought), moderate drought, severe drought, or extreme drought. These categories and their implications are discussed in this section.

Non-Drought

Reservoir water levels fluctuate during “normal”, non-drought climatic periods due to water supply extraction and response to precipitation. Lake Bloomington Reservoir and Evergreen Lake Reservoir water-level fluctuation of less than 6 feet below the spillway level is considered “normal.” Water level variations of this magnitude may reduce impact aesthetic and/or recreation uses of the reservoirs, but is not a concern for Bloomington's water supply. More shoreline will be visible during times of reduced water level and boating ramps may or may not be accessible. These impacts are expected during the normal water fluctuation of the reservoirs.

Moderate Drought

When combined reservoir water levels drop below the spillway greater than six feet, the water supply is experiencing drought conditions. When the water level is reduced between 6 to 8 feet, the City of Bloomington, Illinois Water Department declares the water supply to be under moderate drought conditions and the moderate drought responses are initiated. At this drought stage the city will enact increased leak monitoring and ask it's customers to voluntarily reduce water use. The City of Bloomington, Illinois Water Department will also make operational changes at this stage to help alleviate the drought. The longevity of a moderate drought will depend upon customer cooperation as well as the timing and magnitude of local precipitation events to help raise water levels in the reservoirs.

Severe Drought

When the water levels in the reservoirs reaches a combined reduction of 8-10 feet below the spillway level a severe drought is declared. It is critical at this drought level to reduce water use to ensure the water supply will be sustainable the duration of the drought. Mandatory water-use restrictions are implemented at this drought level to help reduce overall water use by ten percent.

Extreme Drought

Extreme drought is declared when the combined water levels fall greater than 10 feet below the spillway level. At this decreased water volume the remaining water supply is critical and must be conserved. At this stage, water-use restrictions are increased to reduce overall water use by 15%. Restrictions during extreme drought are more heavily enforced to ensure the longevity of the water supply. This is the highest drought level and will only be downgraded when water levels increase in the reservoirs.

Drought Response Plan Actions

For each of the defined drought levels, the City of Bloomington, Illinois Water Department has created an explicit goals and a list of actions to be implemented by the

Water Department and it's customers. The response plan actions are designed to alleviate the drought and help maintain and/or increase water levels in the reservoir. The goal and response actions for each drought level is described below.

Moderate Drought Response

The goals of the moderate drought response are to 1) make the public aware of the drought and water shortage 2) educate the public about drought procedures and water saving tips they can implement to help conserve water and 3) encourage a voluntary five percent water use reduction by all water customers.

During this phase, the City of Bloomington, Illinois Water Department asks residential, commercial, industrial, and institutional water users to voluntarily reduce aesthetic, domestic, landscaping, and water-based recreational activities such as swimming pools, water slides, and other related water activities. Agricultural, irrigation, and livestock water users are requested to implement conservation techniques, explore different water saving methods, and use alternative sources

The City of Bloomington, Illinois Water Department will also implement operational changes within the water supply system to stem the water level reduction. Water from the treatment process that is normally discharged to Mackinaw River will be held in settling lagoons to serve as a small reserve water supply. Also, the department's regular leak detection survey will be enhanced. In addition, all properties owned by the City of Bloomington, Illinois will be prohibited from aesthetic water use and will restrict landscape watering to Tuesday and Saturday, this includes properties leased by the city.

Severe Drought Response

The goals of the severe drought response are to 1) educate the public about drought procedures and water saving tips they can implement to help conserve water 2) generate a public response to the drought and water shortage and 3) initiate a mandatory ten percent water use reduction by all water customers.

Severe drought requires that all customers restrict water use to minimum levels. Specifically, all water users are to use low-volume hand-held water applications only and prohibit sprinklers, other remote broadcast devices, and water runoff in landscape maintenance. Landscape watering is restricted to Tuesday and Saturday for odd-numbered addresses, and Thursday and Sunday for even-numbered addresses. Commercial and institutional customers must limit water-based recreational activities to facilities, such as swimming pools and other water activities that use filtration and/or water recycling. Single-use water supply parks are prohibited. Agriculture, irrigation and livestock water users are limited to irrigating from 7:00 p.m. to 7:00 a.m.

The City of Bloomington, Illinois Water Department will enact a 24-hour, service-area wide, monitoring system to evaluate the communities response and cooperation to drought procedures. Employees of the water department will survey the water supply area and give courtesy warnings to those not following the drought procedures. The department will also reduce the water supply hydraulic grade-line (lower levels in water towers by five feet). Also, the use of water-based recreational activities that rely on single use water supply, such as municipal water-parks, will be prohibited.

Extreme Drought Response

In the case of an extreme drought, the response goal is a 15% water use reduction by all customers through implementation of daily water saving tips and mandatory water restrictions.

Residential, commercial, industrial, and institutional customers are required at this stage to 1) reduce domestic water use to minimum levels necessary to maintain health and safety 2) prohibit water-based recreational activities except facilities, such as swimming pools and other related water activities, that employ filtration and/or water recycling 3) use low-volume hand-held applications only and prohibit sprinklers, other remote broadcast devices, and water runoff in landscape design maintenance and 4) restrict landscape watering on Tuesday and Saturday for odd-numbered addresses, and Thursday and Sunday for even-numbered addresses. Agriculture, irrigation and livestock water users are limited to irrigating from 12:00 a.m. to 4:00 a.m. and are required to implement conservation techniques, explore different water saving methods, and use alternative sources.

In addition to the response actions for a severe drought, during an extreme drought the City of Bloomington, Illinois Water Department will also prohibit water-based street cleaning and water-based recreational activities except facilities, such as swimming pools and other related water activities that employ filtration and/or water recycling.

Recommendations

Historic drought has demonstrated that, given the growth and development in the area and the potential for new demands on the system, the City of Bloomington relies on a vulnerable source of supply for drinking water. As a first step to protect the water supply, the City of Bloomington should adopt the Drought Response Ordinance (Appendix A) created from this Drought Plan. The Ordinance will help the City of Bloomington, Illinois Water Department ensure the longevity of the water supply even in times of drought and/or water shortage.

In addition to this, the City needs to 1) protect water quality and storage in the existing reservoirs, 2) expedite development of local groundwater for supplementing existing sources and begin the process of planning for a long-term sustainable supply. A description of the steps involved in these three recommendations are described below.

Protect Existing Assets

- Continue watershed planning and management
- Use the TMDL analysis to develop operational water management models

- Consider new techniques to manage (and predict) blooms of blue-green algae
- Distribute educational information for the public about water conservation and water-saving tips. The circulation of information should be increased in times of drought to ensure that all customers are knowledgeable in water conservation techniques.
- Supply water-conservation kits for residential customers, *e.g.* low-flow showerheads, faucet aerators, “lather-valve” showerheads, toilet dams, and leak-detection dye. This will enable customers to easily reduce water use.
- Work with the City of Normal to enable the interconnection of the two cities water supplies. Both cities could benefit from the interconnected water supplies during drought and other emergency situations.
- Develop agreement with the City of Normal such that Normal agrees to take over supply of water to those industries located within the city limits of Normal during times of drought. When the drought is over, the City of Bloomington will resume normal supply to these industries. The agreement will relieve the Bloomington water supply and Normal will benefit from the additional revenue.
- Investigate transfer of water from Evergreen Lake Reservoir to Lake Bloomington Reservoir. The ability to move water from one lake to another adds additional and necessary flexibility to the water supply system.

Expedite Development of Groundwater Sources

- Explore groundwater possibilities near the reservoirs. A groundwater source will increase water quantity and, because it has low nitrate concentrations, groundwater can help improve water quality. A location near the existing mains will keep transmission costs down.
- Explore the feasibility of developing groundwater sources in high growth area in the southwest. The increase in demand in this region can be relieved with local groundwater sources. In addition, the infrastructure created in this endeavor will benefit the long-term water supply goal of groundwater as a sole source for the City of Bloomington.
- Develop agreements with local water authorities to pursue the Mahomet Aquifer as a source of groundwater for the City of Bloomington.

Appendix A – Drought Response Ordinance

DROUGHT RESPONSE ORDINANCE

FOR

THE CITY OF BLOOMINGTON, ILLINOIS

Drought Response Ordinance Index

Bloomington Drought Response Ordinance

SECTION I: DECLARATION OF POLICY, PURPOSE, AND INTENT

Purpose: To achieve the greatest public benefit from domestic water use, sanitation, and fire protection, and to provide water for other purposes in an equitable manner and to preserve water quality, the City of Bloomington, Illinois adopts the following regulations and restrictions on the delivery and consumption of water.

This Ordinance is hereby declared necessary for the preservation of public health, safety, welfare, and enhance water supply operational flexibility and shall take effect upon it adoption by the City of Bloomington, Illinois.

Whenever, in the judgment of the governing body of City of Bloomington, Illinois Water Department, it becomes necessary to conserve water in the service area, due to drought, the City of Bloomington, Illinois Water Department is authorized to issue a Proclamation that existing drought conditions prevail over fulfillment of the usual water-use demands. The Proclamation is an attempt to prevent depleting the water supply to the extent that water-use for human consumption, sanitation, fire protection, and other essential needs become endangered.

Immediately upon the issuance of such a Proclamation, regulations and restrictions set forth under this Ordinance shall become more effective and remain in effect until the water shortage is terminated and the Proclamation rescinded.

Water uses, regulated or prohibited under the Ordinance, are considered to be non-essential and continuation of such uses during times of water shortage are deemed to constitute a waste of water, subjecting the offender(s) to penalties.

The provisions of the Ordinance shall apply to customers within the jurisdiction of the City of Bloomington, Illinois Water Department.

SECTION II: DEFINITIONS

For the purposes of this Ordinance, the following definitions shall apply:

Aesthetic water use: water use for ornamental or decorative purposes such as fountains, reflecting pools, and waterfalls

Commercial and industrial water use: water use integral to the production of goods and/or services by any establishment having financial profit as their primary aim.

Customer: any person, company, or organization using water supplied by the City of Bloomington, Illinois Water Department.

Domestic water use: water use for personal needs or for household purposes such as drinking, bathing, heating, cooking, sanitation, or for cleaning a residence, business, industry, or institution.

Drought Alert Phase:

1. Moderate Drought: Combined reservoir water-levels reduced below spillway level by 6 - 8 feet.

2. Severe Drought: Combined reservoir water-levels reduced below spillway level by 8 - 10 feet.

3. Extreme Drought: Combined reservoir water-levels reduced below spillway level by greater than 10 feet and stream flow in Mackinaw River less than 20%.

Essential water uses: water used specifically for fire fighting, and to satisfy federal, state, of local public health and safety requirements.

Even numbered address: street addresses, box numbers or rural route numbers ending in 0, 2, 4, 6, 8 or letters A-M; and locations without addresses.

Institutional water use: water use by government, public and private educational institutions, public medians and rights of way, churches and places of worship, water utilities, and other lands, buildings, and organizations within the public domain.

Landscape water use: water used to maintain gardens, trees, lawns, shrubs, flowers, athletic fields, rights of way and medians.

Odd numbered address: street addresses, box numbers or rural numbers or rural route numbers endings in 1, 3, 5, 7, 9 or letters N-Z

Water shortage: lack of adequate available water to meet normal demands due to lower than normal precipitation, reduced stream flows or soil moisture, and/or deterioration of water quality which causes water supplies to be less than usual.

SECTION III: NON-ESSENTIAL WATER USE

All water use categories, other than essential water use, may be curtailed during severe or extreme drought. Some examples of non-essential water uses follows:

A. Residential and Institutional:

1. Washing down sidewalks, walkways, driveways, parking lots, tennis courts, or other hard surface areas.

2. Washing down buildings or structures for purposes other than immediate fire protection.

3. Flushing gutters or permitting water to run or accumulate in any gutter or street.

4. Washing any motor bike, motor vehicle, boat, trailer, airplane or other vehicle in public or private garages or elsewhere.

5. Maintaining fountains, reflection ponds, and decorative water bodies for aesthetic or scenic purposes.

6. Filling or maintaining public or private swimming pools.

7. Sprinkling lawns, plants, trees, and other flora on private or public property, except as otherwise provided under the Ordinance.

B. Commercial and Industrial:

1. Serving water routinely in restaurants.

2. Increasing water levels in scenic and recreational ponds and lakes.

3. Irrigating golf courses and any portion of its grounds, except greens or as otherwise provided under this Ordinance.

4. Obtaining water from hydrants for any purpose other than firefighting.

5. Serving customers who have been given a 10 day notice to repair one or more leaks and has failed to comply.

6. Expanding commercial nursery facilities, placing new sod on commercial and/or residential sod after the drought proclamation, or planting or landscaping when required by site design review process.

SECTION IV: RESPONSES TO MODERATE, EXTREME, AND SEVERE DROUGHT ALERT PHASES

Levels of drought are set forth in this ordinance as moderate, severe, and extreme. Proclamations issued by the City of Bloomington, Illinois Water Department shall coordinate an appropriate response to the level of drought which exists.

Proclamations setting forth responses to the various drought alert phases shall be made by the City of Bloomington, Illinois Water Department and are to be based upon local and/or regional monitoring data.

A. Moderate Drought Alert Phase: If conditions indicate that a moderate drought condition is present and is expected to persist, the City of Bloomington, Illinois Water Department shall notify municipal and county governments and issue press releases concerning the drought conditions to the news media. Large or key water users will be contacted directly by the Water Department.

1. Goal:

(a) Public awareness and education of drought procedures and water saving.

(b) A five percent voluntary water use reduction for residential, commercial, industrial, institutional, and electric power generation purposes in order to extend the water supply for duration of the drought.

2. General Responses:

(a) Issue a Public Notice of Drought Conditions on water supply and demand in a newspaper or general circulation within the affected community and region. This statement shall include a list of non-essential water uses (SECTION III).

(b) Institute an increased water supply system maintenance effort to identify and correct water leaks by initiating a complete leak detection survey.

(c) Encourage customers of the City of Bloomington, Illinois Water Department to comply with the listed voluntary water-use restrictions in all categories while moderate drought conditions exist.

3. Water-Use Restrictions:

(a) Residential:

- Reduce domestic, landscaping, and water-based recreational activities such as swimming pools, water slides, and other related water activities.

(b) Commercial, Industrial, and Institutional:

- Reduce aesthetic, domestic, landscaping, and water-based recreational activities such as swimming pools, water slides, and other related water activities.

(c) Agricultural, Irrigation and Livestock:

- Implement conservation techniques, explore different water saving methods, and use alternative sources.

(d) Electric Power Generation:

- Implement conservation techniques, explore different water saving methods, and use alternative sources.

B. Severe Drought Alert Phase: A drought of this severity requires official declaration and implementation of mandatory water use restrictions by the City of Bloomington, Illinois Water Department. In such cases, the Department will notify municipal and county governments in the affected drought areas. The Utility will also issue press releases concerning the drought conditions to the news media.

1. Goal:

(a) Generate a public response that helps alleviate drought stress through mandatory water use restrictions.

(b) A ten percent water use reduction for residential, agricultural, commercial, industrial, institutional, and electric power generation purposes.

2. General Responses:

(a) Issue a Public Notice of Drought Conditions on water supply and demand in a newspaper or general circulation within the affected community and region. This statement shall include a list of water- use curtailment measures.

(b) Require customers of the City of Bloomington, Illinois Water Department to comply with the listed water-use restrictions in all categories while severe drought conditions exist.

3. Water-Use Restrictions:

(a) Residential:

- Use low-volume hand-held applications only and prohibit sprinklers, other remote broadcast devices, and water runoff in landscape design maintenance.

- Restrict landscape watering on Tuesday and Saturday for odd-numbered addresses, and Thursday and Sunday for even-numbered addresses.

(b) Commercial, Industrial, and Institutional:

- Prohibit aesthetic water use.

- Reduce domestic water use to minimum levels necessary for maintaining health and safety.

- Prohibit water-based recreational activities except facilities, such as swimming pools and other related water activities that require filtration and/or water recycling.

- Use low-volume hand-held applications only and prohibit sprinklers, other remote broadcast devices, and water runoff in landscape design maintenance.

- Restrict landscape watering on Tuesday and Saturday for odd-numbered addresses, and Thursday and Sunday for even-numbered addresses.

(c) Agriculture, Irrigation and Livestock:

- Implement conservation techniques, explore different water saving methods, and use alternative sources.

- Restrict irrigation use from 7:00 p.m. to 7:00 a.m.

(d) Electric Power Generation

- Implement conservation techniques, explore different water saving methods, and use alternative sources.

4. Water Department Operational Procedures

- Prohibit the use of water-based recreational activities that rely on single use water supply, such as municipal water-parks.

- Enact a 24-hour, service-area wide, monitoring system to evaluate the communities response and cooperation to drought procedures.

- Reduce the water supply hydraulic grade-line (levels in water towers by five feet).

C. <u>Extreme Drought Alert Phase</u>: The City of Bloomington, Illinois Water Department will notify municipal and county governments in the affected drought areas, and issue press releases concerning the drought conditions to the news media. <u>Water-use restrictions imposed during extreme drought conditions are mandatory.</u>

1. Goal:

(a) A fifteen percent water use reduction for residential, institutional, agricultural, commercial, industrial, and electric power generation purposes.

2. General Responses:

(a) Issue a Public Notice of Drought Conditions on water supply and demand in a newspaper or general circulation within the affected community and region. This statement shall include a list of water- use curtailment measures.

(b) Require customers of the City of Bloomington, Illinois Water Department to comply with the listed water-use restrictions in all categories while extreme drought conditions exist.

3. Water-Use Restrictions:

(a) Residential:

- Reduce domestic water use to minimum levels necessary to maintain health and safety.

- Prohibit water-based recreational activities except facilities, such as swimming pools and other related water activities, that employ filtration and/or water recycling.

- Use low-volume hand-held applications only and prohibit sprinklers, other remote broadcast devices, and water runoff in landscape design maintenance.
- Restrict landscape watering on Tuesday and Saturday for odd-numbered addresses, and Thursday and Sunday for even-numbered addresses.

(b) Commercial, Industrial, and Institutional:

- Prohibit aesthetic water use.
- Reduce domestic water use to minimum levels necessary for maintaining health and safety.
- Prohibit water-based recreational activities except facilities, such as swimming pools and other related water activities, that employ filtration and/or water recycling.
- Use low-volume hand-held applications only and prohibit sprinklers, other remote broadcast devices, and water runoff in landscape design maintenance.
- Restrict landscape watering on Tuesday and Saturday for odd-numbered addresses, and Thursday and Sunday for even-numbered addresses.

(c) Agriculture, Irrigation and Livestock:

- Implement conservation techniques, explore different water saving methods, and use alternative sources.
- Restrict irrigation use from 12:00 a.m. to 4:00 a.m.

(d) Electric Power Generation

- Implement conservation techniques, explore different water saving methods, and use alternative sources.

4. Water Department Operational Procedures

- Prohibit water-based recreational activities except facilities, such as swimming pools and other related water activities that require filtration and/or water recycling.
- Prohibit the use of water-based recreational activities that

rely on single use water supply, such as municipal water-parks.

- Prohibit water-based street cleaning.

- Enact a 24-hour Water Department monitoring system to evaluate the communities response and cooperation to drought procedures.

- Reduce the water supply hydraulic grade-line (levels in water towers by ten feet).

SECTION V: NEW WATER SERVICE CONNECTIONS

Correspondence regarding water availability, pipeline extension agreements, and applications requesting service, received and dated after the date of this Ordinance shall include conditions relating to water shortages.

No applications for new, additional, further expanded, or an increase in size of water service connections, meters, service lines, pipeline extensions, approved or installed unless such action is in compliance with provisions of this Ordinance.

SECTION VI: WATER RATES

In the event of an extreme drought related water shortage, the City of Bloomington, Illinois Water Department is hereby authorized to monitor water use. Under extreme drought conditions the Water Department's drought water rates will be enacted through the duration of the drought for all water users.

SECTION VII: RATIONING

In the event that a drought threatens the preservation of public health and safety, the City of Bloomington, Illinois Water Department is hereby authorized to ration water.

SECTION VIII: FINES AND PENALTIES

Except as otherwise stated herein, violators of any provision of this Ordinance shall be penalized.

Violation Classification Penalty

- First offense infraction in severe drought – Courtesy reminder to implement procedures

- First offense infraction in extreme drought -- $50.00

- Second offense infraction within the same drought period -- $100.00

- Third and subsequent offense within the same drought period -- $250.00

- The aforementioned fines and penalties may be in lieu of, or in addition to, any other penalty provided by law.

SECTION IX: ENFORCEMENT

Employees of the City of Bloomington, Illinois Water Department, City of Bloomington police officers, firefighters, and plumbing inspectors have the duty, and are hereby authorized to enforce the provisions of this Ordinance and shall have the power and authority to issue written notices to appear when violations of this Ordinance occur during any declared severe or extreme drought or water shortage.

SECTION X: VARIANCES

Persons not capable of immediate water use reduction, or curtailment, because of equipment damage or other extreme circumstances, shall commence gradual reduction of water use within twenty-four hours of the declaration of water use curtailment/reduction and shall apply for a variance from curtailment.

Persons requesting exemption from the provisions of this Ordinance shall file a petition for variance with the City of Bloomington, Illinois Water Department within ten days after such curtailment becomes effective.

When the Drought Ordinance has been invoked by the City of Bloomington, Illinois Water Department, all petitions for variances shall be reviewed by the City of Bloomington, Illinois Water Department Director. Petitions shall contain the following:

1. Name and address of the petitioner(s).
2. Purpose of water use.
3. Specific provisions from which the petitioner is requesting relief.
4. Detailed statement as to how the curtailment declaration adversely affects the petitioner.
5. Description of the relief desired.
6. Period of time for which the variance is sought.
7. Economic value of the water use.
8. Damage or harm to the petitioner or others if petitioner complies with Ordinance.
9. Restrictions with which the petitioner is expected to comply and the compliance date.
10. Steps the petitioner is taking to meet the restrictions from which variance is sought and the expected date of compliance.
11. Other pertinent information.

In order for a variance to be granted, petitioner must show one of more of the following conditions:

A. Compliance with the Ordinance cannot be technically accomplished during the duration of the water shortage.

B. Alternate methods can be implemented which will achieve the some level of reduction in water use.

The City of Bloomington, Illinois Water Department Director may, in writing, grant temporary variances for existing water uses otherwise prohibited under the Ordinance if it is determined that failure to grant such variances would cause an emergency condition adversely affecting health, sanitation, or fire protection for the public or the petitioner and if one or more aforementioned conditions is met. The City of Bloomington, Illinois Water Department Water Director shall approve or deny any such variance. Any such variance so ratified may be revoked by later action of the City of Bloomington, Illinois Water Department Director. Any such variance denied by the City of Bloomington, Illinois Water Department Director can be appealed to the City of Bloomington, Illinois City Manager.

No such variance shall be retroactive or otherwise justify any violation of this Ordinance occurring prior to the issuance of the variance.

Variances granted by the City of Bloomington, Illinois Water Department Director or City Manager shall be subject to the following conditions, unless waived or modified by the City of Bloomington, Illinois Water Department or City Manager.

A. Variances granted shall include a timetable for compliance.

B. Variances granted shall expire when the water shortage no longer exists, unless the petitioner has filed to meet specified requirements.

SECTION XI: STATUS OF THE ORDINANCE

In the event that any portion of this Ordinance is held to be unconstitutional for any reason, the remaining portions of the Ordinance shall not be effected.

The provisions of this Ordinance shall prevail and control in the event of any inconsistency between this Ordinance and other rules and regulations of the City of Bloomington, Illinois and/or State of Illinois.