WATER TREATMENT PLANT ALTERNATIVES EVALUATION

Final Report

B&V PROJECT NO.183262

PREPARED FOR

City of Ann Arbor

24 AUGUST 2015

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Introduction and Project Background

INTRODUCTION

The City of Ann Arbor provides drinking water to approximately 125,000 people residing in the City and neighboring townships. The City's drinking water is drawn from both surface and ground water sources. The original Water Treatment Plant (WTP) was constructed in 1938, with expansions in 1949, 1965, and 1975. In 1996 ozone disinfection facilities were added as primary disinfectant. The 50 mgd WTP includes lime softening, ozone, chloramines, and biologically active filters for water treatment, and includes residual solids treatment processes. Several chemicals are added to the process to aid in treatment. Water supply to the treatment facilities is typically 85 percent surface water and 15 percent groundwater. The liquid treatment facilities are comprised of two parallel treatment trains: "Plant 1" includes three pretreatment basins and filters constructed in 1938 and 1949; "Plant 2" includes two pretreatment basins and filters constructed in 1965 and 1975.

Some portions of the original plant are still in service (see Figure 1), and in some cases have reached the end of their useful service life. The continued provision of reliable water service to the community requires planning for the future of water supply and treatment facilities. This report summarizes this recent planning effort, and provides a framework for both short and long-term management of water supply assets.

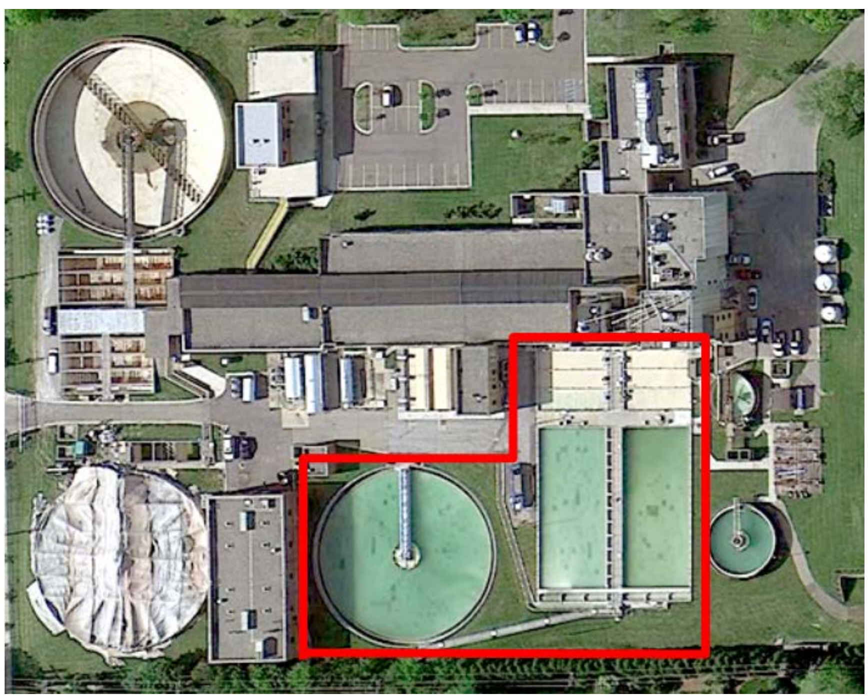

Figure 1: WTP with 1938 and 1949 Pretreatment Facilities Highlighted

BACKGROUND

The City completed a Water Treatment Facilities and Water Resources Master Plan in 2006, prepared by CH_2M-Hill (2006 Master Plan). The 2006 Master Plan forecasted long-term water demands and evaluated water sources and treatment technologies to meet demand through year 2050. The plan determined that future water demands could be met with the existing capacity provided by the current supply and treatment facilities, but noted needs for continuing renewal of infrastructure. Some of those improvement needs have been addressed. In continuing to plan for long-term infrastructure renewal and replacement, City staff has identified several specific challenges that warrant further evaluation of the system's needs going forward:

<u>Source Water Supply Challenges</u>

- The existing surface water source can be impacted by drought.
- Source waters can be subject to contamination from spill events or known groundwater contamination plumes. Additional flexibility in source of supply can mitigate these risks.

<u>Water Treatment Plant Challenges</u>

- The age and condition of the 1938 and 1949 pretreatment facilities necessitates a near-term rehabilitation plan .
- The residual solids management systems of the WTP include aged filter press equipment and residuals lagoons that have reached capacity.
- The Department of Environmental Quality (DEQ) has expressed concerns over the uncovered pretreatment basins at the WTP, and of water quality applied to the WTP filters.
- Future regulatory requirements may impact required treatment facilities.

GOAL: ENSURING A SAFE AND RELIABLE WATER SUPPLY FOR THE FUTURE

In an effort to address the source water and infrastructure challenges, the City engaged Black & Veatch to conduct an Alternatives Analysis to assess options for replacement of the 1938 and 1949 pretreatment infrastructure. Because of the potential magnitude of this investment City staff decided to investigate alternative approaches to determine the most cost-effective long-term solution for the City. In lieu of replacing infrastructure at the WTP, alternatives considered included connecting to neighboring water systems and development of additional sources of supply.

Evaluation of these alternatives was conducted by assessing each against the City's water quality goals and customer service requirements. Following this evaluation, the identified optimum source of supply plan was further developed and evaluated to identify the best configuration of facilities to serve the long-term source of supply plan. All evaluations placed emphasis on regulatory compliance, the City's Sustainability Framework, and Customer Satisfaction.

Assessing Long-term Water Supply Options

In alignment with the City's goals, a detailed evaluation of the City's water supply options was conducted to ensure a long-term reliable supply of quality drinking water to its customers.

The range of possible water supply options was assessed to ensure Ann Arbor's source water provides optimum reliability. In addition to the current supplies, other options were identified and evaluated, including new well fields and purchase of treated water from adjacent water systems.

Three general options were identified for further evaluation:

- Continued supply from the existing sources, with improvements to the Water Treatment Plant (WTP).
- Enhanced groundwater supply either from the existing or a new wellfield.
- Purchased water from the Detroit Water & Sewerage Department/Great Lakes Water Authority.

These alternatives are depicted in Figure 2.

Figure 2: Water Supply Alternatives

Water Supply Alternatives were evaluated and ranked using both economic and non-economic factors. Capital and life cycles costs were considered, along with non-economic factors such as system capacity, reliability, operational flexibility, staffing impacts, and existing facility utilization.

This evaluation concluded that replacing the 1938 treatment basins on site with newer more efficient treatment technology was the most cost effective solution for the City's water system. In particular, this alternative scored high in the areas of system operations, utility staffing, existing facilities utilization, and alignment with the City's sustainability goals. In addition, the evaluation concluded that a blend of river and ground water provides optimum source water reliability. A summary of the key economic and non-economic evaluation results is included in Tables 1 and 2.

Table 1: Water Supply Alternatives

ALTERNATIVE	RANKED HIGH[1]	RANKED LOW[2]
Existing sources with WTP improvements	Distribution water quality Utility staffing Existing facilities utilization Autonomy/IGA's Sustainability	N/A
New groundwater supply	Distribution water quality Existing facilities utilization Autonomy	N/A
Purchased water supply	Water quality vulnerability System operations	Distribution water quality Sustainability

[1] Alternative received a ranking of 10 (out of 10) for the indicated evaluation criteria.
[2] Alternative received a ranking of 4 (out of 10) or lower for the indicated evaluation criteria.

Table 2: Water Supply Alternatives

ALTERNATIVE	CAPITAL COST[1]
Existing sources with WTP improvements	\$65M to \$85M
New groundwater supply	\$95M to \$130M
Purchased water supply	\$250M to \$300M

[1] The cost ranges included in Table 2 are based on the following assumptions:

- Existing sources with WTP improvements: Replacement of existing 1938 and1949 pretreatment facilities.
- New groundwater supply: New/expanded wellfield; new groundwater treatment plant at wellfield; new pumping station for groundwater supply (after treatment); additional pipeline for conveyance of treated groundwater to existing distribution system.
- Purchased water supply: 14 miles of 30" pipeline from DWSD Joy Road Tank, plus Pumping Station; 11 miles of 30" pipeline from DWSD Ypsilanti Tank, plus Pumping Station.

Ensuring Water Treatment Plant Reliability

Upon determining that the most cost-effective approach was to invest in new treatment technology at the existing WTP facilities, the City evaluated several alternative technologies that meet the City's performance goals. Evaluations included the alternatives for replacement of 1938 and 1949 pretreatment facilities and residuals management facilities, as well as assessment of current treatment practices and future regulatory requirements.

1938 AND 1949 PRETREATMENT FACILITIES REPLACEMENT

In 2007 the City invested approximately $1M in addressing structural deficiencies of the 1938 pretreatment basins. This investment only addressed areas that exhibited advanced deterioration. Structural deficiencies remain in these basins, as well as challenges associated with outdated equipment, and the need to maintain exposed treatment basins.

Based on age, condition, on-going excessive maintenance needs, this evaluation confirmed that the 1938 and 1949 pretreatment facilities were at the end of their useful service life and should be replaced with current technology.

Figure 3: Deteriorated Concrete in Plant 1 Basin

Process Treatment Technology Selection

The 1938 and 1949 basins provide pretreatment of the incoming water supply via a precipitative softening process. Several candidate technologies are available that may be appropriate for replacement of these existing facilities. Candidate technologies were identified, screened, and evaluated. Conceptual configurations for each alternative were developed to be located within the footprint of existing facilities.

Initial screening resulted in the exclusion of membrane treatment and ion exchange softening technologies due to significant additional pretreatment requirements ahead of these processes. Also, dissolved air flotation and several proprietary clarification processes were excluded based on their in applicability toward achieving softening goals. The screening favored continued use of a precipitative softening process. The candidate technologies identified for detailed evaluation were conventional solids-contact clarification in a single or dual stage softening mode and high rate solids contact clarification. Several modes of operation and configurations of implementation of these technologies were developed, as illustrated in Figure 4.

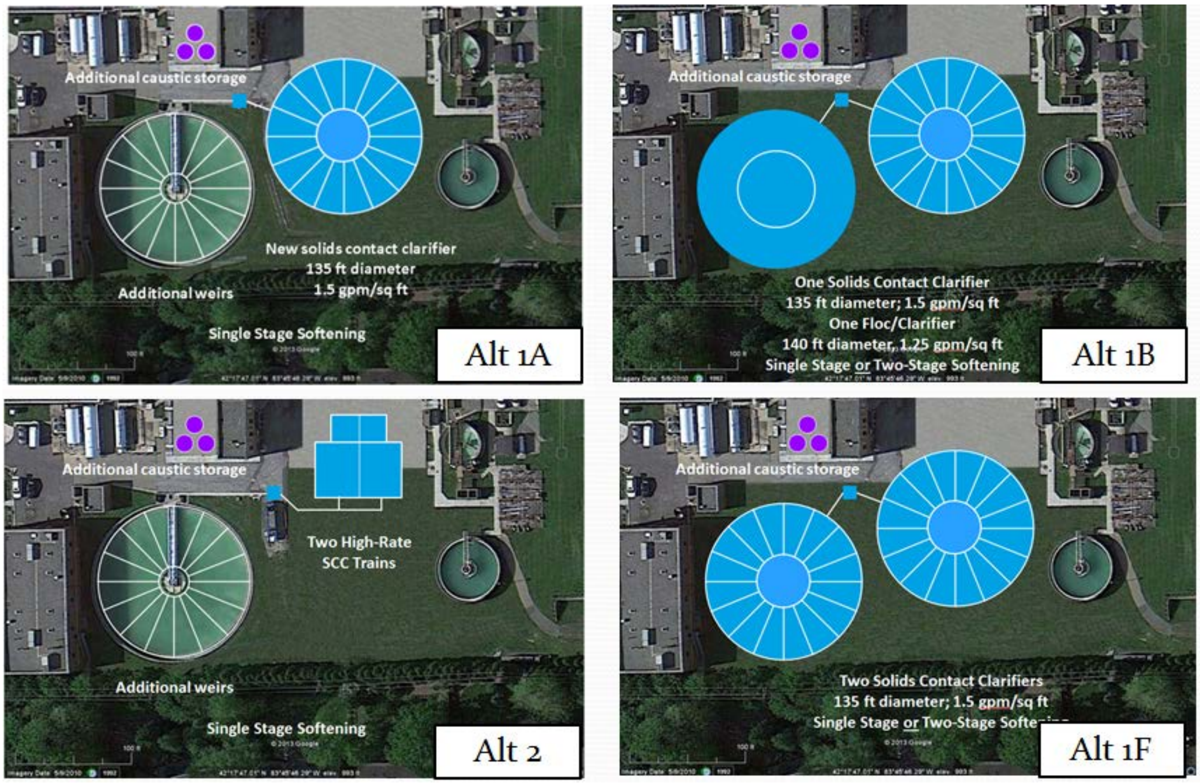

Figure 4: Plant 1 Facilities Replacement Alternatives

Using a structured decision analysis process that incorporated both non-economic and economic criteria, as well as potential adverse consequences of alternatives, conventional solids-contact clarification configured for single stage softening was selected as the preferred Replacement Alternative (alternative 1F depicted in lower right of Figure 4). This alternative allows for a maximum capacity of 44 to 50 mgd (to be determined in detailed engineering). While this proposed capacity exceeds that of the existing pretreatment basins to be replaced, it remains the most cost-effective alternative in the long-term. The remaining pretreatment basins that are not proposed for replacement at this time are 40 to 50 years old and will have similar issues to be addressed in the future. The added capacity available in the proposed alternative provides an economy of scale for future replacement of remaining basins.

SOLIDS MANAGEMENT PLANNING

In the course of water treatment, the solid residuals that are removed in lime softening pretreatment require handling and disposal. Over the history of Ann Arbor's WTP, two methods have been utilized for disposal: storage and infiltration dewatering in nearby sludge lagoons (see Figure 5), or a mechanical process of thickening and dewatering (see Figure 6) for conversion to a drier material suitable for disposal or beneficial use (land application). In the lagoons, the solids are slowly thickened over time through a natural process of infiltration and evaporation of the liquid portion of the solids mixture. Management of residual solids must consider both dewatering methods and disposal practices. Typically, solids are handled with the mechanical dewatering process, and the sludge lagoons are only used for backup.

Figure 5: Solids Disposal Lagoon

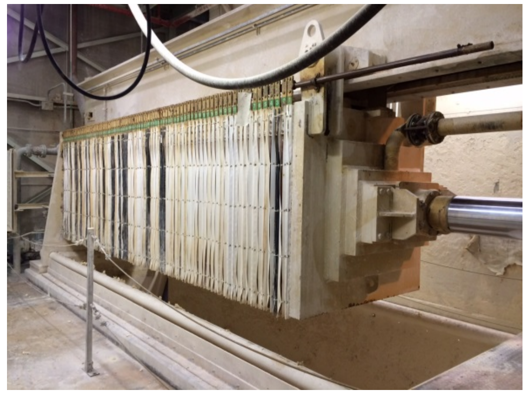

Figure 6: Plate and Frame Press

Existing facilities for solids management exhibit the following concerns to be addressed:

- The sludge lagoons are near capacity and are not able to receive significant amounts of additional solids.
- The mechanical process has proven reliable, but equipment is over 35 years old.

Evaluation of alternatives for solids management included mechanical processes (continued use of existing filter presses, installation of new filter presses, installation of new centrifuges) in concert with appropriate end use alternatives (land application, and lime recalcining and reuse). In addition, alternatives utilizing the existing sludge lagoons were evaluated, which would require the excavation, removal, and disposal of accumulated solids to allow for additional capacity.

Based on operation and maintenance requirements, the City's familiarity with the existing technology, and the significant cost associated with an alternative method of handling residual solids, continued use of the existing filter press equipment and land application of dewatered solids is recommended as the primary solids management mode. The existing equipment has proven to be reliable, and plant staff have had proven success with maintaining the equipment for reliable use. In the future, should the expense or frequency of equipment rebuild increase or if replacement parts become more difficult to obtain, consideration will be given to replacing existing dewatering equipment with new plate and frame filter presses. In addition, it is recommended that to allow continued redundancy of solids management processes, a portion of the stored residual solids be removed from the existing sludge lagoon.

Although not currently recommended, consideration should be made to the potential for participation in a regional lime recalcining operation that may become viable in the future.

REGULATORY COMPLIANCE AND FUTURE TREATMENT ALTERNATIVES

Detailed review and evaluation of current treatment practices from the WTP influent through the filter effluent confirms the City of Ann Arbor readily complies with all applicable regulatory performance requirements governing turbidity of filtered water and consistently meets more stringent City goals with respect to finished water turbidity. Changes in operational practices are unlikely to improve pre-treatment performance, filter operating characteristics, or finished water quality. Based on this assessment and in conjunction with benchmarking with similar facilities elsewhere in the US, it is confirmed that current treatment practices are sufficient for regulatory compliance, and that no significant changes are warranted at this time. However, the recommendation to replace the 1938 and 1949 pretreatment facilities will result in some improvement to pretreatment performance, providing further resiliency to the treatment process.

Evaluation was performed of the multi-barrier treatment schemes in place at the Ann Arbor WTP for various classifications of biological, chemical, and radiological contaminants, and their likely effectiveness for continued and future compliance within the known regulatory horizon. No significant risks are identified given the treatment processes currently implemented at the Ann Arbor WTP. A summary of this assessment is depicted in Figure 7. Barring dramatic and unforeseen changes in source water quality or regulatory requirements, additional barriers for turbidity, DBP precursors, inorganic macro-contaminants, and objectionable taste and odor compounds are not anticipated to be required at this time.

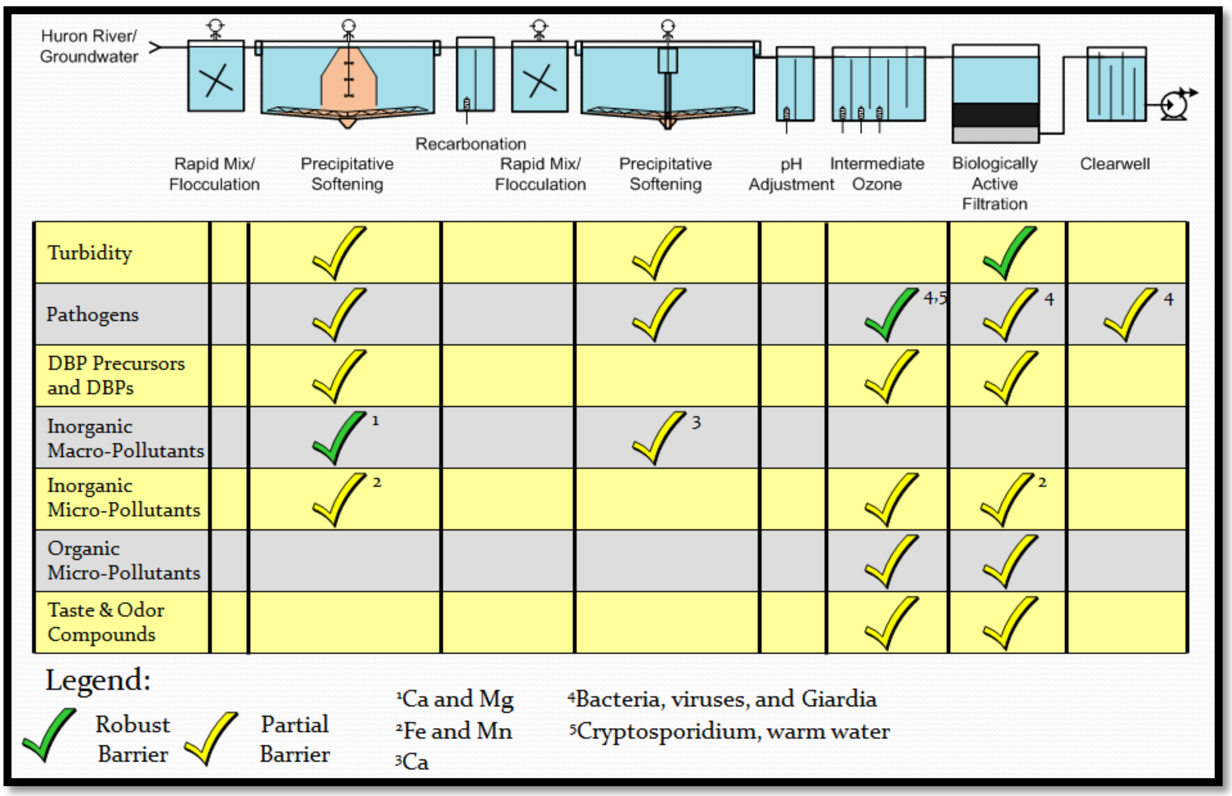

Figure 7: Ann Arbor WTP Contaminant Barriers

Should long-range future regulatory requirements change significantly and require changes for the Ann Arbor WTP, or if significant changes were to be experienced in source water quality, new or modified treatment processes could be required. Several technologies are available that could be implemented at the Ann Arbor WTP to meet unforeseen future source water quality and/or regulatory changes; however, further assessment would be required to determine the best means of implementation, given available space at the treatment plant. Note that the recommendation for replacement of the 1938 and 1949 pretreatment facilities provides opportunity to create additional space on the existing WTP site for potential future needs.

Conclusions

The primary conclusions and recommendations resulting from this project are summarized in Table 3.

Table 3: Water Supply and Treatment Alternatives Evaluation: Conclusions and Recommendations

ITEM	CONCLUSIONS AND RECOMMENDATIONS
Optimum Source of Supply	The preferred source of supply for the City of Ann Arbor continues to be existing sources, treated at the City's WTP, in conjunction with treatment improvements at the WTP.
Future Redundancy Considerations	Future consideration should be made for implementation of redundant sources from additional wellfields and/or purchased water supplies.
1938 and 1949 Pretreatment Facilities Replacement	1938 and 1949 pretreatment facilities are at the end of their service life and should be replaced with conventional solids contact clarification facilities to provide a capacity of 44 to 50 mgd. This alternative allows for coordinated planning for eventual addressing of Plant 2 service life.
Solids Management Planning	Continued use of the existing mechanical processing mode is viable as the primary mode of solids management. End disposal will continue to be through land application of the dewatered material. In addition, a portion of the accumulated solids in the existing sludge lagoon should be removed to provide for additional redundant solids management capacity. This operation should occur on a cyclical (approximately 10 year) basis for long-term redundancy. The future viability of a regional recalcining process should continue to be tracked.
Current Treatment Practices	No significant modifications to current treatment practices are warranted to assure continued regulatory compliance and continued customer level of service. Recommended improvements to 1938 and 1949 pretreatment facilities will provide for enhancement to water quality applied to filters.
Future Regulatory Compliance	Barring dramatic and unforeseen changes in source water quality, additional barriers for turbidity, DBP precursors, inorganic macro-contaminants, and objectionable taste and odor compounds are not anticipated to be required at this time. Continued attention to future regulations is necessary to assess impacts to the Ann Arbor WTP.
Near-term Capital Investment	The major near-term capital investments recommended in this report are the replacement of Plant 1 facilities and the partial cleaning of the sludge lagoons: • Plant 1 facilities replacement is estimated to be \$65M to \$85M. • Capital investment for the partial clean out of the sludge lagoons is estimated to be \$2M.

FINAL

ANN ARBOR WATER TREATMENT PLANT ALTERNATIVES ANALYSIS

Technical Memorandum 1

Source of Supply and System Reliability Alternatives

B&V PROJECT NO. 183262

PREPARED FOR

City of Ann Arbor

24 AUGUST 2015

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1 Introduction

High quality drinking water produced and delivered by a safe and reliable system is central to the health and wellbeing of the residents of Ann Arbor. In addition to complying with all federal and state drinking water regulations and meeting all applicable water quality standards they contain, the City of Ann Arbor has set a number of additional goals related to the aesthetic qualities of the drinking water provided to its customers. City treated drinking water quality goals are listed in **Appendix TM1.A**.

2 Source of Supply and System Reliability Alternatives

Source of Supply and System Reliability (SSSR) Alternatives were developed from a set of 19 common supply, conveyance, and treatment components. Each of these SSSR Alternatives is based on one of three fundamental system reliability strategies: 1) replacement of existing Plant 1 pre-treatment conventional precipitative softening facilities with high-rate precipitative softening facilities, 2) construction of new greenfield groundwater treatment facilities at another location, or 3) purchase of drinking water from Detroit Water and Sewerage District (DWSD). Source of supply, conveyance, and treatment components included in SSSR Alternatives based on each of these fundamental strategies are shown on **Figure TM1-1**, **Figure TM1-2**, and **Figure TM1-3** respectively, and are described further in the following subsections.

2.1 SOURCE OF SUPPLY COMPONENTS

Supply components consisted of the City's existing Huron River supply, existing Steere Farm groundwater supply, additional groundwater supplies located either in the vicinity of the Steere Farm supply or along the Northeast Supply Corridor or treated drinking water purchased from DWSD. Potential sources of supply and their associated capacities are listed in **Table TM1-1**.

2.2 CONVEYANCE COMPONENTS

Conveyance components evaluated included pipelines and pump stations required to deliver additional groundwater and DWSD supplies to either the existing WTP for distribution or new greenfield WTP sites for treatment. Potential conveyance components and their associated capacities are also listed in **Table TM1-1**. A general geographic layout of potential conveyance components is shown on **Figure TM1-4**.

2.3 TREATMENT COMPONENTS

Treatment components evaluated included replacement of Plant 1 pre-treatment facilities at the existing WTP with high-rate precipitative softening facilities, new high-rate precipitative softening facilities and granular media filtration facilities for groundwater treatment at satellite treatment locations, or ammonia feed and pH adjustment facilities for DWSD drinking water residual disinfection and corrosivity control. Potential treatment components and their associated capacities are also listed in **Table TM1-1**.

Table TM1-1: Source of Supply and System Reliability Alternative Components

COMPONENT	DESCRIPTION	CAPACITY (MGD)
0.0	Existing Huron River Supply and Pump Station	40
1.1	New WTP Plant 1 Pre-Treatment Facilities	22
1.2	Existing WTP Plant 2 Pre-Treatment Facilities	28
2.0	Existing Steere Farm Well Field Pipeline to Existing WTP	4.5, 11
3.0	Existing Steere Farm Well Field	11
3.1 SF	New Steere Farm Well Field	11
3.1 NE	New Northeast Well Field	11
3.2 SF	New Steere Farm Well Field Pump Station	11
3.2 NE	New Northeast Wellfield Pump Station	11,22
4.0	New Steere Farm Well Field Parallel Pipeline to Existing WTP	11
5.0	New Northeast Well Field Parallel Pipeline to Existing WTP	11,22,28,50
6.1	New Pipeline from DWSD System to Joy Road Tank	11,22,28,50
6.2	New Pump Station Adjacent to Joy Road Tank	11,22,28,50
7.1 SF	New Groundwater Treatment Plant at Steere Farm Well Field	11, 22
7.1 NE	New Groundwater Treatment Plant at Northeast Well Field	11
8.0	New Pipeline from Steere Farm GWTP to Distribution Loop	11
9.0	New Pipeline from Northeast GWTP to Distribution Loop	11
10.1	New Pipeline from DWSD System in Ypsilanti	22
10.2	New Pump Station from DWSD System in Ypsilanti	22

2.4 SSSR ALTERNATIVES EVALUATED

A set of 16 unique SSSR Alternatives was developed by combining the eleven unique conveyance and treatment infrastructure components considered. More than one capacity was evaluated for several of the infrastructure components to accommodate specific differences among the sixteen SSSR Alternatives evaluated. Source of supply, conveyance, and treatment components included in SSSR Alternatives based on each of these fundamental strategies are shown on **Figure TM1-1**, **Figure TM1-2**, and **Figure TM1-3,** respectively. Conceptual schematics of the SSSR Alternatives evaluated are shown on **Figure TM1.B-1** through **Figure TM1.B-16**, as given in **Appendix TM1.B**. Firm capacities with the largest supply, treatment facility, or conveyance component out-of-service for an extended period of time are also given. The alternatives are generally described in the following **Tables TM1-2** through **Table TM1-4.**

Table TM1-2: Replace Existing Plant 1 Softening Facility Alternatives

ALTERNATIVE	DESCRIPTION
1-1	• Existing Huron River and Steere Farm supplies. • New WTP Plant 1 Pre-treatment facilities (existing Plant 2 and other WTP facilities remain in service).
1-2	Alternative 1-1, plus: • Upgraded Capacity (to 11 mgd) of Steere Farm Pipeline.
1-3	Alternative 1-2, plus: • New (additional) well field at Steere Farm (11 mgd), with pumping and conveyance capacity to WTP.
1-4	Alternative 1-1, plus: • New well field NE of the City (11 mgd), with pumping and conveyance capacity to the WTP.
1-5	Alternative 1-4, plus: • New purchased water supply (11 mgd) from DWSD from their Joy Road tank, including pumping and conveyance into the Ann Arbor system.
1-6	Same as Alternative 1-5, but with a purchased water supply capacity of 22 mgd.

Table TM1-3: Remote Groundwater Treatment Alternatives

ALTERNATIVE	DESCRIPTION
2-1	• Existing Huron River and Steere Farm supplies. • Abandon WTP Plant 1 pre-treatment facilities. • New groundwater treatment plant at Steere Farm, with pumping capacity to the Ann Arbor system.
2-2	Alternative 2-1, plus: • New groundwater treatment plant at Steere Farm providing 22 mgd capacity. • New (additional) well field at Steere Farm (11 mgd), with pumping and conveyance capacity to the WTP.
2-3	Same as Alternative 2-2, but with conveyance capacity to the Ann Arbor distribution loop.
2-4	Alternative 2-1, plus • New well field and groundwater treatment system NE of the City (11 mgd), with pumping and conveyance capacity to the WTP.
2-5	Same as Alternative 2-4, but with conveyance capacity to the Ann Arbor distribution loop.

Table TM1-4: DWSD Wholesale Supply Alternatives

ALTERNATIVE	DESCRIPTION
3-1	• Abandon existing sources of supply and WTP facilities. • New Purchased water supply (50 mgd) from DWSD from their Joy Road tank, including pumping and conveyance into the Ann Arbor system.
3-2	• Existing Huron River and Steere Farm supplies. • Abandon WTP Plant 1 pre-treatment facilities. • New Purchased water supply (50 mgd) from DWSD from their Joy Road tank, including pumping and conveyance into the Ann Arbor system.
3-3	• Abandon existing sources of supply and WTP facilities. • New Purchased water supply (28 mgd) from DWSD from their Joy Road tank, including pumping and conveyance into the Ann Arbor system. • New Purchased water supply (22 mgd) from DWSD from their Ypsilanti Road tank, including pumping and conveyance into the Ann Arbor system.
3-4	• Existing Huron River and Steere Farm supplies. • Abandon WTP Plant 1 pre-treatment facilities. • New Purchased water supply (22 mgd) from DWSD from their Joy Road tank, including pumping and conveyance into the Ann Arbor system.
3-5	Alternative 3-4, plus: • Upgraded Steere Farm conveyance pipeline to WTP.

3 Non-Economic Evaluation

The relative non-economic performance of candidate SSSR Alternatives was evaluated using principles of the Kepner-Tregoe® (K-T®) Decision Analysis procedure. K-T® Decision Analysis is a systematic procedure that encompasses the fundamental thought pattern people use to make choices. The specific techniques that define the systematic procedure used in K-T® Decision Analysis expand and refine the elements of this thought pattern:

- We appreciate that there is a choice to be made.
- We consider the specific factors that should be satisfied for the choice to succeed.
- We decide what course of action best satisfies these factors.
- We consider the risks associated with the chosen course of action that could jeopardize its success.

3.1 STRUCTURED DECISION MODEL

Specific factors unique to each K-T® decision analysis effort are classified as either MUST criteria that each candidate alternative solution must absolutely satisfy in order to be included in the decision process, or WANT criteria that are desirable but not mandatory for each candidate alternative solution to satisfy. At the City's request, the B&V project team developed preliminary SSSR Alternative selection MUST and WANT criteria based on previous experience from other master-planning projects. These preliminary MUST and WANT criteria were then reviewed and refined by City staff based on the consensus opinion of members with operational, engineering, and supervisory knowledge of and experience with the Ann Arbor WTP facilities.

3.1.1 Mandatory MUST Criteria

Four mandatory MUST criteria were established based on compliance with City-specified source of supply and system reliability requirements.

- An SSSR Alternative must have at least two distinctly separate sources of supply to be carried forward for further evaluation. Sources of supply considered here included the City's existing Huron River and Steere Farm groundwater supplies, other potential local groundwater supplies, and treated drinking water purchased from DWSD.
- An SSSR Alternative must have a firm system capacity of 10 mgd with the largest source of supply or treatment facility out of service to be carried forward for further evaluation. Based on previous master planning performed by the City, a firm capacity of 10 mgd would meet sanitary and other indoor demands during an extended outage scenario (COAA, 2006). Examples of conditions that could result in an extended outage scenario include an acute contamination event in one of the City's raw water supplies requiring installation of additional treatment processes or catastrophic damage or failure of a critical facility.
- An SSSR Alternative must have a total of 50 mgd of combined sources of supply and 50 mgd of combined treatment capacity to be carried forward for further evaluation. Drinking water supplied from DWSD counts toward both of these requirements.
- An SSSR Alternative must provide finished water that meets the City's drinking water quality goals under normal supply and extended outage conditions. A summary of the City's drinking water quality goals is given in **Appendix TM1.A**.

3.1.2 Desirable WANT Criteria

Desirable WANT criteria, also termed Desires, were developed in three categories including System Reliability, Operational Flexibility, and Organizational Impacts. Several Contributors that further describe each Desire were then developed. The Desires and Contributors that define the Source of Supply and System Reliability Structured Decision Model are listed in **Table TM1-5** and **Table TM1-6** through **Table TM1-8**, respectively. A brief description of the considerations for each Desire and Contributor is also given in these Tables. Collectively, these Desires and their associated Contributors form the basis of a fair and balanced evaluation of the non-economic performances of SSSR Alternatives.

Table TM1-5: Source of Supply and System Reliability Decision Model Desires

DESIRES	CONSIDERATIONS	WEIGHT (1 TO 10)
System Reliability	Considers factors that impact both the quality and quantity of drinking water supplies	10
Operational Flexibility	Considers factors that influence complexity of treatment, distribution, and maintenance operations as well as distribution system water quality	9

	compatibility issues	
Organizational Impacts	Considers factors that would impact the Ann Arbor Drinking Water Department including staffing, intergovernmental agreements, existing facilities utilization, autonomy, and adherence to the City's Sustainability Framework	8

Table TM1-6: System Reliability Desire – Contributors

CONTRIBUTOR	CONSIDERATIONS	WEIGHT (1 TO 10)
Drinking Water Supply Reliability	Reliability of the Ann Arbor drinking water supply is impacted by the number of unique sources of raw water supply and the ability to treat those supplies	7
Water Quality Vulnerability	Known specific contamination threats that have been identified for sources of supply (e.g., 1,4-dioxane threat to Barton Pond or sulfate threat to Steere Farm groundwater)	5
Firm Capacity	Firm capacity considers treated water capacity with the largest source unavailable for an extended period of time (months or more)	10

Table TM1-7: Operational Flexibility Desire – Contributors

CONTRIBUTOR	CONSIDERATIONS	WEIGHT (1 TO 10)
System Operations	Issues related to the complexity of treatment, distribution, and maintenance operations	10
Distribution Water Quality	Water quality compatibility issues in the distribution system that could affect regulatory compliance, customer acceptance, or system integrity	8

Table TM1-8: Organizational Impacts Desire – Contributors

CONTRIBUTOR	CONSIDERATIONS	WEIGHT (1 TO 10)
Utility Staffing	Considers both the number of staff required to operate treatment facilities and the level of training required to operate treatment technologies in each alternative	9
Intergovernmental Agreements	Issues related to negotiating an intergovernmental agreement that would be required to obtain treated water from DWSD or other providers	6

Existing Facilities Utilization	Some source of supply and system reliability alternatives envision abandonment of relatively high value infrastructure and recent improvements, which may be viewed unfavorably by some stakeholders	7
Autonomy	Alternatives that include wholesale purchase of finished water from other regional providers (DWSD) would limit the City's control over treatment costs and finished water quality	10
Sustainability Framework	Source of supply and system reliability alternatives that would address goals outlined in the City's Sustainability Framework would be viewed more favorably	4

The relative importance of each Desire, as well as its associated Contributors, in the decision process was established by assigning weights as follows:

- The relative importance of the Desires was established by assigning a weight between 1 and 10 to each. If a Desire was deemed of no importance in the decision process and was assigned a weight of 0, it was removed from the decision model.
- The Desire considered most important in the decision process was assigned a weight of 10. If two or more Desires were considered equally more important than the other Desires, each was assigned a weight of 10.
- Remaining Desires were then assigned lower weights in proportion to their importance relative to the most important Desire(s). For example, if a given Desire was considered to be half as important as the most important Desire(s), it was assigned a weight of 5.
- Contributors associated with each Desire were then assigned weights between 1 and 10 in a similar fashion, one Desire at a time. If a Contributor had no importance in the decision process and was assigned a weight of 0, it was removed from the decision model.
- For each Desire, the Contributor considered most important in the decision process was assigned a weight of 10. If two or more Contributors were considered equally more important than the other Contributors associated with the same Desire, each was assigned a weight of 10.
- Remaining Contributors associated with each Desire were then assigned lower weights in proportion to their importance relative to the most important Contributor(s). For example, if a given Contributor was considered to be half as important as the most important Contributor(s), it was assigned a weight of 5.
- The following verbal scale was used as a guide in evaluating the relative importance of Desires and Contributors and assigning decision model weights:
  - Critically important – 10
  - Very important – 8 to 9
  - Moderately important – 5 to 7
  - Somewhat important – 3 to 4
  - Minimally important – 1 to 2

The weights assigned to each Desire and its associated Contributing Factors are also listed in **Table TM1-5** and **Table TM1-6** through **Table TM1-8**, respectively.

3.1.3 Decision Model Structure

The structured decision model developed by linking Desires, their associated Contributors, and SSSR Alternatives is shown on **Figure TM1-5**. Mandatory MUST criteria are not explicitly incorporated in the decision model structure, but rather are used to screen alternatives for further evaluation. Alternatives that did not comply with one or more of the mandatory MUST criteria are not linked to Contributors in the decision model, and their relative non-economic performance was not evaluated further.

3.1.4 Alternatives Scoring

The 13 SSSR Alternatives that satisfied each of the mandatory MUST criteria were scored based on their relative non-economic performances as the first step in selection of a preferred alternative. The following steps describe how SSSR Alternatives were scored against each individual Contributor:

- The relative non-economic performance of each SSSR Alternative was compared against each Contributor one at a time and scores between 1 and 10 assigned to each alternative, with the highest value for the alternative(s) that best satisfied the intent of the Contributor.
- If two or more alternatives were considered to satisfy the intent of a Contributor equally well and better than the other alternatives, each was assigned a score of 10.
- It is important to note that assigning a score of 10 to an alternative for any given Contributor does not imply that the alternative satisfies the given Contributor perfectly, but rather that among all the alternatives under consideration it most closely satisfies the intent of the Contributor.
- Remaining SSSR Alternatives were then assigned lower scores based on their ability to satisfy the given Contributor relative to the alternative(s) that best satisfied that Contributor.
- The following verbal scale was used as a guide in scoring the non-economic performance of SSSR Alternatives against each Contributors in turn:
  - Satisfies the given Contributor with significant noted advantages – 10
  - Satisfies the given Contributor with noted advantages – 8 to 9
  - Satisfies the given Contributor with noted advantages and disadvantages – 5 to 7
  - Satisfies the given Contributor with noted disadvantages – 3 to 4
  - Satisfies the given Contributor with significant noted disadvantages – 1 to 2

The relative scores assigned to each SSSR Alternative for all contributors are listed in **Appendix TM1.D.1**. Metrics used to inform the alternatives scoring process are given in **Appendix TM1.D.2**.

3.2 NON-ECONOMIC COMPARISON OF SSSR ALTERNATIVES

The non-economic performance of the 16 SSSR Alternatives was evaluated in three steps: 1) screening level evaluation for compliance with mandatory requirements specified by the City, 2) ranking of compliant SSSR Alternatives against non-economic factors to establish their relative performance, and 3) sensitivity analysis of the alternatives ranking process.

3.2.1 Source of Supply and System Reliability Alternatives Screening

The four mandatory MUST screening criteria established based on compliance with City-specified source of supply and system reliability requirements (**section 3.1.1**) were applied to each of the 16 SSSR Alternatives, and three were removed from further consideration (Alternative 1-1, Alternative 2-1 and Alternative 3-1) because they did not satisfy one or more of screening criteria.

3.2.2 Non-Economic Performance Ranking

The non-economic performance of each alternative was calculated using the weights assigned to each Desire and Contributor in the decision model (**Figure TM1-5**) and the scores assigned to each SSSR Alternative for each Contributor, as shown in **Appendix TM1.D.1**. The non-economic performance values calculated were normalized to a scale of 0 to 1 for the purpose of comparison and ranking of SSSR Alternatives. A value of 1 calculated for a given alternative indicates that it scored at least as well as or better than all other alternatives for each Contributor, whereas a value of 0 indicates that the alternative scored at least as poorly as or worse than all other alternatives for each Contributor. The cumulative non-economic performance values calculated for the 13 SSSR Alternatives evaluated are listed in **Table TM1-9** and shown graphically on **Figure TM1-6**. The contributions of each Desire to the cumulative non-economic performance values are shown graphically on **Figure TM1-6** and listed in **Appendix TM1.D.1**.

Table TM1-9: Non-Economic Performance Values for SSSR Alternatives

SSSR ALTERNATIVE	NON-ECONOMIC PERFORMANCE(1)
Plant 1 Replacement Alternatives	
Alternative 1-1	n/a(2)
Alternative 1-2	0.788
Alternative 1-3	0.845
Alternative 1-4	0.884
Alternative 1-5	0.762
Alternative 1-6	0.796
Greenfield Groundwater Treatment Alternatives	
Alternative 2-1	n/a(2)
Alternative 2-2	0.743
Alternative 2-3	0.724
Alternative 2-4	0.726
Alternative 2-5	0.708
DWSD Wholesale Alternatives	
Alternative 3-1	n/a(2)

Alternative 3-2	0.595
Alternative 3-3	0.674
Alternative 3-4	0.645
Alternative 3-5	0.645

(1)Scale from 0 to 1
(2)Alternative not carried forward for non-economic evaluation because it did not satisfy all MUST criteria (Section 3.1.1).

The cumulative non-economic performance values of the 13 SSSR Alternatives scored were generally clustered into three distinct groups, with the alternatives that would replace the existing Plant 1 facilities with new precipitative softening facilities having the highest values, the alternatives that would provide new greenfield treatment of additional groundwater supplies having the next highest cluster of values, and the alternatives that would utilize DWSD to augment or replace existing sources of supply and treatment having the lowest values. The contributions of the System Reliability and Operational Flexibility Desires to cumulative non-economic performance varied considerably among SSSR Alternatives, whereas the contribution of the Organization Impacts Desire was less variable, as shown on **Figure TM1-6**. The alternative with the highest non-economic performance (Alt 1-4, replacement of Plant 1 and development of a new Northeast groundwater supply) scored well against each of the Desires. The alternative with the lowest non-economic performance (Alt 3-2, abandon Plant 1, keep plant 2 in emergency standby, and utilize a single connection to DWSD to supply all of the City's drinking water) scored poorly against the Operational Flexibility and Organizational Impacts Desires.

3.2.3 Sensitivity Analysis

The sensitivity of non-economic performance of the 13 SSSR Alternatives considered to potential changes in the weights assigned to the decision model Desires and Contributors was evaluated using the Criterium DecisionPlus® (CDP) Decision Formulation, Analysis, and Presentation Software Package (InfoHarvest, 2001). The weights assigned to the decision model Desires and their associated Contributors (**Section 3.1.2**) and the scores specified for each SSSR Alternative for each Contributor (**Section 3.1.4**) were entered into the CDP program, and the Sensitivity by Weights feature applied. This feature adjusts the values assigned to weights for decision model Desires and Contributors one at a time and then recalculates the relative performance of alternatives evaluated.

Results of the CDP Sensitivity by Weights analysis are shown graphically for each Desire and Contributor on **Figure TM1.D.3-1** to **Figure TM1.D.3-13**, as given in **Appendix TM1.D.3**. The relative performance of the top 5 ranked SSSR Alternatives is shown graphically on these figures as the weight assigned to each individual Desire and Contributor was varied. For each Desire and Contributor, Plant 1 Replacement Alternative 1-4 was ranked the highest over a wide range of potential weights. This ranking was generally not sensitive to varying the weight of Desires or their associated Contributors, with no crossover points for nine of the ten Contributors. Crossover points were present for each of the Desires (**Figure TM1.D.3-1** to **Figure TM1.D.3-3**) and the Firm Capacity Contributor (**Figure TM1.D.3-6**). However, the weights at these crossover points were either greater than 10 (not physically possible) or were less than 2, indicating a dramatic adjustment of weighting was required for another SSSR Alternative to become highest ranked. For the two instances where adjustment of the weight assigned to a Desire within the possible range of 1 to 10 resulted in a valid change in the ranking of alternatives (**Figure TM1.D.3-1** and **Figure TM1.D.3-2**), another Plant 1 Replacement Alternative was highest ranked.

The sensitivity of non-economic performance of the 13 SSSR Alternatives to potential changes in the scores assigned to each alternative for each Contributor was evaluated during Project Workshop # 1 held on July 7 and July 8, 2014. The scores of lower ranked alternatives that would provide new greenfield treatment of additional groundwater supplies or that would utilize DWSD to augment or replace existing sources of supply and treatment were increased for several Contributors, which slightly increased the overall performance of these alternatives. However, alternatives based on replacement of Plant 1 still had higher non-economic performance values after adjustment of Contributor scores of the remaining alternatives.

4 Opinions of Probable Cost

The conceptual level opinions of probable cost (OPCs) presented here were developed using a common set of capital and operations, maintenance, repair, and replacement (OMR&R) unit costs. The Class 4 planning level cost opinions presented here reflect use of standard engineering practices and were prepared without the benefit of detailed engineering designs. As defined by The Association for the Advancement of Cost Engineering (AACE), Class 4 cost opinions of this type are generally considered to have an accuracy range of plus 50 to minus 30 percent. Any actual project cost would depend on current labor and material costs, competitive market conditions, final project scope, bid date, and other variable factors. The opinions of probable cost presented here are most appropriately used to compare the relative costs of various SSSR Alternatives, rather than as estimates of actual project costs for detailed budgeting purposes.

A detailed breakdown of cost assumptions for each evaluated component is provided in **Appendix TM1.C.** The following sections summarize key cost considerations used in the development of component costs.

4.1 OPINIONS OF PROBABLE CAPITAL COST

Opinions of probable capital cost for wellfield, conveyance, and treatment components used to formulate the 16 SSSR Alternatives developed and evaluated here were based on historical cost databases maintained by Black & Veatch. All historical cost data was escalated to present day using the Engineering News Record Construction Cost Index for the Detroit region (ENR CCI 10,634, July 2014). All well head pumping and ancillary equipment, as well as all treatment equipment and facilities, were assumed to be housed in environmentally conditioned structures.

4.1.1 Well Field and Conveyance Components

Opinions of probable capital cost for groundwater well fields, in-line pumping stations, and transmission pipelines were estimated for each SSSR Alternative. Well field OPCs include the cost to drill the well, outfit the well with pump and motor, and install all ancillary mechanical and electrical equipment within a well-house structure. Pumping station OPCs are based on the design flow rate and required pressure lift which ultimately defines the total required horsepower.

Pipeline OPCs are based on the pipe diameter, pipe length, design pressure range, number of highway and stream crossings, and the degree to which the alignment traverses rural, suburban, or heavily congested urban corridors.

Black & Veatch cost databases for these types of facilities were used to produce the capital OPCs. The City was able to provide a database of historical costs realized for previously completed pipeline projects. Upon review, the costs estimates produced by the B&V cost model are within the range of costs realized on past projects.

The opinions of probable capital cost for well field and conveyance components at the various capacities included in SSSR Alternatives are listed in **Appendix TM1.C.1**.

4.1.2 Treatment Components

The opinions of probable capital cost for treatment components provided here include unit process costs, additional project costs, contractor mark-up costs, and non-construction costs. Unit process costs include process equipment and basins, structures needed to house process equipment, and any additional structures required for office, laboratory, and maintenance spaces. A proprietary conceptual design and parametric costing tool developed and maintained by Black & Veatch was used to size selected treatment components and provide capital OPCs for unit processes. Items included in additional project costs, contractor mark-ups, and non-construction costs, as well as the unit multipliers for each, are listed in **Table TM1-10**. The opinions of probable capital cost for treatment components were developed as follows: additional project costs were added to the unit process costs subtotal to give the *facility cost* subtotal, contractor mark-up unit costs were then applied cumulatively to the facility cost subtotal to give the *construction cost* subtotal, and non-construction costs calculated and added to the construction cost subtotal to give the *project capital cost* subtotal.

Table TM1-10: Unit Costs Used to Develop Capital Cost Opinions

CATEGORY	UNIT COST
Additional Project Costs	**Percent of Unit Process Costs (1)**
Site Work	8 %
Yard Piping	20 %
Electrical Service	15 %
Instrumentation and Controls	5 %
Contractor Mark-Ups	**Percent of Facility Costs(2)**
Overhead	7 %
Profit	10 %
General Requirements(3)	3 %
Contingency	4 %
Non-Construction Costs	**Percent of Construction Costs(4)**

Permitting	1 %
Engineering	8 %
Construction Services	7 %
Commissioning/Startup	3 %
Legal/Administration	0.5 %
Contingency	30 %
Rehabilitation Adjustment Factor	50 %

(1)Additional project costs are applied to the unit process costs subtotal additively.
(2)Facility cost is the sum of the unit process cost subtotal and the additional project cost subtotal. Contractor mark-up costs are applied cumulatively to the facility cost.
(3)Mobilization, bonding, and insurance.
(4)Construction cost is the sum of facility cost subtotal and the contractor mark-ups subtotal. Non construction costs are applied to the construction costs subtotal additively.

Due to the uncertainty associated with major rehabilitation and reconstruction projects within the confines of an existing water treatment facility, a rehabilitation adjustment factor was included in the non-construction costs category of alternatives that would replace existing Plant 1 softening facilities. This factor is intended to cover extraordinary costs that often occur associated with maintaining service of existing facilities throughout demolition and construction, incomplete knowledge of existing facility and site conditions, and difficulties related to restricted access and movement on the site. For the current level of definition of the City's Water Treatment Plant Alternatives Analysis Project, industry standard construction costing guidelines recommend using an adjustment factor in the range of 25 percent to 75 percent (CIC, 2011). A rehabilitation adjustment factor of 50 percent was applied during development of the opinions of probable capital cost for Plant 1 Replacement Alternatives.

The opinions of probable capital cost for treatment components at the various capacities included in SSSR Alternatives are listed in **Appendix TM1.C.1**.

4.1.3 SSSR Alternatives

The cumulative opinions of probable capital cost that include all components of each SSSR Alternative are listed in **Table TM1-11**.

Table TM1-11: Opinions of Probable Capital Cost for SSSR Alternatives

SSSR ALTERNATIVE	OPC CAPITAL COST ($M)
Plant 1 Replacement Alternatives	
Alternative 1-1	$26,600,000
Alternative 1-2	$32,500,000
Alternative 1-3	$87,270,000

SSSR ALTERNATIVE	OPC CAPITAL COST ($M)
Alternative 1-4	$93,660,000
Alternative 1-5	$138,920,000
Alternative 1-6	$165,370,000
Greenfield Groundwater Treatment Alternatives	
Alternative 2-1	$51,860,000
Alternative 2-2	$131,290,000
Alternative 2-3	$97,200,000
Alternative 2-4	$152,500,000
Alternative 2-5	$128,930,000
DWSD Wholesale Alternatives	
Alternative 3-1	$212,140,000
Alternative 3-2	$212,140,000
Alternative 3-3	$289,790,000
Alternative 3-4	$120,300,000
Alternative 3-5	$126,200,000

4.2 OPINIONS OF PROBABLE ANNUAL OPERATIONS, MAINTENANCE, REPAIR, AND REPLACEMENT COSTS

Annual operation, maintenance, repair, and replacement (OMR&R) opinions of probable cost include raw water pumping energy costs, treatment chemicals, disposal of dewatered solid residuals, periodic repair and replacement of equipment, and operational and maintenance related labor. Labor costs for each SSSR Alternative were estimated based on current staffing practices and salary rates at the existing Ann Arbor WTP, with adjustments to the number of full time equivalents (FTEs) depending on the facilities included. Annual repair and replacement costs were projected based on set percentages of the capital cost for each facility class.

4.2.1 Well Field and Conveyance Components

Opinions of annual OMR&R costs for groundwater well field operations include pumping energy, typical costs for preventative maintenance associated with keeping the pumps and valves in good working order, as well as occasional repair or replacement of normal wear items such as bearings and seals. The opinions of probable annual OMR&R cost for well field and conveyance components at the various capacities included in SSSR Alternatives are listed in **Appendix TM1.C.2**.

4.2.2 Treatment Components

Opinions of probable annual OMR&R cost for treatment components of SSSR Alternatives include source water pumping, treatment chemical costs, residuals handling and disposal, operational and maintenance related labor, periodic repair and replacement of equipment. Several proprietary unit process analysis tools developed and maintained by Black & Veatch were used to estimate quantities for raw water pumping power, treatment related chemical usage, and residuals production. The opinions of probable annual OMR&R cost for treatment components at the various capacities included in SSSR Alternatives are listed in **Appendix TM1.C.2**.

4.2.3 SSSR Alternatives

The cumulative opinions of probable annual OMR&R cost that include all wellfield, conveyance, and treatment components of each SSSR Alternative are listed in **Table TM1-12**.

Table TM1-12: Opinions of Probable Annual OMR&R cost for SSSR Alternatives

SSSR ALTERNATIVE	OPC ANNUAL OMR&R COST ($)
Plant 1 Replacement Alternatives	
Alternative 1-1	$5,660,000
Alternative 1-2	$5,680,000
Alternative 1-3	$5,760,000
Alternative 1-4	$5,760,000
Alternative 1-5	$5,830,000
Alternative 1-6	$5,870,000
Greenfield Groundwater Treatment Alternatives	
Alternative 2-1	$6,840,000
Alternative 2-2	$7,110,000
Alternative 2-3	$7,080,000
Alternative 2-4	$8,060,000
Alternative 2-5	$8,040,000
DWSD Wholesale Alternatives	
Alternative 3-1	$3,250,000
Alternative 3-2	$4,410,000
Alternative 3-3	$3,350,000
Alternative 3-4	$5,420,000
Alternative 3-5	$5,430,000

4.3 OPINIONS OF PROBABLE LIFE-CYCLE NET PRESENT VALUE

A 30 year life-cycle was assumed for the net present value analysis performed here, consistent with industry standard expected service lives for major drinking water treatment equipment. A 75 year life was assumed for conveyance components, consistent with industry standard expected service life for pipelines. The residual salvage value of conveyance components at 30 years of service life was credited to those SSSR Alternatives that included new pipelines.

The net present values (NPV) calculated here are based on the opinions of probable capital cost (**Section 4.1.3**) and opinions of probable annual OMR&R cost (**Section 4.2.3**) previously presented, and are given in 2014 dollars. Economic parameters used to calculate the net present values of SSSR Alternatives are listed in **Table TM1-13**. The 30-year life-cycle net present values that include all wellfield, conveyance, and treatment components of each SSSR Alternative are listed in **Table TM1-14**.

Table TM1-13: Net Present Value Economic Parameters

PARAMETER	VALUE
Base Year	2014
General Inflation Rate	4 %
OMR&R Inflation Rate	5 %
Loan Interest Rate[1]	3.9 %
Discount Rate[1]	1.9 %
Loan Duration	30 years
[1]Guidelines and Discount Rates for Benefit-Cost Analyses of Federal Programs, Circular A-94, Office of Management and Budget.	

Table TM1-14: Opinions of 30-Year Life Cycle Net Present Value for SSSR Alternatives

SSSR ALTERNATIVE	OPC NET PRESENT VALUE ($)
Plant 1 Replacement Alternatives	
Alternative 1-1	$313,880,000
Alternative 1-2	$322,520,000
Alternative 1-3	$383,130,000
Alternative 1-4	$389,240,000
Alternative 1-5	$439,240,000
Alternative 1-6	$469,780,000
Greenfield Groundwater Treatment Alternatives	
Alternative 2-1	$404,890,000
Alternative 2-2	$506,870,000
Alternative 2-3	$475,560,000
Alternative 2-4	$579,090,000
Alternative 2-5	$564,110,000

DWSD Wholesale Alternatives	
Alternative 3-1	$378,140,000
Alternative 3-2	$435,400,000
Alternative 3-3	$486,660,000
Alternative 3-4	$389,100,000
Alternative 3-5	$397,250,000

5 Cost/Benefit Summary

The SSSR Alternatives were compared and ranked based on the combined impacts of cost and non-economic performance (benefit). All costs are expressed in 2014 dollars.

Figure TM1-7 presents a summary of SSSR Alternative capital costs and benefit scoring.

6 Phase IA Preferred SSSR Alternative

Source of Supply and System Reliability Alternatives that include replacement of existing Plant 1 facilities (Alternative 1-2 to Alternative 1-6) compared favorably with alternatives based on new greenfield groundwater treatment facilities (Alternative 2-2 to Alternative 2-5) or purchase of drinking water from DWSD (Alternative 3-2 to Alternative 3-5). Alternatives based on replacement of Plant 1 facilities had higher non-economic performance values and lower capital costs than other alternatives evaluated (**Figure TM1-7**). In addition, these alternatives generally had lower 30-year life cycle costs (**Table TM1-14**).

Among SSSR Alternatives that would replace Plant 1 facilities, Alternatives 1-2, 1-3, and 1-4 had significantly lower (more favorable) capital costs and 30-year life-cycle costs than Alternatives 1-5 and 1-6. This difference is largely attributable to capital costs associated with constructing an emergency connection to DWSD included in Alternatives 2-5 and 2-6. Added complexity in managing and operating an emergency connection to DWSD offset the potential non-economic benefit of this additional source of supply, resulting in no appreciable improvement in non-economic performance (**Figure TM1-7**).

Enhanced reliability of source water supplies for Alternatives 1-2, 1-3, and 1-4 is provided through improvements to conveyance infrastructure for the existing Steere Farm groundwater supply and potential additional groundwater supplies either in the vicinity of Steere Farm or along the Northeast Supply Corridor (**Figure TM1-4**). For each of these alternatives, all groundwater supplies would be conveyed to the existing Ann Arbor WTP for blending and treatment with the City's Huron River supply. Differences between Alternatives 1-2, 1-3, and 1-4 principally related to the source water conveyance components that are located outside the fence-line of the existing WTP facilities.

Each of the SSSR Alternatives evaluated here included supply reliability features and improvements located outside the fence-line of the existing WTP, as listed in **Table TM1-1** and illustrated on **Figure TM1-B.1** to **Figure TM1.B-16**, to ensure that sustainability, operability, and cost of service of the Ann Arbor drinking water system as a whole would be adequately evaluated. Improvements outside the fence-line of the existing WTP facilities will not be considered in detail in Phase II evaluations of this Project, but are listed in **Table TM1-1** for future reference.

Replacement of Plant 1 facilities will be carried forward to Phase II of the Water Treatment Plant Alternatives Analysis Project for further evaluation of potential precipitative softening technologies based on favorable non-economic performance and life-cycle costs compared with other source of supply and system reliability strategies that envisioned construction of new greenfield groundwater treatment facilities or purchase of treated drinking water from DWSD.

7 References

InfoHarvest (2001) *Criterium Decision Plus: Complete Decision Formulation, Analysis, and Presentation for Windows*", ver. 3.0, Seattle, WA, 2001.

CIC (2011), *Global Construction Cost and Reference Yearbook, 11th Annual Addition*, Compass International Consultants Inc., Morrisville, Pennsylvania, USA, 2011.

COAA (2006) City of Ann Arbor, *Water Treatment Facilities and Water Resources Master Plan: Water Supply Capacity*, Technical Memorandum prepared by CH2M HILL, May 2006.

Replace Existing Plant 1 Softening Facility Alternatives

Alternative 1-1

Supply Components

Existing Supplies	
Huron River	40 mgd
Steere Farm WF	11 mgd
New Supplies	
None	

Conveyance Components

Existing Facilities	
Barton Pond PS	40 mgd
Steere Farm PL	4.5 mgd
New Facilities	
None	

Treatment Components

Existing Facilities	
AA WTP Plant 1[2]	0 mgd
AA WTP Plant 2	28 mgd
New Facilities	
HR-SCC Plant 1	22 mgd

[2] Abandoned in place

Alternative 1-2

Supply Components

Existing Supplies	
Huron River	40 mgd
Steere Farm WF	11 mgd
New Supplies	
None	

Conveyance Components

Existing Facilities	
Barton Pond PS	40 mgd
Steere Farm PL	11 mgd
New Facilities	
None	

Treatment Components

Existing Facilities	
AA WTP Plant 1[2]	0 mgd
AA WTP Plant 2	28 mgd
New Facilities	
HR-SCC Plant 1	22 mgd

[2] Abandoned in place

Alternative 1-3

Supply Components

Existing Supplies	
Huron River	40 mgd
Steere Farm WF	11 mgd
New Supplies	
Steere Farm WF	11 mgd

Conveyance Components

Existing Facilities	
Barton Pond PS	40 mgd
Steere Farm PL	11 mgd
New Facilities	
Steere Farm PS	11 mgd
Steere Farm PL	11 mgd

Treatment Components

Existing Facilities	
AA WTP Plant 1[2]	0 mgd
AA WTP Plant 2	28 mgd
New Facilities	
HR-SCC Plant 1	22 mgd

[2] Abandoned in place

Alternative 1-4

Supply Components

Existing Supplies	
Huron River	40 mgd
Steere Farm WF	11 mgd
New Supplies	
Northeast WF	11 mgd

Conveyance Components

Existing Facilities	
Barton Pond PS	40 mgd
Steere Farm PL	11 mgd
New Facilities	
Northeast PS	11 mgd
Northeast PL	11 mgd

Treatment Components

Existing Facilities	
AA WTP Plant 1[2]	0 mgd
AA WTP Plant 2	28 mgd
New Facilities	
HR-SCC Plant 1	22 mgd

[2] Abandoned in place

Alternative 1-5

Supply Components

Existing Supplies	
Huron River	40 mgd
Steere Farm WF	11 mgd
New Supplies	
Northeast WF	11 mgd
DWSD JR Supply[1]	11 mgd

Conveyance Components

Existing Facilities	
Barton Pond PS	40 mgd
Steere Farm PL	11 mgd
New Facilities	
Northeast PS	11 mgd
Northeast PL	11 mgd
DWSD JR PS[1]	11 mgd
DWSD JR PL[1]	11 mgd

Treatment Components

Existing Facilities	
AA WTP Plant 1[2]	0 mgd
AA WTP Plant 2	28 mgd
New Facilities	
HR-SCC Plant 1	22 mgd

[1] Emergency use only
[2] Abandoned in place

Alternative 1-6

Supply Components

Existing Supplies	
Huron River	40 mgd
Steere Farm WF	11 mgd
New Supplies	
Northeast WF	11 mgd
DWSD JR Supply[1]	22 mgd

Conveyance Components

Existing Facilities	
Barton Pond PS	40 mgd
Steere Farm PL	11 mgd
New Facilities	
Northeast PS	11 mgd
Northeast PL	11 mgd
DWSD JR PS[1]	22 mgd
DWSD JR PL[1]	22 mgd

Treatment Components

Existing Facilities	
AA WTP Plant 1[2]	0 mgd
AA WTP Plant 2	28 mgd
New Facilities	
HR-SCC Plant 1	22 mgd

[1] Emergency use only
[2] Abandoned in place

Abbreviations:
AA – Ann Arbor, DWSD – Detroit Water and Sewerage Department, HR-SCC – High-Rate Solids-Contact Clarification, JR – Joy Road, PL – Pipeline, PS – Pump Station, WF – Wellfield, WTP – Water treatment plant, YP -- Ypsilanti

Figure TM1-1

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Source of Supply and System Reliability Alternatives: Replace Plant 1

Remote Groundwater Treatment Alternatives

Alternative 2-1

Supply Components

Existing Supplies	
Huron River	40 mgd
Steere Farm WF	11 mgd
New Supplies	
None	

Conveyance Components

Existing Facilities	
Barton Pond PS	40 mgd
Steere Farm PL	11 mgd
New Facilities	
Steere Farm PS	11 mgd

Treatment Components

Existing Facilities	
AA WTP Plant 1[2]	0 mgd
AA WTP Plant 2	28 mgd
New Facilities	
Steere Farm WTP	11 mgd

[2]Abandoned in place

Alternative 2-2

Supply Components

Existing Supplies	
Huron River	40 mgd
Steere Farm WF	11 mgd
New Supplies	
Steere Farm WF	11 mgd

Conveyance Components

Existing Facilities	
Barton Pond PS	40 mgd
Steere Farm PL	11 mgd
New Facilities	
Steere Farm PS	22 mgd
Steere Farm PL[1]	11 mgd

Treatment Components

Existing Facilities	
AA WTP Plant 1[2]	0 mgd
AA WTP Plant 2	28 mgd
New Facilities	
Steere Farm WTP	22 mgd

[1]Pipeline to existing WTP
[2]Abandoned in place

Alternative 2-3

Supply Components

Existing Supplies	
Huron River	40 mgd
Steere Farm WF	11 mgd
New Supplies	
Steere Farm WF	11 mgd

Conveyance Components

Existing Facilities	
Barton Pond PS	40 mgd
Steere Farm PL	11 mgd
New Facilities	
Steere Farm PS	22 mgd
Steere Farm PL[1]	11 mgd

Treatment Components

Existing Facilities	
AA WTP Plant 1[2]	0 mgd
AA WTP Plant 2	28 mgd
New Facilities	
Steere Farm WTP	22 mgd

[1]Pipeline to distribution loop
[2]Abandoned in place

Alternative 2-4

Supply Components

Existing Supplies	
Huron River	40 mgd
Steere Farm WF	11 mgd
New Supplies	
Northeast WF	11 mgd

Conveyance Components

Existing Facilities	
Barton Pond PS	40 mgd
Steere Farm PL	11 mgd
New Facilities	
Steere Farm PS	11 mgd
Northeast PS	11 mgd
Northeast PL[1]	11 mgd

Treatment Components

Existing Facilities	
AA WTP Plant 1[2]	0 mgd
AA WTP Plant 2	28 mgd
New Facilities	
Steere Farm WTP	11 mgd
Northeast WTP	11 mgd

[1]Pipeline to existing WTP
[2]Abandoned in place

Alternative 2-5

Supply Components

Existing Supplies	
Huron River	40 mgd
Steere Farm WF	11 mgd
New Supplies	
Northeast WF	11 mgd

Conveyance Components

Existing Facilities	
Barton Pond PS	40 mgd
Steere Farm PL	11 mgd
New Facilities	
Steere Farm PS	11 mgd
Northeast PS	11 mgd
Northeast PL[1]	11 mgd

Treatment Components

Existing Facilities	
AA WTP Plant 1[2]	0 mgd
AA WTP Plant 2	28 mgd
New Facilities	
Steere Farm WTP	11 mgd
Northeast WTP	11 mgd

[1]Pipeline to distribution loop
[2]Abandoned in place

Abbreviations:
AA – Ann Arbor, DWSD – Detroit Water and Sewerage Department, HR-SCC – High-Rate Solids-Contact Clarification, JR – Joy Road, PL – Pipeline, PS – Pump Station, WF – Wellfield, WTP – Water treatment plant, YP -- Ypsilanti

DWSD Wholesale Supply Alternatives

Alternative 3-1

Supply Components

Existing Supplies
- Huron River[1] — 0 mgd
- Steere Farm WF[1] — 0 mgd

New Supplies
- DWSD JR Supply — 50 mgd

Conveyance Components

Existing Facilities
- Barton Pond PS[2] — 0 mgd
- Steere Farm PL[2] — 0 mgd

New Facilities
- DWSD JR PS — 50 mgd
- DWSD JR PL — 50 mgd
- Northeast PL — 50 mgd

Treatment Components

Existing Facilities
- AA WTP Plant 1[2] — 0 mgd
- AA WTP Plant 2[2] — 0 mgd

New Facilities
- None

[1]Not utilized
[2]Abandoned in place

Alternative 3-2

Supply Components

Existing Supplies
- Huron River[1] — 40 mgd
- Steere Farm WF[1] — 11 mgd

New Supplies
- DWSD JR Supply — 50 mgd

Conveyance Components

Existing Facilities
- Barton Pond PS[1] — 40 mgd
- Steere Farm PL[1] — 4.5 mgd

New Facilities
- DWSD JR PS — 50 mgd
- DWSD JR PL — 50 mgd
- Northeast PL — 50 mgd

Treatment Components

Existing Facilities
- AA WTP Plant 1[2] — 0 mgd
- AA WTP Plant 2[1] — 28 mgd

New Facilities
- None

[1]Emergency use only
[2]Abandoned in place

Alternative 3-3

Supply Components

Existing Supplies
- Huron River[1] — 0 mgd
- Steere Farm WF[1] — 0 mgd

New Supplies
- DWSD JR Supply — 28 mgd
- DWSD YP Supply — 22 mgd

Conveyance Components

Existing Facilities
- Barton Pond PS[2] — 0 mgd
- Steere Farm PL — 11 mgd

New Facilities
- DWSD JR PS — 28 mgd
- DWSD JR PL — 28 mgd
- Northeast PL — 28 mgd
- DWSD YP PS — 22 mgd
- DWSD YP PL — 11 mgd

Treatment Components

Existing Facilities
- AA WTP Plant 1[2] — 0 mgd
- AA WTP Plant 2[2] — 0 mgd

New Facilities
- None

[1]Not utilized
[2]Abandoned in place

Alternative 3-4

Supply Components

Existing Supplies
- Huron River — 40 mgd
- Steere Farm WF — 11 mgd

New Supplies
- DWSD JR Supply — 22 mgd

Conveyance Components

Existing Facilities
- Barton Pond PS — 40 mgd
- Steere Farm PL — 4.5 mgd

New Facilities
- DWSD JR PS — 22 mgd
- DWSD JR PL — 22 mgd
- Northeast PL — 22 mgd

Treatment Components

Existing Facilities
- AA WTP Plant 1[2] — 0 mgd
- AA WTP Plant 2 — 28 mgd

New Facilities
- None

[2]Abandoned in place

Alternative 3-5

Supply Components

Existing Supplies
- Huron River — 40 mgd
- Steere Farm WF — 11 mgd

New Supplies
- DWSD JR Supply — 22 mgd

Conveyance Components

Existing Facilities
- Barton Pond PS — 40 mgd
- Steere Farm PL — 11 mgd

New Facilities
- DWSD JR PS — 22 mgd
- DWSD JR PL — 22 mgd
- Northeast PL — 22 mgd

Treatment Components

Existing Facilities
- AA WTP Plant 1[2] — 0 mgd
- AA WTP Plant 2 — 28 mgd

New Facilities
- None

[2]Abandoned in place

Abbreviations:
AA – Ann Arbor, DWSD – Detroit Water and Sewerage Department, HR-SCC – High-Rate Solids-Contact Clarification, JR – Joy Road, PL – Pipeline, PS – Pump Station, WF – Wellfield, WTP – Water treatment plant, YP -- Ypsilanti

Figure TM1-3

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Source of Supply and System Reliability Alternatives: DWSD Supply

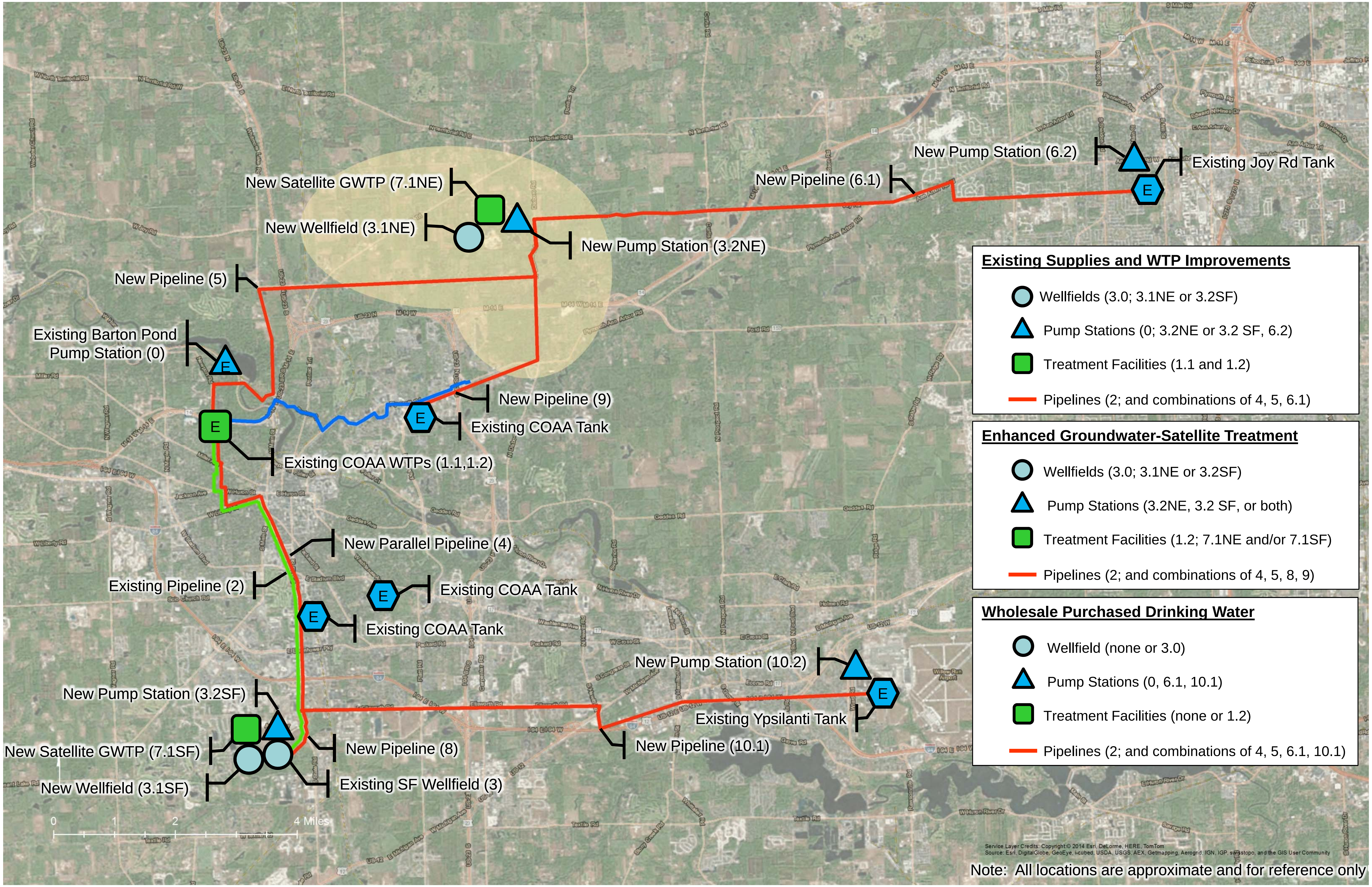


Figure TM1-4

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Source of Supply and System Reliability Alternatives Components

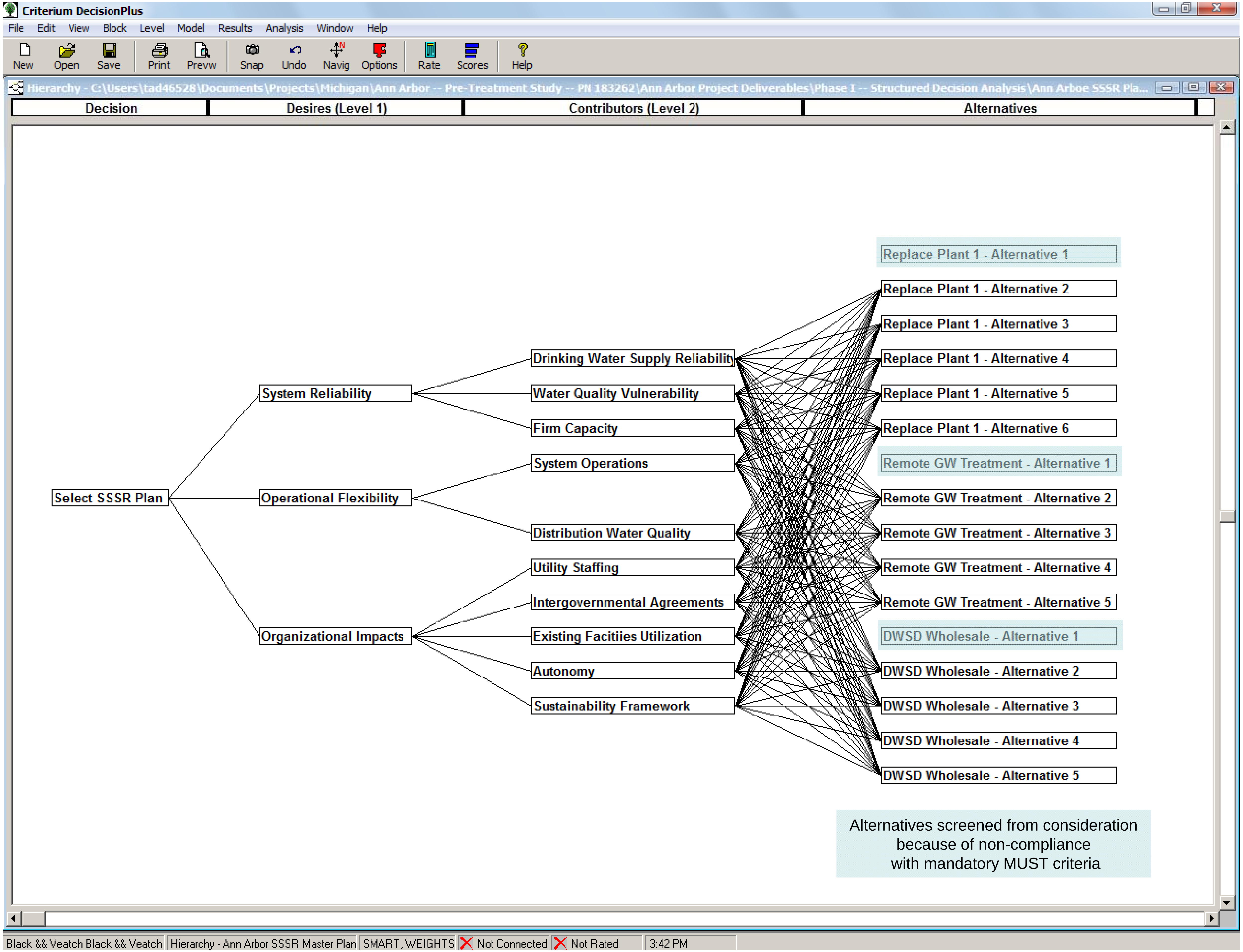
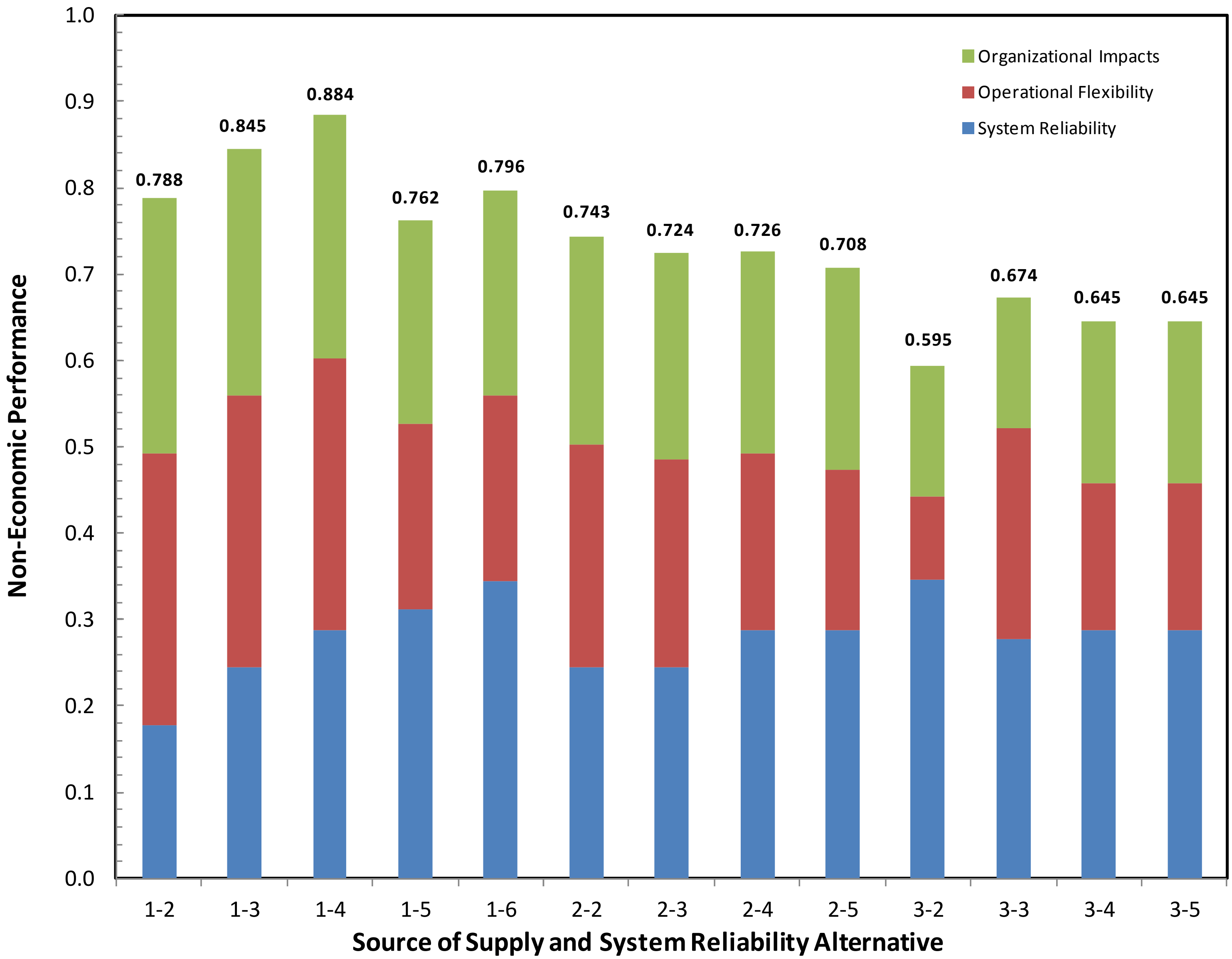


Figure TM1-5

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

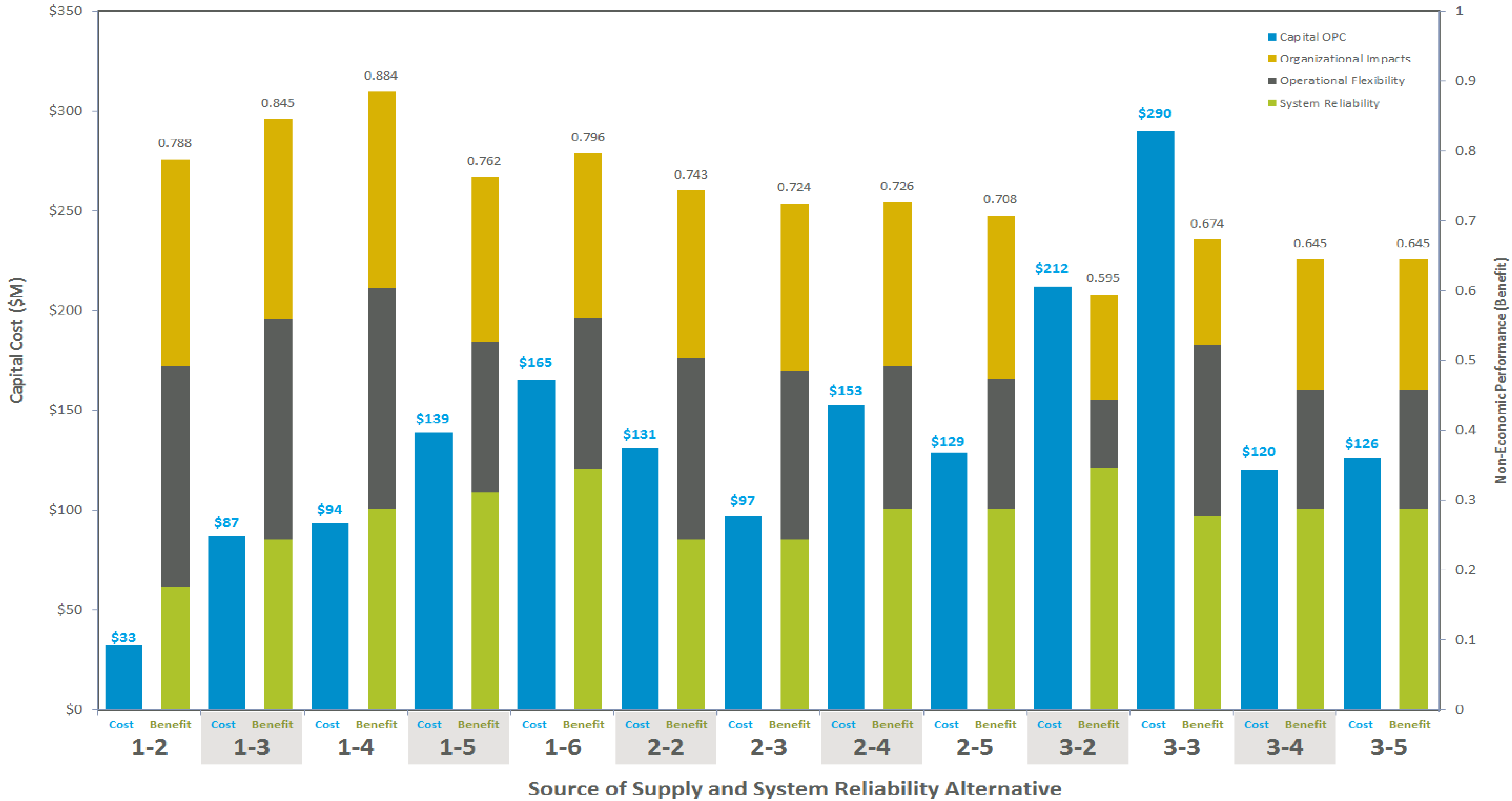
Source of Supply and System Reliability Alternatives Decision Model



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Non-economic Performance Values of SSSR Alternatives

Figure TM1-6



		City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis	Figure TM1-7
		SSSR Alternatives: Summary of Capital Cost and Benefit Scoring	

Appendix TM1.A

City of Ann Arbor Finished Water Quality Goals

OPERATIONAL AND WATER QUALITY GOALS - SUMMER

	Primary Basin	Secondary Basin	Ozone	Wet Well	Filters	CW	Reservoir	Dist. Syst.
pH	11.0-11.3	10	≤8.0	9.3	9.3	9.3	9.3	
Sludge %	8-10%	≤3%						
(OH)		0						
(Polymer)*		0.6 mg/l						
Turbidity		<5 NTU			<0.2 NTU	<0.1 NTU	<0.1 NTU	<0.5 NTU
Average (O_3) Resid			0.1 mg/l 1st cell					
% CT			150%					
(PO_4)				0.95 mg/l as SHMP				
Filter Run					96 hrs @1.0 mgd 48 hrs @ 2 mgd, ie. 4 Mgal, ≤7 ft HL			
Backwash					10-15 NTU			
Cl_2:NH_3-N		<5.0	(4.75-5)			.		
Cl_2:NH_3		≤4.0	(3.75-4)				≤.25 ppm excess ammonia	
Alkalinity							≥50 mg/l	
TH							120 mg/l	
Fluoride							0.7 mg/l	
NH_2Cl							3.0 mg/l	>1.5 mg/l
T&O							0	0
Nitrite								<100 µg/L
HPC								<500 cfu/ml

*Raw water @ Barton Pond - 1 ppm 3 weeks on/ 1 week off when river temp ≥ 12°C

Notes: 1) Maximum well water in primary ≥ 75%. 2) Can move backwash recirculation to secondary if having hexahydrate sludge problems. 3) Add $CaCO_3$ to primary RM as needed for hexahydrate problem.

OPERATIONAL AND WATER QUALITY GOALS - WINTER								
	Primary Basin	**Secondary Basin**	**Ozone**	**Wet Well**	**Filters**	**CW**	**Reservoir**	**Dist. Syst.**
pH	11.0-11.3	10	≤8.0	9.3	9.3	9.3	9.3	
Sludge %	8-10%	≤3%						
(OH)		0						
(Polymer) *		0.6 mg/l						
Turbidity		<5 NTU			<0.2 NTU	<0.1 NTU	<0.1 NTU	<0.5 NTU
Average (O_3) Resid			0.1 mg/l 1st cell					
% CT			150%					
(PO_4)				0.95 mg/l as SHMP				
Filter Run					96 hrs @1.0 mgd 48 hrs @ 2 mgd, ie. 4 Mgal, ≤7 ft HL			
Backwash					10-15 NTU			
Cl_2:NH_3-N		<5.0	(4.75-5)					
Cl_2:NH_3		≤4.0	(3.75-4)				≤.25 ppm excess ammonia	
Alkalinity							>50 mg/l	
TH							140 mg/l	
Fluoride							0.7 mg/l	
NH_2Cl							3.0 mg/l	>2.0 mg/l
T&O							0	0
Nitrite								<100 µg/L
HPC								<500 cfu/ml

Notes: 1) Maximum well water in primary ≥ 75%. 2) Can move backwash recirculation to secondary if having hexahydrate sludge problems. 3) Add $CaCO_3$ to primary RM as needed for hexahydrate problem.

Appendix TM1.B

Source of Supply and System Reliability Alternatives

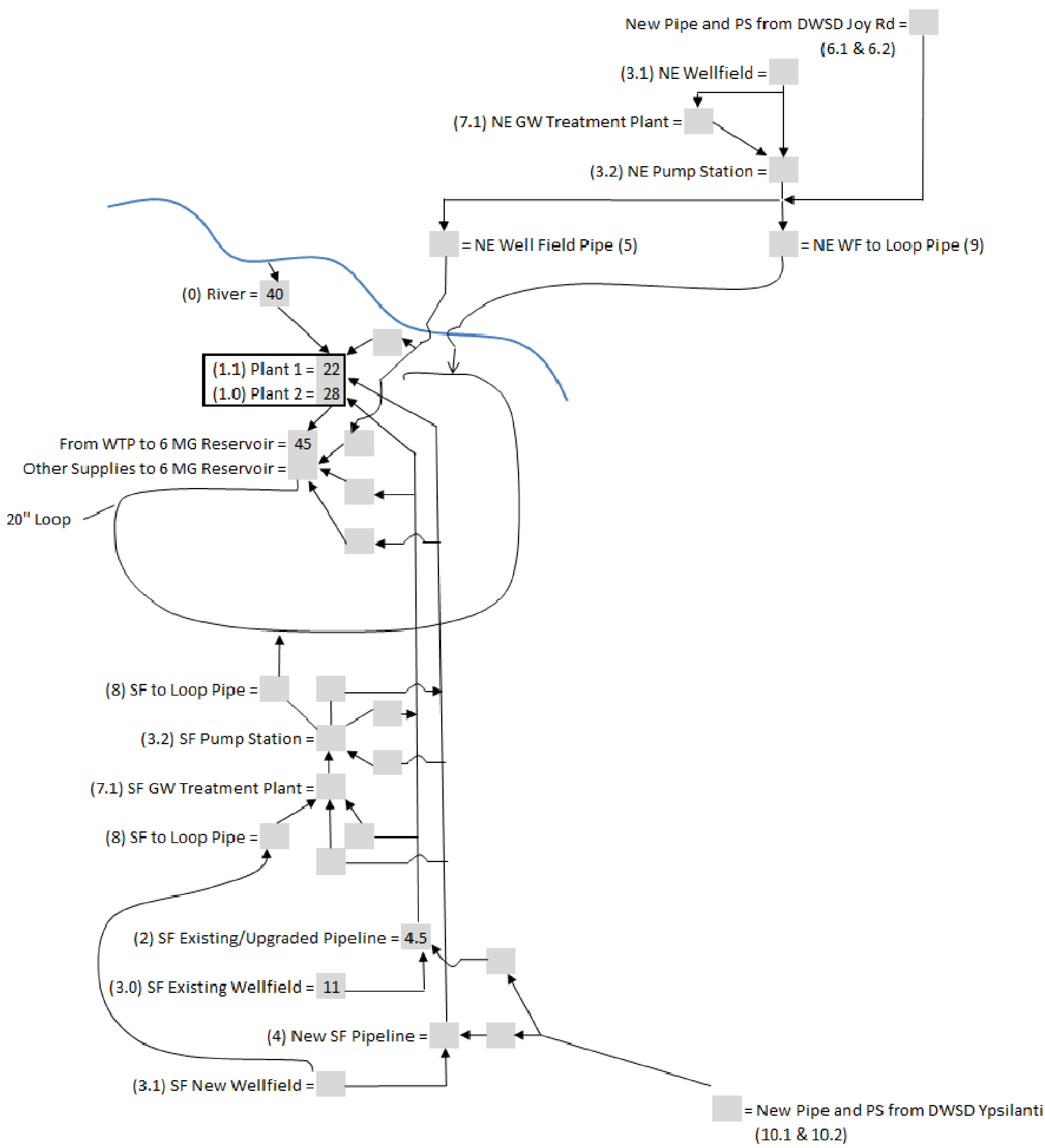
Conceptual Schematics

Reference Notes for Interpretation of Figures:

The figures in this appendix are generated from a pivot table model that generates information based on the Source of Supply and System Reliability Alternative selected (as shown in the upper left of each figure). For the selected alternative in each figure:

- The description and numerical coding of each component in the figure corresponds to those listed in Table TM1-1.
- A numerical value indicated in the gray box adjacent to each component indicates the capacity in MGD provided by that component as part of the selected alternative. A lack of numerical value entry in the box indicates that component is not part of the alternative.
- For existing components, the capacity is limited to existing capacity unless indicated for upgrade (e.g., component 2.0 – Existing Steere Farm Well Field Pipeline to Existing WTP).
- The inclusion of a new or upgraded component in the alternative results in the inclusion of capital costs for that component, as summarized in the Appendix TM1.C.1 Capital Summary Sheet.

Phase IA
Source of Supply and System Reliability Alternatives
Alternative : Plant 1 -- Alternative 1



	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	40	-40	0	0	0	0
SF Wells =	4.5	0	4.5	0	4.5	0
NE Wells =	0	0	0	0	0	0
DWSD JR=	0	0	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	44.5	-40.0	4.5	0.0	4.5	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

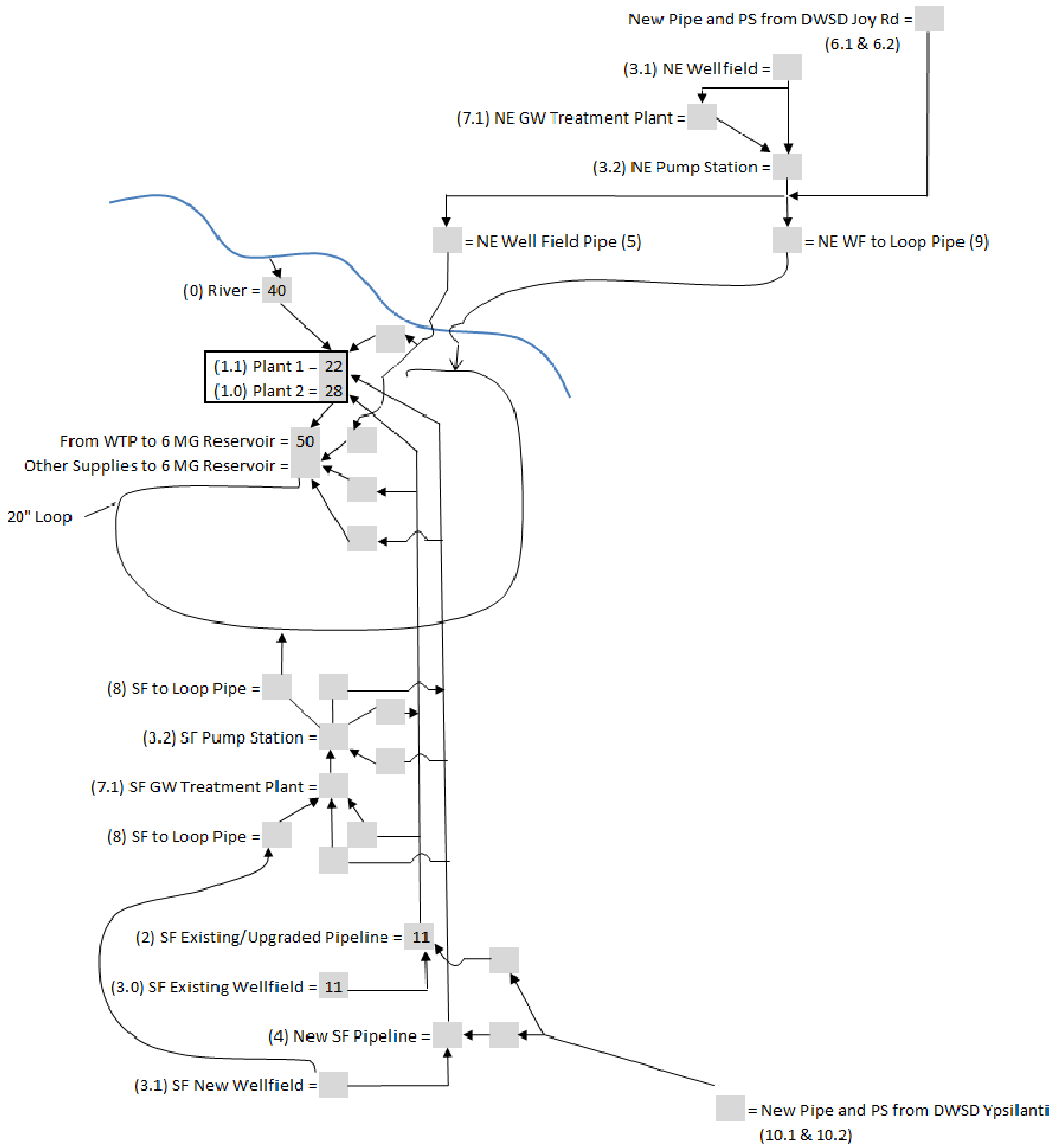
SSSR Alternatives: Replace Plant 1 – Alternative 1-1

Figure TM1.B-1

Phase IA

Source of Supply and System Reliability Alternatives

Alternative : Plant 1 -- Alternative 2



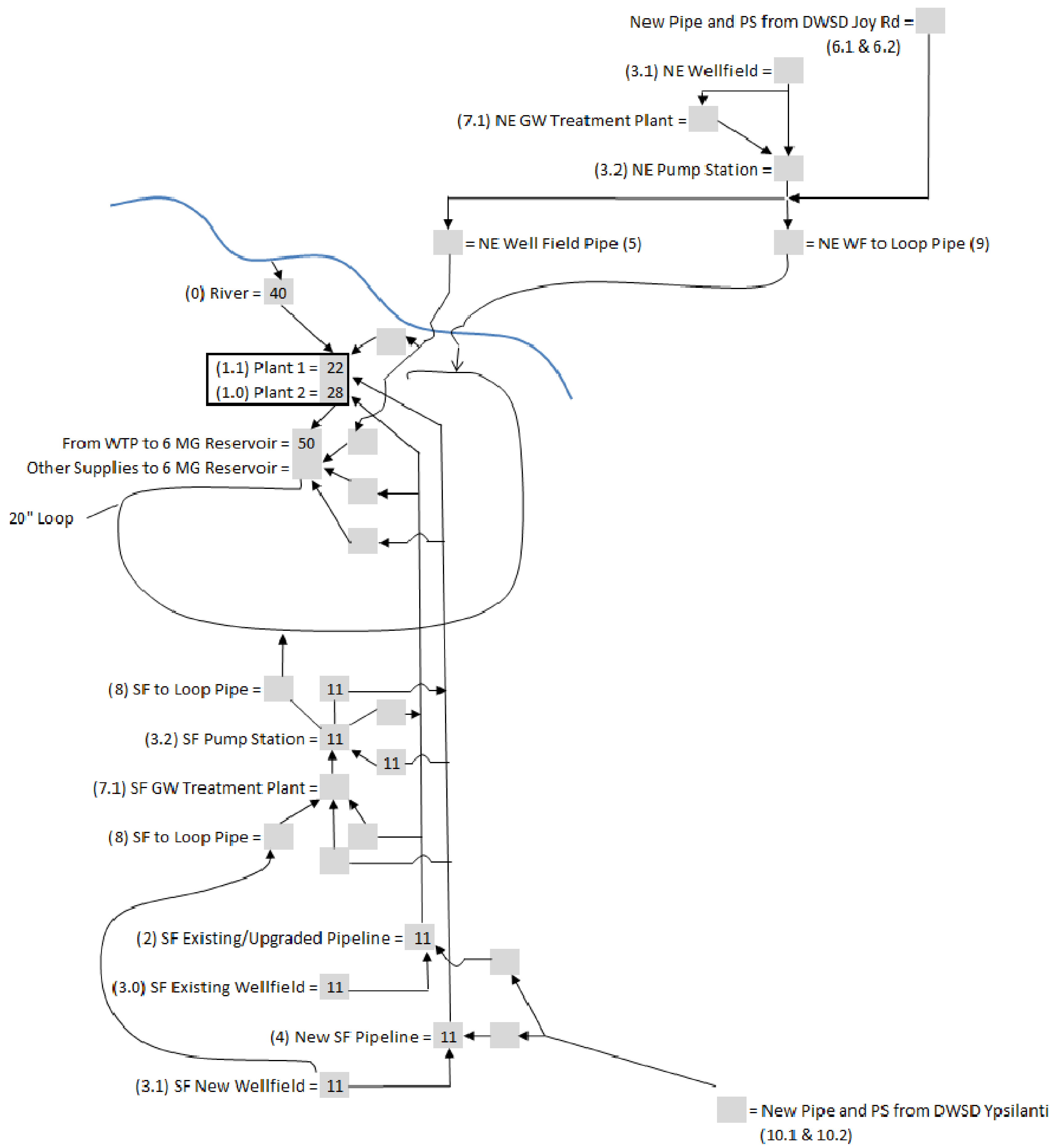
	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	40	-40	0	0	0	0
SF Wells =	11	0	11	0	11	0
NE Wells =	0	0	0	0	0	0
DWSD JR=	0	0	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	51.0	-40.0	11.0	0.0	11.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

SSSR Alternatives: Replace Plant 1 – Alternative 1-2

Figure TM1.B-2

Phase IA
Source of Supply and System Reliability Alternatives
Alternative : Plant 1 -- Alternative 3



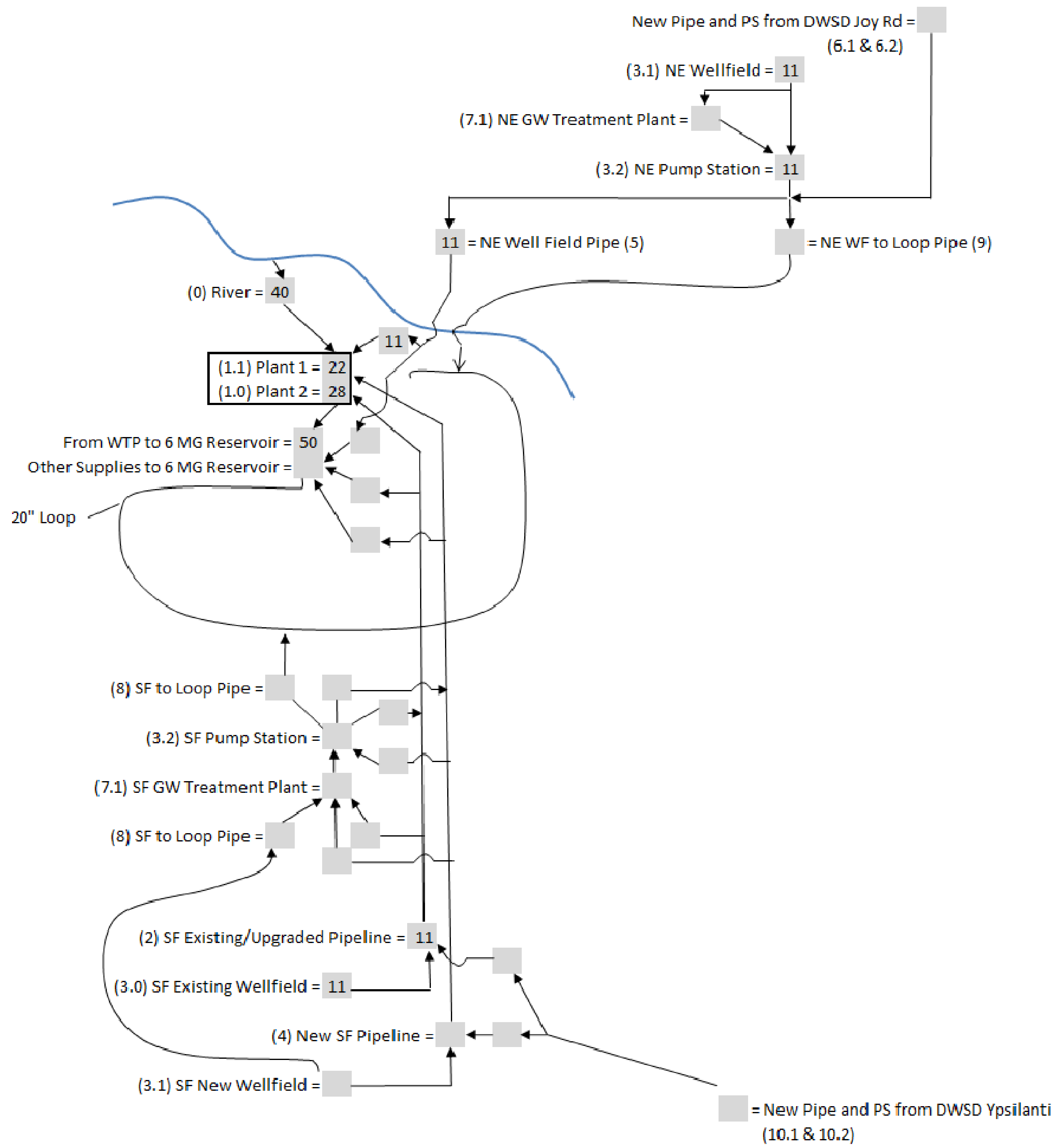
	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	40	-40	0	0	0	0
SF Wells =	22	0	22	0	22	0
NE Wells =	0	0	0	0	0	0
DWSD JR=	0	0	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	62.0	-40.0	22.0	0.0	22.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

SSSR Alternatives: Replace Plant 1 – Alternative 1-3

Figure TM1.B-3

Phase IA
Source of Supply and System Reliability Alternatives
Alternative : Plant 1 -- Alternative 4



	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	40	-40	0	0	0	0
SF Wells =	11	0	11	0	11	0
NE Wells =	11	0	11	0	11	0
DWSD JR=	0	0	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	62.0	-40.0	22.0	0.0	22.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

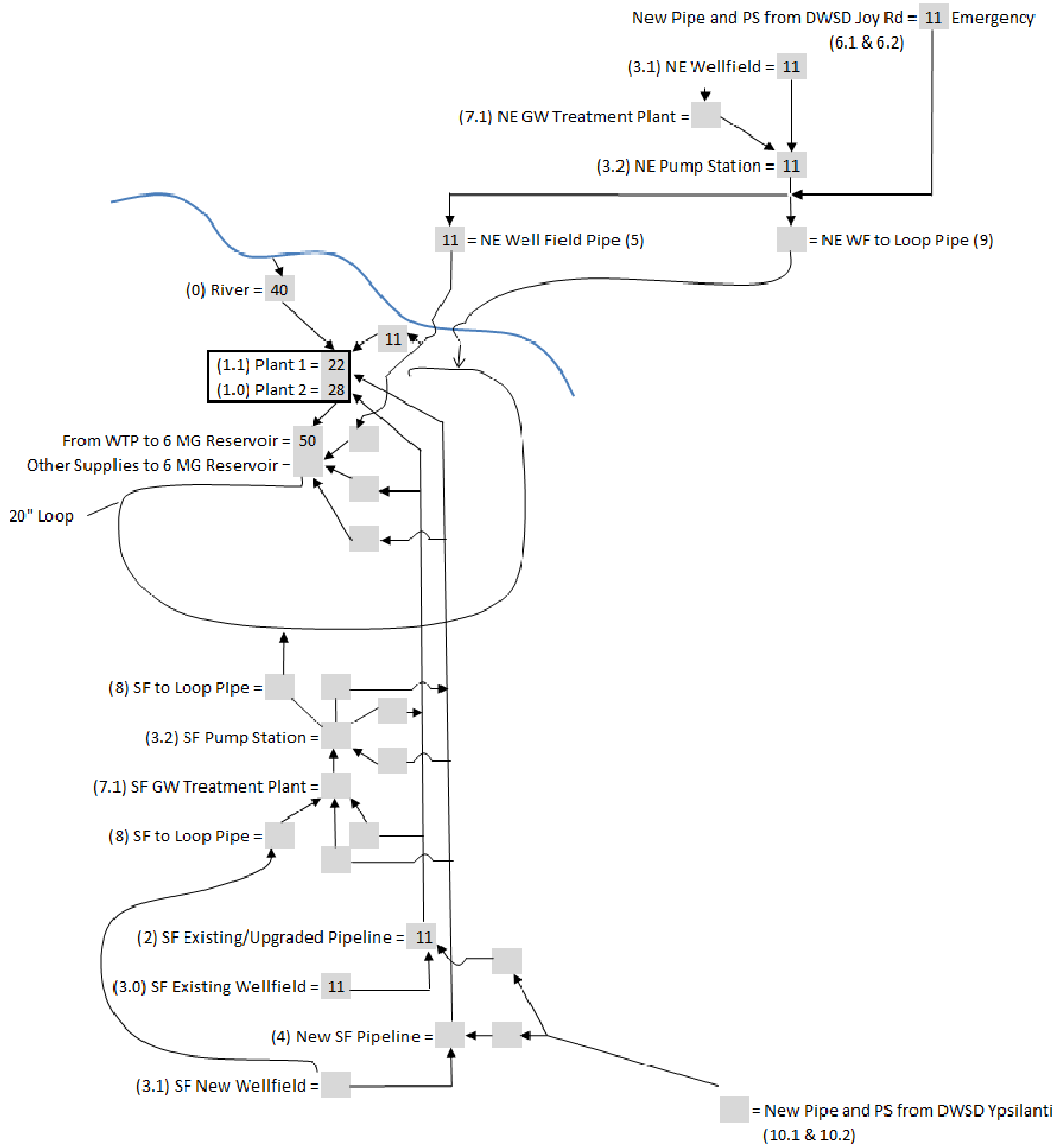
SSSR Alternatives: Replace Plant 1 – Alternative 1-4

Figure TM1.B-4

Phase IA

Source of Supply and System Reliability Alternatives

Alternative : Plant 1 -- Alternative 5



	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	40	-40	0	0	0	0
SF Wells =	11	0	11	0	11	0
NE Wells =	11	0	11	0	11	0
DWSD JR=	11	0	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	73.0	-40.0	22.0	0.0	22.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

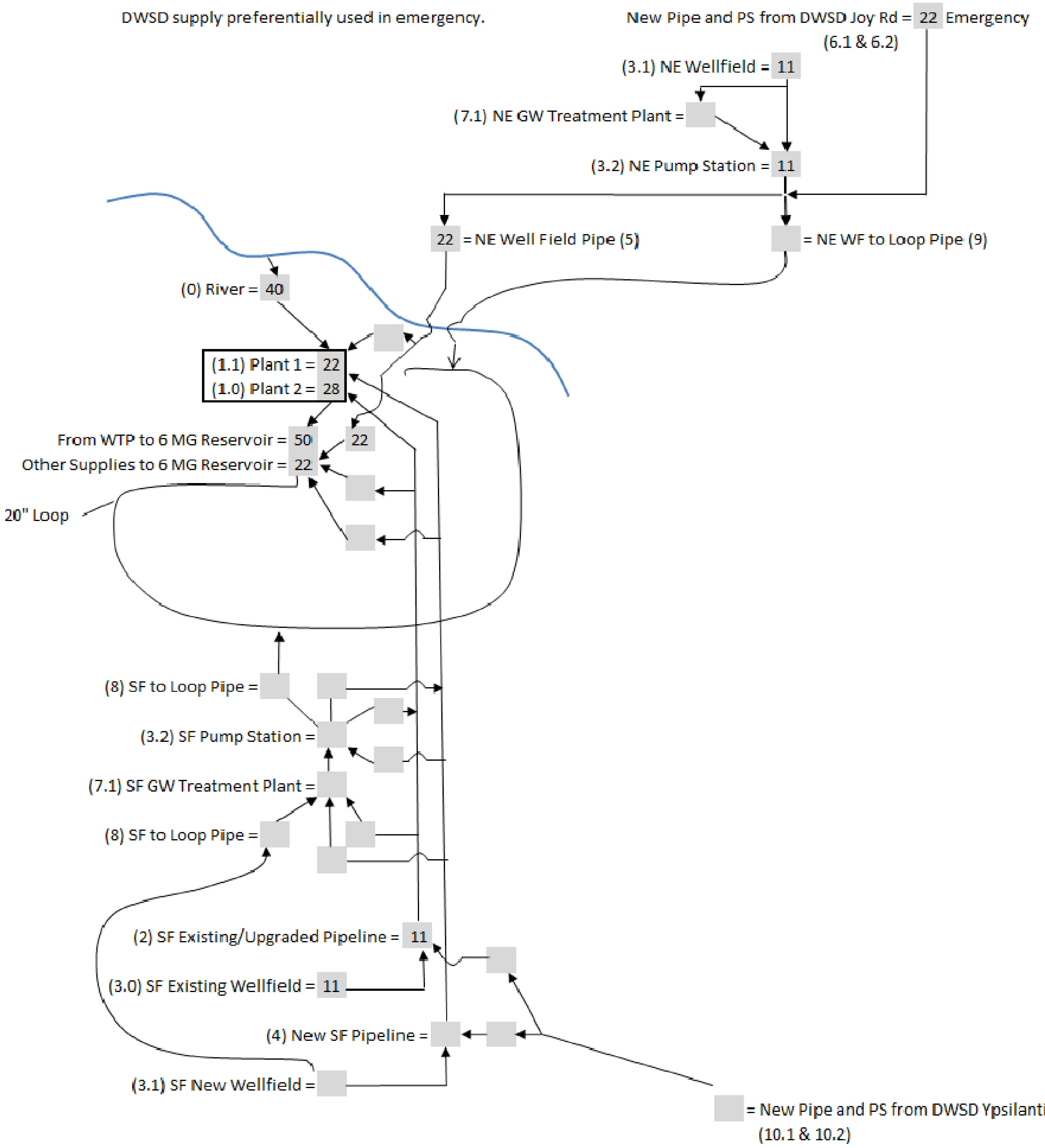
SSSR Alternatives: Replace Plant 1 – Alternative 1-5

Figure TM1.B-5

Phase IA

Source of Supply and System Reliability Alternatives

Alternative : Plant 1 -- Alternative 6



	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	40	-40	0	0	0	0
SF Wells =	11	0	11	0	11	0
NE Wells =	11	0	11	0	0	0
DWSD JR=	22	0	0	0	22	0
DWSD YP=	0	0	0	0	0	0
	84.0	-40.0	22.0	0.0	33.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

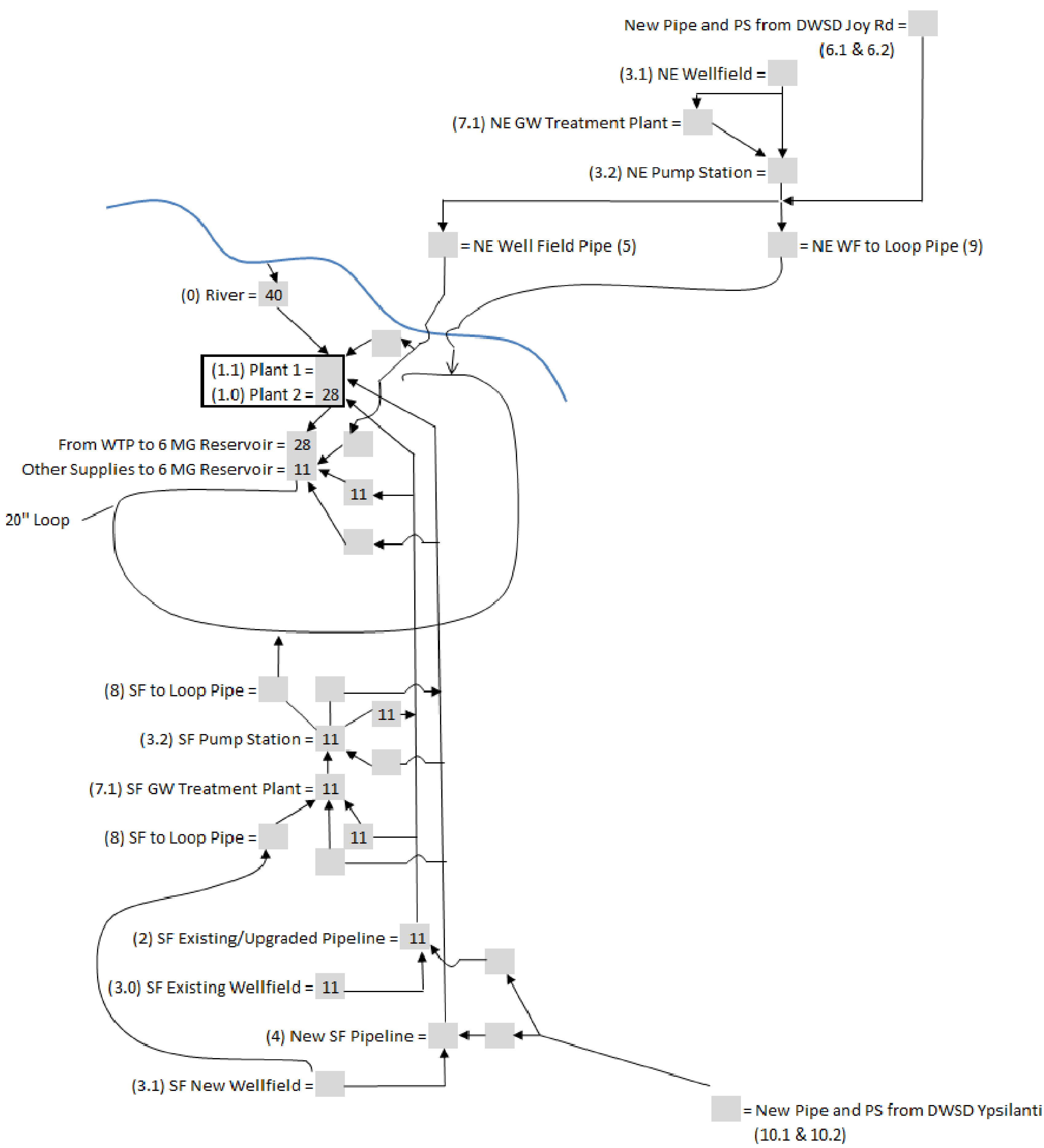
SSSR Alternatives: Replace Plant 1 – Alternative 1-6

Figure TM1.B-6

Phase IA

Source of Supply and System Reliability Alternatives

Alternative : Groundwater -- Alternative 1



	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	28	-28	0	0	0	0
SF Wells =	11	0	0	11	11	0
NE Wells =	0	0	0	0	0	0
DWSD JR=	0	0	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	39.0	-28.0	0.0	11.0	11.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

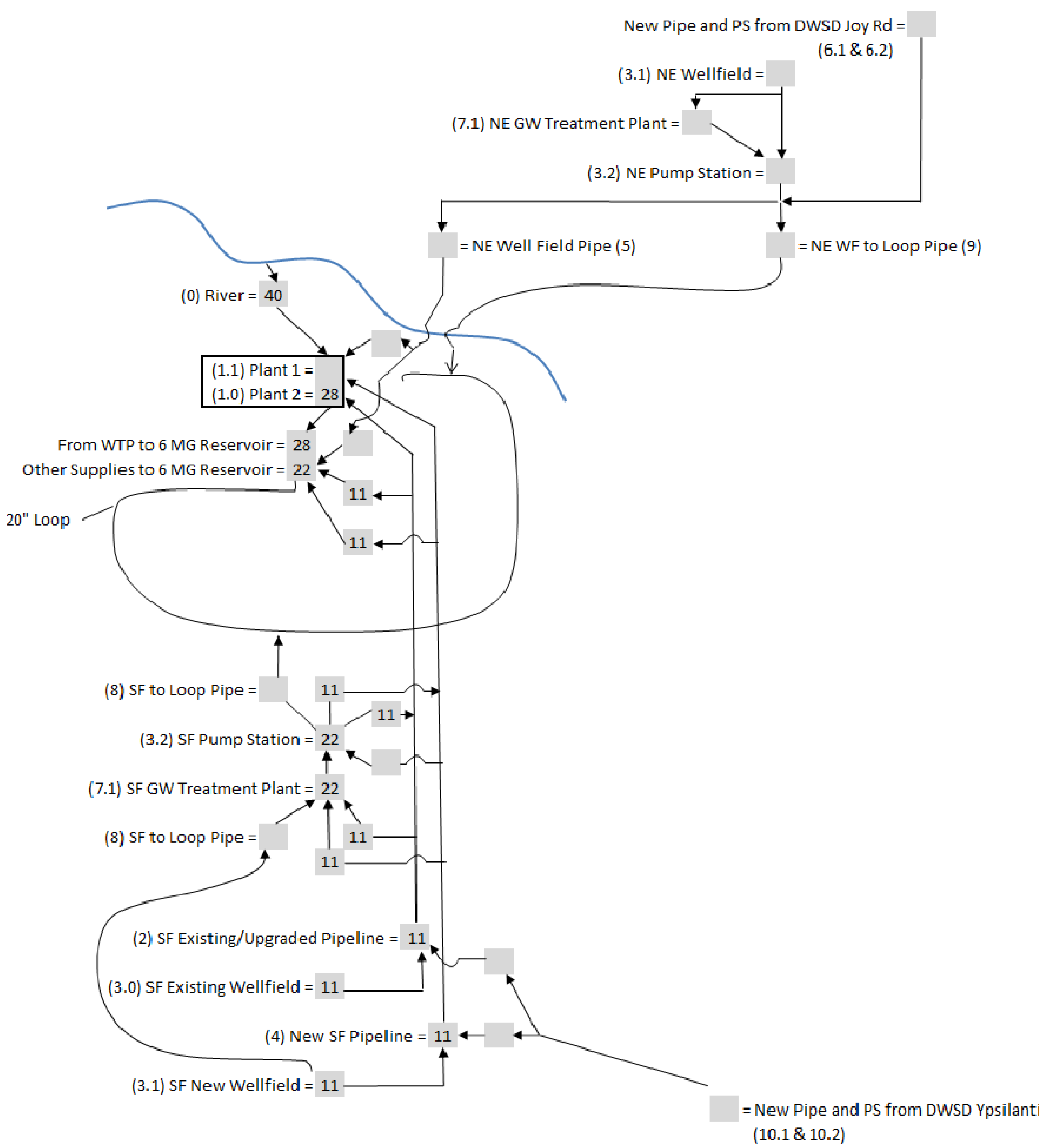
SSSR Alternatives: Groundwater – Alternative 2-1

Figure TM1.B-7

Phase IA

Source of Supply and System Reliability Alternatives

Alternative : Groundwater -- Alternative 2



	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	28	-28	0	0	0	0
SF Wells =	22	0	0	22	22	0
NE Wells =	0	0	0	0	0	0
DWSD JR=	0	0	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	50.0	-28.0	0.0	22.0	22.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

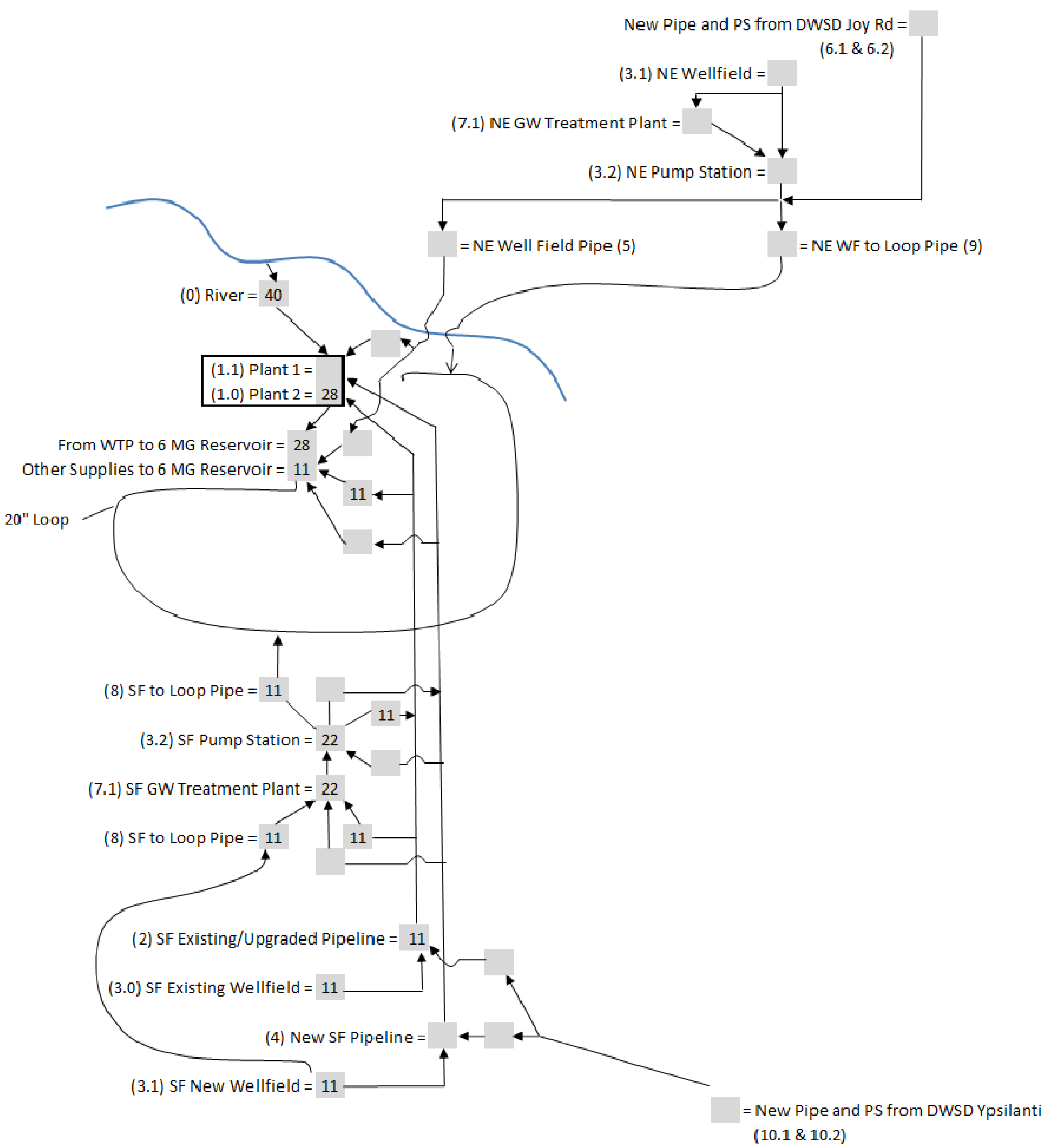
SSSR Alternatives: Groundwater – Alternative 2-2

Figure TM1.B-8

Phase IA

Source of Supply and System Reliability Alternatives

Alternative : Groundwater -- Alternative 3



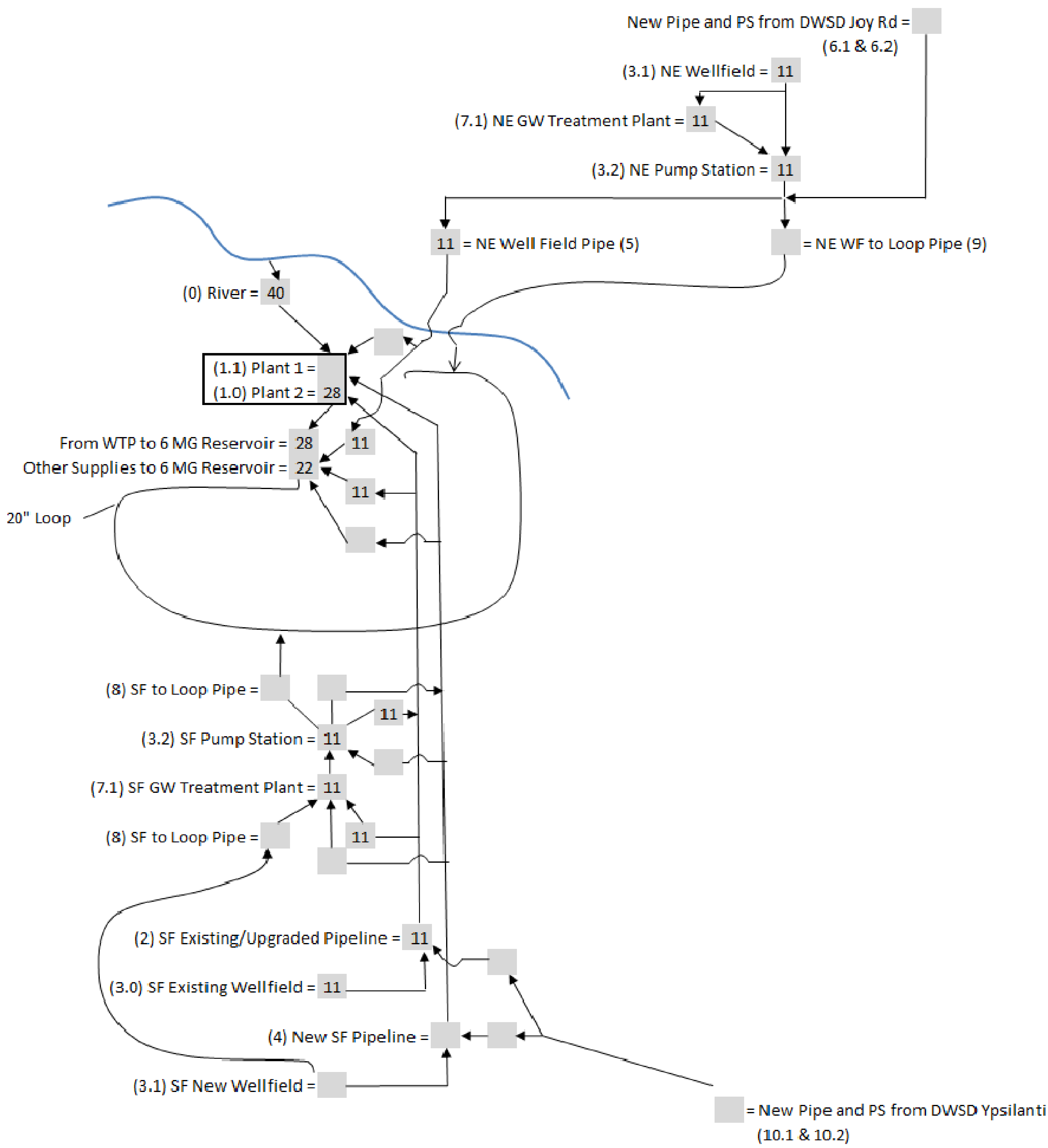
	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	28	-28	0	0	0	0
SF Wells =	22	0	0	22	22	0
NE Wells =	0	0	0	0	0	0
DWSD JR=	0	0	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	50.0	-28.0	0.0	22.0	22.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

SSSR Alternatives: Groundwater – Alternative 2-3

Figure TM1.B-9

Phase IA
Source of Supply and System Reliability Alternatives
Alternative : Groundwater -- Alternative 4



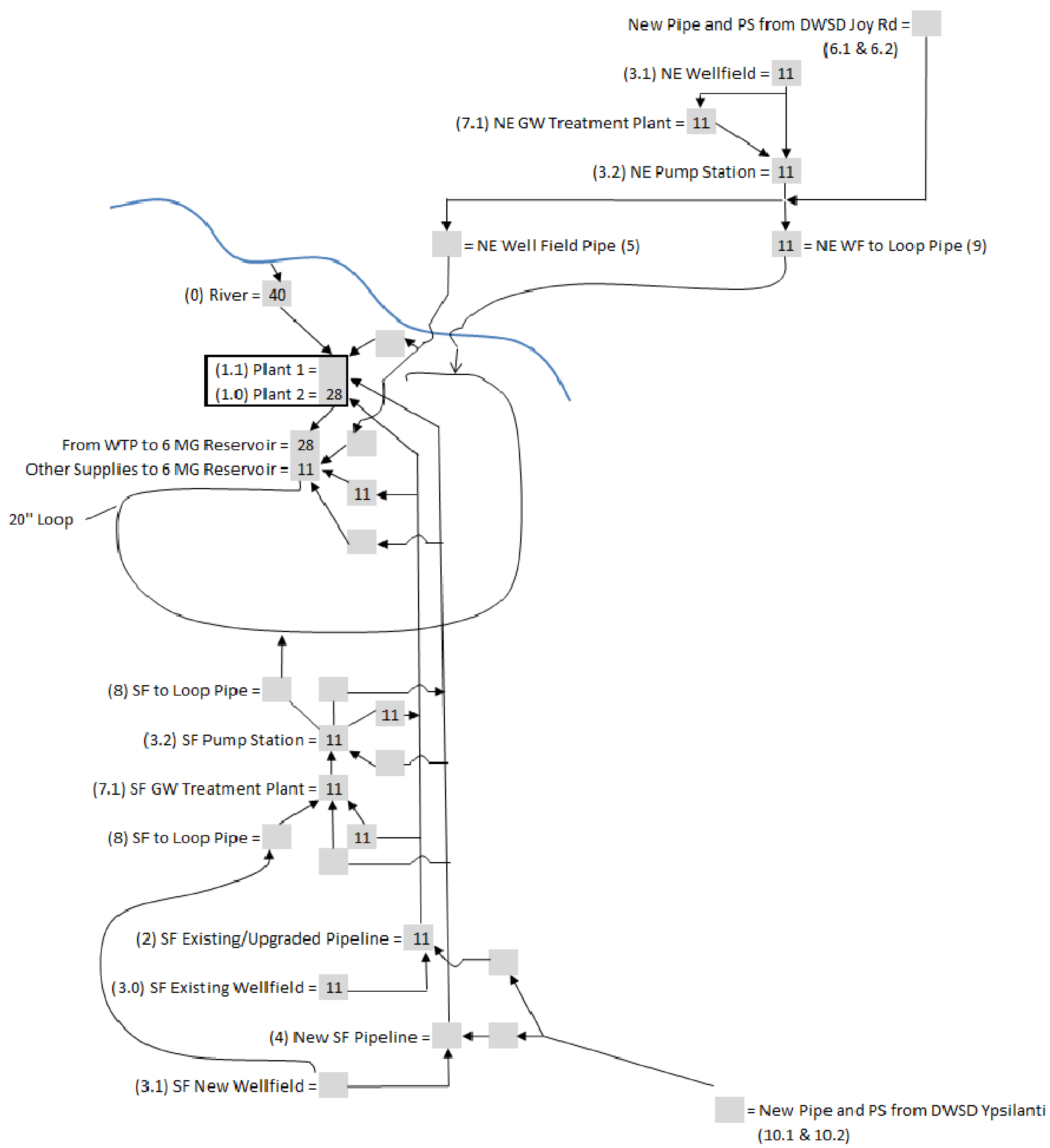
	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	28	-28	0	0	0	0
SF Wells =	11	0	0	11	11	0
NE Wells =	11	0	0	11	11	0
DWSD JR=	0	0	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	50.0	-28.0	0.0	22.0	22.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

SSSR Alternatives: Groundwater – Alternative 2-4

Figure TM1.B-10

Phase IA
Source of Supply and System Reliability Alternatives
Alternative : Groundwater -- Alternative 5



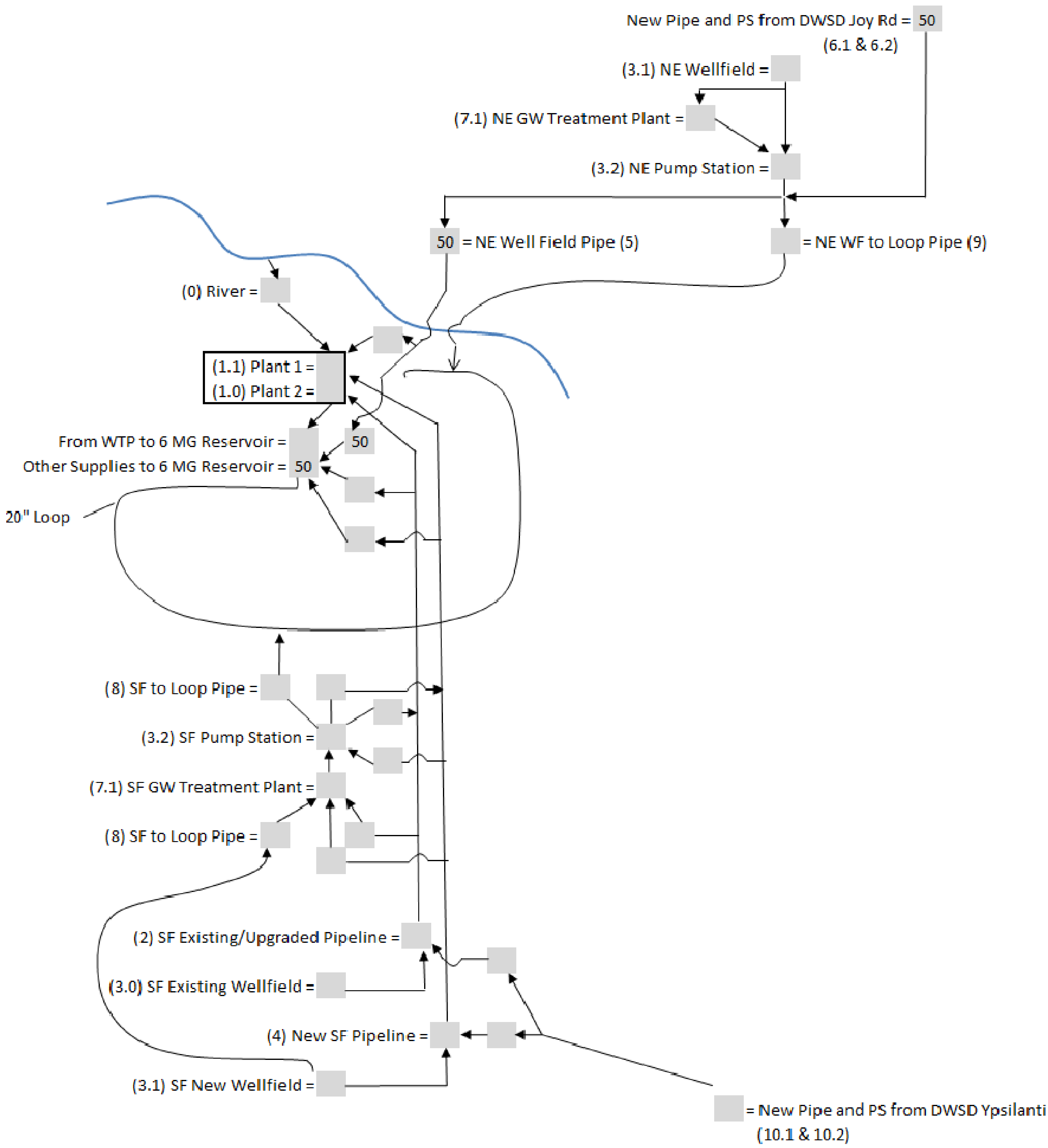
	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	28	-28	0	0	0	0
SF Wells =	11	0	0	11	11	0
NE Wells =	11	0	0	11	11	0
DWSD JR=	0	0	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	50.0	-28.0	0.0	22.0	22.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

SSSR Alternatives: Groundwater – Alternative 2-5

Figure TM1.B-11

Phase IA
Source of Supply and System Reliability Alternatives
Alternative : DWSD -- Alternative 1



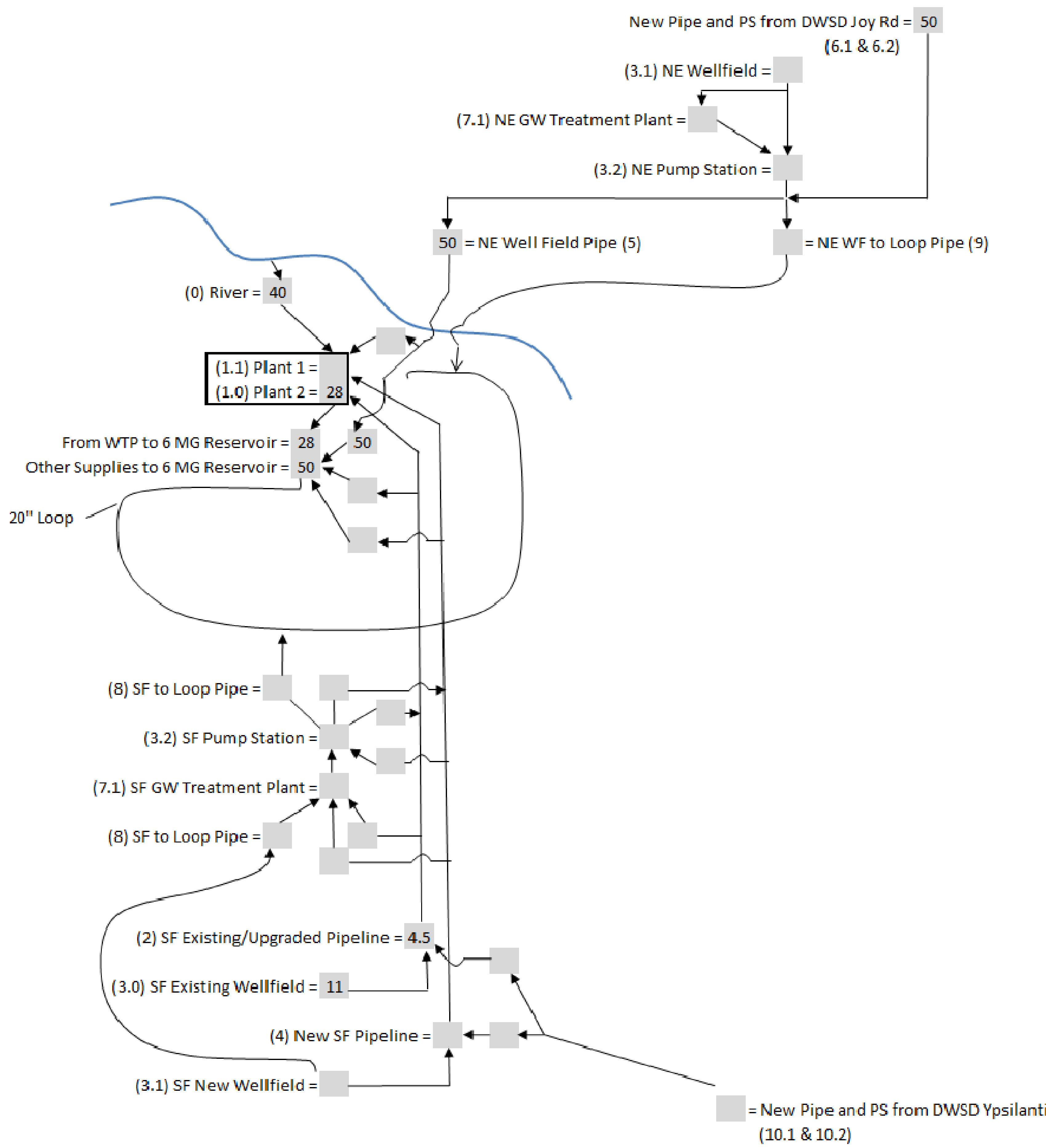
	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	0	0	0	0	0	0
SF Wells =	0	0	0	0	0	0
NE Wells =	0	0	0	0	0	0
DWSD JR=	50	-50	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	50.0	-50.0	0.0	0.0	0.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

SSSR Alternatives: DWSD – Alternative 3-1

Figure TM1.B-12

Phase IA
Source of Supply and System Reliability Alternatives
Alternative : DWSD -- Alternative 2



	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	28	0	28	0	28	0
SF Wells =	4.5	0	0	0	0	4.5
NE Wells =	0	0	0	0	0	0
DWSD JR=	50	-50	0	0	0	0
DWSD YP=	0	0	0	0	0	0
	82.5	-50.0	0.0	0.0	28.0	4.5

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

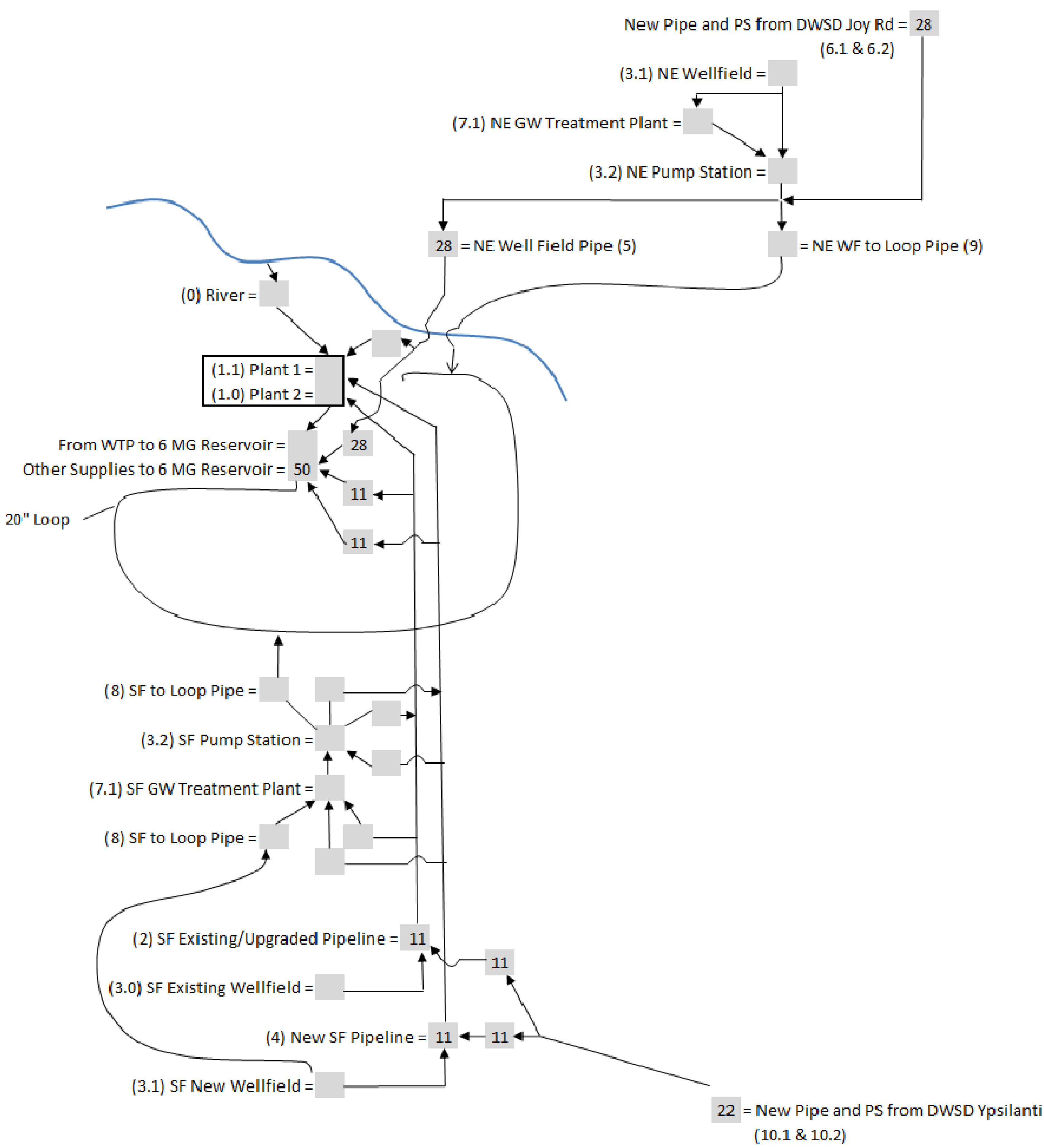
SSSR Alternatives: DWSD – Alternative 3-2

Figure TM1.B-13

Phase IA

Source of Supply and System Reliability Alternatives

Alternative : DWSD -- Alternative 3



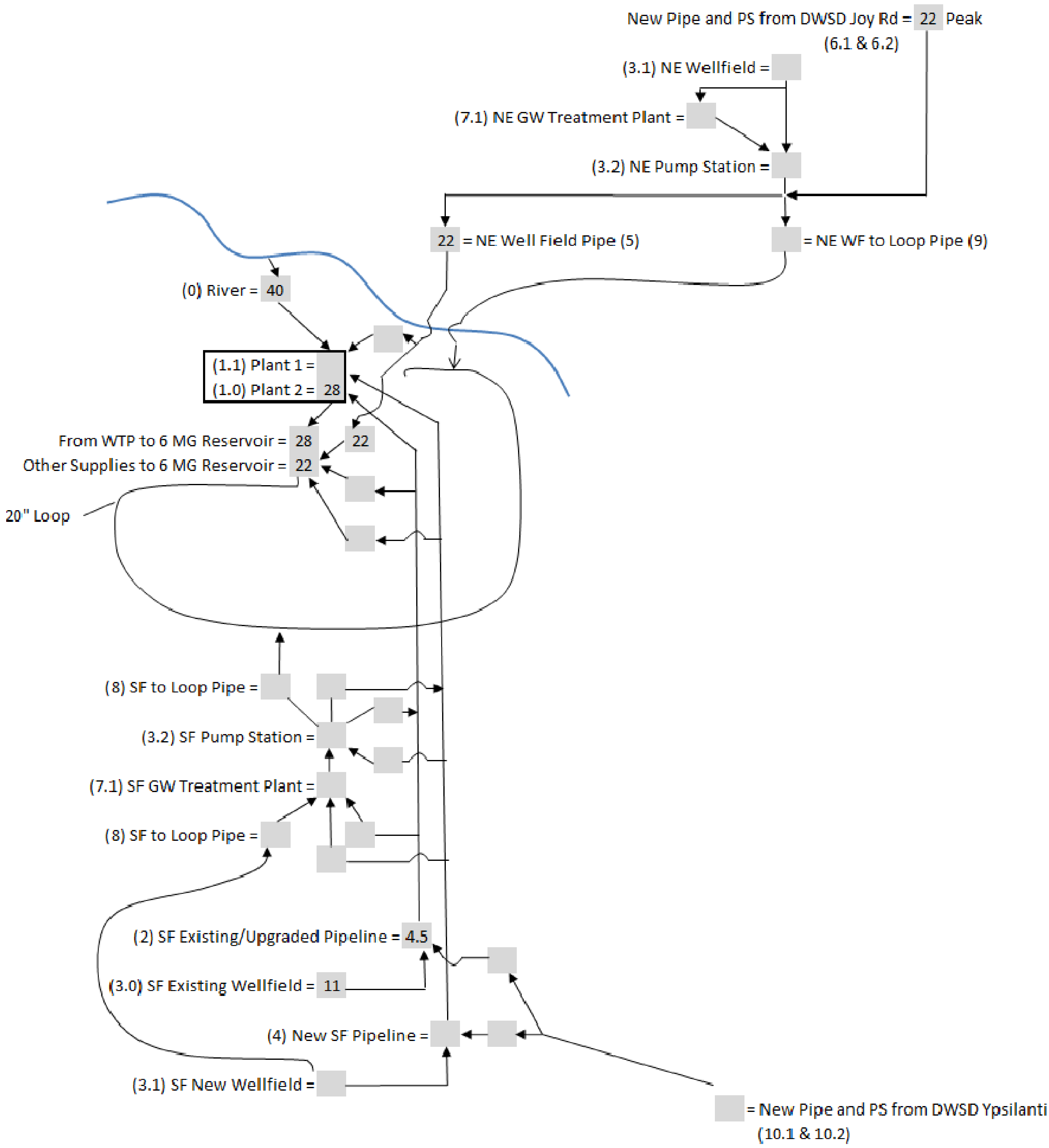
	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	0	0	0	0	0	0
SF Wells =	0	0	0	0	0	0
NE Wells =	0	0	0	0	0	0
DWSD JR=	28	-28	0	0	0	0
DWSD YP=	22	0	0	0	22	0
	50.0	-28.0	0.0	0.0	22.0	0.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

SSSR Alternatives: DWSD – Alternative 3-3

Figure TM1.B-14

Phase IA
Source of Supply and System Reliability Alternatives
Alternative : DWSD -- Alternative 4



	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	28	-28	Unavailable	0	Unavailable	0
SF Wells =	4.5	0	0	0	0	4.5
NE Wells =	0	0	0	0	0	0
DWSD JR=	22	0	0	0	22	0
DWSD YP=	0	0	0	0	0	0
	54.5	-28.0	0.0	0.0	22.0	4.5

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

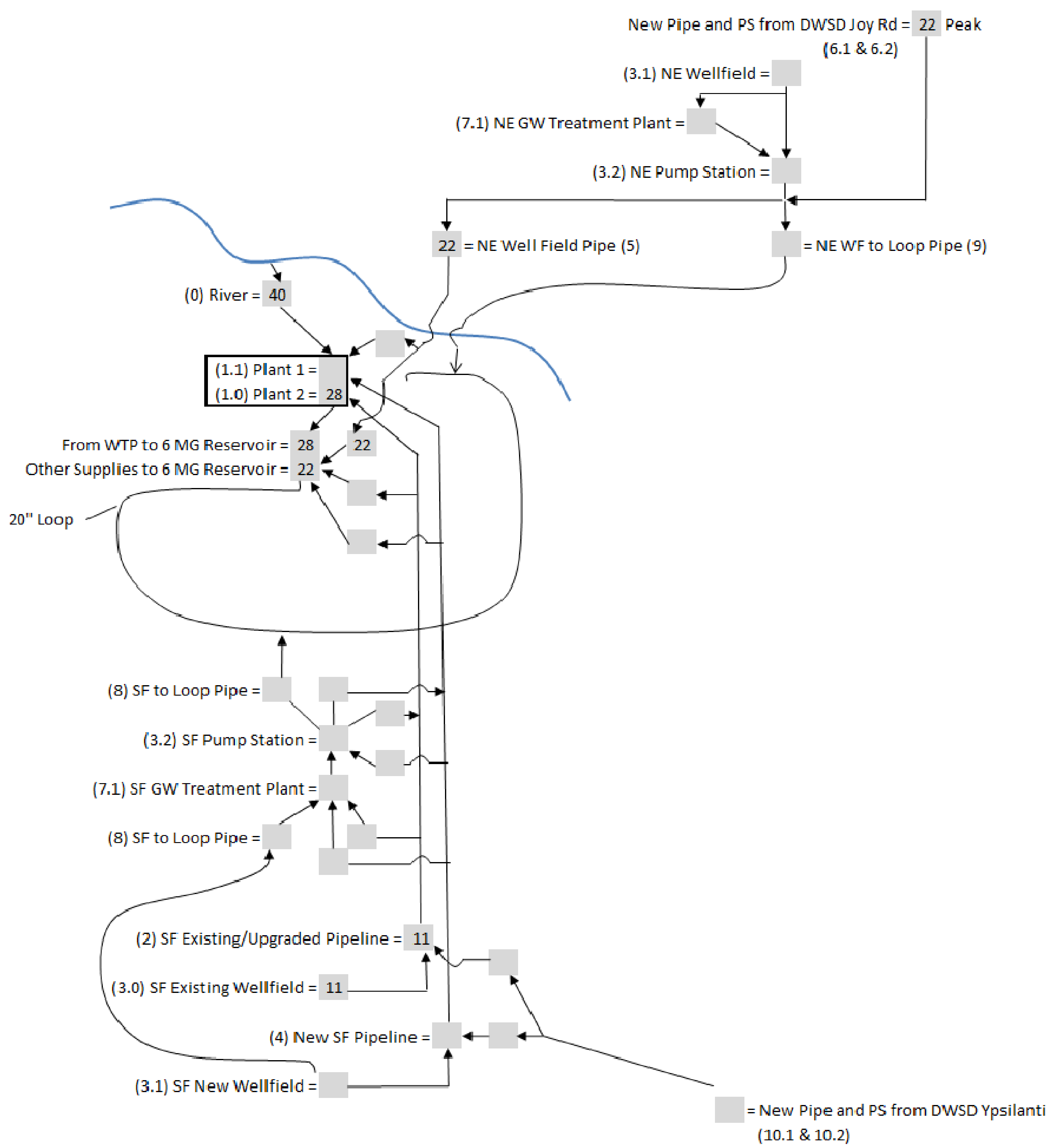
SSSR Alternatives: DWSD – Alternative 3-4

Figure TM1.B-15

Phase IA

Source of Supply and System Reliability Alternatives

Alternative : DWSD -- Alternative 5



	Supplies Available	Supply Unavailable	Plant 1&2 Capacity Used	GWTP Capacity Used	Firm Supply	Extra Supply if Untreated GW Blending is Allowed
River =	28	-28	Unavailable	0	Unavailable	0
SF Wells =	11	0	0	0	0	11
NE Wells =	0	0	0	0	0	0
DWSD JR=	22	0	0	0	22	0
DWSD YP=	0	0	0	0	0	0
	61.0	-28.0	0.0	0.0	22.0	11.0

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

SSSR Alternatives: DWSD – Alternative 3-5

Figure TM1.B-16

Appendix TM1.C

Source of Supply and System Reliability Alternatives Summary Sheets

- **TM1.C.1 Opinions of Probable Capital Cost**
- **TM1.C.2 Opinions of Probable Annual OMR&R Cost**
- **TM1.C.3 Opinions of Probable Life-Cycle Net Present Value**
- **TM1.C.4 Conveyance Component Cost Summary Sheets**
- **TM1.C.5 Treatment Component Cost Summary Sheets**

Appendix TM1.C.1
Capital Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Average Day Demand 15 **mgd**

	Sources of Supply					Sources of Supply					
Alternative	**Huron River (percent)**	**Steere Farm (percent)**	**Northeast Aquifer (percent)**	**DWSD Joy Rd (percent)**	**DWSD Ypsilanti (percent)**	**Huron River (mgd)**	**Steere Farm (mgd)**	**Northeast Aquifer (mgd)**	**DWSD Joy Rd (mgd)**	**DWSD Ypsilanti (mgd)**	**Total (MG)**
Plant 1 -- Alternative 1-1	80%	20%				12.0	3.0				5,475
Plant 1 -- Alternative 1-2	80%	20%				12.0	3.0				5,475
Plant 1 -- Alternative 1-3	80%	20%				12.0	3.0				5,475
Plant 1 -- Alternative 1-4	80%	10%	10%			12.0	1.5	1.5			5,475
Plant 1 -- Alternative 1-5	80%	10%	10%			12.0	1.5	1.5			5,475
Plant 1 -- Alternative 1-6	80%	10%	10%			12.0	1.5	1.5			5,475
GW -- Alternative 2-1	80%	20%				12.0	3.0				5,475
GW -- Alternative 2-2	80%	20%				12.0	3.0				5,475
GW -- Alternative 2-3	80%	20%				12.0	3.0				5,475
GW -- Alternative 2-4	80%	10%	10%			12.0	1.5	1.5			5,475
GW -- Alternative 2-5	80%	10%	10%			12.0	1.5	1.5			5,475
DWSD -- Alternative 3-1				100%					15.0		5,475
DWSD -- Alternative 3-2				100%					15.0		5,475
DWSD -- Alternative 3-3				56%	44%				8.4	6.6	5,475
DWSD -- Alternative 3-4	87%			13%		13.1			2.0		5,475
DWSD -- Alternative 3-5	87%			13%		13.1			2.0		5,475

Appendix TM1.C.1
Capital Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Average Day Demand 15 **mgd**

Capacity (mgd)	Component (0)	(1.1)	(1.2)	(2)	(3.0)	(3.1SF)	(3.1NE)	(3.2SF)	(3.2NE)	(4)	(5)	(6.1)	(6.2)	(7.1SF)	(7.1NE)
	Capital Cost ($M)														
4.5															
11				$5.9		$6.1	$6.1	$6.5	$6.5	$42.2	$48.6	$35.7	$9.6	$39.5	$39.5
22		$26.6						$12.9			$58.3	$42.8	$19.2	$64.1	
28											$68.0	$49.9	$24.4		
50											$97.2	$71.3	$43.6		

Alternative	BP Exist PS (mgd)	Plant 1 (mgd)	Plant 2 (mgd)	SF Pipe (2) (mgd)	SF Exist Wellfield (mgd)	SF New Wellfield (mgd)	NE New Wellfield (mgd)	SF New WF PS (mgd)	NE New WF PS (mgd)	SF Pipe (4) (mgd)	NE WF Pipe (5) (mgd)	DWSD JR Pipe (6) (mgd)	DWSD JR PS (mgd)	SF Remote GW WTP (mgd)	NE Remote GW WTP (mgd)
Plant 1 -- Alternative 1-1	40	22	28	4.5	11										
Plant 1 -- Alternative 1-2	40	22	28	11	11										
Plant 1 -- Alternative 1-3	40	22	28	11	11	11		11		11					
Plant 1 -- Alternative 1-4	40	22	28	11	11		11		11		11				
Plant 1 -- Alternative 1-5	40	22	28	11	11		11		11		11	11	11		
Plant 1 -- Alternative 1-6	40	22	28	11	11		11		11		22	22	22		
GW -- Alternative 2-1	40		28	11	11			11						11	
GW -- Alternative 2-2	40		28	11	11	11		22		11				22	
GW -- Alternative 2-3	40		28	11	11	11		22						22	
GW -- Alternative 2-4	40		28	11	11		11	11	11		11			11	11
GW -- Alternative 2-5	40		28	11	11		11	11	11					11	11
DWSD -- Alternative 3-1											50	50	50		
DWSD -- Alternative 3-2	40		28	4.5	11						50	50	50		
DWSD -- Alternative 3-3				11						11	28	28	28		
DWSD -- Alternative 3-4	40		28	4.5	11						22	22	22		
DWSD -- Alternative 3-5	40		28	11	11						22	22	22		

Alternative	BP Exist PS ($M)	Plant 1 ($M)	Plant 2 ($M)	SF Pipe (2) ($M)	SF Exist Wellfield ($M)	SF New Wellfield ($M)	NE New Wellfield ($M)	SF New WF PS ($M)	NE New WF PS ($M)	SF Pipe (4) ($M)	NE WF Pipe (5) ($M)	DWSD JR Pipe (6) ($M)	DWSD JR PS ($M)	SF Remote GW WTP ($M)	NE Remote GW WTP ($M)
Plant 1 -- Alternative 1-1		$26.6													
Plant 1 -- Alternative 1-2		$26.6		$5.9											
Plant 1 -- Alternative 1-3		$26.6		$5.9		$6.1		$6.5		$42.2					
Plant 1 -- Alternative 1-4		$26.6		$5.9			$6.1		$6.5		$48.6				
Plant 1 -- Alternative 1-5		$26.6		$5.9			$6.1		$6.5		$48.6	$35.7	$9.6		
Plant 1 -- Alternative 1-6		$26.6		$5.9			$6.1		$6.5		$58.3	$42.8	$19.2		
GW -- Alternative 2-1				$5.9				$6.5						$39.5	
GW -- Alternative 2-2				$5.9		$6.1		$12.9		$42.2				$64.1	
GW -- Alternative 2-3				$5.9		$6.1		$12.9						$64.1	
GW -- Alternative 2-4				$5.9			$6.1	$6.5	$6.5		$48.6			$39.5	$39.5
GW -- Alternative 2-5				$5.9			$6.1	$6.5	$6.5					$39.5	$39.5
DWSD -- Alternative 3-1											$97.2	$71.3	$43.6		
DWSD -- Alternative 3-2											$97.2	$71.3	$43.6		
DWSD -- Alternative 3-3				$5.9						$42.2	$68.0	$49.9	$24.4		
DWSD -- Alternative 3-4											$58.3	$42.8	$19.2		
DWSD -- Alternative 3-5				$5.9							$58.3	$42.8	$19.2		
Salvage Value (0=no, 1=yes)	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
Salvage Factor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.34	0.34	0.00	0.00	0.00

Appendix TM1.C.1
Capital Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Capacity (mgd)	Component (8)	(9)	(10.1)	(10.2)
	Capital Cost ($M)			
4.5				
11	$8.1	$25.0		
22			$82.2	$17.1
28				
50				

Alternative	SF Loop Pipe (8) (mgd)	NE Loop Pipe (9) (mgd)	DWSD YP Pipe (10) (mgd)	DWSD YP PS (mgd)
Plant 1 -- Alternative 1-1				
Plant 1 -- Alternative 1-2				
Plant 1 -- Alternative 1-3				
Plant 1 -- Alternative 1-4				
Plant 1 -- Alternative 1-5				
Plant 1 -- Alternative 1-6				
GW -- Alternative 2-1				
GW -- Alternative 2-2				
GW -- Alternative 2-3	11			
GW -- Alternative 2-4				
GW -- Alternative 2-5		11		
DWSD -- Alternative 3-1				
DWSD -- Alternative 3-2				
DWSD -- Alternative 3-3			22	22
DWSD -- Alternative 3-4				
DWSD -- Alternative 3-5				

Alternative	SF Loop Pipe (8) ($M)	NE Loop Pipe (9) ($M)	DWSD YP Pipe (10) ($M)	DWSD YP PS ($M)	Total Capital ($M)	Salvage Value ($M)
Plant 1 -- Alternative 1-1					$27	$0
Plant 1 -- Alternative 1-2					$32	$0
Plant 1 -- Alternative 1-3					$87	$14
Plant 1 -- Alternative 1-4					$94	$17
Plant 1 -- Alternative 1-5					$139	$29
Plant 1 -- Alternative 1-6					$165	$34
GW -- Alternative 2-1					$52	$0
GW -- Alternative 2-2					$131	$14
GW -- Alternative 2-3	$8.1				$97	$0
GW -- Alternative 2-4					$153	$17
GW -- Alternative 2-5		$25.0			$129	$0
DWSD -- Alternative 3-1					$212	$57
DWSD -- Alternative 3-2					$212	$57
DWSD -- Alternative 3-3			$82.2	$17.1	$290	$55
DWSD -- Alternative 3-4					$120	$34
DWSD -- Alternative 3-5					$126	$34
Salvage Value (0=no, 1=yes)	1	1	1	0		
Salvage Factor	0.34	0.34	0.34	0.00		

Appendix TM1.C.2
OMRR Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Average Day Demand	15	mgd

	Sources of Supply					Sources of Supply					
Alternative	Huron River (percent)	Steere Farm (percent)	Northeast Aquifer (percent)	DWSD Joy Rd (percent)	DWSD Ypsilanti (percent)	Huron River (mgd)	Steere Farm (mgd)	Northeast Aquifer (mgd)	DWSD Joy Rd (mgd)	DWSD Ypsilanti (mgd)	Total (MG)
Plant 1 -- Alternative 1-1	80%	20%				12.0	3.0				5,475
Plant 1 -- Alternative 1-2	80%	20%				12.0	3.0				5,475
Plant 1 -- Alternative 1-3	80%	20%				12.0	3.0				5,475
Plant 1 -- Alternative 1-4	80%	10%	10%			12.0	1.5	1.5			5,475
Plant 1 -- Alternative 1-5	80%	10%	10%			12.0	1.5	1.5			5,475
Plant 1 -- Alternative 1-6	80%	10%	10%			12.0	1.5	1.5			5,475
GW -- Alternative 2-1	80%	20%				12.0	3.0				5,475
GW -- Alternative 2-2	80%	20%				12.0	3.0				5,475
GW -- Alternative 2-3	80%	20%				12.0	3.0				5,475
GW -- Alternative 2-4	80%	10%	10%			12.0	1.5	1.5			5,475
GW -- Alternative 2-5	80%	10%	10%			12.0	1.5	1.5			5,475
DWSD -- Alternative 3-1				100%					15.0		5,475
DWSD -- Alternative 3-2				100%					15.0		5,475
DWSD -- Alternative 3-3				56%	44%				8.4	6.6	5,475
DWSD -- Alternative 3-4	87%			13%		13.1			2.0		5,475
DWSD -- Alternative 3-5	87%			13%		13.1			2.0		5,475

Appendix TM1.C.2
OMRR Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Average Day Demand 15 **mgd**

Source Water Pumping

	Pumping Unit Costs (kWh/MG)					Pumping Unit Costs ($/kWh)					
	1,030	1,713	1,713	2,248	2,200	$0.0888	$0.0888	$0.0888	$0.0888	$0.0888	Unit power cost per COAA

	Source Water Pumping					Source Water Pumping Cost					
Alternative	Huron River (kWh)	Steere Farm (kWh)	Northeast Aquifer (kWh)	DWSD Joy Rd (kWh)	DWSD Ypsilanti (kWh)	Huron River ($/yr)	Steere Farm ($/yr)	Northeast Aquifer ($/yr)	DWSD Joy Rd ($/yr)	DWSD Ypsilanti ($/yr)	Total ($/yr)
Plant 1 -- Alternative 1-1	4,511,400	1,875,735				$400,612	$166,565				$567,178
Plant 1 -- Alternative 1-2	4,511,400	1,875,735				$400,612	$166,565				$567,178
Plant 1 -- Alternative 1-3	4,511,400	1,875,735				$400,612	$166,565				$567,178
Plant 1 -- Alternative 1-4	4,511,400	937,868	937,868			$400,612	$83,283	$83,283			$567,178
Plant 1 -- Alternative 1-5	4,511,400	937,868	937,868			$400,612	$83,283	$83,283			$567,178
Plant 1 -- Alternative 1-6	4,511,400	937,868	937,868			$400,612	$83,283	$83,283			$567,178
GW -- Alternative 2-1	4,511,400	1,875,735				$400,612	$166,565				$567,178
GW -- Alternative 2-2	4,511,400	1,875,735				$400,612	$166,565				$567,178
GW -- Alternative 2-3	4,511,400	1,875,735				$400,612	$166,565				$567,178
GW -- Alternative 2-4	4,511,400	937,868	937,868			$400,612	$83,283	$83,283			$567,178
GW -- Alternative 2-5	4,511,400	937,868	937,868			$400,612	$83,283	$83,283			$567,178
DWSD -- Alternative 3-1				12,307,800					$1,092,933		$1,092,933
DWSD -- Alternative 3-2				12,307,800					$1,092,933		$1,092,933
DWSD -- Alternative 3-3				6,892,368	5,299,800				$612,042	$470,622	$1,082,665
DWSD -- Alternative 3-4	4,906,148			1,600,014		$435,666			$142,081		$577,747
DWSD -- Alternative 3-5	4,906,148			1,600,014		$435,666			$142,081		$577,747

Appendix TM1.C.2
OMRR Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Average Day Demand 15 **mgd**

Treatment

Treatment Unit Costs ($/MG)

80%:20% river:GW blend	$175.73	$175.73	$175.73	$123.00	100 % DWSD
100% GW		$487.22	$487.22	$450.00	Peaking DWSD

DWSD unit treatment costs per current wholesaler rates

Alternative	Treated Water Supplies: Huron River (mgd)	Steere Farm (mgd)	Northeast Aquifer (mgd)	DWSD Joy Rd (mgd)	DWSD Ypsilanti (mgd)	Treatment Cost: Huron River ($/yr)	Steere Farm ($/yr)	Northeast Aquifer ($/yr)	DWSD Joy Rd ($/yr)	DWSD Ypsilanti ($/yr)	Total ($/yr)
Plant 1 -- Alternative 1-1	12.0	3.0				$769,711	$192,428				$962,139
Plant 1 -- Alternative 1-2	12.0	3.0				$769,711	$192,428				$962,139
Plant 1 -- Alternative 1-3	12.0	3.0				$769,711	$192,428				$962,139
Plant 1 -- Alternative 1-4	12.0	1.5	1.5			$769,711	$96,214	$96,214			$962,139
Plant 1 -- Alternative 1-5	12.0	1.5	1.5			$769,711	$96,214	$96,214			$962,139
Plant 1 -- Alternative 1-6	12.0	1.5	1.5			$769,711	$96,214	$96,214			$962,139
GW -- Alternative 2-1	12.0	3.0				$769,711	$533,507				$1,303,218
GW -- Alternative 2-2	12.0	3.0				$769,711	$533,507				$1,303,218
GW -- Alternative 2-3	12.0	3.0				$769,711	$533,507				$1,303,218
GW -- Alternative 2-4	12.0	1.5	1.5			$769,711	$266,753	$266,753			$1,303,218
GW -- Alternative 2-5	12.0	1.5	1.5			$769,711	$266,753	$266,753			$1,303,218
DWSD -- Alternative 3-1				15.0					$673,425		$673,425
DWSD -- Alternative 3-2				15.0					$673,425		$673,425
DWSD -- Alternative 3-3				8.4	6.6				$377,118	$296,307	$673,425
DWSD -- Alternative 3-4	13.1			2.0		$837,061			$320,288		$1,157,348
DWSD -- Alternative 3-5	13.1			2.0		$837,061			$320,288		$1,157,348

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Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Average Day Demand 15 **mgd**

Residuals Handling and Disposal

	Residuals Unit Production (Ton/MG)				Residuals Unit Costs ($/Ton)			
Existing Split Treatment	3,970	3,970	3,970	0	$17.46	$17.46	$17.46	0.00
Single Stage (Lime-Caustic)	6,383	6,383	6,383	0				
Solids Content	65%	65%	65%	65%				

Unit disposal cost per COAA

	Residuals Production				Residual Disposal Costs				
Alternative	Huron River (Ton)	Steere Farm (Ton)	Northeast Aquifer (Ton)	DWSD (Ton)	Huron River ($/yr)	Steere Farm ($/yr)	Northeast Aquifer ($/yr)	DWSD ($/yr)	Total ($/yr)
Plant 1 -- Alternative 1-1	13,375	3,344			$233,566	$58,392			$291,958
Plant 1 -- Alternative 1-2	13,375	3,344			$233,566	$58,392			$291,958
Plant 1 -- Alternative 1-3	13,375	3,344			$233,566	$58,392			$291,958
Plant 1 -- Alternative 1-4	13,375	1,672	1,672		$233,566	$29,196	$29,196		$291,958
Plant 1 -- Alternative 1-5	13,375	1,672	1,672		$233,566	$29,196	$29,196		$291,958
Plant 1 -- Alternative 1-6	13,375	1,672	1,672		$233,566	$29,196	$29,196		$291,958
GW -- Alternative 2-1	13,375	5,376			$233,566	$93,880			$327,447
GW -- Alternative 2-2	13,375	5,376			$233,566	$93,880			$327,447
GW -- Alternative 2-3	13,375	5,376			$233,566	$93,880			$327,447
GW -- Alternative 2-4	13,375	2,688	2,688		$233,566	$46,940	$46,940		$327,447
GW -- Alternative 2-5	13,375	2,688	2,688		$233,566	$46,940	$46,940		$327,447
DWSD -- Alternative 3-1									
DWSD -- Alternative 3-2									
DWSD -- Alternative 3-3									
DWSD -- Alternative 3-4	14,546				$254,003				$254,003
DWSD -- Alternative 3-5	14,546				$254,003				$254,003

Appendix TM1.C.2
OMRR Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Average Day Demand 15 **mgd**

Labor

Position descriptions and salary rates per COAA

	Labor FTEs					Labor Costs				
Alternative	Admin (FTE)	Operations (FTE)	Laboratory (FTE)	Maint (FTE)	Total (FTE)	Admin ($/yr)	Operations ($/yr)	Laboratory ($/yr)	Maint ($/yr)	Total ($/yr)
Plant 1 -- Alternative 1-1	5.0	16.0	1.5	5.0	27.5	$639,350	$1,810,700	$141,550	$634,600	$3,226,200
Plant 1 -- Alternative 1-2	5.0	16.0	1.5	5.0	27.5	$639,350	$1,810,700	$141,550	$634,600	$3,226,200
Plant 1 -- Alternative 1-3	5.0	16.0	1.5	5.0	27.5	$639,350	$1,810,700	$141,550	$634,600	$3,226,200
Plant 1 -- Alternative 1-4	5.0	16.0	1.5	5.0	27.5	$639,350	$1,810,700	$141,550	$634,600	$3,226,200
Plant 1 -- Alternative 1-5	5.0	16.0	1.5	5.0	27.5	$639,350	$1,810,700	$141,550	$634,600	$3,226,200
Plant 1 -- Alternative 1-6	5.0	16.0	1.5	5.0	27.5	$639,350	$1,810,700	$141,550	$634,600	$3,226,200
GW -- Alternative 2-1	6.0	21.0	1.5	6.0	34.5	$799,900	$2,300,900	$141,550	$729,600	$3,971,950
GW -- Alternative 2-2	6.0	22.0	1.5	7.0	36.5	$799,900	$2,382,600	$141,550	$805,600	$4,129,650
GW -- Alternative 2-3	6.0	22.0	1.5	7.0	36.5	$799,900	$2,382,600	$141,550	$805,600	$4,129,650
GW -- Alternative 2-4	7.0	28.0	1.5	8.0	44.5	$960,450	$3,009,600	$141,550	$881,600	$4,993,200
GW -- Alternative 2-5	7.0	28.0	1.5	8.0	44.5	$960,450	$3,009,600	$141,550	$881,600	$4,993,200
DWSD -- Alternative 3-1	4.0		1.5	4.0	9.5	$528,200		$141,550	$510,150	$1,179,900
DWSD -- Alternative 3-2	4.0	6.0	1.5	4.0	15.5	$528,200	$649,800	$141,550	$510,150	$1,829,700
DWSD -- Alternative 3-3	4.0		1.5	4.0	9.5	$528,200		$141,550	$510,150	$1,179,900
DWSD -- Alternative 3-4	5.0	12.0	1.5	5.0	23.5	$639,350	$1,360,400	$141,550	$614,650	$2,755,950
DWSD -- Alternative 3-5	5.0	12.0	1.5	5.0	23.5	$639,350	$1,360,400	$141,550	$614,650	$2,755,950

Appendix TM1.C.2
OMRR Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Average Day Demand 15 **mgd**

Capacity (mgd)	Component (0)	(1.1)	(1.0)	(2)	(3.0)	(3.1SF)	(3.1NE)	(3.2SF)	(3.2NE)	(4)	(5)	(6.1)	(6.2)	(7.1SF)	(7.1NE)
	Capital Cost ($M)														
4.5				28.1											
11				42.2	$12.6	$6.1	$6.1	$6.5	$6.5	$42.2	$48.6	$35.7	$9.6	$39.5	$39.5
22		$25.3									$56.4	$41.4	$19.2	$64.1	
28			$75.0								$68.0	$49.9	$24.4		
50	$11.0										$97.2	$71.3	$43.6		

R&R Percentage	0.30%	0.40%	0.60%	0.10%	0.30%	0.30%	0.30%	0.30%	0.30%	0.10%	0.10%	0.10%	0.30%	0.30%	0.30%
Alternative	**BP Exist PS (mgd)**	**Plant 1 (mgd)**	**Plant 2 (mgd)**	**SF Pipe (2) (mgd)**	**SF Exist Wellfield (mgd)**	**SF New Wellfield (mgd)**	**NE New Wellfield (mgd)**	**SF New WF PS (mgd)**	**NE New WF PS (mgd)**	**SF Pipe (4) (mgd)**	**NE WF Pipe (5) (mgd)**	**DWSD JR Pipe (6) (mgd)**	**DWSD JR PS (mgd)**	**SF Remote GW WTP (mgd)**	**NE Remote GW WTP (mgd)**
Plant 1 -- Alternative 1-1	40	22	28	4.5	11										
Plant 1 -- Alternative 1-2	40	22	28	11	11										
Plant 1 -- Alternative 1-3	40	22	28	11	11	11		11		11					
Plant 1 -- Alternative 1-4	40	22	28	11	11		11		11		11				
Plant 1 -- Alternative 1-5	40	22	28	11	11		11		11		11	11	11		
Plant 1 -- Alternative 1-6	40	22	28	11	11		11		11		22	22	22		
GW -- Alternative 2-1	40		28	11	11			11						11	
GW -- Alternative 2-2	40		28	11	11	11		22		11				22	
GW -- Alternative 2-3	40		28	11	11	11		22						22	
GW -- Alternative 2-4	40		28	11	11		11	11	11		11			11	11
GW -- Alternative 2-5	40		28	11	11		11	11	11					11	11
DWSD -- Alternative 3-1											50	50	50		
DWSD -- Alternative 3-2	40		28	4.5	11						50	50	50		
DWSD -- Alternative 3-3				11						11	28	28	28		
DWSD -- Alternative 3-4	40		28	4.5	11						22	22	22		
DWSD -- Alternative 3-5	40		28	11	11						22	22	22		

Alternative	BP Exist PS ($yr)	Plant 1 ($/yr)	Plant 2 ($/yr)	SF Pipe (2) ($/yr)	SF Exist Wellfield ($/yr)	SF New Wellfield ($/yr)	NE New Wellfield ($/yr)	SF New WF PS ($/yr)	NE New WF PS ($/yr)	SF Pipe (4) ($/yr)	NE WF Pipe (5) ($/yr)	DWSD JR Pipe (6) ($/yr)	DWSD JR PS ($/yr)	SF Remote GW WTP ($/yr)	NE Remote GW WTP ($/yr)
Plant 1 -- Alternative 1-1		$101,000	$450,000	$28,133	$37,710										
Plant 1 -- Alternative 1-2		$101,000	$450,000	$42,200	$37,710										
Plant 1 -- Alternative 1-3		$101,000	$450,000	$42,200	$37,710	$18,300		$19,410		$42,200					
Plant 1 -- Alternative 1-4		$101,000	$450,000	$42,200	$37,710		$18,300		$19,410		$48,590				
Plant 1 -- Alternative 1-5		$101,000	$450,000	$42,200	$37,710		$18,300		$19,410		$48,590	$35,660	$28,800		
Plant 1 -- Alternative 1-6		$101,000	$450,000	$42,200	$37,710		$18,300		$19,410		$56,427	$41,412	$57,600		
GW -- Alternative 2-1			$450,000	$42,200	$37,710			$19,410						$118,461	
GW -- Alternative 2-2			$450,000	$42,200	$37,710	$18,300				$42,200				$192,441	
GW -- Alternative 2-3			$450,000	$42,200	$37,710	$18,300								$192,441	
GW -- Alternative 2-4			$450,000	$42,200	$37,710		$18,300	$19,410	$19,410		$48,590			$118,461	$118,461
GW -- Alternative 2-5			$450,000	$42,200	$37,710		$18,300	$19,410	$19,410					$118,461	$118,461
DWSD -- Alternative 3-1											$97,180	$71,320	$130,909		
DWSD -- Alternative 3-2			$450,000	$28,133	$37,710						$97,180	$71,320	$130,909		
DWSD -- Alternative 3-3				$42,200						$42,200	$68,026	$49,924	$73,309		
DWSD -- Alternative 3-4			$450,000	$28,133	$37,710						$56,427	$41,412	$57,600		
DWSD -- Alternative 3-5			$450,000	$42,200	$37,710						$56,427	$41,412	$57,600		

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Average Day Demand 15 **mgd**

Unit Cost of Service

Alternative	RW Pumping ($/MG)	Treatment ($/MG)	Residuals Disposal ($/MG)	Labor ($/MG)	R&R ($/MG)	Total ($/MG)
Plant 1 -- Alternative 1-1	$104	$176	$53	$589	$113	$1,035
Plant 1 -- Alternative 1-2	$104	$176	$53	$589	$115	$1,037
Plant 1 -- Alternative 1-3	$104	$176	$53	$589	$130	$1,052
Plant 1 -- Alternative 1-4	$104	$176	$53	$589	$131	$1,053
Plant 1 -- Alternative 1-5	$104	$176	$53	$589	$143	$1,065
Plant 1 -- Alternative 1-6	$104	$176	$53	$589	$151	$1,072
GW -- Alternative 2-1	$104	$238	$60	$725	$122	$1,249
GW -- Alternative 2-2	$104	$238	$60	$754	$143	$1,299
GW -- Alternative 2-3	$104	$238	$60	$754	$137	$1,292
GW -- Alternative 2-4	$104	$238	$60	$912	$159	$1,473
GW -- Alternative 2-5	$104	$238	$60	$912	$155	$1,468
DWSD -- Alternative 3-1	$200	$123	$0	$216	$55	$593
DWSD -- Alternative 3-2	$200	$123	$0	$334	$149	$806
DWSD -- Alternative 3-3	$198	$123	$0	$216	$75	$611
DWSD -- Alternative 3-4	$106	$211	$46	$503	$123	$989
DWSD -- Alternative 3-5	$106	$211	$46	$503	$125	$992

Total Annual OMR&R Cost

Alternative		Total ($)
Plant 1 -- Alternative 1-1		$5,660,000
Plant 1 -- Alternative 1-2		$5,680,000
Plant 1 -- Alternative 1-3		$5,760,000
Plant 1 -- Alternative 1-4		$5,760,000
Plant 1 -- Alternative 1-5		$5,830,000
Plant 1 -- Alternative 1-6		$5,870,000
GW -- Alternative 2-1		$6,840,000
GW -- Alternative 2-2		$7,110,000
GW -- Alternative 2-3		$7,080,000
GW -- Alternative 2-4		$8,060,000
GW -- Alternative 2-5		$8,040,000
DWSD -- Alternative 3-1		$3,250,000
DWSD -- Alternative 3-2		$4,410,000
DWSD -- Alternative 3-3		$3,350,000
DWSD -- Alternative 3-4		$5,420,000
DWSD -- Alternative 3-5		$5,430,000

Component	(8)	(9)	(10.1)	(10.2)	Capacity (mgd)
Capital Cost ($M)					
					4.5
	$8.1	$25.0			11
			$82.2	$17.1	22
					28
					50

Does not meet MUST criteria

Alternative	SF Loop Pipe (8) (mgd)	NE Loop Pipe (9) (mgd)	DWSD YP Pipe (10) (mgd)	DWSD YP PS (mgd)	Treatment Capacity (mgd)	Purchased Water (mgd)	Firm[1,2] Supply (mgd)
R&R Percentage	0.10%	0.10%	0.10%	0.30%			
Plant 1 -- Alternative 1-1					50	0	4.5
Plant 1 -- Alternative 1-2					50	0	11
Plant 1 -- Alternative 1-3					50	0	22
Plant 1 -- Alternative 1-4					50	0	22
Plant 1 -- Alternative 1-5					50	11	22
Plant 1 -- Alternative 1-6					50	22	33
GW -- Alternative 2-1					39	0	11
GW -- Alternative 2-2					50	0	22
GW -- Alternative 2-3	11				50	0	22
GW -- Alternative 2-4					50	0	22
GW -- Alternative 2-5		11			50	0	22
DWSD -- Alternative 3-1					0	50	0
DWSD -- Alternative 3-2					28	50	28
DWSD -- Alternative 3-3			22	22	0	50	22
DWSD -- Alternative 3-4					28	22	22
DWSD -- Alternative 3-5					28	22	22

[1]Largest supply unavailable
[2]Untreated GW not included

Alternative	SF Loop Pipe (8) ($/yr)	NE Loop Pipe (9) ($/yr)	DWSD YP Pipe (10) ($/yr)	DWSD YP PS ($/yr)	Total R&R Cost ($/yr)
Plant 1 -- Alternative 1-1					$616,843
Plant 1 -- Alternative 1-2					$630,910
Plant 1 -- Alternative 1-3					$710,820
Plant 1 -- Alternative 1-4					$717,210
Plant 1 -- Alternative 1-5					$781,670
Plant 1 -- Alternative 1-6					$824,059
GW -- Alternative 2-1					$667,781
GW -- Alternative 2-2					$782,851
GW -- Alternative 2-3	$8,110				$748,761
GW -- Alternative 2-4					$872,542
GW -- Alternative 2-5		$25,020			$848,972
DWSD -- Alternative 3-1					$299,409
DWSD -- Alternative 3-2					$815,252
DWSD -- Alternative 3-3			$82,170	$51,390	$409,219
DWSD -- Alternative 3-4					$671,282
DWSD -- Alternative 3-5					$685,349

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Appendix TM1.C.3
Life-Cycle Net Present Value Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Ave Day Demand	15	mgd
Annual Production	5,475	MG

Economic Evaluation

Capital cost based on design flow, OMR&R cost based on average flow.

Life-Cycle Economic Parameters

Base Year =	2014
General Inflation Rate =	4.0%
OMR&R Inflation Rate =	5.0%
Loan Interest Rate =	3.9%
Discount Rate (PW) =	1.9%
Loan Duration (yrs) =	30

NPV Factor	NPV Factor
1.30	49.36

Alternative	Capital Cost ($)	Annual OMR&R Cost ($)	Life-Cycle NVP ($)	Relative Value Capital	Relative Value OMR&R	Relative Value NPV
Plant 1 -- Alternative 1-1	$26,600,000	$5,660,000	$313,880,000	100%	174%	100%
Plant 1 -- Alternative 1-2	$32,500,000	$5,680,000	$322,520,000	122%	175%	103%
Plant 1 -- Alternative 1-3	$87,270,000	$5,760,000	$383,130,000	328%	177%	122%
Plant 1 -- Alternative 1-4	$93,660,000	$5,760,000	$389,240,000	352%	177%	124%
Plant 1 -- Alternative 1-5	$138,920,000	$5,830,000	$439,240,000	522%	179%	140%
Plant 1 -- Alternative 1-6	$165,370,000	$5,870,000	$469,780,000	622%	181%	150%
GW -- Alternative 2-1	$51,860,000	$6,840,000	$404,890,000	195%	210%	129%
GW -- Alternative 2-2	$131,290,000	$7,110,000	$506,870,000	494%	219%	161%
GW -- Alternative 2-3	$97,200,000	$7,080,000	$475,560,000	365%	218%	152%
GW -- Alternative 2-4	$152,500,000	$8,060,000	$579,090,000	573%	248%	184%
GW -- Alternative 2-5	$128,930,000	$8,040,000	$564,110,000	485%	247%	180%
DWSD -- Alternative 3-1	$212,140,000	$3,250,000	$378,140,000	798%	100%	120%
DWSD -- Alternative 3-2	$212,140,000	$4,410,000	$435,400,000	798%	136%	139%
DWSD -- Alternative 3-3	$289,790,000	$3,350,000	$486,660,000	1089%	103%	155%
DWSD -- Alternative 3-4	$120,300,000	$5,420,000	$389,100,000	452%	167%	124%
DWSD -- Alternative 3-5	$126,200,000	$5,430,000	$397,250,000	474%	167%	127%

Appendix TM1.C.3
Life-Cycle Net Present Value Summary Sheet

Capital NPV Factor	1.30	Pipe Useful Life	75
OMR&R NPV Factor	49.36	Pipe Salvage Factor	0.34

Year	Yr	PW	General	OM&R	Current Annual	Present Value	Current Annual	Inflated Annual	Present Value	Net Present
2014	0	1.000	1	1	$0	$0	$0	$0	$0	$0
2015	1	0.981	1.040	1.050	$1,256,860	$1,233,425	$100,000	$105,000	$103,042	$1,336,467
2016	2	0.963	1.082	1.103	$1,256,860	$1,210,427	$100,000	$110,250	$106,177	$1,316,604
2017	3	0.945	1.125	1.158	$1,256,860	$1,187,858	$100,000	$115,763	$109,407	$1,297,265
2018	4	0.927	1.170	1.216	$1,256,860	$1,165,709	$100,000	$121,551	$112,735	$1,278,444
2019	5	0.910	1.217	1.276	$1,256,860	$1,143,974	$100,000	$127,628	$116,165	$1,260,139
2020	6	0.893	1.265	1.340	$1,256,860	$1,122,643	$100,000	$134,010	$119,699	$1,242,342
2021	7	0.877	1.316	1.407	$1,256,860	$1,101,711	$100,000	$140,710	$123,341	$1,225,051
2022	8	0.860	1.369	1.477	$1,256,860	$1,081,169	$100,000	$147,746	$127,093	$1,208,261
2023	9	0.844	1.423	1.551	$1,256,860	$1,061,009	$100,000	$155,133	$130,959	$1,191,969
2024	10	0.828	1.480	1.629	$1,256,860	$1,041,226	$100,000	$162,889	$134,943	$1,176,169
2025	11	0.813	1.539	1.710	$1,256,860	$1,021,812	$100,000	$171,034	$139,048	$1,160,860
2026	12	0.798	1.601	1.796	$1,256,860	$1,002,759	$100,000	$179,586	$143,279	$1,146,038
2027	13	0.783	1.665	1.886	$1,256,860	$984,062	$100,000	$188,565	$147,637	$1,131,700
2028	14	0.768	1.732	1.980	$1,256,860	$965,714	$100,000	$197,993	$152,129	$1,117,842
2029	15	0.754	1.801	2.079	$1,256,860	$947,707	$100,000	$207,893	$156,757	$1,104,464
2030	16	0.740	1.873	2.183	$1,256,860	$930,036	$100,000	$218,287	$161,526	$1,091,562
2031	17	0.726	1.948	2.292	$1,256,860	$912,695	$100,000	$229,202	$166,440	$1,079,135
2032	18	0.713	2.026	2.407	$1,256,860	$895,677	$100,000	$240,662	$171,503	$1,067,180
2033	19	0.699	2.107	2.527	$1,256,860	$878,977	$100,000	$252,695	$176,721	$1,055,697
2034	20	0.686	2.191	2.653	$1,256,860	$862,588	$100,000	$265,330	$182,097	$1,044,684
2035	21	0.674	2.279	2.786	$1,256,860	$846,504	$100,000	$278,596	$187,637	$1,034,141
2036	22	0.661	2.370	2.925	$1,256,860	$830,720	$100,000	$292,526	$193,345	$1,024,065
2037	23	0.649	2.465	3.072	$1,256,860	$815,231	$100,000	$307,152	$199,227	$1,014,458
2038	24	0.637	2.563	3.225	$1,256,860	$800,030	$100,000	$322,510	$205,288	$1,005,318
2039	25	0.625	2.666	3.386	$1,256,860	$785,113	$100,000	$338,635	$211,533	$996,646
2040	26	0.613	2.772	3.556	$1,256,860	$770,474	$100,000	$355,567	$217,968	$988,442
2041	27	0.602	2.883	3.733	$1,256,860	$756,108	$100,000	$373,346	$224,599	$980,707
2042	28	0.590	2.999	3.920	$1,256,860	$742,010	$100,000	$392,013	$231,432	$973,442
2043	29	0.579	3.119	4.116	$1,256,860	$728,175	$100,000	$411,614	$238,473	$966,647
2044	30	0.569	3.243	4.322	$1,256,860	$714,597	$100,000	$432,194	$245,727	$960,325
	Total				$37,705,800	**$28,540,141**	$3,000,000	$6,976,079	**$4,935,926**	**$33,476,066**

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Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Component
(2.0) Upgrades to Existing Steere Farms Pipeline

			ENR CCI =	10,634
Item Description	Quantity	Unit	Unit Cost $	Total Cost $
Construction / Installation Costs				
Pipeline Lining / Replacement (Per CH2 2006 Report Escalated)	1	Lump Sum	2,952,376	2,952,376
Subtotal				2,952,376
General Requirements				
Mobilization	5.0%	Lump Sum		147,619
Supervision/Overhead	8.0%	Lump Sum		236,190
Bonds/Insurance	3.0%	Lump Sum		88,571
Profit	4.0%	Lump Sum		118,095
Subtotal				590,475
Construction Subtotal (w/o Contingency)				3,542,851
30% Contingencies Class 4				1,062,855
Construction Subtotal (w/ Contingency)				4,605,706
28% Engineering, Legal, Admin, Permitting, and Construction Phase Services				1,289,598
Subtotal				5,895,304
Land/Easement		Lump Sum		0
Total Cost				5,895,304
				5,900,000

Full Replacement Value of Steere Farms Well Field and Pipeline =	54,770,000
Annual Maintenance and Repair Cost (Excluding Labor) =	0.10%
Annual Maintenance and Repair Cost (Excluding Labor) =	54,770

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Component
(3.1) New 11 mgd Well Field

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
			ENR CCI =	10,634
Construction / Installation Costs				
Well & Pump House (Less than 250 feet deep)	1	Lump Sum	308,431	308,431
Site Electrical	1	Lump Sum	64,256	64,256
16" Lateral Pipes per Well (Up to 4 mgd flow in light urban areas)	750	Feet	217	162,000
Subtotal				534,687
General Requirements				
Mobilization	5.0%	Lump Sum		26,734
Supervision/Overhead	8.0%	Lump Sum		42,775
Bonds/Insurance	3.0%	Lump Sum		16,041
Profit	4.0%	Lump Sum		21,387
Subtotal				106,937
Construction Subtotal (w/o Contingency)				641,624
30% Contingencies Class 4				192,487
Construction Subtotal (w/ Contingency)				834,112
28% Engineering, Legal, Admin, Permitting, and Construction Phase Services				233,551
Subtotal				1,067,663
Land/Easement	1	Lump Sum	150,000	150,000
Total Cost				1,217,663
				1,220,000

Target Well Field Production (mgd) =	11
Average Production per Well (mgd) =	3.33
Number of Wells Required =	4
Standby Well =	1
Total Number of Wells =	5
Total Cost for 11 mgd Well Field =	6,100,000
Electricity Unit Cost ($/kwh)=	0.10
Pump Head- Just Pump to Transfer Pump Station (ft) =	50
Wellfield Power Draw (hp) =	138
Wellfield Power Draw (kw) =	103
(kw-hr/ mil gal) =	225
Cost per mill gal =	22.48
Annual Maintenance and Repair Cost (Excluding Labor) =	0.30%
Annual Maintenance and Repair Cost (Excluding Labor) =	18,300

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Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Component
(3.2) New 11 mgd Well Field Transfer Pump Station

			ENR CCI =	10,634
Item Description	Quantity	Unit	Unit Cost $	Total Cost $
Construction / Installation Costs				
Vertical Pumps in Cans, 325' lift (1000 HGL - 800 HGL + friction)	848	hp	2,850	2,416,581
Site Electrical	1	Lump Sum	750,000	750,000
Subtotal				3,166,581
General Requirements				
Mobilization	5.0%	Lump Sum		158,329
Supervision/Overhead	8.0%	Lump Sum		253,326
Bonds/Insurance	3.0%	Lump Sum		94,997
Profit	4.0%	Lump Sum		126,663
Subtotal				633,316
Construction Subtotal (w/o Contingency)				3,799,897
30% Contingencies Class 4				1,139,969
Construction Subtotal (w/ Contingency)				4,939,867
28% Engineering, Legal, Admin, Permitting, and Construction Phase Services				1,383,163
Subtotal				6,323,029
Land/Easement	1	Lump Sum	150,000	150,000
Total Cost				6,473,029
				6,470,000

Electricity Unit Cost ($/kwh)=	0.10
Power Draw (hp) =	848
Wellfield Power Draw (kw) =	633
(kw-hr/ mil gal) =	1,382
Cost per mill gal =	138.20
Annual Maintenance and Repair Cost (Excluding Labor) =	0.30%
Annual Maintenance and Repair Cost (Excluding Labor) =	19,410

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Component
(4) Steere Farms Well Field Parallel Pipeline

			ENR CCI =	10,634
Item Description	Quantity	Unit	Unit Cost $	Total Cost $
Construction / Installation Costs				
30" Pipeline Moderate Urban	12,870	Feet	487	6,273,000
30" Pipeline Heavy Urban	26,130	Feet	569	14,860,000
Subtotal				21,133,000
General Requirements				
Mobilization	5.0%	Lump Sum		1,056,650
Supervision/Overhead	8.0%	Lump Sum		1,690,640
Bonds/Insurance	3.0%	Lump Sum		633,990
Profit	4.0%	Lump Sum		845,320
Subtotal				4,226,600
Construction Subtotal (w/o Contingency)				25,359,600
30% Contingencies Class 4				7,607,880
Construction Subtotal (w/ Contingency)				32,967,480
28% Engineering, Legal, Admin, Permitting, and Construction Phase Services				9,230,894
Subtotal				42,198,374
Land/Easement (Included in Unit Cost)		Lump Sum		0
Total Cost				42,198,374
				42,200,000

Annual Maintenance and Repair Cost (Excluding Labor) = 0.10%
Annual Maintenance and Repair Cost (Excluding Labor) = 42,200

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Component
(5) Northeast Well Field Pipeline for 11 mgd

ENR CCI = 10,634

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
Construction / Installation Costs				
30" Pipeline Light Urban	40,128	Feet	406	16,300,000
30" Pipeline Heavy Urban	10,022	Feet	569	5,699,000
30" Pipeline River Crossing	1,100	Feet	1,016	1,117,000
30" Pipeline Highway Crossings (2 times)	750	Feet	1,625	1,219,000
Subtotal				24,335,000
General Requirements				
Mobilization	5.0%	Lump Sum		1,216,750
Supervision/Overhead	8.0%	Lump Sum		1,946,800
Bonds/Insurance	3.0%	Lump Sum		730,050
Profit	4.0%	Lump Sum		973,400
Subtotal				4,867,000
Construction Subtotal (w/o Contingency)				29,202,000
30% Contingencies Class 4				8,760,600
Construction Subtotal (w/ Contingency)				37,962,600
28% Engineering, Legal, Admin, Permitting, and Construction Phase Services				10,629,528
Subtotal				48,592,128
Land/Easement (Included in Unit Cost)		Lump Sum		0
Total Cost				48,592,128
				48,590,000

Annual Maintenance and Repair Cost (Excluding Labor) = 0.10%
Annual Maintenance and Repair Cost (Excluding Labor) = 48,590

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Component
(6.1) Joy Rd Pipe from DWSD Joy Rd Tank to NE Well Field Pipe

ENR CCI = 10,634

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
Construction / Installation Costs				
30" Pipeline Light Urban	21,120	Feet	406	8,579,000
30" Pipeline Rural	26,880	Feet	345	9,281,000
30" Pipeline River Crossing		Feet	1,016	0
30" Pipeline Highway Crossings (2 times)		Feet	1,625	0
Subtotal				17,860,000
General Requirements				
Mobilization	5.0%	Lump Sum		893,000
Supervision/Overhead	8.0%	Lump Sum		1,428,800
Bonds/Insurance	3.0%	Lump Sum		535,800
Profit	4.0%	Lump Sum		714,400
Subtotal				3,572,000
Construction Subtotal (w/o Contingency)				21,432,000
30% Contingencies Class 4				6,429,600
Construction Subtotal (w/ Contingency)				27,861,600
28% Engineering, Legal, Admin, Permitting, and Construction Phase Services				7,801,248
Subtotal				35,662,848
Land/Easement (Included in Unit Cost)		Lump Sum		0
Total Cost				35,662,848
				35,660,000

Annual Maintenance and Repair Cost (Excluding Labor) = 0.10%
Annual Maintenance and Repair Cost (Excluding Labor) = 35,660

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Component
(6.2) New Pump Station at Joy Road DWSD Tank

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
			ENR CCI =	10,634
Construction / Installation Costs				
Vertical Pumps in Cans, 500' lift (1000 HGL - 700 HGL + friction)	1,379	hp	2,850	3,930,264
Site Electrical	1	Lump Sum	750,000	750,000
Subtotal				4,680,264
General Requirements				
Mobilization	5.0%	Lump Sum		234,013
Supervision/Overhead	8.0%	Lump Sum		374,421
Bonds/Insurance	3.0%	Lump Sum		140,408
Profit	4.0%	Lump Sum		187,211
Subtotal				936,053
Construction Subtotal (w/o Contingency)				5,616,317
30% Contingencies Class 4				1,684,895
Construction Subtotal (w/ Contingency)				7,301,212
28% Engineering, Legal, Admin, Permitting, and Construction Phase Services				2,044,339
Subtotal				9,345,551
Land/Easement	1	Lump Sum	250,000	250,000
Total Cost				9,595,551
				9,600,000

Electricity Unit Cost ($/kwh)=	0.10
Power Draw (hp) =	1,379
Wellfield Power Draw (kw) =	1,030
(kw-hr/ mil gal) =	2,248
Cost per mill gal =	224.76
Annual Maintenance and Repair Cost (Excluding Labor) =	0.30%
Annual Maintenance and Repair Cost (Excluding Labor) =	28,800

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Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Component
(8) Pipeline from Steere Farms Well Field to 20" Loop

ENR CCI = 10,634

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
Construction / Installation Costs				
30" Pipeline Moderate Urban	7,000	Feet	406	2,843,000
30" Highway Crossing	750	Feet	1,625	1,219,000
Subtotal				4,062,000
General Requirements				
Mobilization	5.0%	Lump Sum		203,100
Supervision/Overhead	8.0%	Lump Sum		324,960
Bonds/Insurance	3.0%	Lump Sum		121,860
Profit	4.0%	Lump Sum		162,480
Subtotal				812,400
Construction Subtotal (w/o Contingency)				4,874,400
30% Contingencies Class 4				1,462,320
Construction Subtotal (w/ Contingency)				6,336,720
28% Engineering, Legal, Admin, Permitting, and Construction Phase Services				1,774,282
Subtotal				8,111,002
Land/Easement (Included in Unit Cost)		Lump Sum		0
Total Cost				8,111,002
				8,110,000

Annual Maintenance and Repair Cost (Excluding Labor) = 0.10%
Annual Maintenance and Repair Cost (Excluding Labor) = 8,110

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Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Component
(9) Pipeline from NE Well Field to 20" Loop

ENR CCI = 10,634

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
Construction / Installation Costs				
30" Pipeline Light Urban	22,250	Feet	406	9,038,000
30" Pipeline Heavy Urban	4,000	Feet	569	2,275,000
30" Pipeline River Crossing	0	Feet	1,016	0
30" Pipeline Highway Crossings (1 times)	750	Feet	1,625	1,219,000
Subtotal				12,532,000
General Requirements				
Mobilization	5.0%	Lump Sum		626,600
Supervision/Overhead	8.0%	Lump Sum		1,002,560
Bonds/Insurance	3.0%	Lump Sum		375,960
Profit	4.0%	Lump Sum		501,280
Subtotal				2,506,400
Construction Subtotal (w/o Contingency)				15,038,400
30% Contingencies Class 4				4,511,520
Construction Subtotal (w/ Contingency)				19,549,920
28% Engineering, Legal, Admin, Permitting, and Construction Phase Services				5,473,978
Subtotal				25,023,898
Land/Easement (Included in Unit Cost)		Lump Sum		0
Total Cost				25,023,898
				25,020,000

Annual Maintenance and Repair Cost (Excluding Labor) = 0.10%
Annual Maintenance and Repair Cost (Excluding Labor) = 25,020

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Component
(10.1) Pipe from DWSD Ypsilanti PS to Steere Farms Well Field

ENR CCI = 10,634

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
Construction / Installation Costs				
30" Pipeline Light Urban	7,200	Feet	487	3,510,000
30" Pipeline Heavy Urban	44,800	Feet	682	30,572,000
30" Pipeline River Crossing	1,000	Feet	1,219	1,219,000
30" Pipeline Highway Crossings (4 times)	3,000	Feet	1,950	5,849,000
Subtotal				41,150,000
General Requirements				
Mobilization	5.0%	Lump Sum		2,057,500
Supervision/Overhead	8.0%	Lump Sum		3,292,000
Bonds/Insurance	3.0%	Lump Sum		1,234,500
Profit	4.0%	Lump Sum		1,646,000
Subtotal				8,230,000
Construction Subtotal (w/o Contingency)				49,380,000
30% Contingencies Class 4				14,814,000
Construction Subtotal (w/ Contingency)				64,194,000
28% Engineering, Legal, Admin, Permitting, and Construction Phase Services				17,974,320
Subtotal				82,168,320
Land/Easement (Included in Unit Cost)		Lump Sum		0
Total Cost				82,168,320
				82,170,000

Annual Maintenance and Repair Cost (Excluding Labor) = 0.10%
Annual Maintenance and Repair Cost (Excluding Labor) = 82,170

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Component
(10.2) New Pump Station co-located at DWSD Ypsilanti PS

ENR CCI = 10,634

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
Construction / Installation Costs				
Vertical Pumps in Cans, 500' lift (1000 HGL - 700 HGL + friction)	2,703	hp	2,850	7,703,317
Site Electrical	1	Lump Sum	750,000	750,000
Subtotal				8,453,317
General Requirements				
Mobilization	5.0%	Lump Sum		422,666
Supervision/Overhead	8.0%	Lump Sum		676,265
Bonds/Insurance	3.0%	Lump Sum		253,600
Profit	4.0%	Lump Sum		338,133
Subtotal				1,690,663
Construction Subtotal (w/o Contingency)				10,143,981
30% Contingencies Class 4				3,043,194
Construction Subtotal (w/ Contingency)				13,187,175
28% Engineering, Legal, Admin, Permitting, and Construction Phase Services				3,692,409
Subtotal				16,879,584
Land/Easement	1	Lump Sum	250,000	250,000
Total Cost				17,129,584
				17,130,000

Electricity Unit Cost ($/kwh)=	0.10
Power Draw (hp) =	2,703
Wellfield Power Draw (kw) =	2,019
(kw-hr/ mil gal) =	2,203
Cost per mill gal =	220.26
Annual Maintenance and Repair Cost (Excluding Labor) =	0.30%
Annual Maintenance and Repair Cost (Excluding Labor) =	51,390

Appendix TM1.C.5
Treatment Component Cost Summary: High-Rate SCC

Facility Design Parameters:

Ann Arbor, Michigan	Facility Design Capacity, mgd	22		
WTP Alternatives Analysis	Average Day Demand, mgd	15		

Equipment Cost Basis:

Cost Index:	ENR CCI
Location	Detroit
Date	7/7/2014
ENR CCI	10,634

Process Enclosure Unit Costs:

Unit Costs:	($/ft^2)
Conditioned	$250
Shaded	$50
None	$0

Facilities:

		Process Enclosure		Process	Equipment/Basins		Process Enclosure					Footprint	Capital Cost
	Include	Feed Equipment Enclosure	Storage Equipment Enclosure	Flow (mgd)	Installed Cost ($)	Unit Cost ($/gpd)	Area (1) (ft2)	Unit Cost ($/ft^2)	Area (2) (ft2)	Unit Cost ($/ft^2)	Cost ($)	Total (ft2)	Total ($)
Unit Processes	Yes	Varies	Varies	22	$3,677,786	$0.17	5,468	Varies	0	Varies	$1,366,929	5,468	$5,044,716
Chemical Feed Systems	Yes	Varies	Varies	22	$0	$0.00	0	Varies	0	Varies	$0	0	$0
Project Total	Yes	Varies	Varies	22	$3,677,786	$0.17	5,468	Varies	0	Varies	$1,366,929	5,468	$5,044,716

Additional Project Costs (Additive)

Sitework	Yes	Percent of Process Unit Cost	8.0%	$403,577
Yard Piping	Yes	Percent of Process Unit Cost	20.0%	$1,008,943
Site Electrical	Yes	Percent of Process Unit Cost	15.0%	$756,707
Instrumentation/Controls	Yes	Percent of Process Unit Cost	5.0%	$252,236
Total Additional Project Costs			**48.0%**	**$2,421,464**
		Subtotal Including Additional Project Costs		$7,466,179

Contractor Markup Costs (Cumulative)

Overhead	Yes	Percent of Facility Cost + Markups	7.0%	$522,633
Profit	Yes	Percent of Facility Cost + Markups	10.0%	$798,881
Mobilization/Bonds/Insurance	Yes	Percent of Facility Cost + Markups	3.0%	$263,631
Contingency	Yes	Percent of Facility Cost + Markups	4.0%	$362,053
Total Contractor Markups			**26.1%**	**$1,947,197**
		Subtotal Including Construction Markup Costs		$9,413,377

Non-Construction Costs (Additive)

Permitting	Yes	Percent of Construction Cost	1.0%	$94,134
Engineering	Yes	Percent of Construction Cost	8.0%	$753,070
Legal/Administration	Yes	Percent of Construction Cost	0.5%	$47,067
Construction Services	Yes	Percent of Construction Cost	7.0%	$658,936
Commissioning/Startup	Yes	Percent of Construction Cost	3.0%	$282,401
Contingency	Yes	Percent of Construction Cost	30.0%	$2,824,013
Total Non-Construction Costs			**49.5%**	**$4,659,622**
		Subtotal Including Non-Project Costs		$14,072,998

Demolition

Existing Plant 1 Facilities	Yes	Basin 1 and 2		**$900,000**	
		Subtotal Including Demolition Costs		$14,972,998	
Rehabilitation Adjustment Factor			50.0%	$7,486,499	
		Total Project Cost		**$22,459,497**	**$1.02 $/gpd**

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Appendix TM1.C.5
Treatment Component Cost Summary: Rapid Mix

Facility Design Parameters:

			Equipment Cost Basis:		**Process Enclosure Unit Costs:**	
			Cost Index:	ENR CCI	Unit Costs:	($/ft^2)
Ann Arbor, Michigan	Facility Design Capacity, mgd	22	Location	Detroit	Conditioned	$250
WTP Alternatives Analysis	Average Day Demand, mgd	15	Date	7/7/2014	Shaded	$50
			ENR CCI	10,634	None	$0

Facilities:

	Include	Process Enclosure: Feed Equipment Enclosure	Process Enclosure: Storage Equipment Enclosure	Process Flow (mgd)	Equipment/Basins: Installed Cost ($)	Equipment/Basins: Unit Cost ($/gpd)	Process Enclosure: Area (1) (ft2)	Process Enclosure: Unit Cost ($/ft^2)	Process Enclosure: Area (2) (ft2)	Process Enclosure: Unit Cost ($/ft^2)	Process Enclosure: Cost ($)	Footprint Total (ft2)	Capital Cost Total ($)
Unit Processes	Yes	Varies	Varies	22	$55,808	$0.00	51	Varies	0	Varies	$12,765	51	$68,573
Chemical Feed Systems	Yes	Varies	Varies	22	$0	$0.00	0	Varies	0	Varies	$0	0	$0
Project Total	Yes	Varies	Varies	22	$55,808	$0.00	51	Varies	0	Varies	$12,765	51	$68,573

Additional Project Costs (Additive)

Sitework	Yes	Percent of Process Unit Cost	8.0%	$5,486
Yard Piping	Yes	Percent of Process Unit Cost	20.0%	$13,715
Site Electrical	Yes	Percent of Process Unit Cost	15.0%	$10,286
Instrumentation/Controls	Yes	Percent of Process Unit Cost	5.0%	$3,429
Total Additional Project Costs			**48.0%**	**$32,915**
		Subtotal Including Additional Project Costs		$101,488

Contractor Markup Costs (Cumulative)

Overhead	Yes	Percent of Facility Cost + Markups	7.0%	$7,104
Profit	Yes	Percent of Facility Cost + Markups	10.0%	$10,859
Mobilization/Bonds/Insurance	Yes	Percent of Facility Cost + Markups	3.0%	$3,584
Contingency	Yes	Percent of Facility Cost + Markups	4.0%	$4,921
Total Contractor Markups			**26.1%**	**$26,468**
		Subtotal Including Construction Markup Costs		$127,956

Non-Construction Costs (Additive)

Permitting	Yes	Percent of Construction Cost	1.0%	$1,280
Engineering	Yes	Percent of Construction Cost	8.0%	$10,236
Legal/Administration	Yes	Percent of Construction Cost	0.5%	$640
Construction Services	Yes	Percent of Construction Cost	7.0%	$8,957
Commissioning/Startup	Yes	Percent of Construction Cost	3.0%	$3,839
Contingency	Yes	Percent of Construction Cost	30.0%	$38,387
Total Non-Construction Costs			**49.5%**	**$63,338**
		Subtotal Including Non-Project Costs		$191,294

Demolition

Existing Plant 1 Facilities	No	Basin 1 and 2		**$0**	
		Subtotal Including Demolition Costs		$191,294	
Rehabilitation Adjustment Factor			50.0%	$95,647	
		Total Project Cost		**$286,942**	**$0.01 $/gpd**

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Appendix TM1.C.5
Treatment Component Cost Summary: Basin 3 Rehabilitiation

Facility Design Parameters:

			Equipment Cost Basis:		**Process Enclosure Unit Costs:**	
			Cost Index:	ENR CCI	Unit Costs:	($/ft^2)
Ann Arbor, Michigan	Facility Design Capacity, mgd	22	Location	Detroit	Conditioned	$250
WTP Alternatives Analysis	Average Day Demand, mgd	15	Date	7/7/2014	Shaded	$50
			ENR CCI	10,634	None	$0

Facilities:

	Include	Process Enclosure: Feed Equipment Enclosure	Process Enclosure: Storage Equipment Enclosure	Process Flow (mgd)	Equipment/Basins: Installed Cost ($)	Equipment/Basins: Unit Cost ($/gpd)	Process Enclosure: Area (1) (ft2)	Process Enclosure: Unit Cost ($/ft^2)	Process Enclosure: Area (2) (ft2)	Process Enclosure: Unit Cost ($/ft^2)	Process Enclosure: Cost ($)	Footprint Total (ft2)	Capital Cost Total ($)
Unit Processes	Yes	Varies	Varies	22	$175,000	$0.00	0	Varies	0	Varies	$0	0	$175,000
Chemical Feed Systems	Yes	Varies	Varies	22	$0	$0.00	0	Varies	0	Varies	$0	0	$0
Project Total	Yes	Varies	Varies	22	$175,000	$0.00	0	Varies	0	Varies	$0	0	$175,000

Additional Project Costs (Additive)

Sitework	Yes	Percent of Process Unit Cost	5.0%	$8,750
Yard Piping	Yes	Percent of Process Unit Cost	5.0%	$8,750
Site Electrical	Yes	Percent of Process Unit Cost	15.0%	$26,250
Instrumentation/Controls	Yes	Percent of Process Unit Cost	5.0%	$8,750
Total Additional Project Costs			**30.0%**	**$52,500**
		Subtotal Including Additional Project Costs		$227,500

Contractor Markup Costs (Cumulative)

Overhead	Yes	Percent of Facility Cost + Markups	7.0%	$15,925
Profit	Yes	Percent of Facility Cost + Markups	10.0%	$24,343
Mobilization/Bonds/Insurance	Yes	Percent of Facility Cost + Markups	3.0%	$8,033
Contingency	Yes	Percent of Facility Cost + Markups	4.0%	$11,032
Total Contractor Markups			**26.1%**	**$59,333**
		Subtotal Including Construction Markup Costs		$286,833

Non-Construction Costs (Additive)

Permitting	Yes	Percent of Construction Cost	1.0%	$2,868
Engineering	Yes	Percent of Construction Cost	8.0%	$22,947
Legal/Administration	Yes	Percent of Construction Cost	0.5%	$1,434
Construction Services	Yes	Percent of Construction Cost	7.0%	$20,078
Commissioning/Startup	Yes	Percent of Construction Cost	3.0%	$8,605
Contingency	Yes	Percent of Construction Cost	30.0%	$86,050
Total Non-Construction Costs			**49.5%**	**$141,982**
		Subtotal Including Non-Project Costs		$428,815

Demolition

Existing Plant 1 Facilities	No			**$0**	
		Subtotal Including Demolition Costs		$428,815	
Rehabilitation Adjustment Factor			50.0%	$214,407	
		Total Project Cost		**$643,222**	**$0.03 $/gpd**

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Appendix TM1.C.5
Treatment Component Cost Summary: Caustic Storage

Facility Design Parameters:

Ann Arbor, Michigan	Facility Design Capacity, mgd	11
WTP Alternatives Analysis	Average Day Demand, mgd	11

Equipment Cost Basis:

Cost Index:	ENR CCI
Location	Detroit
Date	7/7/2014
ENR CCI	10,634

Process Enclosure Unit Costs:

Unit Costs:	($/ft2)
Conditioned	$250
Shaded	$50
None	$0

Facilities:

		Process Enclosure		Process	Equipment/Basins		Process Enclosure					Footprint	Capital Cost
	Include	Feed Equipment Enclosure	Storage Equipment Enclosure	Flow (mgd)	Installed Cost ($)	Unit Cost ($/gpd)	Area (1) (ft2)	Unit Cost ($/ft2)	Area (2) (ft2)	Unit Cost ($/ft2)	Cost ($)	Total (ft2)	Total ($)
Unit Processes	Yes	Varies	Varies	11	$0	$0.00	0	Varies	0	Varies	$0	0	$0
Chemical Feed Systems	Yes	Varies	Varies	11	$371,962	$0.03	106	Varies	1,459	Varies	$391,400	1,566	$763,362
Project Total	Yes	Varies	Varies	11	$371,962	$0.03	106	Varies	1,459	Varies	$391,400	1,566	$763,362

Additional Project Costs (Additive)

Sitework	Yes	Percent of Process Unit Cost	8.0%	$61,069
Yard Piping	Yes	Percent of Process Unit Cost	20.0%	$152,672
Site Electrical	Yes	Percent of Process Unit Cost	15.0%	$114,504
Instrumentation/Controls	Yes	Percent of Process Unit Cost	5.0%	$38,168
Total Additional Project Costs			**48.0%**	**$366,414**
		Subtotal Including Additional Project Costs		$1,129,776

Contractor Markup Costs (Cumulative)

Overhead	Yes	Percent of Facility Cost + Markups	7.0%	$79,084
Profit	Yes	Percent of Facility Cost + Markups	10.0%	$120,886
Mobilization/Bonds/Insurance	Yes	Percent of Facility Cost + Markups	3.0%	$39,892
Contingency	Yes	Percent of Facility Cost + Markups	4.0%	$54,786
Total Contractor Markups			**26.1%**	**$294,648**
		Subtotal Including Construction Markup Costs		$1,424,424

Non-Construction Costs (Additive)

Permitting	Yes	Percent of Construction Cost	1.0%	$14,244
Engineering	Yes	Percent of Construction Cost	8.0%	$113,954
Legal/Administration	Yes	Percent of Construction Cost	0.5%	$7,122
Construction Services	Yes	Percent of Construction Cost	7.0%	$99,710
Commissioning/Startup	Yes	Percent of Construction Cost	3.0%	$42,733
Contingency	Yes	Percent of Construction Cost	30.0%	$427,327
Total Non-Construction Costs			**49.5%**	**$705,090**
		Subtotal Including Non-Project Costs		$2,129,514

Demolition

Existing Plant 1 Facilities	No			**$0**	
		Subtotal Including Demolition Costs		$2,129,514	
Rehabilitation Adjustment Factor			50.0%	$1,064,757	
		Total Project Cost		**$3,194,272**	**$0.15 $/gpd**

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Appendix TM1.D

Source of Supply and System Reliability Alternatives

Structured Decision Analysis

- **TM1.D.1 Non-Economic Performance Ranking**
- **TM1.D.2 Alternatives Scoring Metrics**
- **TM1.D.3 Sensitivity Analysis**

Appendix TM1.D.1
Decision Model Scoring Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Scoring of Alternatives Against Contributors

	Decision Model Weights				Replace Plant 1 Alternatives					GW Treatment Alternatives				DWSD Wholesale Alternatives			
Decision Statement	**Desires (level-1)**	**Weights**	**Contributors (Level-2)**	**Weights**	**1-2**	**1-3**	**1-4**	**1-5**	**1-6**	**2-2**	**2-3**	**2-4**	**2-5**	**3-2**	**3-3**	**3-4**	**3-5**
Select an SSSR Plan	System Reliability	0.370	DW Supply Reliability	0.118	5	5	8	10	10	5	5	8	8	8	5	8	8
			WQ Vulnerability	0.084	6	6	7	7	7	6	6	7	7	10	10	7	7
			Firm Capacity	0.168	4	8	8	8	10	8	8	8	8	10	8	8	8
	Operational Flexibility	0.333	System Operations	0.185	9	9	9	6	6	6	5	3	2	2	10	6	6
			Distribution Water Quality	0.148	10	10	10	7	7	10	10	10	10	4	4	4	4
	Organizational Impacts	0.296	Utility Staffing	0.074	10	10	10	9	9	5	5	5	5	5	5	5	5
			Intergovernmental Agreements	0.049	10	8	7	1	1	8	8	7	7	7	7	5	5
			Existing Facilities Utilization	0.058	10	10	10	10	10	10	10	10	10	5	5	10	10
			Autonomy	0.082	10	10	10	9	9	10	10	10	10	5	5	7	7
			Sustainability Framework	0.033	10	10	10	10	10	7	7	7	7	3	3	3	3
		1.000		**1.000**													

Alternatives 1-1, 2-1, and 3-1 not listed because they did not meet initial MUST screening criteria

		1-2	1-3	1-4	1-5	1-6	2-2	2-3	2-4	2-5	3-2	3-3	3-4	3-5
System Reliability		0.177	0.244	0.288	0.311	0.345	0.244	0.244	0.288	0.288	0.347	0.278	0.288	0.288
Operational Flexibility		0.315	0.315	0.315	0.215	0.215	0.259	0.241	0.204	0.185	0.096	0.244	0.170	0.170
Organizational Impacts		0.296	0.286	0.281	0.236	0.236	0.240	0.240	0.235	0.235	0.151	0.151	0.187	0.187
Non-Economic Performance Score		**0.788**	**0.845**	**0.884**	**0.762**	**0.796**	**0.743**	**0.724**	**0.726**	**0.708**	**0.595**	**0.674**	**0.645**	**0.645**
Capital Cost	$M	$33	$87	$94	$139	$165	$131	$97	$153	$129	$212	$290	$120	$126
Life-Cycle Net Present Value	$M	$322	$383	$389	$439	$470	$507	$475	$579	$564	$435	$486	$389	$397
Cost/Benefit Ratio -- Capital		$41	$103	$106	$182	$208	$177	$134	$210	$182	$357	$430	$186	$196
Cost/Benefit Ratio -- NPV		$409	$453	$440	$576	$590	$682	$656	$798	$797	$732	$722	$603	$616

Appendix TM1.D.1
Decision Model Scoring Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives
Calculation of Normalized Weights

Desires (Level-1)

Desires (Level-1)		
System Reliability	10	0.370
Operational Flexibility	9	0.333
Organizational Impacts	8	0.296
	27	

Contributors (Level-2)

System Reliability		
DW Supply Reliability	7	0.118
WQ Vulnerability	5	0.084
Firm Capacity	10	0.168
	22	**0.370**

Operational Flexibility		
System Operations	10	0.185
Distribution Water Quality	8	0.148
	18	**0.333**

Organizational Impacts		
Utility Staffing	9	0.074
Intergovernmental Agreements	6	0.049
Existing Facilities Utilization	7	0.058
Autonomy	10	0.082
Sustainability Framework	4	0.033
	36	**0.296**

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Appendix TM1.D.2
Alternative Scoring Metrics

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Drinking Water Supply Reliability Contributor Scoring Summary

Source of Supply and System Reliability Alternatives		**Number of Supplies[1,2]**	**Score[3]**
Replace Plant 1 Options	Plant 1 Replacement Only	2	5
	Plant 1 Replacement & Steere Farm Well Field Conveyance Upgrades	2	5
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd more Steere Farm Wells & Parallel Pipe from Wellfield to WTP	2	5
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wellfield & Pipe from Northeast wells to WTP	3	8
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 11 mgd capacity	4	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 22 mgd capacity	4	10
New Groundwater Treatment Options	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site	2	5
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Parallel Pipeline from Steere Farm	2	5
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Pipe from Steere Farm Wellfield to 20-inch Distribution System Loop	2	5
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to WTP	3	8
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to 20-inch Distribution System Loop	3	8
DWSD Supply Options[4]	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, Build one 50 mgd pipe from DWSD	1	3
	Abandon Plant 1, Keep Plant 2 in Emergency Standby, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 50 mgd pipe from DWSD	3	8
	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, & Build one 28 mgd pipes from DWSD and another 22 mgd pipe from DWSD	2	5
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 22 mgd pipe from DWSD	3	8
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby w/ Conveyance Upgrades, & Build one 22 mgd pipe from DWSD	3	8

(1) No additional benefit for more than 4 unique sources of supply

(2) Must screening criteria required at least 2 unique supplies

(3) Score = round(10*alternative supplies/max supplies)

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Appendix TM1.D.2
Alternative Scoring Metrics

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Water Quality Vulnerability Contributor Scoring Summary

MDEQ SWAP Susceptibility[1]	6	4	2	5	5
Consequence[2]	4	6	6	3	3

Source of Supply and System Reliability Alternatives		BP (mgd)	SF GW (mgd)	NW GW (mgd)	DWSD JR (mgd)	DWSD YP (mgd)	Raw Score[3]	Norm Score[4]
Replace Plant 1 Options	Plant 1 Replacement Only	40	4.5				24.00	6
	Plant 1 Replacement & Steere Farm Well Field Conveyance Upgrades	40	11				24.00	6
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd more Steere Farm Wells & Parallel Pipe from Wellfield to WTP	40	22				24.00	6
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wellfield & Pipe from Northeast wells to WTP	40	11	11			21.87	7
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 11 mgd capacity	40	11	11	11		20.84	7
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 22 mgd capacity	40	11	11	22		20.07	7
New Groundwater Treatment Options	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site	28	11				24.00	6
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Parallel Pipeline from Steere Farm	28	22				24.00	6
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Pipe from Steere Farm Wellfield to 20-inch Distribution System Loop	28	22				24.00	6
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to WTP	28	11	11			21.36	7
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to 20-inch Distribution System Loop	28	11	11			21.36	7
DWSD Supply Options[4]	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, Build one 50 mgd pipe from DWSD				50		15.00	10
	Abandon Plant 1, Keep Plant 2 in Emergency Standby, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 50 mgd pipe from DWSD				50		15.00	10
	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, & Build one 28 mgd pipes from DWSD and another 22 mgd pipe from DWSD				28	22	15.00	10
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 22 mgd pipe from DWSD	28	4.5		22		20.37	7
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby w/ Conveyance Upgrades, & Build one 22 mgd pipe from DWSD	28	11		22		20.75	7

(1) MDEQ SWAP susceptibility rating: 6 is most susceptible to contamination, 1 is least susceptible to contamination

(2) Consequence of contamination: 6 has the most significant long-term consequence if contaminated, 1 has the least significant long-term consequence if contaminated

(3) Raw score = sum(susceptibility*consequence*source capacity)/total source capacity

(4) Normalized score = round(10*minimum raw score/alternative raw score)

Appendix TM1.D.2
Alternative Scoring Metrics

Water Treatment Plant Alternatives Analysis
Source of Supply and System Reliability Alternatives

Firm Capacity Contributor Scoring Summary

Maximum day demand 28 mgd

Source of Supply and System Reliability Alternatives		Firm Capacity	Score(3)
Replace Plant 1 Options	Plant 1 Replacement Only	4.5	2
	Plant 1 Replacement & Steere Farm Well Field Conveyance Upgrades	11	4
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd more Steere Farm Wells & Parallel Pipe from Wellfield to WTP	22	8
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wellfield & Pipe from Northeast wells to WTP	22	8
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 11 mgd capacity	22	8
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 22 mgd capacity	33	10
New Groundwater Treatment Options	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site	11	4
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Parallel Pipeline from Steere Farm	22	8
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Pipe from Steere Farm Wellfield to 20-inch Distribution System Loop	22	8
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to WTP	22	8
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to 20-inch Distribution System Loop	22	8
DWSD Supply Options(4)	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, Build one 50 mgd pipe from DWSD	0	0
	Abandon Plant 1, Keep Plant 2 in Emergency Standby, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 50 mgd pipe from DWSD	28	10
	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, & Build one 28 mgd pipes from DWSD and another 22 mgd pipe from DWSD	22	8
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 22 mgd pipe from DWSD	22	8
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby w/ Conveyance Upgrades, & Build one 22 mgd pipe from DWSD	22	8

(3)Score = round(10*alternative sum/max sum)

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

System Operations Contributor Scoring Summary

Source of Supply and System Reliability Alternatives		EPDS[1]	WTPs[2]	WTPs[3]	Blending[4]	Standby[5]	Score
	Deductions	1	1	3	3	5	
Replace Plant 1 Options	Plant 1 Replacement Only	1	1	0	0	0	9
	Plant 1 Replacement & Steere Farm Well Field Conveyance Upgrades	1	1	0	0	0	9
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd more Steere Farm Wells & Parallel Pipe from Wellfield to WTP	1	1	0	0	0	9
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wellfield & Pipe from Northeast wells to WTP	1	1	0	0	0	9
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 11 mgd capacity	1	1	0	1	0	6
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 22 mgd capacity	1	1	0	1	0	6
New Groundwater Treatment Options	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site	1	1	1	0	0	6
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Parallel Pipeline from Steere Farm	1	1	1	0	0	6
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Pipe from Steere Farm Wellfield to 20-inch Distribution System Loop	2	1	1	0	0	5
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to WTP	1	1	2	0	0	3
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to 20-inch Distribution System Loop	2	1	2	0	0	2
DWSD Supply Options[4]	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, Build one 50 mgd pipe from DWSD	1	0	0	0	0	10
	Abandon Plant 1, Keep Plant 2 in Emergency Standby, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 50 mgd pipe from DWSD	1	0	0	1	1	2
	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, & Build one 28 mgd pipes from DWSD and another 22 mgd pipe from DWSD	1	0	0	0	0	10
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 22 mgd pipe from DWSD	1	1	0	1	0	6
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby w/ Conveyance Upgrades, & Build one 22 mgd pipe from DWSD	1	1	0	1	0	6

(1) Subtract 1 for each entry point to the distribution system (EPDS) greater than 1
(2) Subtract 1 for the first WTP that must be operated
(3) Subtract 3 for each additional WTP that must be operated at a new location
(4) Subtract 3 for each DWSD wholesale alternative that would require blending in the WTP clearwell or distribution system.
(5) Subtract 5 if existing Plant 2 must be maintained in standby

Appendix TM1.D.2
Alternative Scoring Metrics

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Distribution Water Quality Contributor Scoring Summary

		Deductions			
		3	2	1	
Source of Supply and System Reliability Alternatives		**DBPs[(1)]**	**Corr[(2)]**	**Residual[(3)]**	**Score**
Replace Plant 1 Options	Plant 1 Replacement Only	0	0	0	10
	Plant 1 Replacement & Steere Farm Well Field Conveyance Upgrades	0	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd more Steere Farm Wells & Parallel Pipe from Wellfield to WTP	0	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wellfield & Pipe from Northeast wells to WTP	0	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 11 mgd capacity	0	1	1	7
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 22 mgd capacity	0	1	1	7
New Groundwater Treatment Options	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site	0	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Parallel Pipeline from Steere Farm	0	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Pipe from Steere Farm Wellfield to 20-inch Distribution System Loop	0	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to WTP	0	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to 20-inch Distribution System Loop	0	0	0	10
DWSD Supply Options[(4)]	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, Build one 50 mgd pipe from DWSD	1	1	1	4
	Abandon Plant 1, Keep Plant 2 in Emergency Standby, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 50 mgd pipe from DWSD	1	1	1	4
	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, & Build one 28 mgd pipes from DWSD and another 22 mgd pipe from DWSD	1	1	1	4
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 22 mgd pipe from DWSD	1	1	1	4
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby w/ Conveyance Upgrades, & Build one 22 mgd pipe from DWSD	1	1	1	4

(1) Subtract 3 for DBP issues from alternatives that would use DWSD supply on a continuous basis

(2) Subtract 2 for corrosion/colored water issues for all DWSD Alternatives

(3) Subtract 1 for disinfectant residual issues for all DWSD Alternatives

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Utility Staffing Contributor Scoring Summary

		Scores						
		10	9	7	5	3	1	
Source of Supply and System Reliability Alternatives		**None(1)**	**Modest Training(2)**	**Moderate Increase or Training(3)**	**Moderate Increase and Training(4)**	**Significant Increase or Training(5)**	**Significant Increase and Training(6)**	**Score(1)**
Replace Plant 1 Options	Plant 1 Replacement Only	1	0	0	0	0	0	10
	Plant 1 Replacement & Steere Farm Well Field Conveyance Upgrades	1	0	0	0	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd more Steere Farm Wells & Parallel Pipe from Wellfield to WTP	1	0	0	0	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wellfield & Pipe from Northeast wells to WTP	1	0	0	0	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 11 mgd capacity	0	1	0	0	0	0	9
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 22 mgd capacity	0	1	0	0	0	0	9
New Groundwater Treatment Options	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site	0	0	0	1	0	0	5
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Parallel Pipeline from Steere Farm	0	0	0	1	0	0	5
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Pipe from Steere Farm Wellfield to 20-inch Distribution System Loop	0	0	0	1	0	0	5
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to WTP	0	0	0	1	0	0	5
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to 20-inch Distribution System Loop	0	0	0	1	0	0	5
DWSD Supply Options(4)	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, Build one 50 mgd pipe from DWSD	0	0	0	1	0	0	5
	Abandon Plant 1, Keep Plant 2 in Emergency Standby, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 50 mgd pipe from DWSD	0	0	0	1	0	0	5
	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, & Build one 28 mgd pipes from DWSD and another 22 mgd pipe from DWSD	0	0	0	1	0	0	5
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 22 mgd pipe from DWSD	0	0	0	1	0	0	5
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby w/ Conveyance Upgrades, & Build one 22 mgd pipe from DWSD	0	0	0	1	0	0	5

(1) Alternative does not require a significant increase in staffing of significant re-training
(2) Alternative requires some modest level of staff re-training
(3) Alternative requires either a moderate increase in level of staffing or moderate level of staff re-training
(4) Alternative requires both a moderate increase in level of staffing and moderate level of staff re-training
(5) Alternative requires either a significant increase in level of staffing or significant level of staff re-training
(6) Alternative requires both a significant increase in level of staffing and significant level of staff re-training

Appendix TM1.D.2
Alternative Scoring Metrics

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Intergovernmental Agreements Contributor Scoring Summary

		Deductions					
		2	3	6	5	3	
Source of Supply and System Reliability Alternatives		**SF GW Permit[(1)]**	**NE GW Permit[(2)]**	**DWSD IGA Emerg[(3)]**	**DWSD IGA Peak[(4)]**	**DWSD IGA Whole[(5)]**	**Score**
Replace Plant 1 Options	Plant 1 Replacement Only	0	0	0	0	0	10
	Plant 1 Replacement & Steere Farm Well Field Conveyance Upgrades	0	0	0	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd more Steere Farm Wells & Parallel Pipe from Wellfield to WTP	1	0	0	0	0	8
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wellfield & Pipe from Northeast wells to WTP	0	1	0	0	0	7
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 11 mgd capacity	0	1	1	0	0	1
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 22 mgd capacity	0	1	1	0	0	1
New Groundwater Treatment Options	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site	0	0	0	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Parallel Pipeline from Steere Farm	1	0	0	0	0	8
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Pipe from Steere Farm Wellfield to 20-inch Distribution System Loop	1	0	0	0	0	8
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to WTP	0	1	0	0	0	7
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to 20-inch Distribution System Loop	0	1	0	0	0	7
DWSD Supply Options[(4)]	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, Build one 50 mgd pipe from DWSD	0	0	0	0	1	7
	Abandon Plant 1, Keep Plant 2 in Emergency Standby, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 50 mgd pipe from DWSD	0	0	0	0	1	7
	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, & Build one 28 mgd pipes from DWSD and another 22 mgd pipe from DWSD	0	0	0	0	1	7
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 22 mgd pipe from DWSD	0	0	0	1	0	5
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby w/ Conveyance Upgrades, & Build one 22 mgd pipe from DWSD	0	0	0	1	0	5

[(1)]Subtract 3 for permitting of additional GW supply in NE groundwater basin aquifer

[(1)]Subtract 2 for permitting of additional GW supply in Steere Farms aquifer

[(3)]Subtract 1 for disinfectant residual issues for all DWSD Alternatives

Appendix TM1.D.2
Alternative Scoring Metrics

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Existing Facilities Utilization Contributor Scoring Summary

		Scores			
		10	7	5	
Source of Supply and System Reliability Alternatives		**None**	**> $1M but < $5M**	**> $5M**	**Score[1]**
Replace Plant 1 Options	Plant 1 Replacement Only	1	0	0	10
	Plant 1 Replacement & Steere Farm Well Field Conveyance Upgrades	1	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd more Steere Farm Wells & Parallel Pipe from Wellfield to WTP	1	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wellfield & Pipe from Northeast wells to WTP	1	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 11 mgd capacity	1	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 22 mgd capacity	1	0	0	10
New Groundwater Treatment Options	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site	1	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Parallel Pipeline from Steere Farm	1	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Pipe from Steere Farm Wellfield to 20-inch Distribution System Loop	1	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to WTP	1	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to 20-inch Distribution System Loop	1	0	0	10
DWSD Supply Options[4]	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, Build one 50 mgd pipe from DWSD	0	0	1	5
	Abandon Plant 1, Keep Plant 2 in Emergency Standby, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 50 mgd pipe from DWSD	0	0	1	5
	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, & Build one 28 mgd pipes from DWSD and another 22 mgd pipe from DWSD	0	0	1	5
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 22 mgd pipe from DWSD	1	0	0	10
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby w/ Conveyance Upgrades, & Build one 22 mgd pipe from DWSD	1	0	0	10

[1]Examples of potentially abandoned facilities include new lime feed system at the WTP and new raw water pumping improvements

Appendix TM1.D.2
Alternative Scoring Metrics

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Autonomy Contributor Scoring Summary

		Deductions			
		1	3	5	
Source of Supply and System Reliability Alternatives		**DWSD Emerg(1)**	**DWSD Peak(2)**	**DWSD Whole(3)**	**Score**
Replace Plant 1 Options	Plant 1 Replacement Only	0	0	0	10
	Plant 1 Replacement & Steere Farm Well Field Conveyance Upgrades	0	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd more Steere Farm Wells & Parallel Pipe from Wellfield to WTP	0	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wellfield & Pipe from Northeast wells to WTP	0	0	0	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 11 mgd capacity	1	0	0	9
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 22 mgd capacity	1	0	0	9
New Groundwater Treatment Options	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site	0	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Parallel Pipeline from Steere Farm	0	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Pipe from Steere Farm Wellfield to 20-inch Distribution System Loop	0	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to WTP	0	0	0	10
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to 20-inch Distribution System Loop	0	0	0	10
DWSD Supply Options(4)	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, Build one 50 mgd pipe from DWSD	0	0	1	5
	Abandon Plant 1, Keep Plant 2 in Emergency Standby, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 50 mgd pipe from DWSD	0	0	1	5
	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, & Build one 28 mgd pipes from DWSD and another 22 mgd pipe from DWSD	0	0	1	5
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 22 mgd pipe from DWSD	0	1	0	7
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby w/ Conveyance Upgrades, & Build one 22 mgd pipe from DWSD	0	1	0	7

(1) Subtract 1 from alternatives that would use DWSD as an emergency supply

(2) Subtract 3 from alternatives that would use DWSD as a peaking supply

(3) Subtract 5 from alternatives that would use DWSD as a sole-source wholesale supply

Appendix TM1.D.2
Alternative Scoring Metrics

Water Treatment Plant Alternatives Analysis -- Phase IA
Source of Supply and System Reliability Alternatives

Sustainability Framework Contributor Scoring Summary

Source of Supply and System Reliability Alternatives		Energy Cons.	Economic Vitality	Integrated Land Use	Score(1)
Replace Plant 1 Options	Plant 1 Replacement Only	1	1	1	10
	Plant 1 Replacement & Steere Farm Well Field Conveyance Upgrades	1	1	1	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd more Steere Farm Wells & Parallel Pipe from Wellfield to WTP	1	1	1	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wellfield & Pipe from Northeast wells to WTP	1	1	1	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 11 mgd capacity	1	1	1	10
	Plant 1 Replacement & Steere Farm Wellfield Conveyance Upgrades & 11 mgd Northeast Wells and Pipeline & Emergency Connection to DWSD w/ 22 mgd capacity	1	1	1	10
New Groundwater Treatment Options	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site	1	1	0	7
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Parallel Pipeline from Steere Farm	1	1	0	7
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of additional wells & 11 mgd of additional Groundwater Treatment & Pipe from Steere Farm Wellfield to 20-inch Distribution System Loop	1	1	0	7
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to WTP	1	1	0	7
	Abandon Plant 1 & Keep Plant 2 & Upgrade Steere Farm Wellfield Conveyance & Build 11 mgd of New Groundwater Treatment at Steere Farm Wellfield Site & Build 11 mgd of Northeast wells & 11 mgd of additional Groundwater Treatment & Pipe from Northeast Wellfield to 20-inch Distribution System Loop	1	1	0	7
DWSD Supply Options(4)	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, Build one 50 mgd pipe from DWSD	0	0	1	3
	Abandon Plant 1, Keep Plant 2 in Emergency Standby, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 50 mgd pipe from DWSD	0	0	1	3
	Abandon Plant 1, Abandon Plant 2, Abandon Steere Farm Well Field, & Build one 28 mgd pipes from DWSD and another 22 mgd pipe from DWSD	0	0	1	3
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby, & Build one 22 mgd pipe from DWSD	0	0	1	3
	Abandon Plant 1, Keep Plant 2 as Base Load Plant, Keep Steere Farm Wellfield and Conveyance in Standby w/ Conveyance Upgrades, & Build one 22 mgd pipe from DWSD	0	0	1	3

Sustainability Framework Elements considered include: Energy Conservation, Economic Vitality, and Integrated Land Use

(1)Score = 10 if an alternative supports each Sustainability Framework Element considered

(1)Score = 7 if an alternative supports 2 of the 3 Sustainability Framework Element considered

(1)Score = 3 if an alternative supports 1 of the 3 Sustainability Framework Element considered

(1)Score = 0 if an alternative does not support any of 3 Sustainability Framework Element considered

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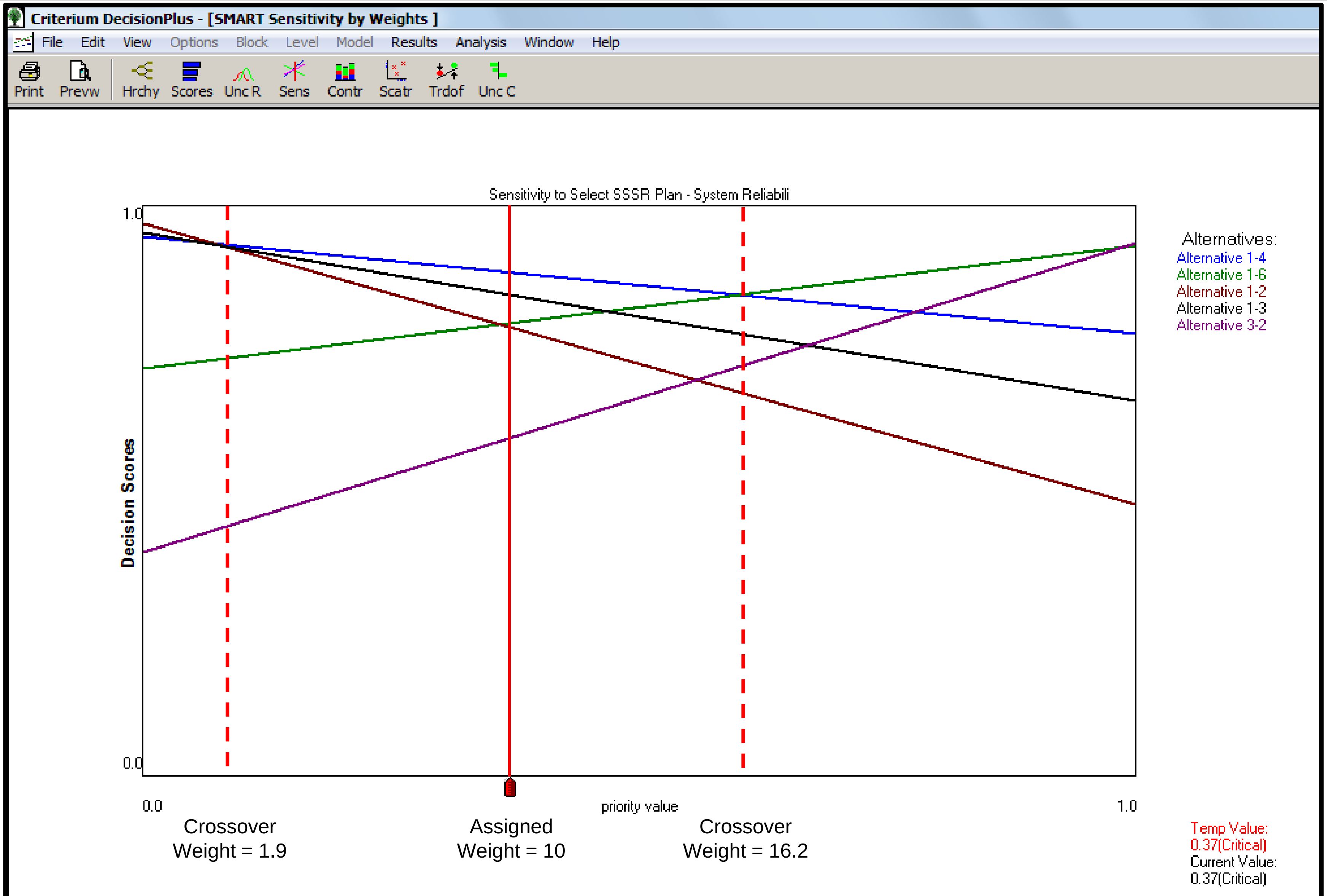
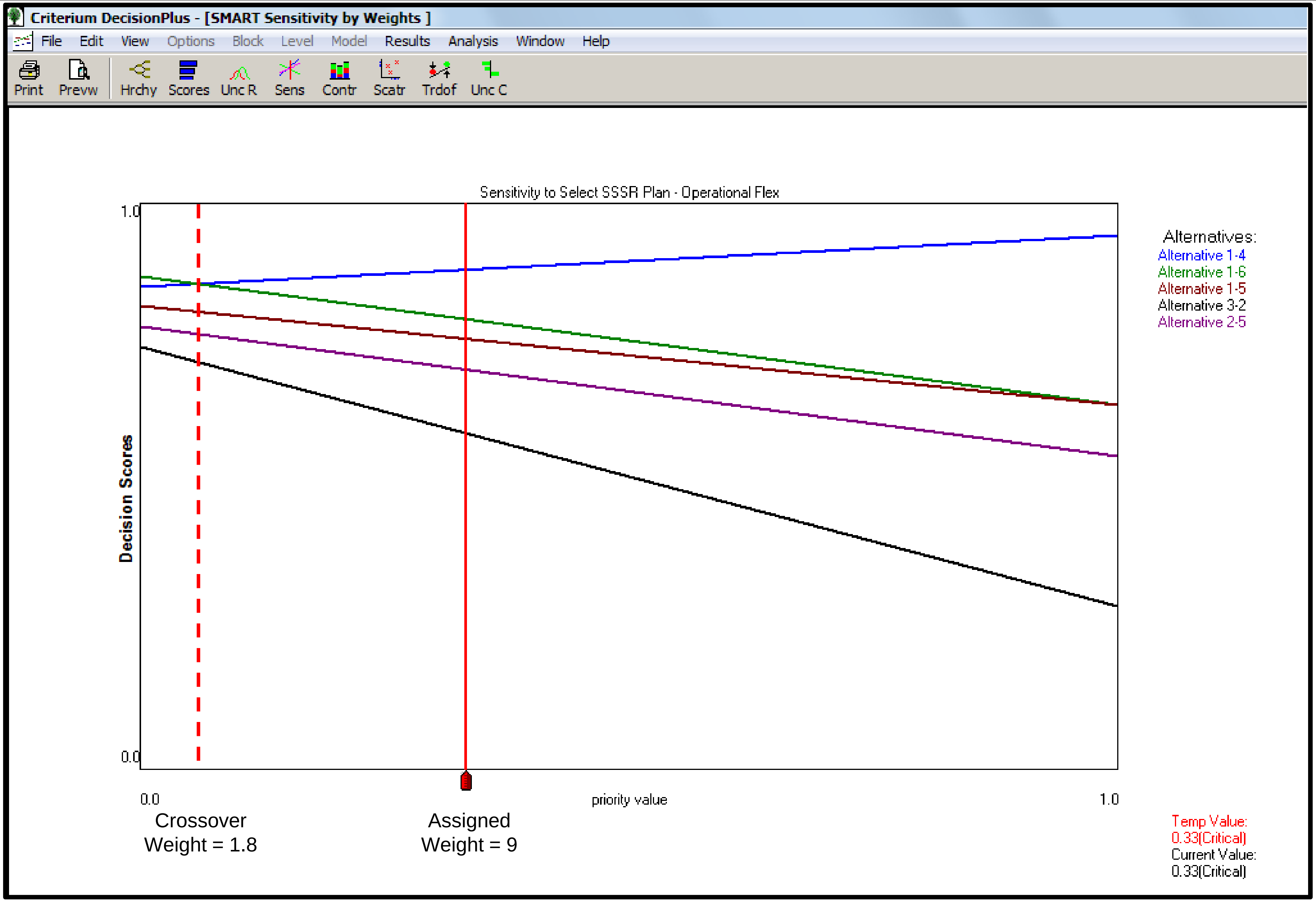


City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Desires – System Reliability

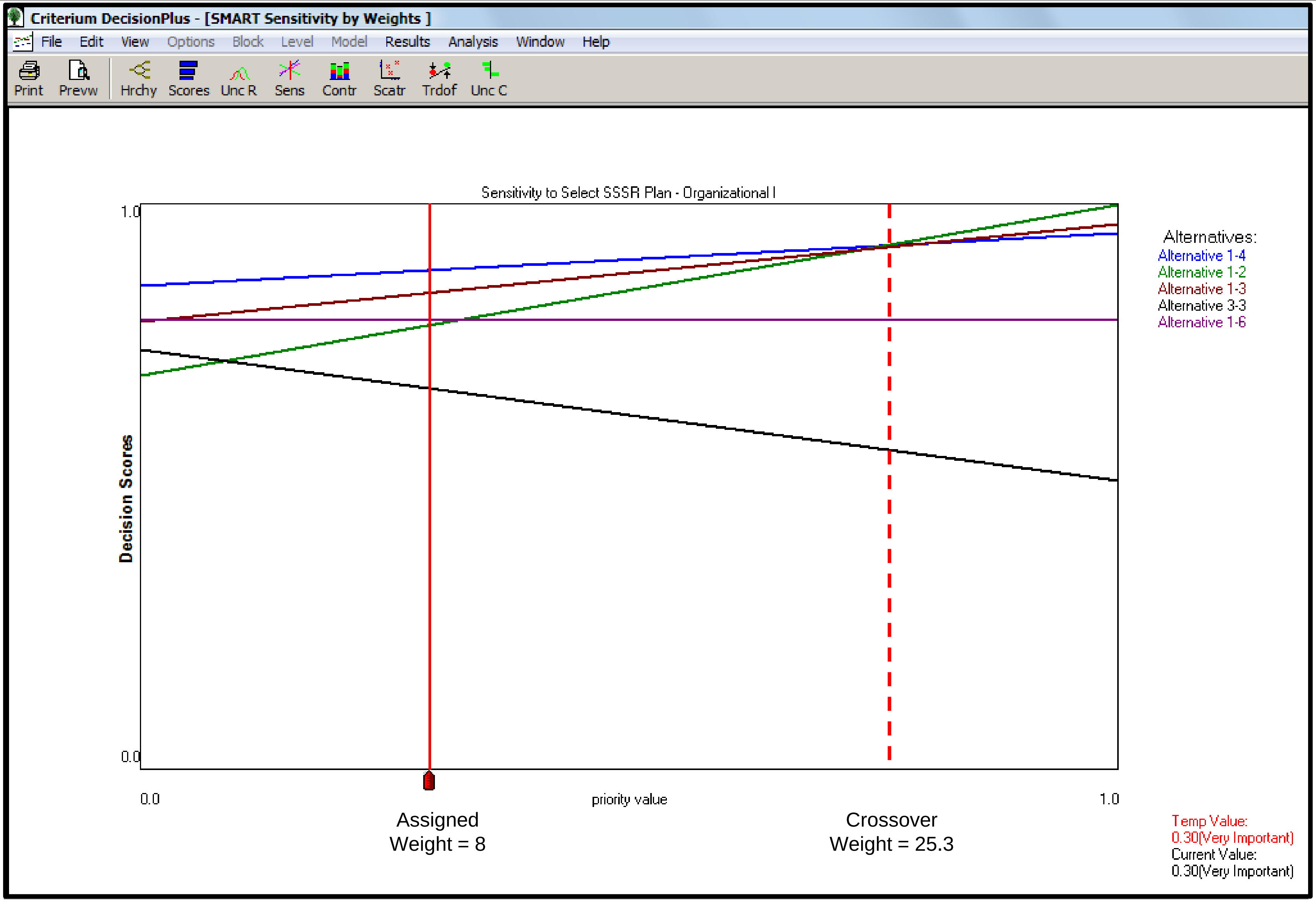
Figure TM1.D-1



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Desires – Operational Flexibility

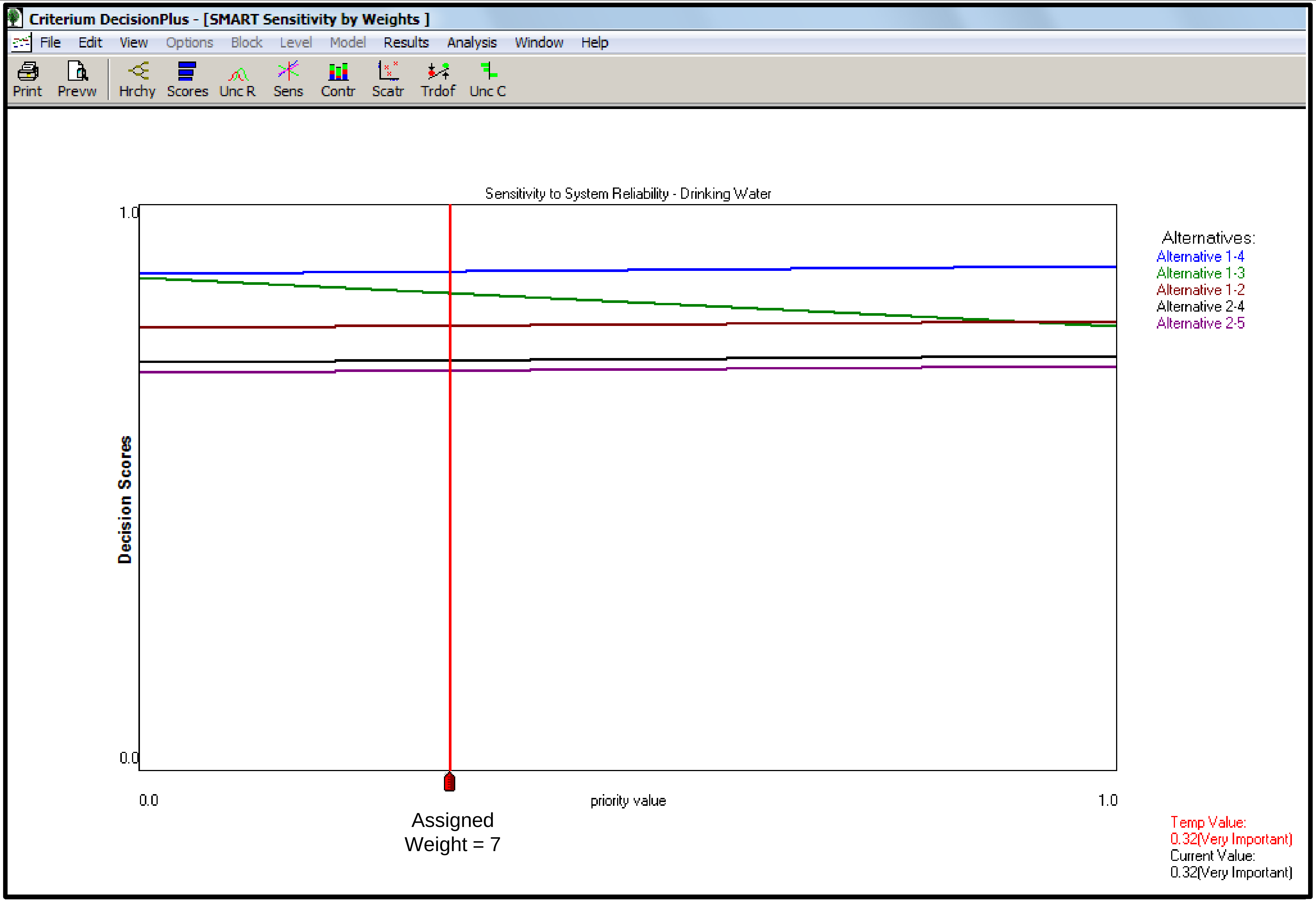
Figure TM1.D-2



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Desires – Organizational Impacts

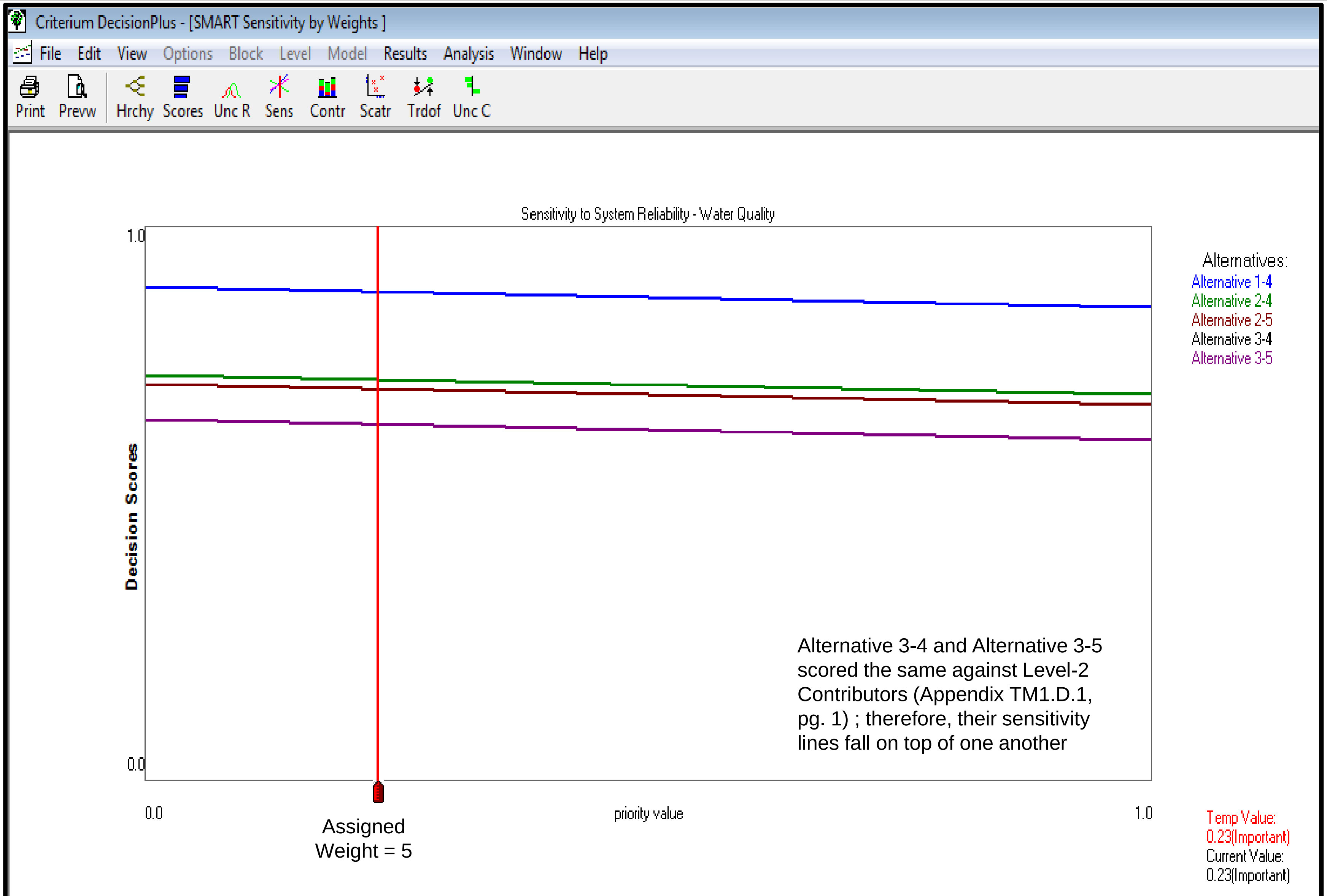
Figure TM1.D-3



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Drinking Water Supply Reliability

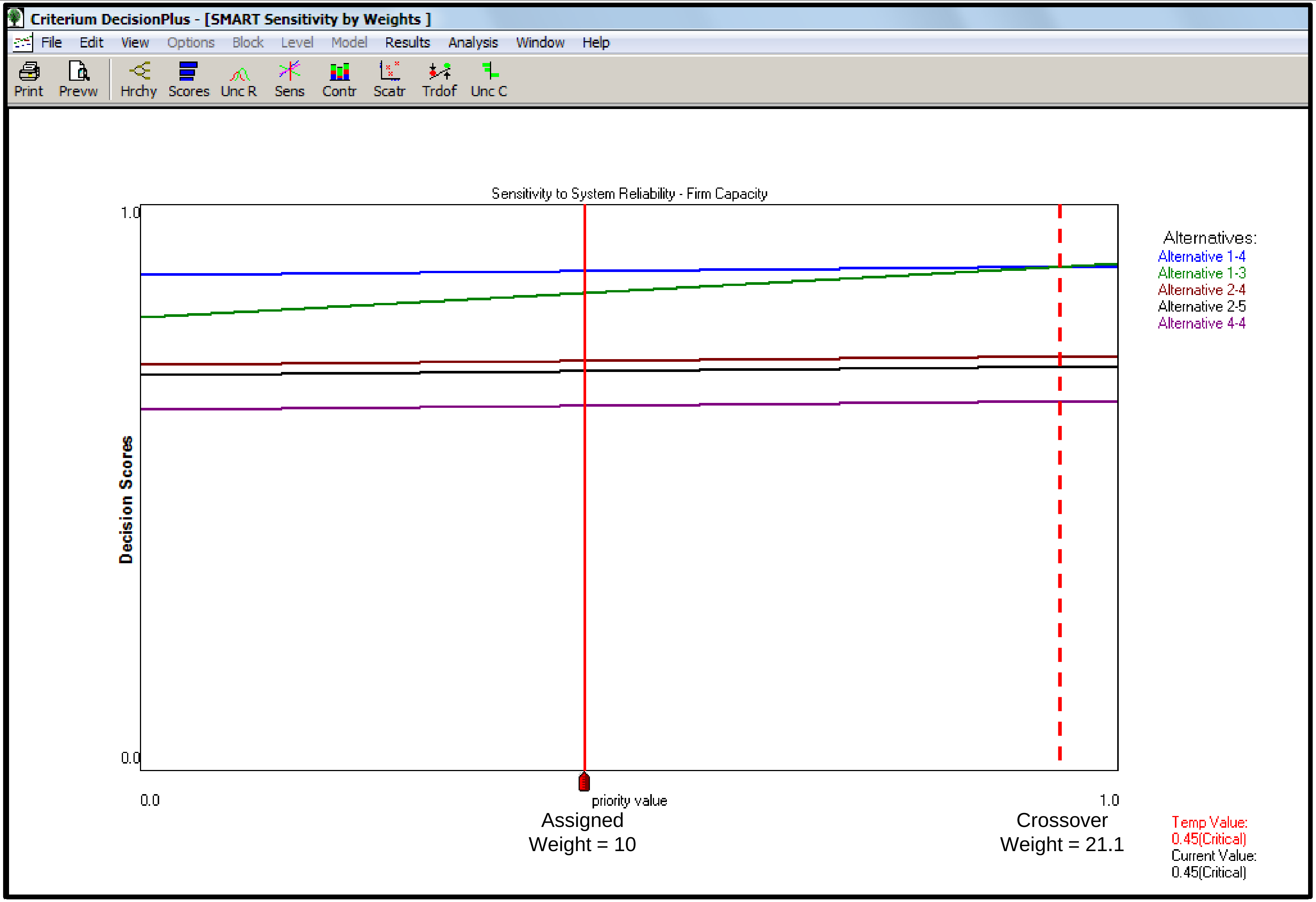
Figure TM1.D-4



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Water Quality Vulnerability

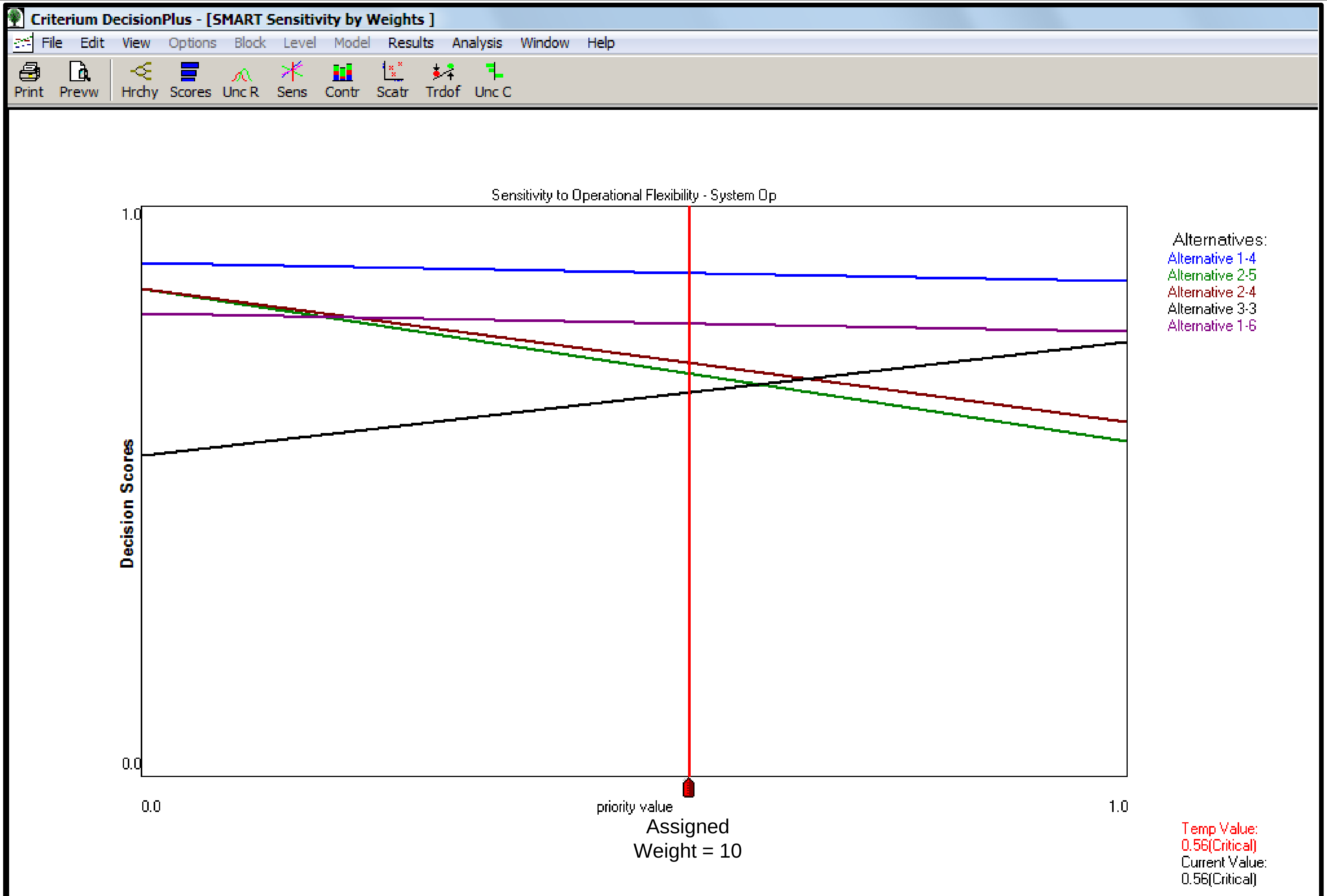
Figure TM1.D-5



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Firm Capacity

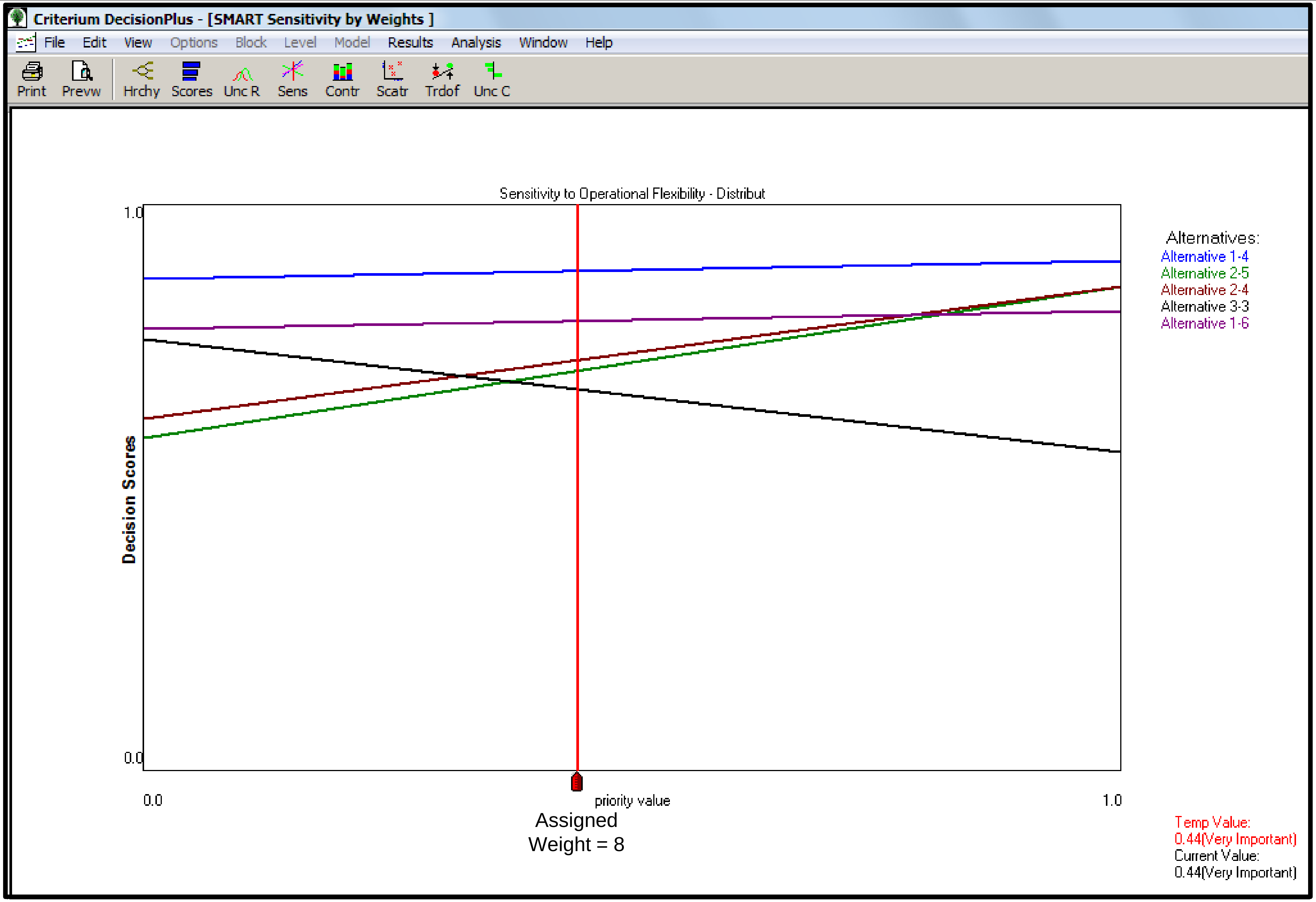
Figure TM1.D-6



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – System Operations

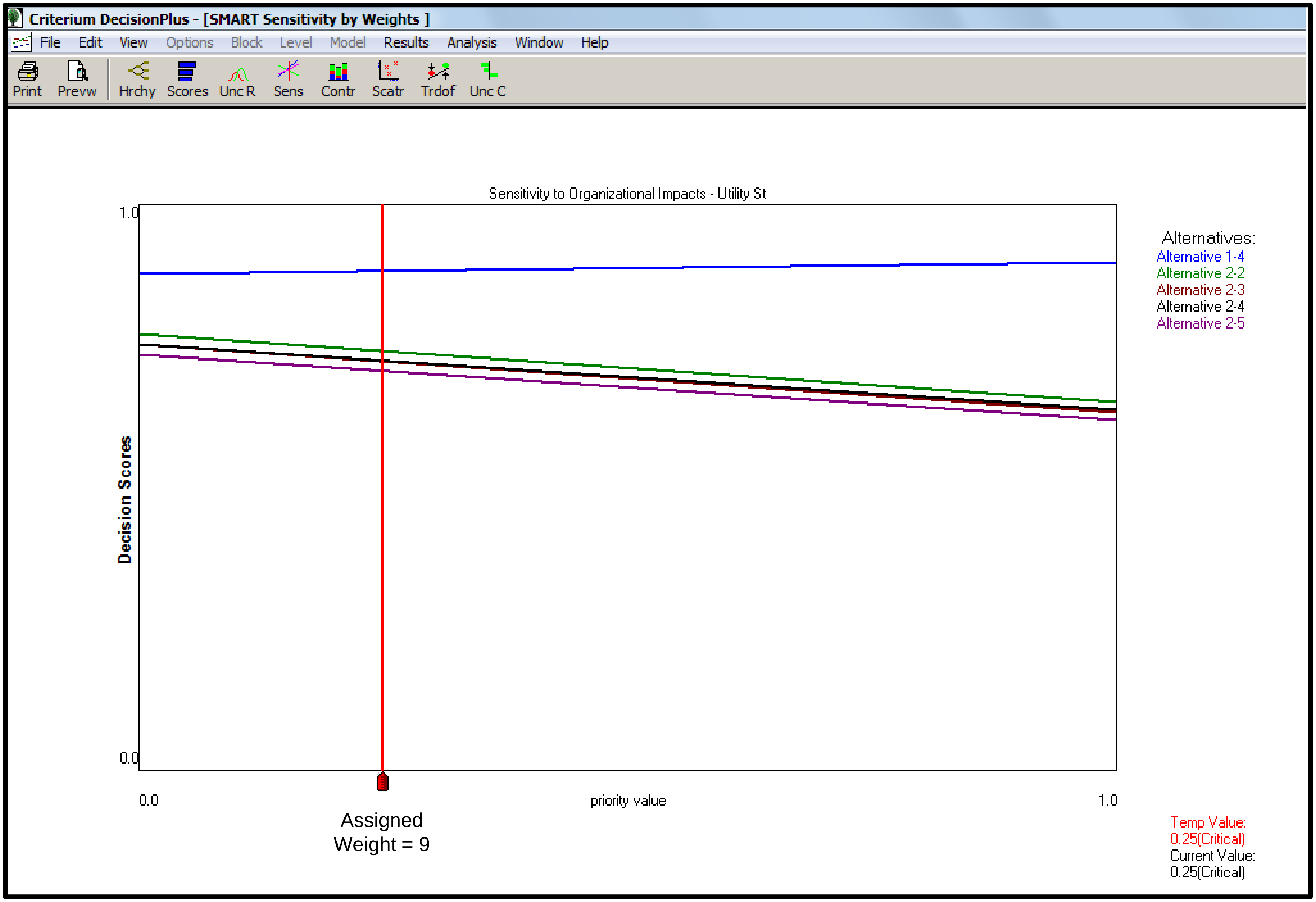
Figure TM1.D-7



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Distribution Water Quality

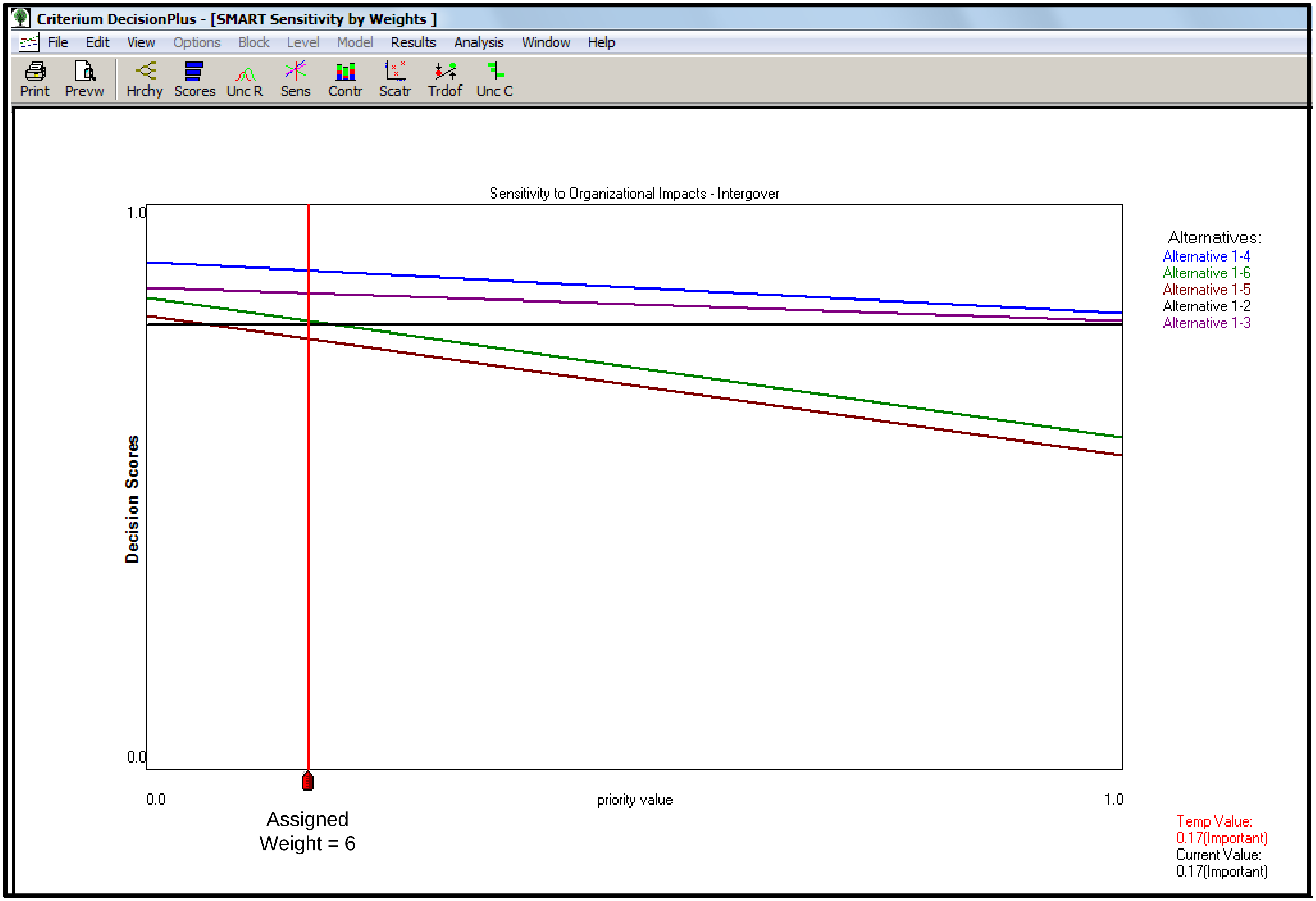
Figure TM1.D-8



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Utility Staffing

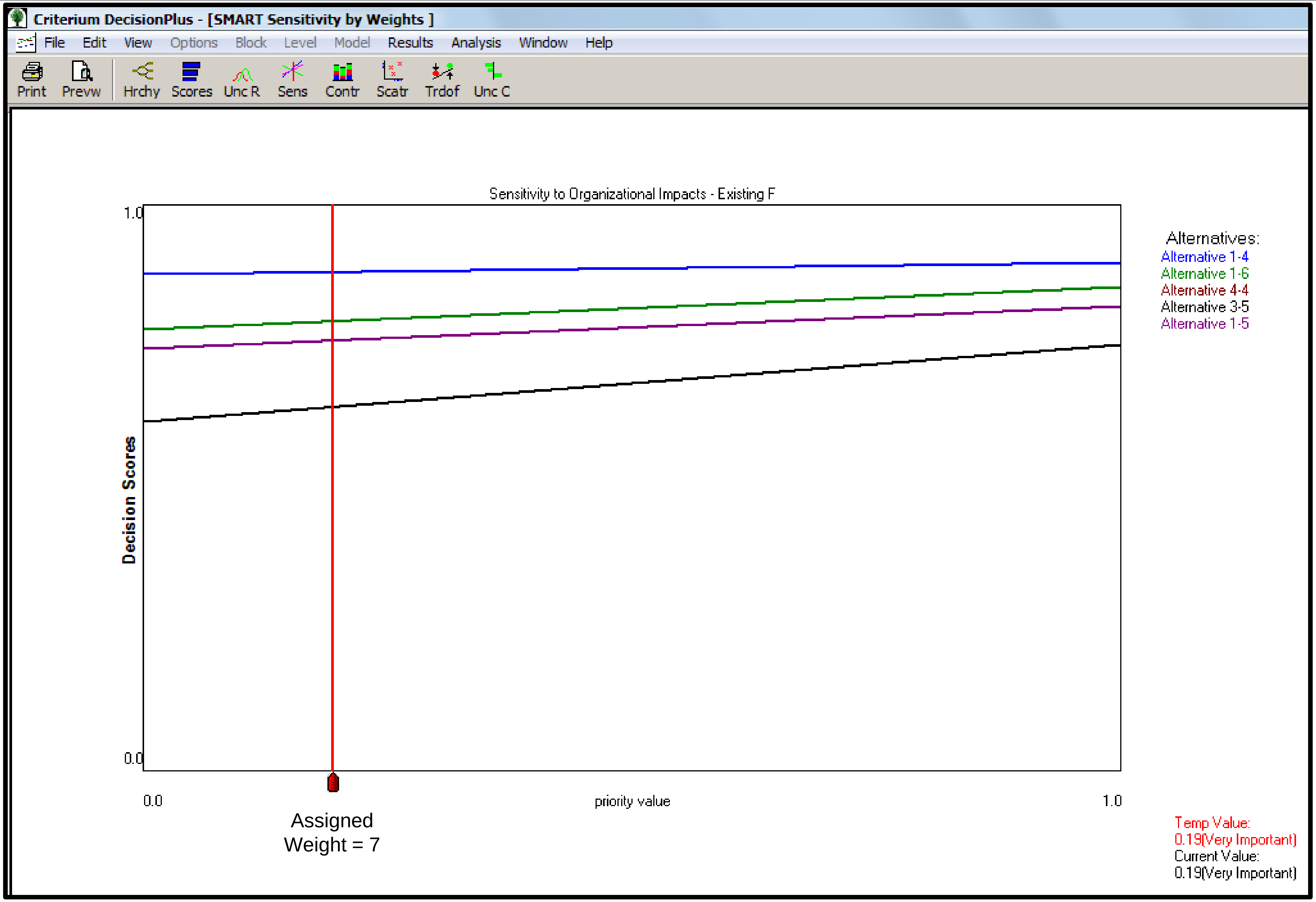
Figure TM1.D-9



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Intergovernmental Agreements

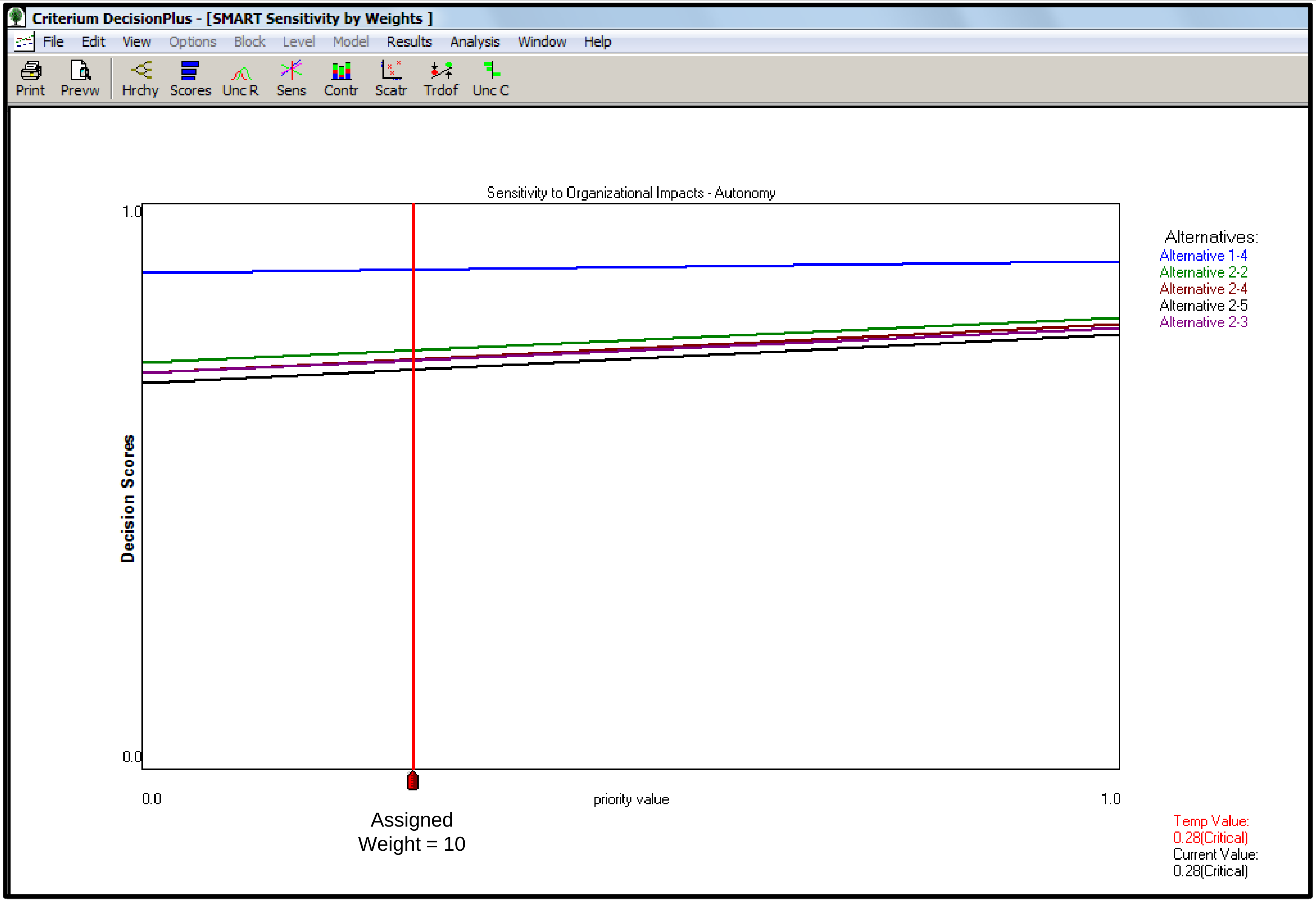
Figure TM1.D-10



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Existing Facilities Utilization

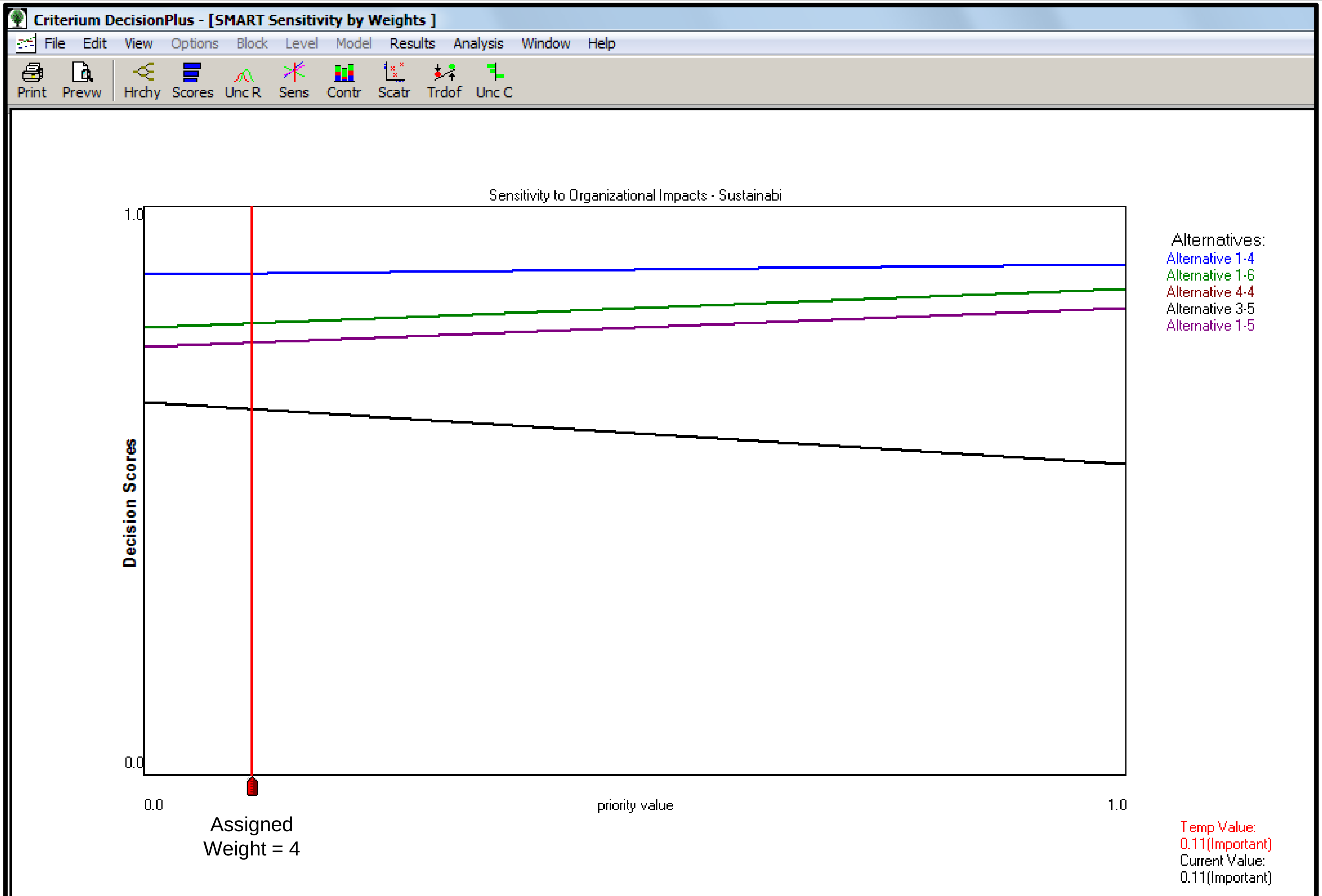
Figure TM1.D-11



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Autonomy

Figure TM1.D-12



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Sustainability Framework

Figure TM1.D-13

FINAL

ANN ARBOR WATER TREATMENT PLANT ALTERNATIVES ANALYSIS

Technical Memorandum 2

Plant 1 Condition Assessment

B&V PROJECT NO. 183262

PREPARED FOR

City of Ann Arbor

4 MAY 2015

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Table of Contents

APPENDICES

1 Introduction

This technical memorandum serves to update and confirm the findings documented in the condition assessment performed as part of the 2006 Water Treatment Facilities and Water Resources Master Plan (COAA, 2006). The 2006 Master Plan recommended replacement of aging Plant 1 pre-treatment facilities by 2016. Pre-treatment Basin Nos. 1 & 2 have been in operation since 1938 and Basin No. 3 was added in 1954. Structures are original and a majority of their piping and equipment is original, with modifications and component replacements performed as needed to maintain service.

To support the evaluation, a visual inspection was conducted, the 2006 Master Plan was reviewed, interviews with key supervisory, operational, and maintenance staff were conducted, and corrective work orders and contract documents for improvements projects were referenced. Documentation of known deficiencies with associated opinion of replacement/improvement cost is provided in **Appendix TM2.A**. A photo journal of the existing facilities is provided in **Appendix TM2.B**.

2 Plant 1 Condition Assessment

The Plant 1 pre-treatment facilities were evaluated, including the well water split treatment chamber, rapid mix Nos. 1, 2, & 3, flocculation/sedimentation basin Nos. 1 & 2, flocculation basin No. 3, clarifier No. 3, settled water effluent channels, related treatment equipment, and ancillary systems (piping, valves, electrical, etc.). The following paragraphs describe improvements made after the previous condition assessment and summarize observations and findings of the current evaluation.

2.1 2006 MASTER PLAN UPDATE

Several improvements projects have been implemented after publication of the 2006 Master Plan. The most significant improvement resulting from the recommendations made in the Master Plan was a restoration of concrete, guard railings, gratings, hatches, miscellaneous steel, and effluent weirs. A majority of this work was done in and around pretreatment Basin Nos. 1 & 2, but similar work was also performed in Clarifier No. 3 and other 1938 and 1954 facilities. The construction cost of these improvements was approximately $1 million.

Another 2006 project replaced sludge pumps, interior sludge piping, and valves related to Clarifier No. 3. The interior sludge piping and valves related to Basin Nos. 1 & 2 were also replaced under the same contract. Dewatering pumps Nos. 1 & 2 were replaced in 2013.

2.2 OBSERVATIONS AND FINDINGS

New dewatering pumps, sludge pumps, sludge piping and valves, and miscellaneous basin steel installed since 2006 remain in good condition, but the structural concrete improvements from the 2006 project were insufficient for long-term service. Corrosion of reinforcing steel, which may not have been exposed at the time of repair, has caused significant concrete spalling throughout basin Nos. 1 & 2, Flocculation Basin No. 3, and Clarifier No. 3. steel corrosion, concrete spalling, and cracking has also occurred at many locations where concrete restoration was performed. The original concrete and reinforcing steel is in poor condition and typical concrete restoration methods are largely ineffective and cannot be relied upon as long-term structural solutions. Examples of these concrete deficiencies are depicted in the photo journal provided in **Appendix TM2.B**.

Although a significant amount of guard railing surrounding Basin No. 1, Basin No. 2, and Basin No. 3 was replaced under the 2006 improvements contract, some portions of the remaining original guard railing surrounding Plant 1 pre-treatment structures is not in compliance with minimum height and kick-plate requirements of the 2009 Michigan Building Code (Section 1013) and OSHA Part 1910 Subpart D.

All flocculation, settling, and sludge collection equipment in pre-treatment Basin Nos. 1 & 2, Flocculation Basin No. 3, and Clarifier No. 3 are unreliable and in need of significant improvement or replacement. Electrical components related to each system are generally of the same vintage as the equipment and should be replaced with future equipment replacements. No significant electrical improvements have been made since 2006. Specific observed deficiencies are documented in **Appendix TM2.A**. Pre-treatment equipment deficiencies result in frequent service interruptions and unusually high maintenance effort and expense. Basin Nos. 1 & 2 equipment is insufficient to operate at intended design flow conditions. Therefore, the basins are typically not operated until the water system demand requires them to be placed in service.

3 Opinions of Probable Cost

The conceptual level opinions of probable cost (OPCs) presented here were developed using a common set of capital and operations, maintenance, repair, and replacement (OMR&R) unit costs. The Class 5 planning level cost opinions presented here reflect use of standard engineering practices and were prepared without the benefit of detailed engineering designs. As defined by The Association for the Advancement of Cost Engineering (AACE), Class 5 cost opinions of this type are generally considered to have an accuracy range of plus 100 to minus 50 percent. Any actual project cost would depend on current labor and material costs, competitive market conditions, final project scope, bid date, and other variable factors. The opinions of probable cost presented here are most appropriately used to compare the relative costs of various SSSR Alternatives, rather than as an estimate of actual project costs for detailed budgeting purposes.

The following sections summarize key cost considerations used in the development of component costs.

3.1 OPINIONS OF PROBABLE CAPITAL COST

Opinions of probable capital cost to replace treatment components to restore long-term reliability of existing Plant 1 are based primarily on costs provided in the 2006 Master Plan, escalated to present day using the Engineering News Record Construction Cost Index for the Detroit region (ENR CCI 10,634, July 2014). Historical cost databases maintained by Black & Veatch (escalated to present day) and cost quotes solicited from equipment suppliers were used to develop cost for components for which costs were not included in the 2006 Master Plan.

The opinions of probable capital cost for treatment components provided in Appendix TM2.A include unit process cost to replace the component listed in the Asset Description, additional project costs, contractor mark-up costs, and non-construction costs.

4 Conclusion and Recommendations

A majority of the existing Plant 1 infrastructure has served the City's drinking water system for over 75 years, with Flocculation Basin No. 3 and Clarifier No. 3 each providing over 60 years of service. The City has invested significant cost in recent years to continue Plant 1 service, and the improvements made are not suitable to serve as long-term solutions. In addition to extensive structural and process equipment deficiencies, Plant 1 pre-treatment basins and equipment are open to the atmosphere. The Michigan Department of Environmental Quality has suggested enclosing Basin Nos. 1 & 2, Flocculation Basin No. 3, and Clarifier No.3 if continued use is to be considered. The existing structures are in poor condition and are not designed for the addition of a superstructure. Enclosing the basins would require significant structural modification or construction of new footings surrounding each basin.

Based on the age, condition, maintenance requirements, and regulatory requirements related to the existing Plant 1 pre-treatment facilities, we recommend the City screen out restoration alternatives from the Water Treatment Plant Alternatives Analysis. The Plant 1 pre-treatment facilities should be removed and replaced with new basins equipped with current pre-treatment technology.

5 References

COAA (2006) City of Ann Arbor, *Water Treatment Facilities and Water Resources Master Plan*: prepared by CH2M HILL, May 2006.

Appendix TM2.A

Plant 1 Condition Assessment

Summary of Observations and Reported Deficiencies

Water Treatment Plant Alternatives Analysis
Appendix TM2.A - Plant 1 Condition Assessment
Summary of Observations and Reported Deficiencies

Asset Description	Asset Features	Installation Date	Estimated Replacement Cost	Observed & Reported Deficiencies	Consequences of Observed Deficiencies
Main Building (Basin Nos. 1 &2 Pretreatment Equipment)					
Raw River Influent Piping	24-inch cast iron, 1 - 24-inch gate valve, 1 - 24-inch butterfly valve, venturi meter	1938	$ 150,000	Piping and hardware are significantly corroded and require leakage repair. The raw water influent valve is laborious to operate. Valves do not seal well. Piping is in need of protective coating.	Piping failure, additional damage, service disruption. Poor isolation capability.
Sludge Piping Basin Nos. 1 & 2	4-inch steel and ductile iron, 8-inch cast iron	1938/2006	$ 150,000	Piping and hardware are significantly corroded.	Piping failure, additional damage, service disruption.
Sludge Valves & Actuators Basin Nos. 1 & 2	(4) 4-inch plug valves with motorized actuators, 6-inch isolation plug valves with manual actuators	1938/2006	$ 30,000	No deficiencies observed.	
Sludge Pumps Basin Nos. 1 & 2	(2) 3Hp centrifugal pumps	1997	$ 40,000	Complete pump skid, including starters, was replaced in 1997. Previous pumping system was 1980's vintage, indicating pumps are nearing the end of their estimated 20-year service life.	
Basin Drain/Dewatering Pump No. 1 Basin Nos. 1 & 2	(1) 25Hp centrifugal pump	2013	$ 23,000	No deficiencies observed.	
Rapid Mix Nos. 1 & 2	(2) covered interior 10' X 10' X 16' sidewall concrete basins, each equipped with 5Hp vertical basin mixers	1974	$ 115,000	Wall guides and steady-bearings were added to address balancing issues in 2003. However, the plant staff reports operational deficiency due to unbalanced mixers. Short service life due to potential for scaling on mixer mechanisms. Mixers are 40-years old and beyond typical service life. Mixers have been abandoned in place.	Mixing is inadequate and relies on horizontal paddle flocculators, which are not intended for chemical mixing. Poor mixing reduces settling efficiency of downstream settling equipment, which results in poor quality of sludge, causing inefficiency of sludge handling processes.
Influent Isolation Gate Nos. 1 & 2	(2) 42" X 60" rising stem manually operated cast iron slide gates	1938	$ 60,000	Leakage occurs during basin cleaning.	Continuous dewatering may be required during basin maintenance.
Settling Basin Nos. 1 & 2					
Influent Distribution Gates and Carbonation Channel Isolation Gate	(8, 4 per basin) 2' X 2' rising stem manually operated cast iron slide gates, (1) 3'-6" X 5' rising stem manually operated cast iron slide gate	1938	$ 110,000	Distribution gates are positioned for proportioning influent throughout the front end of the basins and are not routinely operated.	Flow proportioning is not be ideal throughout the flow range, which can impact mixing efficiency and allow potential short circuiting. Gates may no longer function if not exercised.
Flocculation Basin Sludge Piping	8-inch cast iron sludge piping	1938	$ 20,000	Sludge piping exposed in the basin requires submergence to prevent freezing when the basin is out of service. Piping shows signs of corrosion and is in need of protective coating.	Basin equipment is susceptible to icing damage when removed from service due to the requirement to maintain water level above sludge piping.
Flocculation Equipment	(6, 3 per basin) 1Hp, exterior drive, horizontal paddle flocculator, coated steel mechanism with steel paddles, split lubricated bearings, exterior drive, steel chain & sprocket	1938 (Most parts have been replaced)	$ 640,000	Equipment is nearing the end of typical service life and requires extensive bi-annual repair to maintain service. Staff have modified shafts, couplings, bearings, and flights to extend service. Chains and sprockets are replaced every two years. Bearings were replaced in 1997 with split bearings and are beyond the typical 5 to 10 year service life. Motors and gear reducers were replaced in 1995 and beyond the typical 10 to 15 year service life. I31Mechanism is corroded and in need of recoating. Motors run hot. Gear boxes show wear and moderate corrosion. Converted to an annual basis, required maintenance is on the order of $30,000.	Broken paddles could cause damage or torque overload to rotating equipment, disrupting service. Overheated motor may fail and cause treatment challenges. Exterior coating requires more frequent repair and replacement compared with interior coating. Configuration of equipment is susceptible to short-circuiting and sludge accumulation at low flow. Inability to adjust speed of flocculation drives does not allow for optimization.
Baffles	(4, 2 per basin) 3'-8" horizontally arranged wood baffle walls per basin, (1) vertically arranged wood full-height baffle wall	1938	$ 125,000	Wood baffles require occasional repair/replacement. Partial walls are intended to be adjustable but are wedged into place and not moved.	Broken baffles could cause damage or torque overload to rotating equipment, disrupting service. Exterior coating requires more frequent repair and replacement compared with interior coating. Broken baffles may result in short-circuiting of the flow path. Inoperable baffle positions may not allow for ideal distribution of flow for optimum pretreatment performance.
Sludge Collectors	(3 longitudinal & 1 cross basin chain & flight collectors per basin, 1 exterior drive per basin) 1 Hp, self-lubricated bearings, steel chain & sprocket drive, coated steel mechanism, wood flights, steel guides with non-metallic slides	1938	$ 750,000	Equipment is nearing the end of typical service life and requires extensive routine repair to maintain service. Wood flights require occasional repair/replacement. Flight chain guides are severely corroded and require replacement. Flight boards are replaced on a 2 to 3-year cycle. Chains and sprockets are replaced on a 5 to 10-year cycle and are beyond their typical service life. Non-metallic slides require replacement on a 5-year cycle. Drives (gear box and motor) show wear and moderate corrosion and are at the end of their typical service life. Converted to an annual basis, required maintenance is on the order of $25,000.	Broken flights or guides or sprockets cause damage or torque overload to moving equipment, disrupting service. Accumulation of sludge in the flocculation basins result in excessive maintenance.
Effluent Weirs	Stainless steel flat stock slotted weirs	2006	$ 40,000	Effluent weirs are in good condition with no visible signs of corrosion. However, weir length is insufficient to prevent filter overloading at rated pretreatment flow capacity.	Effluent weir length is insufficient to prevent filter overloading at rated pretreatment flow capacity. Overloaded filters could reduce plant flow capacity Overflow at the effluent of Basin Nos. 1 & 2 can flood due to limited capacity of weirs. Overflow will impact adjacent properties.
Basin Nos. 1 & 2 (Structure, Guard Railing, Grating, Hatches)	(2) Open exterior rectangular 2-stage settling basins (flocculation basin 50' X 50' X 13' sidewall + settling basin 50' X 39' X 13' sidewall) coated steel guard railing and uncoated galvanized steel guard railing, steel & FRP grating, stainless steel hatches. (1) covered well water split treatment chamber with overflow and isolation valve at northeast corner of Basin No. 1.	1938	$5,340,000	Several concrete restoration projects have been implemented, most recently in 2006. Older restoration is failing and significant spalling of original concrete continues around the top of both basins and along structural beams, generally above the normal operating water level. Vertical wall cracks are evident in each basin but additional cracks are expected if lime deposits are removed. When removed from service, basin water depth must be maintained to offset groundwater pressure. Guard railing was replaced in 2006 and is in good condition but is only partially coated. Perimeter railing does not meet current code requirements for kick plate. Well water chamber/split treatment box and valve are in acceptable condition and are functioning as intended.	Uncovered pretreatment basins are no longer allowed by MDEQ, due to public health risks. Spalling concrete could cause damage or torque overload to moving equipment, disrupting service. Cracked and spalling concrete exposes reinforcing steel, causing corrosion, and additional cracking & spalling. Equipment is susceptible to icing damage when removed from service due to the requirement to maintain water level to offset groundwater pressure. Non-conforming guard railing system is a safety risk.

Asset Description	Asset Features	Installation Date	Estimated Replacement Cost	Observed & Reported Deficiencies	Consequences of Observed Deficiencies
Settled Water Effluent Stop Logs	(7) 3'-6" X 5'-0" manual aluminum & wood stop logs with cast in place steel frames	1954	$ 50,000	Concrete surrounding the slide frames was restored in 2006, but slide frames are significantly corroded and adjacent concrete spalling continues, including previously restored concrete. Wood stop logs are in poor condition with significant deterioration and severe corrosion of steel hardware.	Unreliable operation of stop logs, difficult installation and removal.
Revised Settled Water Effluent Channel (Structure, Guard Railing)	(1) 3'-6" X (+/-)7'-6" open concrete rectangular channel, galvanized steel grating	1954	$ 70,000	Concrete has been repaired along the top of the channel walls in 2006, but spalling continues where it was not repaired. Select crack and surface repair was performed in 2006. Grating was installed over the channel in 2006.	Cracked and spalling concrete exposes reinforcing steel, causing corrosion, and additional cracking & spalling.
Basin No. 3 Pretreatment Area Carbon House					
Recarbonation Chamber	Rectangular (open structure, covered by Carbon House) concrete dual chamber with (3) manual wood stop logs with cast in place steel frames	1954	$ 25,000	Wood stop logs are in poor condition with significant deterioration and severe corrosion of steel hardware. Plant staff have identified the recarbonation chamber as a bottleneck in plant flow capacity, creating significant headloss.	Unreliable operation of stop logs, difficult installation and removal. Excessive headloss at high flow limits capacity of pretreatment train No. 3.
Rapid Mix No. 3	(1) covered interior concrete basin, 7.5Hp vertical basin mixer	1974	$ 57,000	The mixer is not used and mixing paddles have been removed. The shaft has been reported to have a slight misalignment.	Mixing is inadequate and relies on horizontal paddle flocculators, which are not intended for chemical mixing. Poor mixing reduces settling efficiency of downstream settling equipment, which results in poor quality of sludge, causing inefficiency of sludge handling processes.
Sludge Piping Basin No. 3 & Sludge Valves & Actuators Basin No. 3	6-inch ductile iron pipe, (2) 6-inch automated plug valves with motorized actuators, (15) 6-inch isolation plug valves with manual actuators	2006	$ 320,000	No deficiencies observed.	
Sludge Pumps Basin No. 3	(2) 3Hp centrifugal pumps	2006	$ 40,000	No deficiencies observed.	
Basin No. 3 Drain/Dewatering Pump	(1) 25Hp centrifugal pump	2013	$ 23,000	No deficiencies observed.	
Flocculation Basin No. 3					
Flocculation Equipment	(3) 5Hp Variable Frequency Drives (VFD), horizontal paddle flocculators, coated steel mechanism, wood paddles, split lubricated bearings, exterior drive, steel chain & sprocket	1954 (Most parts have been replaced))	$ 320,000	VFDs are typically not adjusted and operate at a set constant speed. Gear boxes show wear and moderate corrosion. Equipment is nearing the end of typical service life and requires extensive bi-annual repair to maintain service. Staff have modified shafts, couplings, bearings, and flights to extend service. Paddles were replaced with wood in 2005 for $30,000 and are beyond their typical service life. Chains and sprockets are replaced every two years. Bearings were replaced in 1997 with split bearings and are beyond the typical 5 to 10 year service life. Motors and gear reducers were replaced in 1995 and beyond the typical 10 to 15 year service life. VFD's are typically replaced every 5 to 10 years. Staff reports sludge accumulation has caused equipment damage. Wood paddles require occasional repair/replacement. Mechanism is corroded and in need of recoating. Motors run hot. Converted to an annual basis, required maintenance is on the order of $20,000.	Broken paddles or baffles could cause damage or torque overload to rotating equipment, disrupting service. Exterior coating requires more frequent repair and replacement compared with interior coating.
Baffles	(2) wood horizontally arranged baffle walls with vertical coated steel angle supports	1954	$ 45,000	Steel baffle supports are severely corroded and failing.	Broken supports or baffles could cause damage or torque overload to rotating equipment, disrupting service. Broken baffles may result in short-circuiting of the flow path.
Effluent Plates	(6) aluminum manual wall opening covers (approx. 2' X 2' square)	1954	N/A	Plates are supported from guard railing and manually positioned for proportioning effluent throughout the basin outlet are not routinely adjusted (normally open). Precise adjustment is not practical with the current system.	Flow proportioning may not be ideal throughout the flow range, which can impact mixing efficiency and allow potential short circuiting.
Flocculation Basin No. 3 (Structure, Guard Railing, Grating)	(1) 48' X 48' X 18' sidewall open exterior rectangular flocculation basin (uncoated concrete), coated steel guard railing	1954	$1,132,000	East walkway is severely spalling and corroded reinforcing steel is exposed. Guard railing appears to be original and in need of protective coating, but is in good condition overall. Railing does not meet current code requirements for minimum height and kick plate.	Uncovered pretreatment basins are no longer allowed by MDEQ, due to public health risks. Non-conforming guard railing system is a safety risk.
Settling Basin No. 3					
Basin Settling & Sludge Removal Equipment	(1) 3/4Hp, exterior drive, coated steel clarifier & scraper, steel center walkway and drive platform with galvanized steel grating	1954	$ 380,000	Drive and sludge removal equipment is original and nearing the end of typical service life. Scraper arms are reported to be out of alignment, which requires occasional field modification (cutting the scraper) when contacting the floor. Structural steel is in acceptable condition and in need of recoating. Platform grating has been recently replaced. Perimeter guard railing appears to be original and in need of protective coating but is in good condition overall. Perimeter railing does not meet current code requirements for kick plate.	Exterior coating requires more frequent repair and replacement compared with interior coating. Scraper misalignment can cause torque overload and/or further equipment damage. Its condition could result in extended out of service duration. Non-conforming guard railing system is a safety risk.
Baffles & Effluent Weirs	coated steel flat stock peripheral wall baffles, coated steel flat stock slotted effluent weirs	1954 weirs / 1995 baffles	$ 160,000	Perimeter effluent weirs are severely corroded and replacement should be considered. Peripheral wall baffles were added in 1995 and are in need of recoating. Walkway has been restored and is in good condition.	Exterior coating requires more frequent repair and replacement compared with interior coating. Effluent weir length is insufficient to prevent filter overloading at rated pretreatment flow capacity. Overloaded filters could reduce plant flow capacity. Basin size does not provide detention time in accordance with Recommended Standards for Water Works at intended pretreatment flow capacity.
Settled Water Effluent Stop Logs and Mud Valve	South (2) manual aluminum & wood stop log with cast in place steel frames and (1) 8-inch mud valve with rising stem handwheel actuator. North (5) FRP slide plates and cast in place FRP frames	1954 North / 1966 South	$ 17,500	Concrete spalling observed adjacent to one of the FRP stop plate frames. FRP stop plates and frames are in poor condition, with chips, delamination, and severely corroded steel plate framing. Plant staff report inoperable slide plates/frames in the north effluent structure.	Inoperable slide plates do not allow for operational flexibility and isolation.

Asset Description	Asset Features	Installation Date	Estimated Replacement Cost	Observed & Reported Deficiencies	Consequences of Observed Deficiencies
Settling Basin No. 3 (Structure, Guard Railing, Grating)	(1) 132' dia., 12' sidewall, open exterior circular settling basin (uncoated concrete)	1954	$1,540,000	Floor grout is failing and in need of rehabilitation. Concrete is significantly spalling and cracking around the perimeter above the water line. The splitter box is significantly cracked, leaking, and spalling. Perimeter guard railing appears to be original and in need of protective coating, but is in good condition overall. Railing does not meet current code requirements for height or kick plate.	Uncovered pretreatment basins are no longer allowed by MDEQ, due to public health risks. Floor grout is drawn into sludge piping and can damage sludge pumps. Failed grout could interfere with equipment operation and can damage sludge scrapers and cause torque overload to rotating equipment, disrupting service. Non-conforming guard railing system is a safety risk.
Basin No. 3 Settled Water Channel toward Pretreatment Basin Nos. 1&2 (Structure, Guard Railing)	(1) 3'-6" X (+/-)7'-6" covered concrete rectangular channel, stainless steel access hatches, galvanized grating, coated steel guard railing	1954	$ 70,000	Select concrete surface and crack repair was performed in 2006.	

Notes:

1. Motors are across-the-line unless noted otherwise.
2. Plant 1 220V and 440V motor starters are local to equipment and generally of the same vintage as equipment listed. Replacement parts may be difficult to procure so electrical upgrades should be made with related equipment replacements.
3. Plant 1 exterior basin and equipment estimated replacement costs do not include the addition of a new superstructure. If restoring existing facilities, superstructure is required for Basin Nos. 1, 2, Flocculation Basin No. 3, and Settling Basin No. 3.

References:

Water Treatment Facilities and Water Resources Master Plan, May 2006
MDEQ Sanitary Survey
City of Ann Arbor Corrective Work Orders
08 July 2014 Plant walkthrough guided by Duane Weible
08 July 2014 Workshop discussion with City of Ann Arbor staff: Mike Culpepper, Molly Robinson, Larry Sanford, Brian Steglitz, Duane Weible
11 August 2014 Site visit with Mike Switzenberg, City of Ann Arbor Maintenance Supervisor

Appendix TM2.B
Plant 1 Condition Assessment
Photo Journal

24-inch Raw Influent, 8-inch Sludge (Basin 1 & 2)

24-inch Raw Influent to Rapid Mix 1 &2, 8-inch Sludge (Basin 1 & 2)

Sludge Pumps 1 & 2, 4-inch Sludge and Control Valves (Basin 1 & 2)

Motorized Sludge Valve Electrical/Control (Basin 1 & 2)

Drain Pump No. 1 and Electrical/Control

Basin 1 & 2 Influent Isolation Gate Nos. 1 & 2 Actuators

Rapid Mix No. 1 Drive and Basin Nos.1 & 2 Flocculator Electrical/Control

Rapid Mix No. 2 Drive and Rapid Mix 1 & 2 Electrical/Control

Well Water Influent Chamber/Overflow

Well Water Influent Chamber/Overflow

Concrete deck, northeast corner of Basin 1 near Well Influent Chamber

Basin No. 1 perimeter walkway at northeast corner

Basin No. 1 Influent Distribution Gate Actuators

Basin No. 1 Stage 1 Flocculator Drive

Basin No. 1 Flocculator Drive, Chain, and Upper Sprocket

Basin No. 1 Flocculator Chain & Lower Sprocket

Basin No. 1 Stage 1 & 2 Flocculators and Baffles

Basin No. 1 Stage 3 Flocculator and Baffle Wall

Basin 1 Stage 3 Flocculator and Baffle Wall

Basin No. 2 Cantilevered Concrete Walkway, Northeast Corner

Basin No. 2 Influent Distribution Gates

Basin 2 Influent Distribution Gate Actuators and Stage 1 Flocculator Drive

Basin No. 2 Stage 1 Flocculator

Basin No. 2 Influent Distribution Gates and Sludge Piping

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Basin No. 1 Sludge Collection Drive and Upper Sprockets

Basin No. 1 Sludge Collection Equipment

Basin No. 2 Sludge Collection Drive

Basin No. 2 Sludge Collection Drive

Basin No. 2 Sludge Collection Chain and Upper Sprocket

Basin Nos. 1 & 2 Sludge Collection Electrical/Control


Basin No. 2 Sludge Collection Drive and Equipment


Basin No. 2 Cross Collector and Sludge Collection Chain & Sprockets


Basin No. 2 Sludge Collection Equipment


Basin 2 Sludge Collection Equipment and Effluent Weirs

Basin Nos. 1 & 2 Walkway Concrete

Basin Nos. 1 & 2 Walkway Concrete

Basin Nos. 1 & 2 Walkway Concrete

Basin Nos. 1 & 2 Settled Water Effluent Channel

Basin Nos. 1 & 2 Settled Water Effluent Channel and Center Walkway

Basin Nos. 1 & 2 Settled Water Effluent Channel and Center Walkway

Basin Nos. 1 & 2 Settled Water Effluent Channel and Center Walkway

Basin No. 2 Settling Basin Concrete Wall and Center Walkway

Basin Nos. 1 & 2 Center Walkway

Basin Nos. 1 & 2 Effluent Stop Log Structures

Basin No. 1 Effluent Weirs

Basin No. 2 Effluent Weirs and Revised Effluent Channel

Basin Nos. 1 & 2 Effluent Stop Logs

Basin Nos. 1 & 2 Effluent Stop Logs

Basin Nos. 1 & 2 Effluent Stop Log Frame

Basin Nos. 1 & 2 Effluent Stop Log Frame


Basin Nos. 1 & 2 Effluent Stop Log Frame


Basin Nos. 1 & 2 Effluent Stop Log Frame

Basin No. 2 Effluent Weirs and Revised Effluent Channel

Basin Nos. 1 & 2 Revised Effluent Channel

Basin Nos. 1 & 2 Revised Effluent Channel

Basin Nos. 1 & 2 Revised Effluent Channel


Basin Nos. 1 & 2 Revised Effluent Channel


Basin Nos. 1 & 2 Revised Effluent Channel

Basin Nos. 1 & 2 Revised Effluent Channel

Flocculation Basin No. 3 Recarbonation Chamber Stop Log Structures

Rapid Mix 3 Drive

Rapid Mix 3 Electrical/Control

Flocculation Basin No. 3 Electrical/Control

Flocculation Basin No. 3

Flocculation Basin No. 3 Stage 1

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Flocculation Basin No. 3 Stage 1 Cantilevered Concrete Slab

Flocculation Basin No. 3 Stage 1 Cantilevered Concrete Slab

Flocculation Basin No. 3 Stage 1 Cantilevered Concrete Slab

Flocculation Basin No. 3 Stage 1 and Baffle Wall

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Flocculation Basin No. 3 Flocculator Drives

Flocculation Basin No. 3 Flocculator Drives

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Settling Basin No. 3

Settling Basin No. 3

Settling Basin No. 3


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Basin No. 3 Effluent Weir and Effluent Channel

Basin No. 3 Effluent Weir and Effluent Channel


Basin No. 3 Effluent Weir and Effluent Channel


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Basin No. 3 North Effluent Structure

Basin No. 3 North Effluent Structure and Slide Plate

Basin No. 3 North Effluent Structure and Slide Plate Frame

Basin No. 3 North Effluent Structure and Slide Plates

Basin No. 3 North Effluent Structure, Slide Plate, and Slide Plate Frame

Basin No. 3 North Effluent Structure, Slide Plate, and Slide Plate Frame

Basin No. 3 North Effluent Structure and Slide Plate Frame

Basin No. 3 North Effluent Structure and Slide Plate

Sludge Pumps 3A & 3B, Drain Pump 2 and 6-inch Control Valves

Sludge Pumps 3 & 3A and Drain Pump 2
Electrical/Control

Piping Gallery Wall

FINAL

WATER TREATMENT PLANT ALTERNATIVES ANALYSIS

Technical Memorandum 3:

Plant 1 Replacement Alternatives

B&V PROJECT NO. 183262

PREPARED FOR

City of Ann Arbor

24 AUGUST 2015

BLACK & VEATCH
Building a world of difference.

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APPENDICES

1 Introduction

High quality drinking water produced and delivered by a safe and reliable system is central to the health and wellbeing of the residents of Ann Arbor. In addition to complying with all federal and state drinking water regulations and meeting all applicable water quality standards they contain, the City of Ann Arbor has set a number of additional goals related to the aesthetic qualities of the drinking water provided to its customers. City treated drinking water quality goals are listed in **Appendix TM3.A**. The evaluations described in this technical memorandum were performed with these City goals in mind, as well as applicable Michigan Department of Environmental Quality (MDEQ) and United States Environmental Protection Agency (EPA) drinking water regulations.

Phase IA of this project evaluated 16 Source of Supply and System Reliability (SSSR) Alternatives that were developed from a set of 19 common supply, conveyance, and treatment components. Each of these SSSR Alternatives was based on one of three fundamental system reliability strategies: 1) replacement of existing Plant 1 conventional precipitative softening facilities with solids-contact clarification or high-rate precipitative softening facilities, 2) construction of new groundwater treatment facilities at another location, or 3) purchase of drinking water from Detroit Water and Sewerage Department (DWSD). Three of these SSSR Alternatives did not meet minimum requirements established by the City, and were not evaluated in detail. The remaining 13 SSSR Alternatives were compared and ranked based on both non-economic performance and economic considerations.

As detailed in Technical Memorandum 1, SSSR Alternatives based on replacement of Plant 1 facilities had superior non-economic performance and lower 30-year life-cycle cost-benefit ratios than alternatives based on construction of new greenfield groundwater treatment facilities or purchase of drinking water from DWSD. Therefore, Replacement of Plant 1 facilities was selected as the system reliability strategy to be brought forward to Phase II of the project for further analysis and evaluation.

This technical memorandum evaluates potential precipitative softening technologies that may be appropriate for replacement of existing Plant 1 pre-treatment facilities, and develops several alternative configurations for their implementation within the footprint of existing Plant 1 facilities. Comparison and ranking of these alternatives considered both non-economic performance and economic factors, and used conceptual costing methods and structured decision analysis procedures similar to those utilized in Phase IA SSSR Alternatives evaluations.

2 Plant 1 Replacement Alternatives

Three unique replacement alternatives were developed that provide precipitative softening pre-treatment within the footprint of the existing Plant 1 facilities. Each of these baseline alternatives would provide 22 mgd of pre-treatment capacity. A capacity of 22 mgd was utilized as the basis of the evaluations in Phase II of the Study for consistency with the existing capacity of Plant 1 that was used for evaluations in Phase I of the Study. However, it is recognized that the eventual design capacity for Plant 1 replacement facilities may vary based on optimal site/space utilization, and the capabilities of the technology selected which may offer an opportunity for increased capacity.

Collectively, the three baseline alternatives consider both single-stage and two-stage split-treatment precipitative softening processes, which may be configured in either conventional of high-rate basin configurations. The physical layout of existing Plant 1 pre-treatment facilities, as well as the design criteria for existing clarification Basin 1 through Basin 3 are shown on **Figure TM3-1**. The three baseline Plant 1 Replacement Alternatives evaluated here are described in further detail in **Sub-Sections 2.3** through **2.5.**

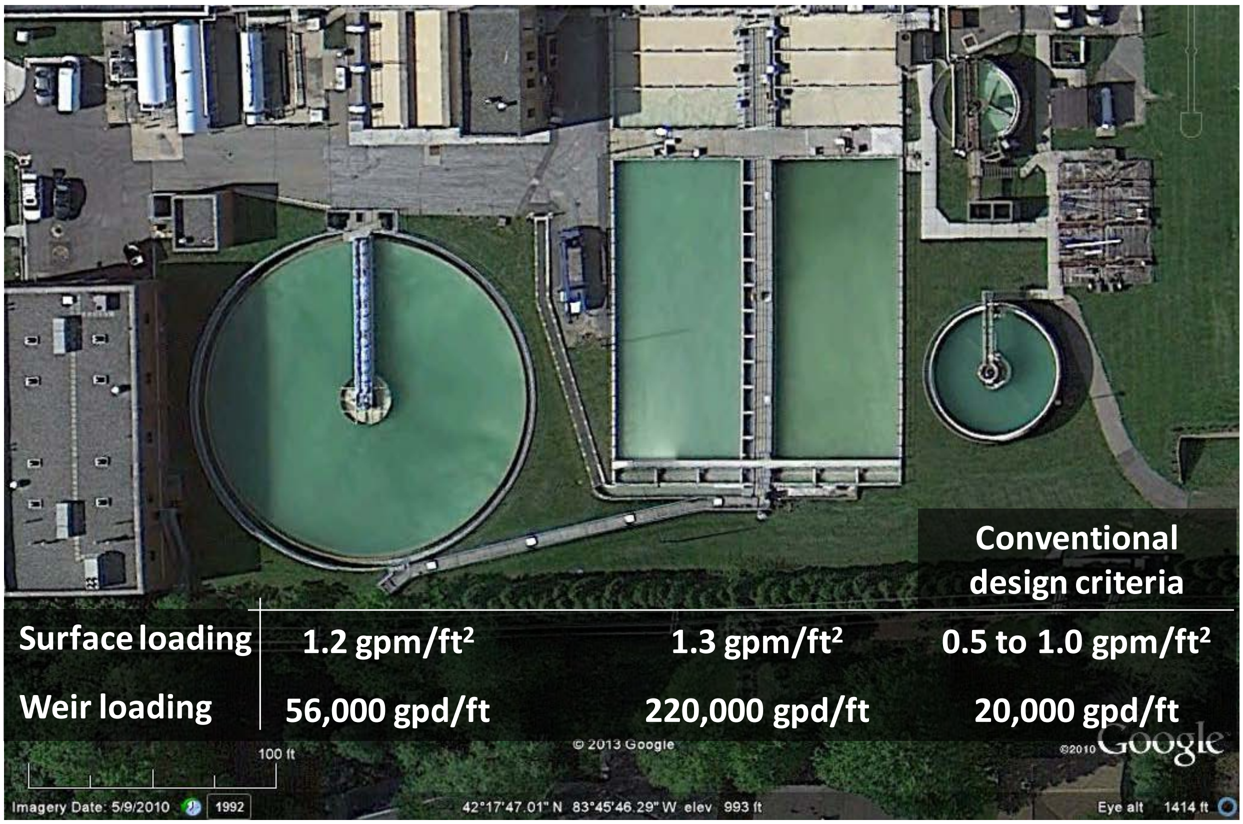


Figure TM3-1: Existing Plant 1 Softening Facilities Layout and Design Criteria

Two additional potential alternative configurations that would provide as much as 50 mgd of softening capacity within the footprint of existing Plant 1 facilities were also conceptually developed, but were not explicitly evaluated here. These two pre-treatment configurations are logical extensions of the three baseline Plant1 Replacement Alternatives evaluated here, and would allow space currently used for pre-treatment to be reallocated for additional treatment processes that may become necessary in the future due to changes in source water quality or drinking water regulations. Single-stage precipitative softening would be utilized in these potential future pre-treatment facilities, configured either in circular solids-contact clarification basins or in proprietary high-rate facilities, as described in **Sub-Section 2.6**.

2.1 PRECIPITATIVE SOFTENING OPERATIONS

Softening facilities at the Ann Arbor WTP are typically operated in a two-stage split-treatment mode with Steere Farm groundwater blended with second stage influent to lower recarbonation requirements. Two-stage split-treatment provides a stable treatment scheme that helps accommodate treatment performance issues associated with the outdated design of Plant 1 pre-treatment facilities. Split-treatment using groundwater minimizes formation of undesirable calcium carbonate hexahydrate precipitates during cold weather operation. The groundwater bypass ratio varies between 5 to 25 percent of treated water flow depending on seasonal water quality variations. Existing softening facilities have also occasionally been operated in single-stage mode.

The City has expressed the desire that any new Plant 1 Replacement facilities have the capability to treat any blend ratio of Huron River and Steere Farm groundwater supplies. Because the Steere Farm supply has markedly higher hardness and alkalinity compared with the surface-groundwater blend historically treated, considerably higher caustic soda doses will be required to treat 100 percent groundwater.

Softening chemical doses for two-stage split-treatment and single-stage softening operations required to treat an 85 percent Huron River to 15 percent Steere Farm groundwater blend, 100 percent Huron River supply, or 100 percent Steere Farm groundwater, are given in **Table TM3-1**. Softening chemical storage values of existing facilities under these operational conditions are listed in **Table TM3-2**. Additional caustic storage will be required to treat 100 percent groundwater for extended periods.

Table TM3-1: Softening Chemical Doses

CHEMICAL	TWO-STAGE(1) / SINGLE-STAGE CHEMICAL DOSE(2)
Historical Surface Water-Groundwater Blend(3)	
Lime(93 percent CaO)	178 / 178
Caustic (50 percent)	8 / 22
Carbon Dioxide	21 / 35
100 Percent Huron River Supply	
Lime(93 percent CaO)	127 / 161
Caustic (50 percent)	9 / 6
Carbon Dioxide	22 / 24
100 Percent Steere Farm Groundwater	
Lime(93 percent CaO)	151 / 220
Caustic (50 percent)	177 / 132
Carbon Dioxide	24 / 35
(1)Split treatment with 25 percent raw water bypassing the primary softening basin (2)Chemical doses are in mg/L expressed as 100 percent chemical. (3)85 percent Huron River -- 15 percent Steere Farm supply added to second-stage	

Table TM3-2: Existing Softening Chemical Storage

CHEMICAL	TWO-STAGE[1] / SINGLE-STAGE DAYS OF STORAGE[2]
Historical Surface Water-Groundwater Blend[3]	
Lime(93 percent CaO)	13 / 13
Caustic (50 percent)	22 / 8
Carbon Dioxide	41 / 24
100 Percent Huron River Supply	
Lime(93 percent CaO)	18 / 14
Caustic (50 percent)	20 / 29
Carbon Dioxide	39 / 36
100 Percent Steere Farm Groundwater[4]	
Lime(93 percent CaO)	37 / 27
Caustic (50 percent)	2.5 / 3.4
Carbon Dioxide	91 / 62

[1] Split treatment with 25 percent raw water bypassing the primary softening basin
[2] Historical maximum day demand of 28 mgd.
[3] 85 percent Huron River -- 15 percent Steere Farm supply added to second-stage
[4] 11 mgd Steere Farm supply only.

2.2 PLANT 1 REPLACEMENT COMPONENTS

The three baseline Plant 1 Replacement Alternatives evaluated here include six softening basin and ancillary facility components that were combined in several different configurations, as listed in **Table TM3-3**. Physical dimensions, treatment capacities, and basic design criteria for these components are given in the following sub-sections.

Table TM3-3: Plant 1 Pre-Treatment Replacement Alternative Components

COMPONENT	DESCRIPTION	CAPACITY (MGD)
1.0	Conventional Solids-Contact Clarifier	22
2.0	Conventional Flocculating Clarifier	22
3.0	High-Rate Solids-Contact Clarification Units	22
4.0	Intermediate Rapid-Mix Basin	22
5.0	Existing Basin 3 Modifications	22
6.0	Caustic Soda Storage and Feed Improvements	11

2.2.1 Conventional Solids Contact Clarification

Several of the Plant 1 Replacement Alternatives evaluated include a conventional-rate circular solids-contact clarifier (SCC). This basin would have a center-feed mechanical mixing zone for softening chemical dispersion and a flocculation zone with mechanical mixing separated from the clarification zone by a baffle wall. Radial effluent launders would collect clarified water. Recirculation of settled softening solids to the primary mixing zone would also be provided. Design criteria for a new SCC are listed in **Table TM3-4**.

Table TM3-4: Conventional Solids-Contact Clarifier Design Criteria

DESIGN PARAMETER	UNITS	VALUE	STANDARD(1)
Diameter	ft	135	n/a
Water Depth	ft	18	n/a
Surface Loading Rate	gpm/ft^2	1.5	1.75
Flocculation Detention Time	min	30	30
Clarification Detention Time	min	96	120(2)
Weir Loading Rate	gpd/ft	19,728	28,800
Slurry Recirculation Rate	×Q	3 to 10	n/a

Abbreviations: ft – feet, gpd/ft – gallons per day per foot, gpm/ft^2 – gallons per minute per square foot, min – minutes, n/a – not applicable, Q – basin influent flow
(1)Recommended Standards for Water Works (Ten States Standards, 2012)
(2)Reduced detention time may also be approved

2.2.2 Conventional Flocculating Clarifier

One of the Plant 1 Replacement Alternatives evaluated here includes a circular flocculating clarifier that would provide the capability for two-stage split-treatment softening. This basin would have a center-feed well design, with flow passing into a flocculation well with mechanical mixing. The central flocculation well would be separated from the outer radial clarification zone by a baffle wall. Radial effluent launders would collect clarified water. Radial sludge collector arms would direct settled solids to a sludge trough located under the center feed well for removal. Recirculation of settled softening solids would not be provided in this basin. Design criteria for a new flocculating clarifier are listed in **Table TM3-5**.

Table TM3-5: Conventional Flocculating Clarifier Design Criteria

DESIGN PARAMETER	UNITS	VALUE	STANDARD(1)
Diameter	ft	140	n/a
Water Depth	ft	18	n/a
Surface Loading Rate	gpm/ft^2	1.25	n/a(2)
Flocculation Detention Time	min	30	30

DESIGN PARAMETER	UNITS	VALUE	STANDARD(1)
Clarification Detention Time	min	121	240(3)
Weir Loading Rate	gpd/ft	17,712	20,000

Abbreviations: ft – feet, gpd/ft – gallons per day per foot, gpm/ft^2 – gallons per minute per square foot, min – minutes, n/a – not applicable, Q – basin influent flow
(1)Recommended Standards for Water Works (Ten States Standards, 2012)
(2)Surface loading rate is not specified, only clarification detention time
(3)Reduced detention time may also be approved

2.2.3 High-Rate Solids Contact Clarification

High-rate solids-contact clarification is considered in one of the Plant 1 Replacement Alternatives evaluated here. These treatment facilities would include discrete rapid-mix, reaction, and clarification zones arranged in square-plan compartments separated by common reinforced concrete walls. Vertical turbine mixers would be provided in the rapid-mix and reaction compartments, with tube settling modules located in the clarification compartment. Radial sludge collector arms would direct settled solids to a sludge trough located in the center of the clarification compartment for removal. Recirculation of settled softening solids to the reaction zone would also be provided. Treatment capacity would be split between two trains of 11 mgd capacity each. Design criteria for high-rate solids-contact clarification are listed in **Table TM3-6**.

Table TM3-6: High-Rate Solids-Contact Clarifier Design Criteria

DESIGN PARAMETER	UNITS	VALUE	STANDARD(1)
Rapid Mix Detention Time	min	3	n/a
Reaction Time	min	10	n/a
Clarification Detention Time	min	28	n/a
Tube Module Loading Rate	gpm/ft^2	10	n/a

Abbreviations: gpm/ft^2 – gallons per minute per square foot, min – minutes, n/a – not applicable
(1)Recommended Standards for Water Works (Ten States Standards, 2012)

2.2.4 Intermediate Rapid-Mix Basin

A new intermediate rapid-mix basin may be included in each of the Plant 1 Replacement Alternatives. The basin would be located between a new primary softening basin(s) and either existing Basin 3 or a new secondary softening basin. A vertically mounted propeller type mixer was assumed for this evaluation. Design criteria for intermediate rapid mixing are listed in **Table TM3-7**.

Table TM3-7: Intermediate Rapid Mix Basin Design Criteria

DESIGN PARAMETER	UNITS	VALUE	STANDARD[1]
Rapid Mix Detention Time	sec	10	< 30
Velocity Gradient, G	fps/ft	750	750
Stages	n/a	1	n/a
Basin Depth	ft	10	n/a

Abbreviations: ft – feet, fps/ft – feet per second per foot, n/a – not applicable, sec – seconds
[1]Recommended Standards for Water Works (Ten States Standards, 2012)

2.2.5 Secondary Settling in Basin 3

Several of the Plant 1 Replacement Alternatives evaluated here consider retaining existing softening Basin 3 to provide secondary settling following single-stage softening in a new basin(s). Improvements to existing Basin 3 would be included to address known material deficiencies (see **TM2-Plant 1 Condition Assessment**) and to add radial effluent launders to lower the weir loading rate to be consistent with current industry standards. Design criteria for Basin 3 as it currently exists and after modification are listed in **Table TM3-8**.

Table TM3-8: Secondary Clarification Design Criteria

DESIGN PARAMETER	UNITS	VALUE	STANDARD[1]
Diameter	ft	125	n/a
Water Depth	ft	12.8	n/a
Surface Loading Rate	gpm/ft^2	1.28	n/a
Flocculation Detention Time	min	n/a	n/a
Clarification Detention Time	min	88	240[2]
Weir Loading Rate Existing Modified	gpd/ft	 55,980 14,700	20,000

Abbreviations: ft – feet, gpd/ft – gallons per day per foot, gpm/ft^2 – gallons per minute per square foot, min – minutes, n/a – not applicable,
[1]Recommended Standards for Water Works (Ten States Standards, 2012)
[2]Reduced detention time may also be approved

2.2.6 Caustic Soda Storage and Feed Improvements

Plant 1 Replacement Alternatives were developed to address the City's desire to have the capability to treat any blend of current Huron River and Steere Farm source water supplies. Additional caustic storage and feed facilities would be required to treat 100 percent groundwater for extended periods (see **Section 2.1**). Design criteria for additional caustic soda storage and feed facilities required to treat 11 mgd of Steere Farm groundwater on a sustained basis are listed in **Table TM3-9**.

Table TM3-9: Caustic Soda Storage and Feed Design Criteria

DESIGN PARAMETER	UNITS	VALUE	STANDARD[1]
Storage	days	14	n/a
Volume	gal	39,900	n/a
Storage Tanks	number	3	n/a
Tank Diameter	ft	12	n/a
Feed Rate	gal/hr	106	n/a

Abbreviations: ft – feet, gal – gallons, gal/hr – gallons per hour, n/a – not applicable
[1]Recommended Standards for Water Works (Ten States Standards, 2012)

2.3 ALTERNATIVE 1A – CONVENTIONAL SCC WITH SECONDARY SETTLING IN BASIN 3

Plant 1 Replacement Alternative 1A consists of a new circular solids-contact clarifier with secondary settling in existing Basin 3. This alternative would be operated in a single-stage softening process mode, with all softening reactions occurring within the new SCC. Improvements to existing Basin 3 would be included to address known material deficiencies (see **TM2-Plant 1 Condition Assessment**) and to add radial effluent launders to lower the weir loading rate to be consistent with current industry standards. A new intermediate rapid mixing basin would be located between the new SCC and existing Basin 3 for addition of a secondary coagulant or flocculant aid polymer prior to Basin 3. Additional caustic soda storage would be provided to support treatment of the City's groundwater supply for extended periods without the benefit of blending with the City's Huron River supply. One possible conceptual layout for Plant 1 Replacement Alternative 1A facilities is shown on **Figure TM3.B-1**, as given in **Appendix TM3.B.**

2.4 ALTERNATIVE 1B – CONVENTIONAL SCC AND SECOND-STAGE FLOCCULATING CLARIFIER

Plant 1 Replacement Alternative 1B consists of a new circular solids-contact clarifier and a new circular flocculating clarifier configured for series treatment only. This alternative could be operated in a single-stage softening process mode with all softening reactions occurring within the new SCC, or in two-stage split-treatment mode with softening in both basins. A new intermediate rapid mixing basin would be located between the new basins for addition of softening chemicals when operated in a two-stage mode or a secondary coagulant or flocculant aid polymer when operated in single-stage mode. Additional caustic soda storage would be provided to support treatment of the City's groundwater supply for extended periods without the benefit of blending with the City's Huron River supply. One possible conceptual layout for Plant 1 Replacement Alternative 1A facilities is shown on **Figure TM3.B-2**, as given in **Appendix TM3.B**.

2.5 ALTERNATIVE 2 – HIGH-RATE SCC WITH SECONDARY SETTLING IN BASIN 3

Plant 1 Replacement Alternative 2 consists of two new high-rate solids-contact clarifier trains of 11 mgd capacity each. Improvements to existing Basin 3 would be included to address known material deficiencies (see **TM2-Plant 1 Condition Assessment**) and to add radial effluent weirs to lower the weir loading rate to be consistent with current industry standards. This alternative would be operated in a single-stage softening process mode with all softening reactions occurring within the new high-rate SCC trains. A new intermediate rapid mixing basin would be located between the new basins for addition of a secondary coagulant or flocculant aid polymer prior to Basin 3. Additional caustic soda storage would be provided to support treatment of the City's groundwater supply for extended periods without the benefit of blending with the City's Huron River supply. One possible conceptual layout for Plant 1 Replacement Alternative 1A facilities is shown on **Figure TM3.B-3**, as given in **Appendix TM3.B**.

2.6 ALTERNATIVES FOR FUTURE PLANT 1 CAPACITY EXPANSION

Two additional alternatives that would expand the treatment capacity of future Plant 1 facilities to 50 mgd were also developed. Plant 1 Replacement Alternative 1F envisions modifying Alternative 1A by replacing existing Basin 3 with a second conventional SCC, as shown on **Figure TM3.B-4** given in **Appendix TM3.B**. If operated in parallel (single-stage softening) at a marginally higher surface loading rate of 1.6 gpm/ft^2, a total treatment capacity of 50 mgd would be realized. Alternatively, if operated in series up to 25 mgd of two-stage softening pre-treatment would be provided. However, the basin configuration of Alternative 1F would not retain any sizable portion of the existing Plant 1 footprint for additional future treatment process that may be required by changes in source water quality or regulations or other potential future uses.

Plant 1 Replacement Alternative 2F envisions modifying Alternative 2 by constructing two additional high-rate SCC trains, as shown on **Figure TM3.B-5** given in **Appendix TM3.B**. If operated in parallel (single-stage softening) at a marginally higher tube module loading rates of 11 gpm/ft^2, a total treatment capacity of 50 mgd would be realized. Alternatively, high-rate SCC trains 3 and 4 could be sized for 14 mgd each, also providing a total single-stage softening capacity of 50 mgd. The basin configuration of Alternative 2F retains the space occupied by existing Basin 3 for additional future treatment process that may be required by changes in source water quality or regulations or other potential future uses.

3 Non-Economic Evaluation

The relative non-economic performance of candidate Plant 1 Replacement Alternatives was evaluated using principles of the Kepner-Tregoe® (K-T®) Decision Analysis procedure. K-T® Decision Analysis is a systematic procedure that encompasses the fundamental thought pattern people use to make choices. The specific techniques that define the systematic procedure used in K-T® Decision Analysis expand and refine the elements of this thought pattern:

- We appreciate that there is a choice to be made.
- We consider the specific factors that should be satisfied for the choice to succeed.
- We decide what course of action best satisfies these factors.
- We consider the risks associated with the chosen course of action that could jeopardize its success.

3.1 STRUCTURED DECISION MODEL

Specific factors unique to each K-T® decision analysis effort are classified as either MUST criteria that each candidate alternative solution must absolutely satisfy in order to be included in the decision process, or WANT criteria that are desirable but not mandatory for each candidate alternative to satisfy. The Project Team, including City WTP staff and B&V professionals, developed preliminary Plant 1 Replacement Alternative selection MUST and WANT criteria during Workshop #1 held on Tuesday July 8, 2014. These preliminary MUST and WANT criteria were then reviewed and refined by the Project Team based on the consensus opinion of members with operational, engineering, and supervisory knowledge of and experience with the Ann Arbor WTP facilities during Workshop #2 held on Thursday August 21, 2014.

3.1.1 Mandatory MUST Criteria

Six mandatory MUST criteria were established based on compliance with City-specified Plant 1 Replacement requirements.

- Plant 1 Replacement Alternatives <u>must</u> provide at least 22 mgd of precipitative softening pre-treatment capacity. Either two-stage split-treatment or single-stage treatment technologies may be utilized.
- Plant 1 Replacement Alternatives <u>must</u> have all new pre-treatment facilities housed in an environmentally conditioned structure. If existing Basin 3 is included in an alternative to provide secondary settling, it is assumed that Basin 3 would not have to be covered.
- Plant 1 Replacement Alternatives <u>must</u> be capable of being constructed in a manner that would allow the Ann Arbor WTP to meet maximum day demand throughout the construction period. Maximum day demand was defined as 28 mgd based on review of historical operations data from 2009 through 2013.
- Plant 1 Replacement Alternatives <u>must</u> provide pre-treatment facilities that are capable of treating a minimum flow of 4 mgd.
- Plant 1 Replacement Alternatives <u>must</u> be configured to allow access for construction activities and operational requirements such as chemical delivery and de-watered softening solids removal.
- Plant 1 Replacement Alternatives <u>must</u> provide finished water that meets the City's drinking water quality goals for all possible blends of the City's existing Huron River and Steere Farm groundwater supplies. A summary of the City's drinking water quality goals is given in **Appendix TM3.A**.

3.1.2 Desirable WANT Criteria

Desirable WANT criteria, also termed Desires, were developed in three categories including Operational Flexibility, Process Performance, and Level of Service. Contributors that further describe each Desire were then developed. The Desires and Contributors that define the Plant 1 Replacement structured decision model are listed in **Table TM3-10** and

Table TM3-11 through **Table TM3-13**, respectively. A brief description of the considerations for each Desire and Contributor is also given in these Tables. Collectively, these Desires and their associated Contributors form the basis of a fair and balanced evaluation of the non-economic performances of Plant 1 Replacement Alternatives.

Table TM3-10: Plant 1 Replacement Decision Model Desires

DESIRES	CONSIDERATIONS	WEIGHT (1 TO 10)
Operational Flexibility	Considers factors that influence complexity of treatment, distribution, and maintenance operations	2
Process Performance	Considers factors that influence applied (settled) water turbidity and process stability	10
Level of Service	Considers factors that influence future capacity of facilities in Plant 1, potential to add additional processes in response to water quality or regulatory changes, and adherence to the City's Sustainability Framework	10

Table TM3-11: Operational Flexibility Desire – Contributors

CONTRIBUTOR	CONSIDERATIONS	WEIGHT (1 TO 10)
Operational Simplicity	Number of chemical addition and monitoring points, solid residuals removal, and maintenance operations	10

Table TM3-12: Process Performance Desire – Contributors

CONTRIBUTOR	CONSIDERATIONS	WEIGHT (1 TO 10)
Applied Turbidity	Specific features of new pre-treatment facilities such as tube- or plate-settling modules designed to improve settled water turbidity	7
Process Stability	Response of pre-treatment processes to changes in plant production, source water blend, and start-up operations	10

Table TM3-13: Level of Service Desire – Contributors

CONTRIBUTOR	CONSIDERATIONS	WEIGHT (1 TO 10)
Future Capacity	Plant 1 Replacement Alternatives that would allow more than 22 mgd of treatment capacity (up to 50 mgd) to be located in the existing Plant 1 footprint would be viewed more favorably	10

CONTRIBUTOR	CONSIDERATIONS	WEIGHT (1 TO 10)
Future Processes	Plant 1 Replacement Alternatives that would recover some of the area currently occupied by pre-treatment basins for potential future treatment processes would be viewed more favorably	9
Sustainability Framework	Plant 1 Replacement Alternatives that would address goals outlined in the City's Sustainability Framework would be viewed more favorably	6

The relative importance of each Desire, as well as its associated Contributors, in the decision process was established by assigning weights as follows:

- The relative importance of the Desires was established by assigning a weight between 1 and 10 to each. If a Desire was deemed of no importance in the decision process and was assigned a weight of 0, it was removed from the decision model.
- The Desire considered most important in the decision process was assigned a weight of 10. If two or more Desires were considered equally more important than the other Desires, each was assigned a weight of 10.
- Remaining Desires were then assigned lower weights in proportion to their importance relative to the most important Desire(s). For example, if a given Desire was considered to be half as important as the most important Desire(s), it was assigned a weight of 5.
- Contributors associated with each Desire were then assigned weights between 1 and 10 in a similar fashion, one Desire at a time. If a Contributor had no importance in the decision process and was assigned a weight of 0, it was removed from the decision model.
- For each Desire, the Contributor considered most important in the decision process was assigned a weight of 10. If two or more Contributors were considered equally more important than the other Contributors associated with the same Desire, each was assigned a weight of 10.
- Remaining Contributors associated with each Desire were then assigned lower weights in proportion to their importance relative to the most important Contributor(s). For example, if a given Contributor was considered to be half as important as the most important Contributor(s), it was assigned a weight of 5.

The following verbal scale was used as a guide in evaluating the relative importance of Desires and Contributors and assigning decision model weights:

- Critically important – 10
- Very important – 8 to 9
- Moderately important – 5 to 7
- Somewhat important – 3 to 4
- Minimally important – 1 to 2

The weights assigned to each Desire and its associated Contributing Factors are also listed in **Table TM3-10** and

Table TM3-11 through **Table TM3-13**, respectively.

3.1.3 Model Structure

The structured decision model developed by linking Desires, their associated Contributors, and Plant 1 Replacement Alternatives is shown on **Figure TM3-2**. Mandatory MUST criteria are not explicitly incorporated in the decision model structure, but rather are used to screen alternatives for further evaluation. Alternatives that did not comply with one or more of the mandatory MUST criteria are not linked to Contributors in the decision model, and their relative non-economic performance was not evaluated further.

3.1.4 Alternatives Scoring

The three Plant 1 Replacement Alternatives that satisfied each of the mandatory MUST criteria were scored based on their relative non-economic performances as the first step in selection of a preferred alternative. The following steps describe how Plant 1 Replacement Alternatives were scored against each individual Contributor:

- The relative non-economic performance of each Plant 1 Replacement Alternative was compared against each Contributor one at a time and scores between 1 and 10 assigned to each alternative, with the highest value for the alternative(s) that best satisfied the intent of the Contributor.
- If two or more alternatives were considered to satisfy the intent of a Contributor equally well and better than the other remaining alternatives, each was assigned a score of 10.
- It is important to note that assigning a score of 10 to an alternative for any given Contributor does not imply that the alternative satisfies the given Contributor perfectly, but rather that among all the alternatives under consideration it most closely satisfies the intent of the Contributor.
- Remaining Plant 1 Replacement Alternatives were then assigned lower scores based on their ability to satisfy the given Contributor relative to the alternative(s) that best satisfied that Contributor.

The following verbal scale was used as a guide in scoring the non-economic performance of Plant 1 Replacement Alternatives against each Contributor in turn:

- Satisfies the given Contributor with significant noted advantages – 10
- Satisfies the given Contributor with noted advantages – 8 to 9
- Satisfies the given Contributor with noted advantages and disadvantages – 5 to 7
- Satisfies the given Contributor with noted disadvantages – 3 to 4
- Satisfies the given Contributor with significant noted disadvantages – 1 to 2

The relative scores assigned to each Plant 1 Replacement Alternative for all contributors are listed in **Appendix TM3.D**.

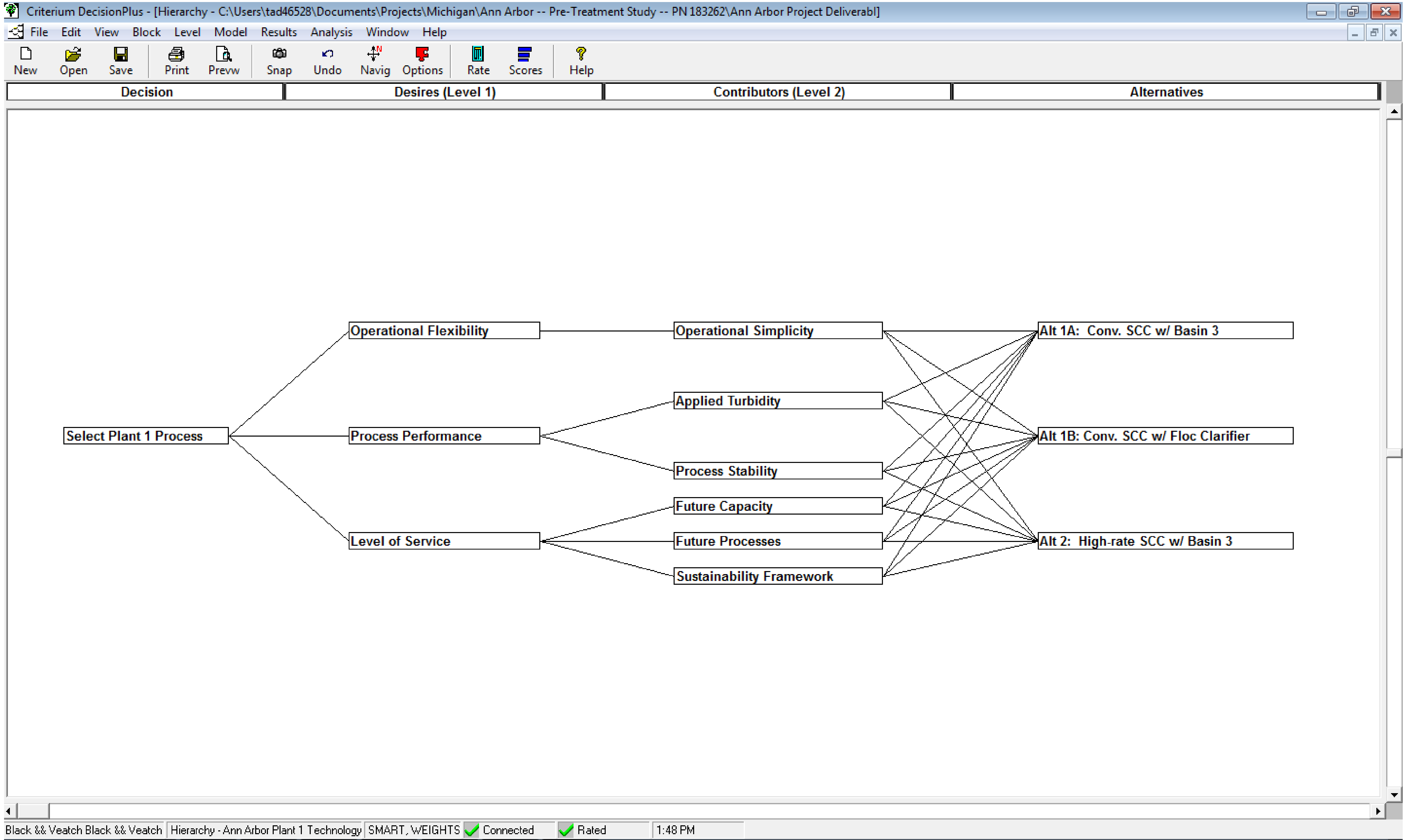


Figure TM3-2: Plant 1 Replacement Process Technology Selection Decision Model

3.2 NON-ECONOMIC COMPARISON OF PLANT 1 REPLACEMENT ALTERNATIVES

The non-economic performance of the three Plant 1 Replacement Alternatives was evaluated in three steps: 1) screening level evaluation for compliance with mandatory requirements specified by the City, 2) ranking of compliant Plant 1 Replacement Alternatives against non-economic factors to establish their relative performance, and 3) sensitivity analysis of the alternatives ranking process.

3.2.1 Plant 1 Replacement Alternatives Screening

The six mandatory MUST screening criteria established based on compliance with City-specified requirements (**Section 3.1.1**) were applied to each of the three Plant 1 Replacement Alternatives that would provide 22 mgd of new precipitative softening capacity, and each complied with all screening criteria. The two additional alternatives that would expand the treatment capacity of future Plant 1 facilities to 50 mgd were not evaluated further.

3.2.2 Non-Economic Performance Ranking

The non-economic performance of each alternative was calculated using the weights assigned to each Desire and Contributor in the decision model (**Figure TM3-2**) and the scores assigned to each Plant 1 Replacement Alternative for each Contributor, as shown in **Appendix TM3.D**. The non-economic performance values calculated were normalized to a scale of 0 to 1 for the purpose of comparison and ranking of Plant 1 Replacement Alternatives. A value of 1 calculated for a given alternative indicates that it scored at least as well as or better than all other alternatives for each Contributor, whereas a value of 0 indicates that the alternative scored at least as poorly as or worse than all other alternatives for each Contributor. The cumulative non-economic performance values calculated for Plant 1 Replacement Alternatives evaluated are listed in **Table TM3-14** and shown graphically on **Figure TM3-3**. The contributions of each Desire to the cumulative non-economic performance values are shown graphically on **Figure TM3-3** and listed in **Appendix TM3.D**.

Table TM3-14: Non-Economic Performance Values for Plant 1 Replacement

PLANT 1 REPLACEMENT ALTERNATIVE	NON-ECONOMIC PERFORMANCE SCALE FROM 0 TO 1
Alternative 1A	0.701
Alternative 1B	0.499
Alternative 2	1.000

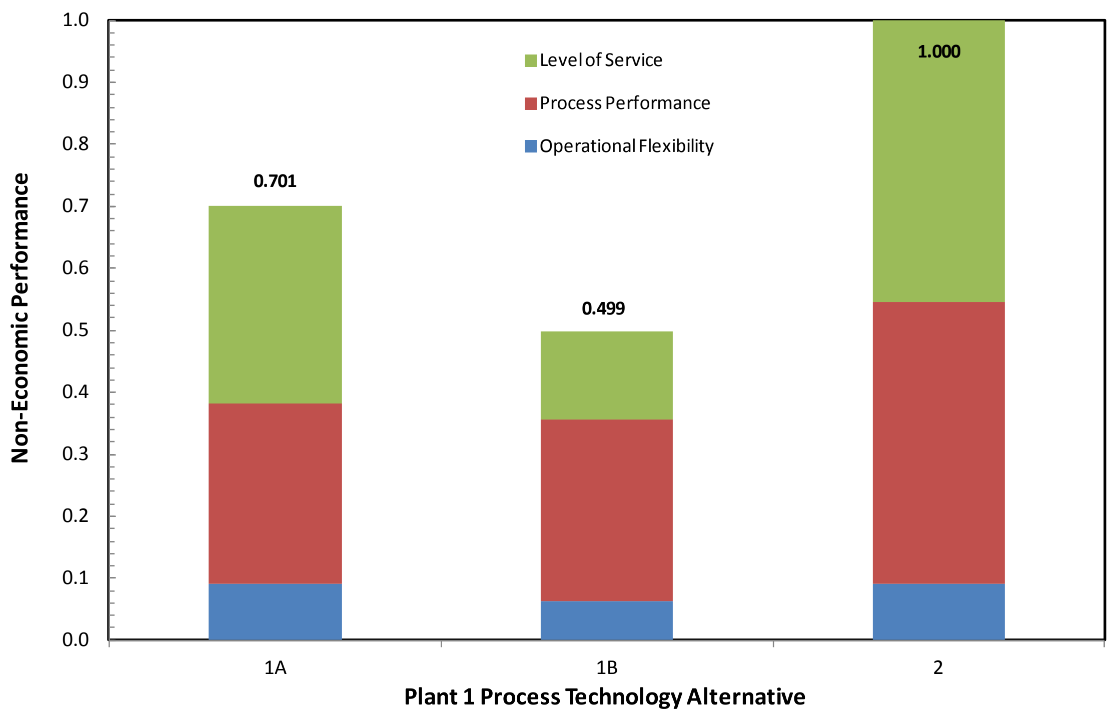


Figure TM3-3: Non-Economic Performance Values of Plant 1 Replacement Alternatives

The cumulative non-economic performance values of the three Plant 1 Replacement Alternatives scored here varied considerably, as shown on **Figure TM3-3**. Alternative 2 (high-rate solids-contact clarification) performed at least as well or better than Alternatives 1A (conventional solids-contact clarification with secondary settling in Basin 3) and 1B (conventional solids-contact clarification with a new second-stage flocculating clarifier) against all Contributors, as evidenced by its performance ranking of 1.0. Alternative 1B scored considerably lower than the other alternatives for the Level of Service Desire, due primarily to its larger footprint compared to other alternatives. The larger footprint required for Alternative 1B would not preserve space within the footprint of existing Plant 1 Facilities for implementation of potential future treatment processes that may become necessary due to changes in source water quality or regulatory requirements, nor would it accommodate more than 22 mgd of softening pre-treatment in the existing Plant 1 footprint.

3.2.3 Sensitivity Analysis

The sensitivity of non-economic performance of the three Plant 1 Replacement Alternatives considered to potential changes in the weights assigned to the decision model Desires and Contributors was evaluated using the Criterium DecisionPlus® (CDP) Decision Formulation, Analysis, and Presentation Software Package (InfoHarvest, 2001). The weights assigned to the decision model Desires and their associated Contributors (**Section 3.1.2**) and the scores specified for each Plant 1 Replacement Alternative for each Contributor (**Section Error! Reference source not found.**) were entered into the CDP program, and the Sensitivity by Weights feature applied. This feature adjusts the values assigned to weights for decision model Desires and Contributors one at a time and then recalculates the relative performance of alternatives evaluated.

Results of the CDP Sensitivity by Weights analysis are shown graphically for each Desire and Contributor on **Figure TM3.D.1** to **Figure TM3.D.9**, as given in **Appendix TM3.D**. The relative performance of each Plant 1 Replacement Alternative is shown graphically on these figures as the weight assigned to each individual Desire and Contributor was varied. For each Desire and Contributor, Plant 1 Replacement Alternative 2 was ranked the highest over the entire range of potential weights. This ranking was not sensitive to varying the weight of Desires or their associated Contributors, with no crossover points for any of the three Desires or six Contributors. Therefore, changing the weight assigned to any single Desire or Contributor within the allowed range of 1 to 10 would not change the outcome of Alternative 2 being highest ranked among those considered here based on non-economic considerations.

4 Opinions of Probable Cost

The conceptual level opinions of probable cost (OPCs) presented here were developed using a common set of capital and operations, maintenance, repair, and replacement (OMR&R) unit costs. The Class 4 planning level cost opinions presented here reflect use of standard engineering practices and were prepared without the benefit of detailed engineering designs. As defined by The Association for the Advancement of Cost Engineering (AACE), Class 4 cost opinions of this type are generally considered to have an accuracy range of plus 50 to minus 30 percent. Any actual project cost would depend on current labor and material costs, competitive market conditions, final project scope, bid date, and other variable factors. The opinions of probable cost presented here are most appropriately used to compare the relative costs of various Plant 1 Replacement Alternatives, rather than as estimates of actual project costs for detailed budgeting purposes.

A detailed breakdown of cost assumptions for each evaluated component is provided in **Appendix TM3.C.** The following sections summarize key cost considerations used in the development of Plant 1 Replacement Alternative costs.

4.1 OPINIONS OF PROBABLE CAPITAL COST

Opinions of probable capital cost for treatment components used to formulate the three Plant 1 Replacement Alternatives developed and evaluated here were based on historical cost databases maintained by Black & Veatch and cost quotes solicited from softening equipment suppliers. All historical cost data was escalated to present day using the Engineering News Record Construction Cost Index for the Detroit region (ENR CCI 10,634, July 2014). All treatment equipment and facilities were assumed to be housed in environmentally conditioned structures.

4.1.1 Treatment Components

The opinions of probable capital cost for treatment components provided here include unit process costs, additional project costs, contractor mark-up costs, and non-construction costs. Unit process costs include process equipment and basins, structures needed to house process equipment, and any additional structures required for office, laboratory, and maintenance spaces. A proprietary conceptual design and parametric costing tool developed and maintained by Black & Veatch was used to size selected treatment components and provide capital OPCs for unit processes. Items included in additional project costs, contractor mark-ups, and non-construction costs, as well as the unit multipliers for each, are listed in **Table TM3-15**. The opinions of probable capital cost for treatment components were developed as follows: additional project costs were added to the unit process costs subtotal to give the *facility cost* subtotal, contractor mark-up unit costs were then applied cumulatively to the facility cost subtotal to give the *construction cost* subtotal, and non-construction costs calculated and added to the construction cost subtotal to give the *total project capital cost* sub-total.

Due to the uncertainty associated with major rehabilitation and reconstruction projects within the confines of an existing water treatment facility, a rehabilitation adjustment factor was included in the non-construction costs category. This factor is intended to cover extraordinary costs that often occur associated with maintaining service of existing facilities throughout demolition and construction, incomplete knowledge of existing facility and site conditions, and difficulties related to restricted access and movement on the site. For the current level of definition of the City's Water Treatment Plant Alternatives Analysis Project, industry standard construction costing guidelines recommend using an adjustment factor in the range of 25 percent to 75 percent (CIC, 2011). A rehabilitation adjustment factor of 50 percent was applied during development of the opinions of probable capital cost for Plant 1 Replacement Alternatives.

Table TM3-15: Unit Costs Used to Develop Capital Cost Opinions

CATEGORY	UNIT COST
Additional Project Costs	**Percent of Unit Process Costs [(1)]**
Site Work	8 %
Yard Piping	20 %
Electrical Service	15 %
Instrumentation and Controls	5 %
Contractor Mark-Ups	**Percent of Facility Costs[(2)]**
Overhead	7 %
Profit	10 %
General Requirements[(3)]	3 %
Contingency	4 %
Non-Construction Costs	**Percent of Construction Costs[(4)]**
Permitting	1 %
Engineering	8 %
Construction Services	7 %
Commissioning/Startup	3 %
Legal/Administration	0.5 %
Contingency	30 %
Rehabilitation Adjustment Factor	50%

CATEGORY	UNIT COST
[1]Additional project costs are applied to the unit process costs subtotal additively. [2]Facility cost is the sum of the unit process cost subtotal and the additional project cost subtotal. Contractor mark-up costs are applied cumulatively to the facility cost. [3]Mobilization, bonding, and insurance. [4]Construction cost is the sum of facility cost subtotal and the contractor mark-ups subtotal. Non construction costs are applied to the construction costs subtotal additively.	

The opinions of probable capital cost for treatment components at the various capacities included in Plant 1 Replacement Alternatives are listed in **Appendix TM3.C**.

4.1.2 Plant 1 Replacement Alternatives

The cumulative opinions of probable capital cost that include all components of each Plant 1 Replacement Alternative are listed in **Table TM3-16**.

Table TM3-16: Opinions of Probable Capital Cost for Plant 1 Replacement

PLANT 1 REPLACEMENT ALTERNATIVE	OPC CAPITAL COST ($)
Alternative 1A	$39,680,000
Alternative 1B	$73,970,000
Alternative 2	$26,580,000

4.2 OPINIONS OF PROBABLE ANNUAL OPERATIONS, MAINTENANCE, REPAIR, AND REPLACEMENT COSTS

Annual operation, maintenance, repair, and replacement (OMR&R) opinions of probable cost include raw water pumping energy costs, treatment chemicals, disposal of dewatered solid residuals, periodic repair and replacement of equipment, and operational and maintenance related labor. Labor costs for each Plant 1 Replacement Alternative were estimated based on current staffing practices and salary rates at the existing Ann Arbor WTP, with adjustments to the number of full time equivalents (FTEs) depending on the facilities included. Annual repair and replacement costs were projected based on set percentages of the capital cost for each facility class.

4.2.1 Treatment Components

Opinions of probable annual OMR&R cost for treatment components of Plant 1 Replacement Alternatives include source water pumping, treatment chemical costs, residuals handling and disposal, operational and maintenance related labor, periodic repair and replacement of equipment. Several proprietary unit process analysis tools developed and maintained by Black & Veatch were used to estimate quantities for raw water pumping power, treatment related chemical usage, and residuals production. The opinions of probable annual OMR&R cost for treatment components at the various capacities included in Plant 1 Replacement Alternatives are listed in **Appendix TM3.C**.

4.2.2 Plant 1 Replacement Alternatives

The cumulative opinions of probable annual OMR&R cost that include all treatment components of each Plant 1 Replacement Alternative are listed in **Table TM3-17**.

Table TM3-17: Opinions of Probable Annual OMR&R cost for Plant 1 Replacement

PLANT 1 REPLACEMENT ALTERNATIVE	OPC CAPITAL COST ($)
Alternative 1A	$5,210,000
Alternative 1B	$5,290,000
Alternative 2	$5,150,000

4.3 OPINIONS OF PROBABLE LIFE-CYCLE NET PRESENT VALUE

A 30 year life-cycle was assumed for the net present value (NPV) analysis performed here, consistent with industry standard expected service lives for major drinking water treatment equipment. The net present values calculated here are based on the opinions of probable capital cost (**Section 4.1.2**) and opinions of probable annual OMR&R cost (**Section 4.2.2**) previously presented, and are given in 2014 dollars. Economic parameters used to calculate the net present values of Plant 1 Replacement Alternatives are listed in **Table TM3-18**. The 30-year life-cycle net present values that include all treatment components of each Plant 1 Replacement Alternative are listed in **Table TM3-19**.

Table TM3-18: Net Present Value Economic Parameters

PARAMETER	VALUE
Base Year	2014
General Inflation Rate	4 %
OMR&R Inflation Rate	5 %
Loan Interest Rate(1)	3.9 %
Discount Rate(1)	1.9 %
Loan Duration	30 years

(1)Guidelines and Discount Rates for Benefit-Cost Analyses of Federal Programs, Circular A-94, Office of Management and Budget.

Table TM3-19: Opinions of Life Cycle Net Present Value for Plant 1 Replacement

PLANT 1 REPLACEMENT ALTERNATIVE	OPC NET PRESENT VALUE ($)
Alternative 1A	$308,640,000
Alternative 1B	$357,070,000
Alternative 2	$288,680,000

5 Cost/Benefit Summary

The Plant 1 Replacement Alternatives were compared based on the combined impacts of cost and non-economic performance (benefit). All costs are expressed in 2014 dollars.

Figure TM3-4 presents a summary of Plant 1 Replacement Alternative capital costs and benefit scoring.

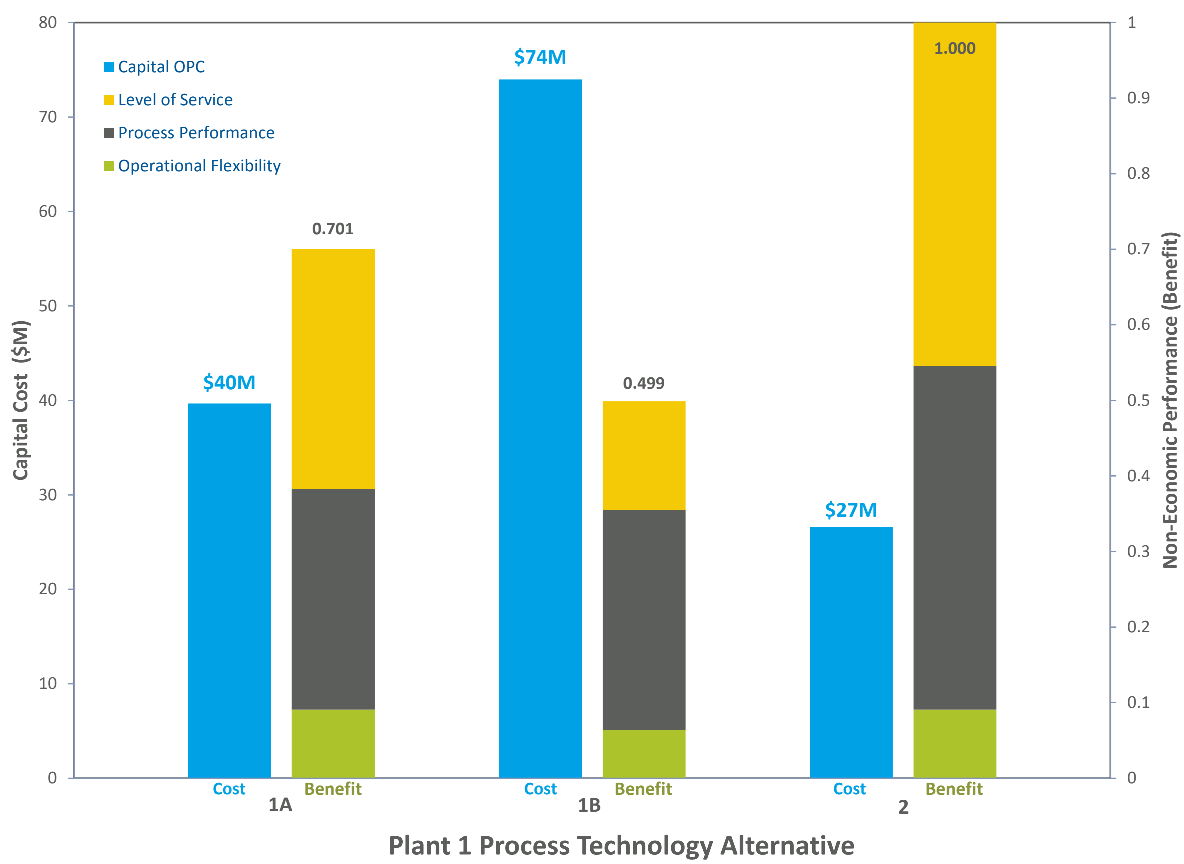


Figure TM3-4: Plant 1 Replacement Alternatives Cost and Benefit Summary

6 Phase II Preferred Plant 1 Replacement Alternative

The following sub-sections summarize the ranking of Plant 1 Replacement Alternatives based on non-economic and economic considerations, discuss adverse consequences associated with selection of each alternative in turn, and document the preferred Water Treatment Plant Alternatives Analysis Phase II Plant 1 Replacement Alternative.

6.1.1 Summary of Plant 1 Replacement Alternatives Ranking

Plant 1 Replacement Alternative 2 (high-rate solids-contact clarification) compared favorably with Alternatives 1A (conventional solids-contact clarification with secondary settling in Basin 3) and 1B (conventional solids-contact clarification with a new second-stage flocculating clarifier) based on evaluation of costs and benefit ranking. Alternative 2 was evaluated as having significantly lower capital (**Table TM3-16**) and life-cycle cost net present value (**Table TM3-18**) opinions of probable cost, as well as substantially higher non-economic performance (benefit) (**Table TM3-14**). Of particular note is the fact that Alternative 2 is the only baseline alternative that has the potential to provide 50 mgd of new softening facilities and retain a sizable portion of the existing Plant 1 footprint for additional future treatment process that may be required by changes in source water quality or regulations or other potential future uses.

6.1.2 Adverse Consequences Evaluation

After alternatives are ranked, the last step of the K-T® Decision Analysis procedure considers adverse consequences associated with choosing an alternative. Alternatives are evaluated one at a time, starting with the highest ranked alternative, until an alternative which <u>does not</u> have unacceptable adverse consequences is reached. Questions that should be asked as adverse consequences of each alternative are considered include:

- What could go wrong, both short term and long term, if this alternative were selected?
- What are the implications of being close to a MUST criteria?
- What disadvantages are associated with this alternative?
- Where might information about this alternative be invalid, and what are the implications of incorrect information?

As part of the evaluation of adverse consequences associated with choosing an alternative, several City operations staff members visited other facilities that currently utilize the precipitative softening technologies included in Plant 1 Replacement Alternatives considered here. These facilities included the Water One Wolcott and Hansen WTPs (Johnson County, KS), the Topeka, Kansas WTP and the Peter D. Binney Water Purification Facility in Aurora, Colorado.

6.1.2.1 Plant 1 Replacement Alternative 2 (High-Rate Solids-Contact Clarification)

Plant 1 Replacement Alternative 2 (high-rate solids-contact clarification) was highest ranked based on non-economic and economic criteria, so adverse consequences associated with its selection were considered first. Potential adverse consequences associated with selection of this technology for Plant 1 replacement include:

- There are only a small number of facilities that use this technology for precipitative softening of surface water supplies to produce drinking water treatment.

- There is very limited design and operational experience using this technology in the capacity range desired by the City (i.e., greater than 20 mgd).
- The proprietary nature of basin equipment limits flexibility in design and maintenance of precipitative softening facilities using this technology. Also, integration of manufacturer supplied SCADA systems can require extensive modification of existing systems.
- Catastrophic failure of rapid mix and reaction zone impeller shafts has occurred recently at one the few facilities that use this technology. Requirements for redesign and replacement of these components have not yet been identified.
- Optimization of treatment operations has been reported to be a challenging process, requiring significant operator attention for an extended period.

Based on the high degree of operational uncertainty and potential risk associated with these adverse consequences, Plant 1 Replacement Alternative 2 (high-rate solids-contact clarification) <u>was not</u> selected as the preferred Plant 1 Replacement Alternative. Therefore, potential adverse consequences associated with the second highest ranked Plant 1 Replacement Alternative 1A were considered.

6.1.2.2 Plant 1 Replacement Alternative 1A (Conventional Solids-Contact Clarification with Secondary Settling in Basin 3)

Plant 1 Replacement Alternative 1A (conventional solids-contact clarification with secondary settling in Basin 3) was second highest ranked based on non-economic and economic criteria, so adverse consequences associated with its selections were considered next. Potential adverse consequences associated with selection of this technology for Plant 1 replacement include:

- This Plant 1 Replacement Alternative would only provide the capability for 22 mgd of single-stage precipitative softening. However, this adverse consequence could be mitigated in the future by removing existing Basin 3 and replacing it with either a flocculating clarifier (Alternative 1B) or a second solids-contact clarifier (Alternative 1F).
- This Plant 1 Replacement Alternative would not recover any sizable portion of the WTP site currently occupied by Plant 1 facilities that could be used to house potential future treatment processes.
- This Plant 1 Replacement Alternative would require continued use of existing Basin 3, which has noted condition issues. Mitigation of these material issues was evaluated here to include superficial concrete repair and replacement of installed mechanical equipment, which were included in capital costs for this alternative. However, enclosing Basin 3 was not considered practical based on its design and proximity of adjacent structures.

These potential adverse consequences largely impact future Plant 1 capacity and alternative site uses, but would not adversely impact treatment performance, operability, or maintainability. Conventional solids-contact clarification is a robust and time-tested precipitative softening technology. It has been used in municipal drinking water treatment applications for 60 years, and is available is several equipment configurations. Facilities toured by Ann Arbor staff that utilize solids-contact clarification technology for precipitative softening of surface water supplies with water quality similar to that of the City's Huron river supply, reported consistently successful operation under a wide range of treatment conditions.

After careful consideration City staff concluded that the potential adverse consequences identified for Plant 1 Replacement Alternative 1A were either acceptable, or could be made acceptable through mitigation measures. Therefore, conventional solids-contact clarification with secondary settling in Basin 3 (Alternative 1A) was selected as the preferred Plant 1 Replacement Alternative for Phase II of the Water Treatment Plant Alternatives Analysis Study.

6.1.2.3 Plant 1 Replacement Alternative 1B (Conventional Solids-Contact Clarification and Second-Stage Flocculating Clarifier)

Potential adverse consequences associated with Plant 1 Replacement Alternative 1B (conventional solids-contact clarification and second stage flocculating clarifier) were not considered because a higher ranked alternative was selected as the preferred alternative.

6.1.3 Preferred Plant 1 Replacement Alternative

Based on consideration of non-economic and economic criteria, as well as potential adverse consequences of alternatives, conventional solids-contact clarification with secondary settling in existing Basin 3 (Alternative 1A) was selected as the preferred Plant 1 Replacement Alternative in Phase II of the Water Treatment Plant Alternatives Analysis Study.

7 Next Steps

Further detailed technical evaluations should be performed as the next steps in implementation of the preferred Plant 1 Replacement Alternative selected in Phase II of the Water Treatment Plant Alternatives Analysis Study. Specific evaluations to be performed would include the following.

7.1.1 Plant 1 Pre-Treatment Capacity

For consistency with the basis of source of supply and system reliability evaluations in Phase I of this study, Phase II of this study evaluated replacing the current 22 mgd pre-treatment capacity of Plant 1 in kind. However, if operated at a marginally higher surface loading rate (1.6 gpm/ft^2 as opposed to 1.4 gpm.ft^2), the solids-contact clarification basin conceptually outlined in preferred Alternative 1A would provide up to 25 mgd of single-stage precipitative softening pre-treatment capacity. Increasing the rated pre-treatment capacity for Plant 1 provides greater flexibility for operation of the Ann Arbor WTP in its current configuration, and offers the opportunity to reconfigure pre-treatment facilities in the future if changes in source water quality or regulations require incorporation of additional treatment processes.

7.1.2 Future Pre-Treatment Configuration

Precipitative softening pre-treatment at the Ann Arbor WTP could be reconfigured in the future by addition of a second solids-contact clarification basin, thereby extending preferred Phase II Alternative 1A to Alternative 1F, as previously described in **Sub-Section 2.6**, and shown conceptually on **Figure TM3.B-4**. Further consideration should be given to the spatial arrangement and hydraulics of Alternative 1A facilities so that the ability to implement Alternative 1F in the future is maintained.

7.1.3 Implementation Plan for Pre-Treatment Improvements

An implementation plan for Plant 1 pre-treatment improvements should be developed. Important considerations for this implementation plan include planning for staged construction over multiple seasons, preparations to maintain continuity of operations during construction, and special requirements associated with construction in close proximity to a residential area. Given the challenging and disruptive nature of construction on the Ann Arbor WTP site and rehabilitation costs associated with maintaining existing Plant 1 Basin 3 in service, the potential benefits of moving directly to implementation of Alternative 1F should also be considered.

8 Recommendations

Black & Veatch recommends that the City of Ann Arbor proceed with further detailed evaluation of Plant 1 Replacement Alternative 1A. We also recommend further detailed evaluation of Alternative 1F for the following reasons

- Uncertainty related to the as yet unidentified staging plan for implementation of Alternative 1A that could substantially increase the duration of construction.
- Uncertainty related to the potential presence of unknown site conditions in the vicinity of existing Plant 1 Basins and construction in close proximity to existing Basin 3.
- Uncertainty related to actual costs for rehabilitation of existing Basin 3.

9 References

InfoHarvest (2001), *Criterium Decision Plus: Complete Decision Formulation, Analysis, and Presentation for Windows*", ver. 3.0, Seattle, WA, 2001.

CIC (2011), *Global Construction Cost and Reference Yearbook, 11th Annual Addition*, Compass International Consultants Inc., Morrisville, Pennsylvania, USA, 2011.

Ten States Standards (2012), *Recommended Standards for Water Works*, Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, 2012 Edition.

Appendix TM3.A

City of Ann Arbor Finished Water Quality Goals

OPERATIONAL AND WATER QUALITY GOALS - SUMMER								
	Primary Basin	**Secondary Basin**	**Ozone**	**Wet Well**	**Filters**	**CW**	**Reservoir**	**Dist. Syst.**
pH	11.0-11.3	10	≤8.0	9.3	9.3	9.3	9.3	
Sludge %	8-10%	≤3%						
(OH)		0						
(Polymer)*		0.6 mg/l						
Turbidity		<5 NTU			<0.2 NTU	<0.1 NTU	<0.1 NTU	<0.5 NTU
Average (O_3) Resid			0.1 mg/l 1st cell					
% CT			150%					
(PO_4)				0.95 mg/l as SHMP				
Filter Run					96 hrs @1.0 mgd 48 hrs @ 2 mgd, ie. 4 Mgal, ≤7 ft HL			
Backwash					10-15 NTU			
Cl_2:NH_3-N		<5.0	(4.75-5)			.		
Cl_2:NH_3		≤4.0	(3.75-4)				≤.25 ppm excess ammonia	
Alkalinity							≥50 mg/l	
TH							120 mg/l	
Fluoride							0.7 mg/l	
NH_2Cl							3.0 mg/l	>1.5 mg/l
T&O							0	0
Nitrite								<100 µg/L
HPC								<500 cfu/ml

*Raw water @ Barton Pond - 1 ppm 3 weeks on/ 1 week off when river temp ≥ 12°C

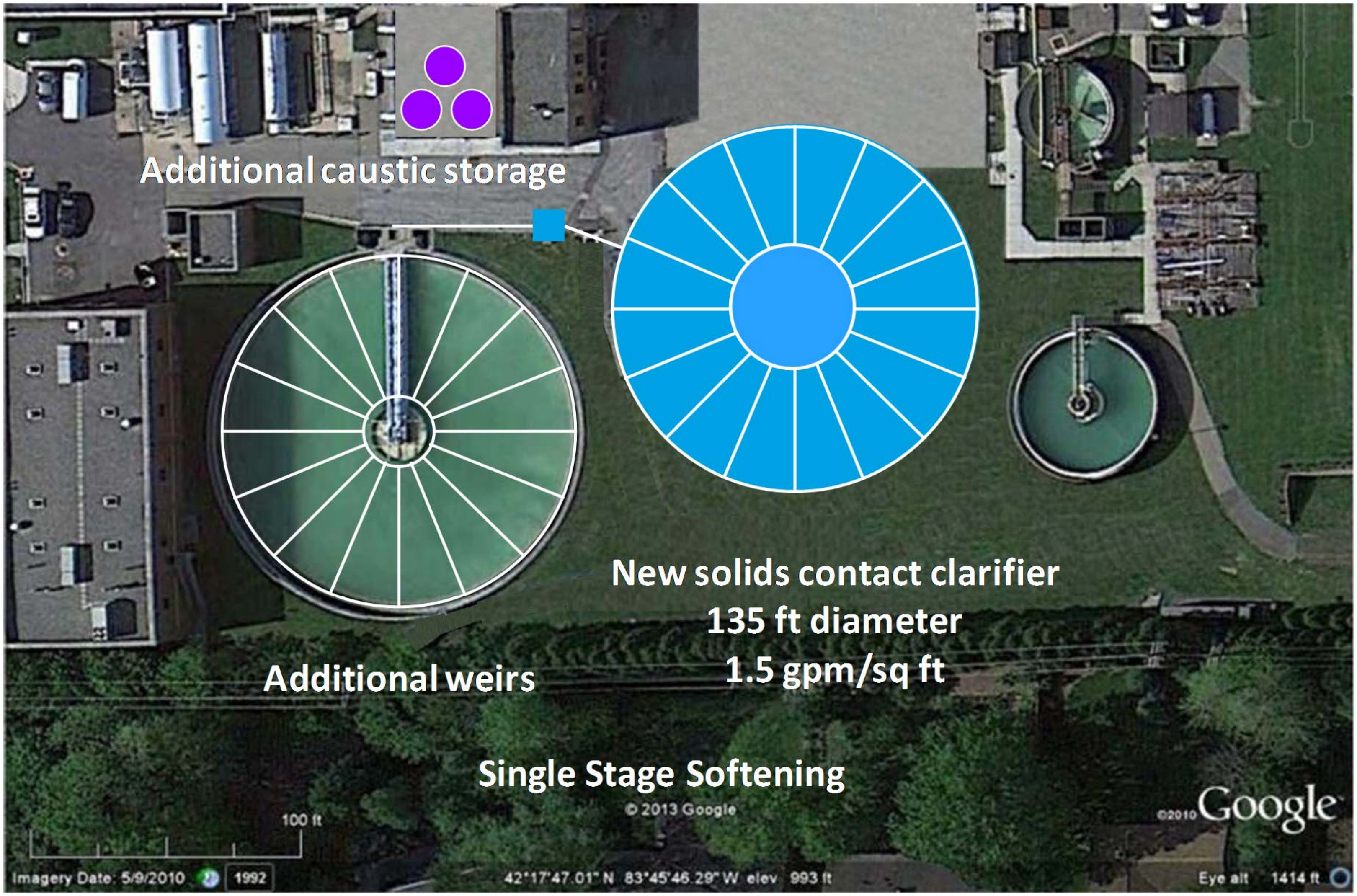
Notes: 1) Maximum well water in primary ≥ 75%. 2) Can move backwash recirculation to secondary if having hexahydrate sludge problems. 3) Add $CaCO_3$ to primary RM as needed for hexahydrate problem.

OPERATIONAL AND WATER QUALITY GOALS - WINTER								
	Primary Basin	**Secondary Basin**	**Ozone**	**Wet Well**	**Filters**	**CW**	**Reservoir**	**Dist. Syst.**
pH	11.0-11.3	10	≤8.0	9.3	9.3	9.3	9.3	
Sludge %	8-10%	≤3%						
(OH)		0						
(Polymer) *		0.6 mg/l						
Turbidity		<5 NTU			<0.2 NTU	<0.1 NTU	<0.1 NTU	<0.5 NTU
Average (O_3) Resid			0.1 mg/l 1st cell					
% CT			150%					
(PO_4)				0.95 mg/l as SHMP				
Filter Run					96 hrs @1.0 mgd 48 hrs @ 2 mgd, ie. 4 Mgal, ≤7 ft HL			
Backwash					10-15 NTU			
Cl_2:NH_3-N		<5.0	(4.75-5)					
Cl_2:NH_3		≤4.0	(3.75-4)				≤.25 ppm excess ammonia	
Alkalinity							>50 mg/l	
TH							140 mg/l	
Fluoride							0.7 mg/l	
NH_2Cl							3.0 mg/l	>2.0 mg/l
T&O							0	0
Nitrite								<100 µg/L
HPC								<500 cfu/ml

Notes: 1) Maximum well water in primary ≥ 75%. 2) Can move backwash recirculation to secondary if having hexahydrate sludge problems. 3) Add $CaCO_3$ to primary RM as needed for hexahydrate problem.

Appendix TM3.B

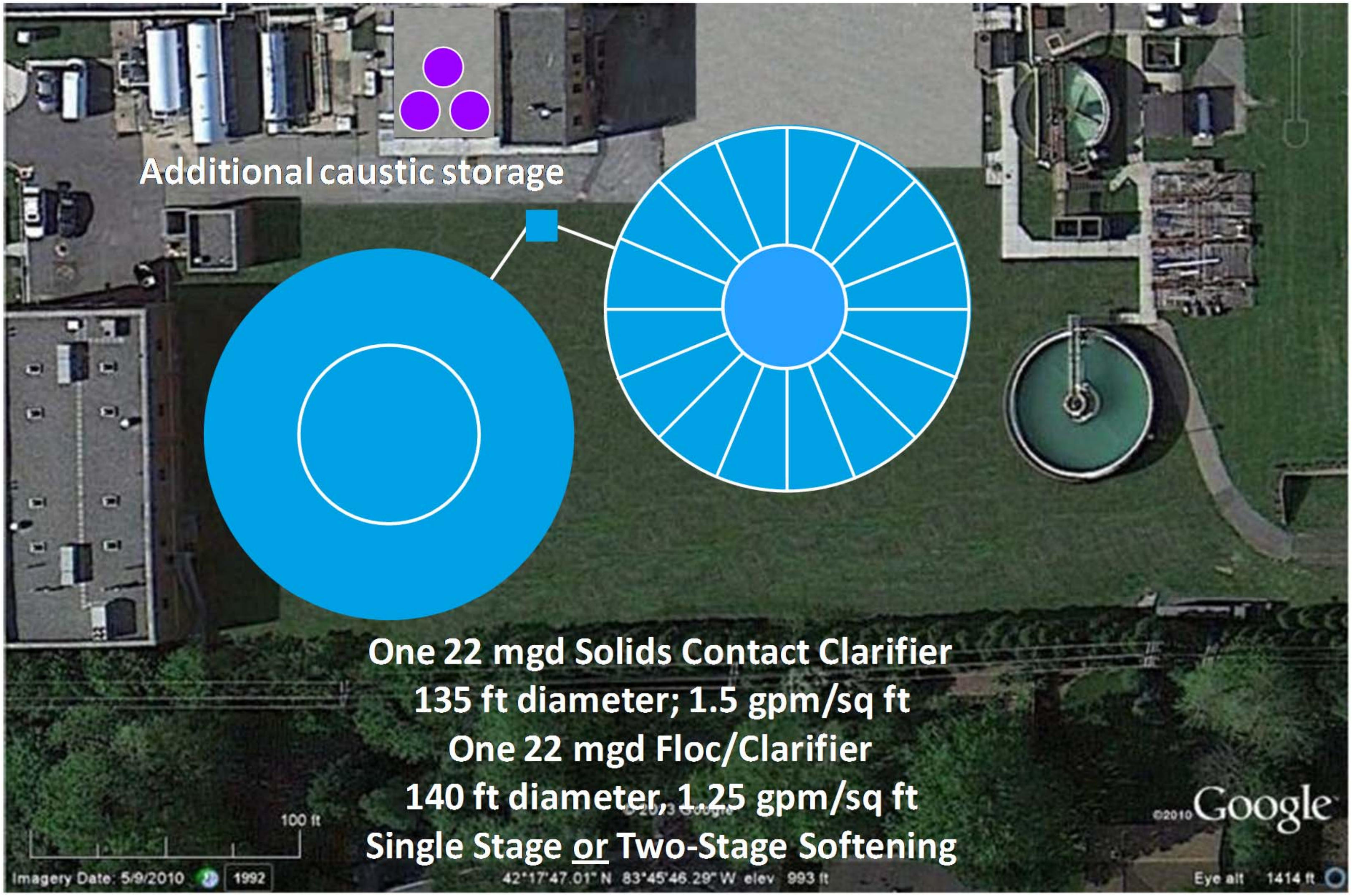
Plant 1 Replacement Alternative Conceptual Schematics



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Plant 1 Replacement Alternative 1A: Single-Stage Softening
Conventional Solids-Contact Clarification with Secondary Settling in Basin 3

Figure TM3.B-1



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

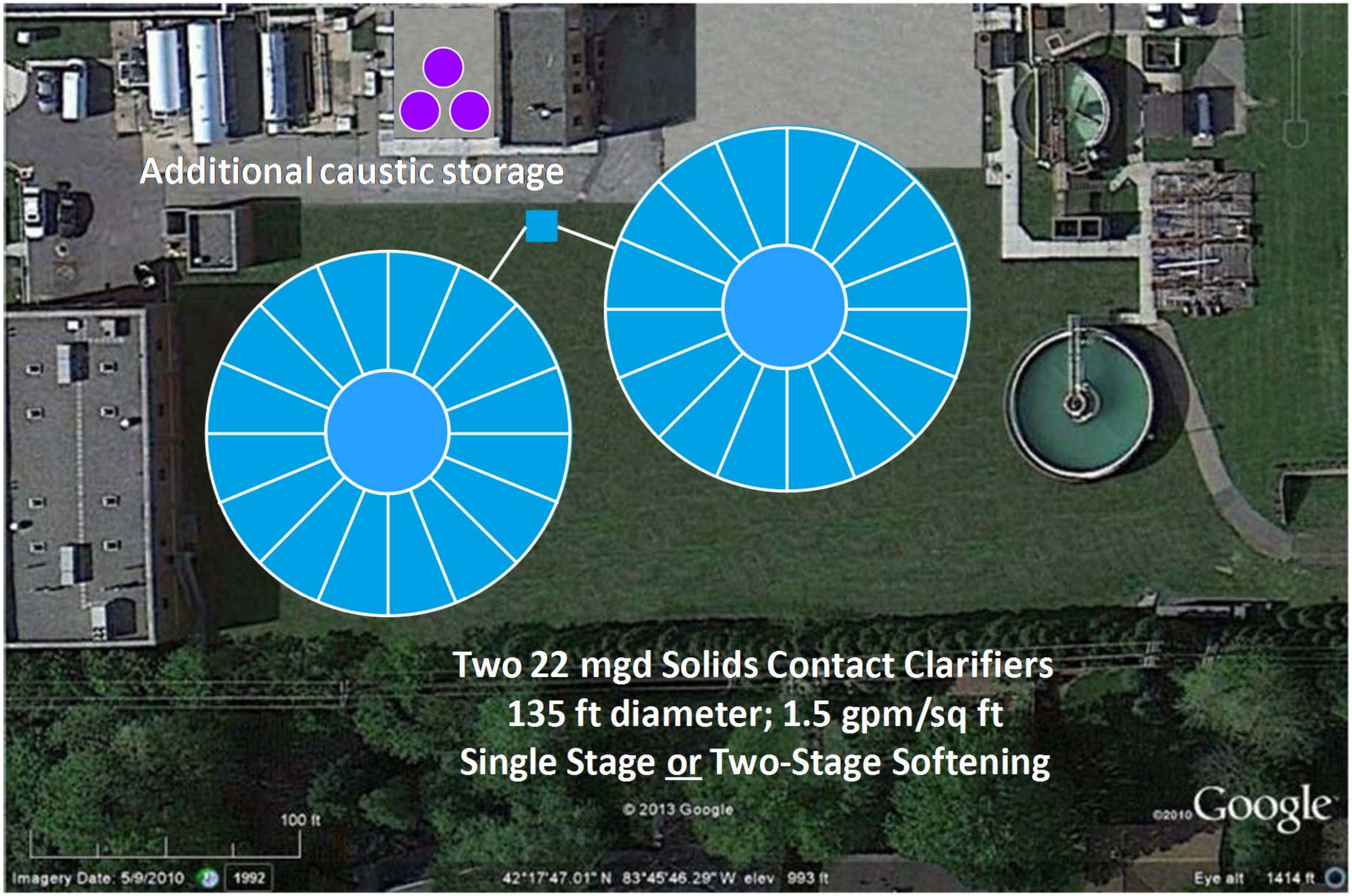
Plant 1 Replacement Alternative 1B: Single-Stage or Two-Stage Softening
Conventional Solids-Contact Clarification with a Flocculating Clarifier

Figure TM3.B-2

City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Plant 1 Replacement Alternative 2: Single-Stage Softening
High-Rate Solids-Contact Clarification with Secondary Settling in Basin 3

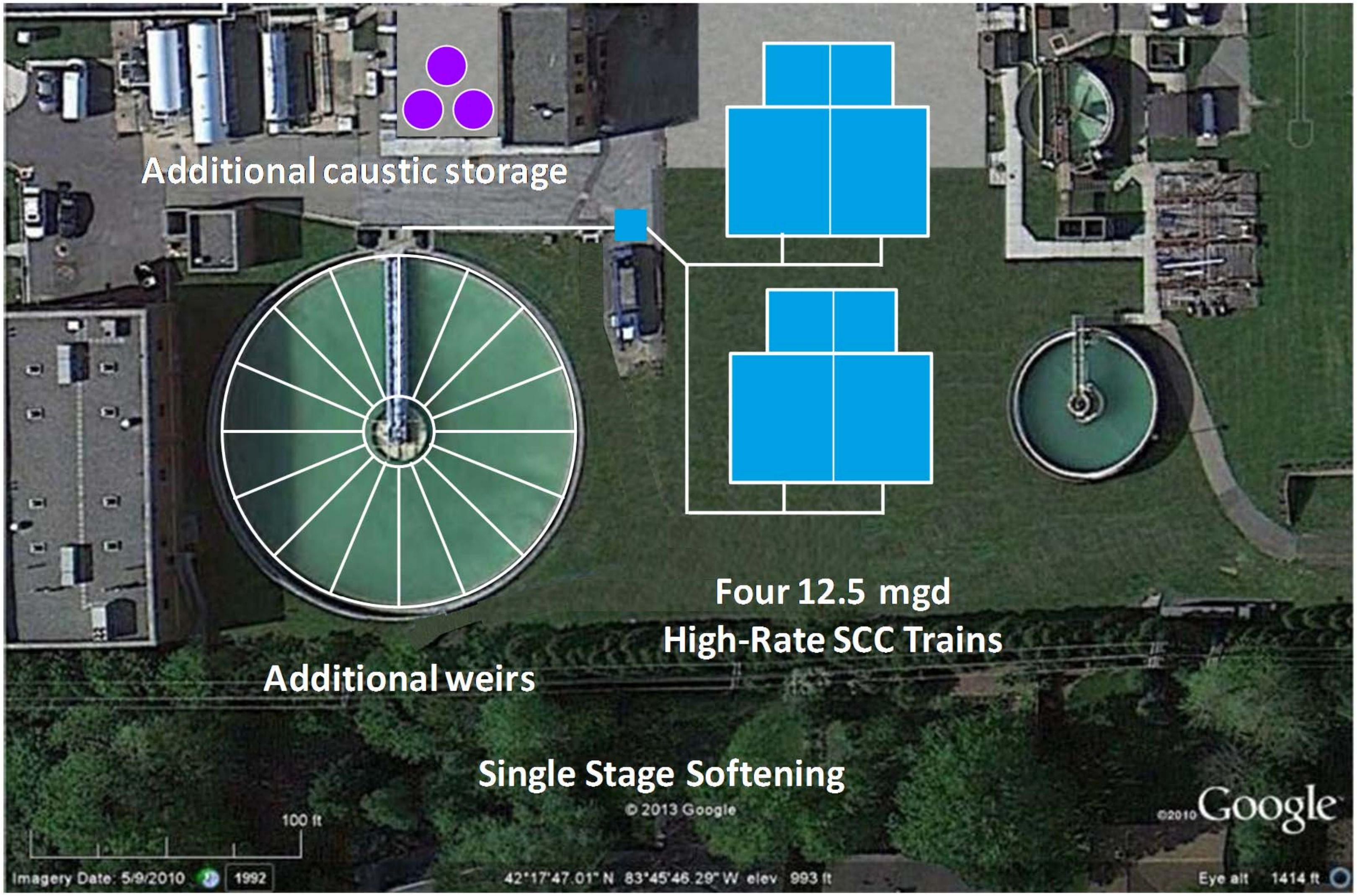
Figure
TM3.B-3



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Plant 1 Replacement Alternative 1F: Single-Stage or Two-Stage Softening Conventional Solids-Contact Clarifiers (Series – 25 mgd, Parallel – 50 mgd)

Figure TM3.B-4



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Plant 1 Replacement Alternative 2F: Single-Stage Softening
High-Rate Solids-Contact Clarification with Secondary Settling in Basin 3

Figure
TM3.B-5

Appendix TM3.C

Plant 1 Replacement Alternatives Summary Sheets

- TM3.C.1 Opinions of Probable Capital Cost
- TM3.C.2 Opinions of Probable Annual OMR&R Cost
- TM3.C.3 Opinions of Probable Life-Cycle Net Present Value

Appendix TM3.C.1
Capital OPC Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Average Day Demand	15	mgd

Sources of Supply

Alternative	Huron River (percent)	Steere Farm (percent)	Huron River (mgd)	Steere Farm (mgd)	Total (MG)
Plant 1 -- Alternative 1A	80%	20%	12.0	3.0	5,475
Plant 1 -- Alternative 1B	80%	20%	12.0	3.0	5,475
Plant 1 -- Alternative 2	80%	20%	12.0	3.0	5,475

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Average Day Demand	15	**mgd**
Capacity	22	**mgd**

Component

Capital Cost ($M)

Alternative	(1) Conv SCC ($M)	(2) Floc/Clar ($M)	(3) HR SCC ($M)	(4) RM Basin ($M)	(5) Basin 3 Mod ($M)	(6) Caustic Feed/Stor ($M)
Component Cost	$23.7	$23.3	$15.0	$0.19	$0.43	$2.13
Rehab. Adjustment Factor	1.50	1.50	1.50	1.50	1.50	1.50
Adjusted Component Cost	$35.6	$34.9	$22.5	$0.29	$0.64	$3.19

Alternative	Conv SCC (mgd)	Floc/Clar (mgd)	HR SCC (mgd)	RM Basin (mgd)	Basin 3 Mod (mgd)	Caustic Feed/Stor (mgd)
Plant 1 -- Alternative 1A	22			22	22	11
Plant 1 -- Alternative 1B	22	22		22		11
Plant 1 -- Alternative 2			22	22	22	11

Alternative	Conv SCC ($M)	Floc/Clar ($M)	HR SCC ($M)	RM Basin ($M)	Basin 3 Mod ($M)	Caustic Feed/Stor ($M)	Total Capital ($M)
Plant 1 -- Alternative 1A	$35.6			$0.29	$0.6	$3.2	$39.7
Plant 1 -- Alternative 1B	$35.6	$34.9		$0.29		$3.2	$74.0
Plant 1 -- Alternative 2			$22.5	$0.29	$0.6	$3.2	$26.6

Appendix TM3.C.2
Annual OMRR OPC Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Average Day Demand	15	mgd

Alternative	Sources of Supply				
	Huron River (percent)	Steere Farm (percent)	Huron River (mgd)	Steere Farm (mgd)	Total (MG)
Plant 1 -- Alternative 1A	80%	20%	12.0	3.0	5,475
Plant 1 -- Alternative 1B	80%	20%	12.0	3.0	5,475
Plant 1 -- Alternative 2	80%	20%	12.0	3.0	5,475

Average Day Demand 15 **mgd**

Source Water Pumping

Pumping Unit Costs (kWh/MG)		Pumping Unit Costs ($/kWh)	
1,030	1,713	$0.0888	$0.0888

Unit power cost per COAA

Alternative	Source Water Power		Source Water Pumping Cost		
	Huron River (kWh)	Steere Farm (kWh)	Huron River ($/yr)	Steere Farm ($/yr)	Total ($/yr)
Plant 1 -- Alternative 1A	4,511,400	1,875,735	$400,612	$166,565	$567,178
Plant 1 -- Alternative 1B	4,511,400	1,875,735	$400,612	$166,565	$567,178
Plant 1 -- Alternative 2	4,511,400	1,875,735	$400,612	$166,565	$567,178

Average Day Demand 15 **mgd**

Treatment

	Treatment Unit Costs ($/MG)	
Two-stage softening	$151.69	$151.69
Single-stage softening	$167.98	$167.98

Unit treatment cost per Softening Analysis Memo
Softening chemicals only

Alternative	Treated Water Supplies		Treatment Cost		
	Huron River (mgd)	Steere Farm (mgd)	Huron River ($/yr)	Steere Farm ($/yr)	Total ($/yr)
Plant 1 -- Alternative 1A	12.0	3.0	$735,755	$183,939	$919,694
Plant 1 -- Alternative 1B	12.0	3.0	$664,421	$166,105	$830,526
Plant 1 -- Alternative 2	12.0	3.0	$735,755	$183,939	$919,694

Appendix TM3.C.2
Annual OMRR OPC Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Average Day Demand 15 **mgd**

Residuals Handling and Disposal

	Residuals Production (Ton/MG)		Residuals Unit Costs ($/Ton)	
Existing Split Treatment	3,970	3,970	$17.46	$17.46
Single Stage (Lime-Caustic)	4,126	4,126		
Solids Content	65%	65%		

Unit disposal cost per COAA
Unit solids production per Softening Analysis Memo

Alternative	Residuals Production: Huron River (Ton)	Residuals Production: Steere Farm (Ton)	Residual Disposal Costs: Huron River ($/yr)	Residual Disposal Costs: Steere Farm ($/yr)	Total ($/yr)
Plant 1 -- Alternative 1A	13,901	3,475	$242,742	$60,686	$303,428
Plant 1 -- Alternative 1B	13,375	3,344	$233,566	$58,392	$291,958
Plant 1 -- Alternative 2	13,901	3,475	$242,742	$60,686	$303,428

Average Day Demand 15 **mgd**

Labor

Position descriptions and salary rates per COAA

Alternative	Labor FTEs: Admin (FTE)	Operations (FTE)	Laboratory (FTE)	Maint (FTE)	Total (FTE)	Labor Costs: Admin ($/yr)	Operations ($/yr)	Laboratory ($/yr)	Maint ($/yr)	Total ($/yr)
Plant 1 -- Alternative 1A	5.0	16.0	1.5	5.0	27.5	$639,350	$1,810,700	$141,550	$634,600	$3,226,200
Plant 1 -- Alternative 1B	5.0	16.0	1.5	5.0	27.5	$639,350	$1,810,700	$141,550	$634,600	$3,226,200
Plant 1 -- Alternative 2	5.0	16.0	1.5	5.0	27.5	$639,350	$1,810,700	$141,550	$634,600	$3,226,200

Appendix TM3.C.2
Annual OMRR OPC Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Average Day Demand 15 **mgd**

Capacity 22 **mgd**

	Component					
	(1)	(2)	(3)	(4)	(5)	(6)
	Capital Cost ($M)					
Alternative	**Conv SCC (mgd)**	**Floc/Clar (mgd)**	**HR SCC (mgd)**	**RM Basin (mgd)**	**Basin 3 Mod (mgd)**	**Caustic Feed/Stor (mgd)**
	$35.6	$34.9	$22.5	$0.29	$0.64	$3.19
R&R Percentage	0.50%	0.50%	0.50%	0.50%	0.10%	0.50%

Alternative	**Conv SCC (mgd)**	**Floc/Clar (mgd)**	**HR SCC (mgd)**	**RM Basin (mgd)**	**Basin 3 Mod (mgd)**	**Caustic Feed/Stor (mgd)**
Plant 1 -- Alternative 1A	22			22	22	11
Plant 1 -- Alternative 1B	22	22		22		11
Plant 1 -- Alternative 2			22	22	22	11

Alternative	**Conv SCC ($/yr)**	**Floc/Clar ($/yr)**	**HR SCC ($/yr)**	**RM Basin ($/yr)**	**Basin 3 Mod ($/yr)**	**Caustic Feed/Stor ($/yr)**	**Total R&R Cost ($/yr)**
Plant 1 -- Alternative 1A	$177,780			$1,435	$643	$15,971	$195,829
Plant 1 -- Alternative 1B	$177,780	$174,683		$1,435		$15,971	$369,869
Plant 1 -- Alternative 2			$112,298	$1,435	$643	$15,971	$130,347

Average Day Demand 15 **mgd**

Unit Cost of Service

Alternative	**RW Pumping ($/MG)**	**Treatment ($/MG)**	**Residuals Disposal ($/MG)**	**Labor ($/MG)**	**R&R ($/MG)**	**Total ($/MG)**
Plant 1 -- Alternative 1A	$104	$168	$55	$589	$36	$952
Plant 1 -- Alternative 1B	$104	$152	$53	$589	$68	$965
Plant 1 -- Alternative 2	$104	$168	$55	$589	$24	$940

Total Annual OMR&R

Alternative		**Total ($)**
Plant 1 -- Alternative 1A		$5,210,000
Plant 1 -- Alternative 1B		$5,290,000
Plant 1 -- Alternative 2		$5,150,000

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Appendix TM3.C.3
Life-Cycle Net Present Value OPC Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Ave Day Demand	15	mgd
Annual Production	5,475	MG

Economic Evaluation

Capital cost based on design flow, OM&R cost based on average flow.

Life-Cycle Economic Parameters

Base Year =	2014
General Inflation Rate =	4.0%
OM&R Inflation Rate =	5.0%
Loan Interest Rate =	3.9%
Discount Rate (PW) =	1.9%
Loan Duration (yrs) =	30

NPV Factor	NPV Factor
1.30	49.36

Alternative	Capital Cost ($)	Annual OMR&R Cost ($)	Life-Cycle NVP ($)	Relative Value Capital	Relative Value OMR&R	Relative Value NPV
Plant 1 -- Alternative 1A	$39,680,000	$5,210,000	$308,640,000	149%	101%	107%
Plant 1 -- Alternative 1B	$73,970,000	$5,290,000	$357,070,000	278%	103%	124%
Plant 1 -- Alternative 2	$26,580,000	$5,150,000	$288,680,000	100%	100%	100%

Appendix TM3.C.3
Life-Cycle Net Present Value OPC Summary Sheet

Loan Amount =	$22,000,000
Annual O&M Costs=	$100,000

Capital NPV Factor	1.30	Pipe Useful Life	75
OMR&R NPV Factor	49.36	Pipe Salvage Factor	0.34

Year	Yr	PW	General	OM&R	Current Annual	Present Value	Current Annual	Inflated Annual	Present Value	Net Present
2014	0	1.000	1	1	$0	$0	$0	$0	$0	$0
2015	1	0.981	1.040	1.050	$1,256,860	$1,233,425	$100,000	$105,000	$103,042	$1,336,467
2016	2	0.963	1.082	1.103	$1,256,860	$1,210,427	$100,000	$110,250	$106,177	$1,316,604
2017	3	0.945	1.125	1.158	$1,256,860	$1,187,858	$100,000	$115,763	$109,407	$1,297,265
2018	4	0.927	1.170	1.216	$1,256,860	$1,165,709	$100,000	$121,551	$112,735	$1,278,444
2019	5	0.910	1.217	1.276	$1,256,860	$1,143,974	$100,000	$127,628	$116,165	$1,260,139
2020	6	0.893	1.265	1.340	$1,256,860	$1,122,643	$100,000	$134,010	$119,699	$1,242,342
2021	7	0.877	1.316	1.407	$1,256,860	$1,101,711	$100,000	$140,710	$123,341	$1,225,051
2022	8	0.860	1.369	1.477	$1,256,860	$1,081,169	$100,000	$147,746	$127,093	$1,208,261
2023	9	0.844	1.423	1.551	$1,256,860	$1,061,009	$100,000	$155,133	$130,959	$1,191,969
2024	10	0.828	1.480	1.629	$1,256,860	$1,041,226	$100,000	$162,889	$134,943	$1,176,169
2025	11	0.813	1.539	1.710	$1,256,860	$1,021,812	$100,000	$171,034	$139,048	$1,160,860
2026	12	0.798	1.601	1.796	$1,256,860	$1,002,759	$100,000	$179,586	$143,279	$1,146,038
2027	13	0.783	1.665	1.886	$1,256,860	$984,062	$100,000	$188,565	$147,637	$1,131,700
2028	14	0.768	1.732	1.980	$1,256,860	$965,714	$100,000	$197,993	$152,129	$1,117,842
2029	15	0.754	1.801	2.079	$1,256,860	$947,707	$100,000	$207,893	$156,757	$1,104,464
2030	16	0.740	1.873	2.183	$1,256,860	$930,036	$100,000	$218,287	$161,526	$1,091,562
2031	17	0.726	1.948	2.292	$1,256,860	$912,695	$100,000	$229,202	$166,440	$1,079,135
2032	18	0.713	2.026	2.407	$1,256,860	$895,677	$100,000	$240,662	$171,503	$1,067,180
2033	19	0.699	2.107	2.527	$1,256,860	$878,977	$100,000	$252,695	$176,721	$1,055,697
2034	20	0.686	2.191	2.653	$1,256,860	$862,588	$100,000	$265,330	$182,097	$1,044,684
2035	21	0.674	2.279	2.786	$1,256,860	$846,504	$100,000	$278,596	$187,637	$1,034,141
2036	22	0.661	2.370	2.925	$1,256,860	$830,720	$100,000	$292,526	$193,345	$1,024,065
2037	23	0.649	2.465	3.072	$1,256,860	$815,231	$100,000	$307,152	$199,227	$1,014,458
2038	24	0.637	2.563	3.225	$1,256,860	$800,030	$100,000	$322,510	$205,288	$1,005,318
2039	25	0.625	2.666	3.386	$1,256,860	$785,113	$100,000	$338,635	$211,533	$996,646
2040	26	0.613	2.772	3.556	$1,256,860	$770,474	$100,000	$355,567	$217,968	$988,442
2041	27	0.602	2.883	3.733	$1,256,860	$756,108	$100,000	$373,346	$224,599	$980,707
2042	28	0.590	2.999	3.920	$1,256,860	$742,010	$100,000	$392,013	$231,432	$973,442
2043	29	0.579	3.119	4.116	$1,256,860	$728,175	$100,000	$411,614	$238,473	$966,647
2044	30	0.569	3.243	4.322	$1,256,860	$714,597	$100,000	$432,194	$245,727	$960,325
	Total				$37,705,800	**$28,540,141**	$3,000,000	$6,976,079	**$4,935,926**	**$33,476,066**
										$33,476,066

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Appendix TM3.D
Plant 1 Replacement Alternatives
Structured Decision Analysis Model

- TM3.D.1 Non-Economic Performance Summary
- TM3.D.2 Alternatives Scoring Metrics
- TM3.D.3 Sensitivity Analysis

Appendix TM3.D.1
Decision Model Scoring Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Scoring Against Contributors

	Decision Model Weights				Alternatives		
Decision Statement	**Desires (level-1)**	**Weights**	**Contributors (Level-2)**	**Weights**	**1A**	**1B**	**2**
Select a Plant 1 Process	Operational Flexibility	0.091	Operational Simplicity	0.091	10	7	10
	Process Performance	0.455	Applied Turbidity	0.187	7	7	10
			Process Stability	0.267	6	6	10
	Level of Service	0.455	Future Capacity	0.182	10	4	10
			Future Processes	0.164	5	1	10
			Sustainability Framework	0.109	5	5	10
		1.000		**1.000**			

		1A	1B	2
Operational Flexibility		0.091	0.064	0.091
Process Performance		0.291	0.291	0.455
Level of Service		0.318	0.144	0.455
Non-Economic Performance Score		**0.701**	**0.499**	**1.000**
Capital Cost	$M	$40	$74	$27
Annual OMR&R Cost	$M	$5.21	$5.29	$5.15
Life-Cycle Net Present Value	$M	$309	$357	$289
Cost/Benefit Ratio -- Capital		$57	$148	$27
Cost/Benefit Ratio -- NPV		$441	$716	$289

Appendix TM3.D.1
Decision Model Scoring Summary Sheet

Water Treatment Plant Alternatives Analysis -- Phase II
Calculation of Normalized Weights

Desires (Level-1)

Operational Flexibility	2	0.091
Process Performance	10	0.455
Level of Service	10	0.455
	22	

Contributors (Level-2)

	Operational Flexibility	
Operational Simplicity	10	0.091
	10	**0.091**

	Process Performance	
Applied Turbidity	7	0.187
Process Stability	10	0.267
	17	**0.455**

	Level of Service	
Future Capacity	10	0.182
Future Processes	9	0.164
Sustainability Framework	6	0.109
	25	**0.455**

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Operational Simplicity Contributor Scoring Summary

Two-Stage Deduction 3

Plant 1 Replacement Process Technology Alternatives		Future Processes	Score[1]
Replace Plant 1 Options	Conventional Solids-Contact Clarifier with Basin 3	Single-Stage	10
	Conventional Solids-Contact Clarifier with a Conventional Flocculating Clarifier	Two-Stage	7
	High-Rate Solids-Contact Clarifier with Basin 3	Single-Stage	10

[1]Score = (10-Deduction)

Single-stage softening
- Fewer chemical addition points
- Fewer process monitoring points
- Consolidated sludge removal

Appendix TM3.D.2
Alternatives Scoring Metrics

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Applied Turbidity Contributor Scoring Summary

Conventional SCC Deduction: 3

Plant 1 Replacement Process Technology Alternatives		Future Processes	Score[(1)]
Replace Plant 1 Options	Conventional Solids-Contact Clarifier with Basin 3	Conv-SCC	7
	Conventional Solids-Contact Clarifier with a Conventional Flocculating Clarifier	Conv-SCC	7
	High-Rate Solids-Contact Clarifier with Basin 3	HR-SCC	10

[(1)]Score = (10-Deduction)

Tube settlers in HR-SCC
Higher sludge concentration from HR-SCC

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Process Stability Contributor Scoring Summary

Conventional SCC Deduction: 4

Plant 1 Replacement Process Technology Alternatives		Future Processes	Score[1]
Replace Plant 1 Options	Conventional Solids-Contact Clarifier with Basin 3	Conv-SCC	6
	Conventional Solids-Contact Clarifier with a Conventional Flocculating Clarifier	Conv-SCC	6
	High-Rate Solids-Contact Clarifier with Basin 3	HR-SCC	10

[1]Score = (10-Deduction*10)

Tube settlers in HR-SCC
Reduced basin volume in HR-SCC
Lower sludge inventory for start-up operations

Appendix TM3.D.2
Alternatives Scoring Metrics

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Future Capacity Contributor Scoring Summary

Maximum future capacity 50 mgd

Plant 1 Replacement Process Technology Alternatives		Future Capacity	Score(1)
Replace Plant 1 Options	Conventional Solids-Contact Clarifier with Basin 3	50	10
	Conventional Solids-Contact Clarifier with a Conventional Flocculating Clarifier	22	4
	High-Rate Solids-Contact Clarifier with Basin 3	50	10

(1)Score = Round(10*Future Capacity/Maximum Future Capacity)

Appendix TM3.D.2
Alternatives Scoring Metrics

Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Future Processes Contributor Scoring Summary

Plant 1 Replacement Process Technology Alternatives		Future Processes	Score[1]
Replace Plant 1 Options	Conventional Solids-Contact Clarifier with Basin 3	No[2]	5
	Conventional Solids-Contact Clarifier with a Conventional Flocculating Clarifier	No	1
	High-Rate Solids-Contact Clarifier with Basin 3	Yes	10

[1]Preserves space for future additional treatment processes = 10

[1]Does not preserve space for future additional treatment processes = 1

[2]Does not preserve space for future additional treatment processes at 50 mgd future capacity = 5

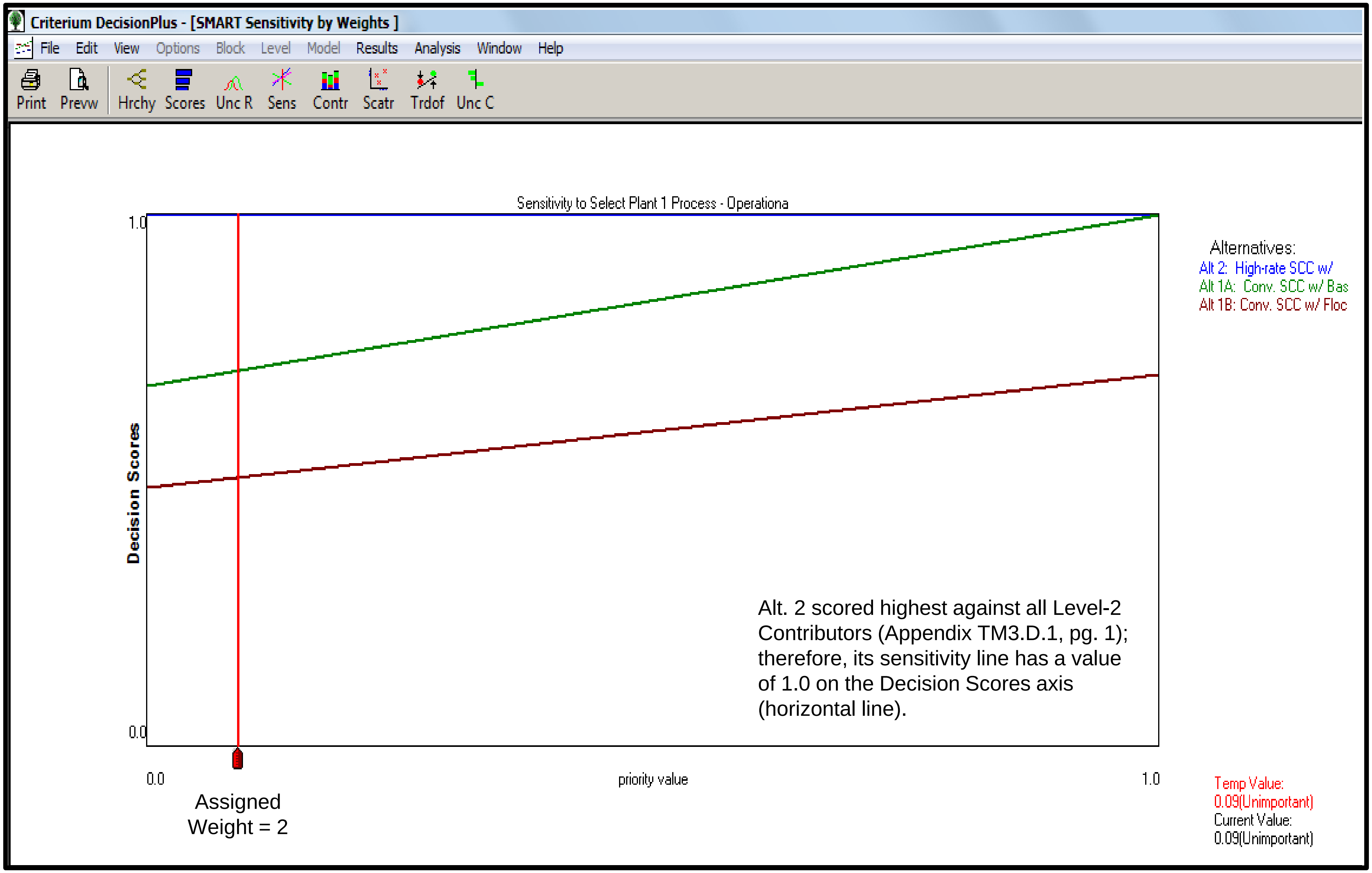
Water Treatment Plant Alternatives Analysis -- Phase II
Plant 1 Replacement Alternatives

Sustainability Framework Contributor Scoring Summary

Plant 1 Replacement Process Technology Alternatives		**Sustainable Buildings**	**Sustainable Systems**	**Score[1]**
Replace Plant 1 Options	Conventional Solids-Contact Clarifier with Basin 3	0.5	0.5	5
	Conventional Solids-Contact Clarifier with a Conventional Flocculating Clarifier	0.5	0.5	5
	High-Rate Solids-Contact Clarifier with Basin 3	1	1	10

Sustainability Framework Elements considered include: Sustainable Buildings and Sustainable Systems

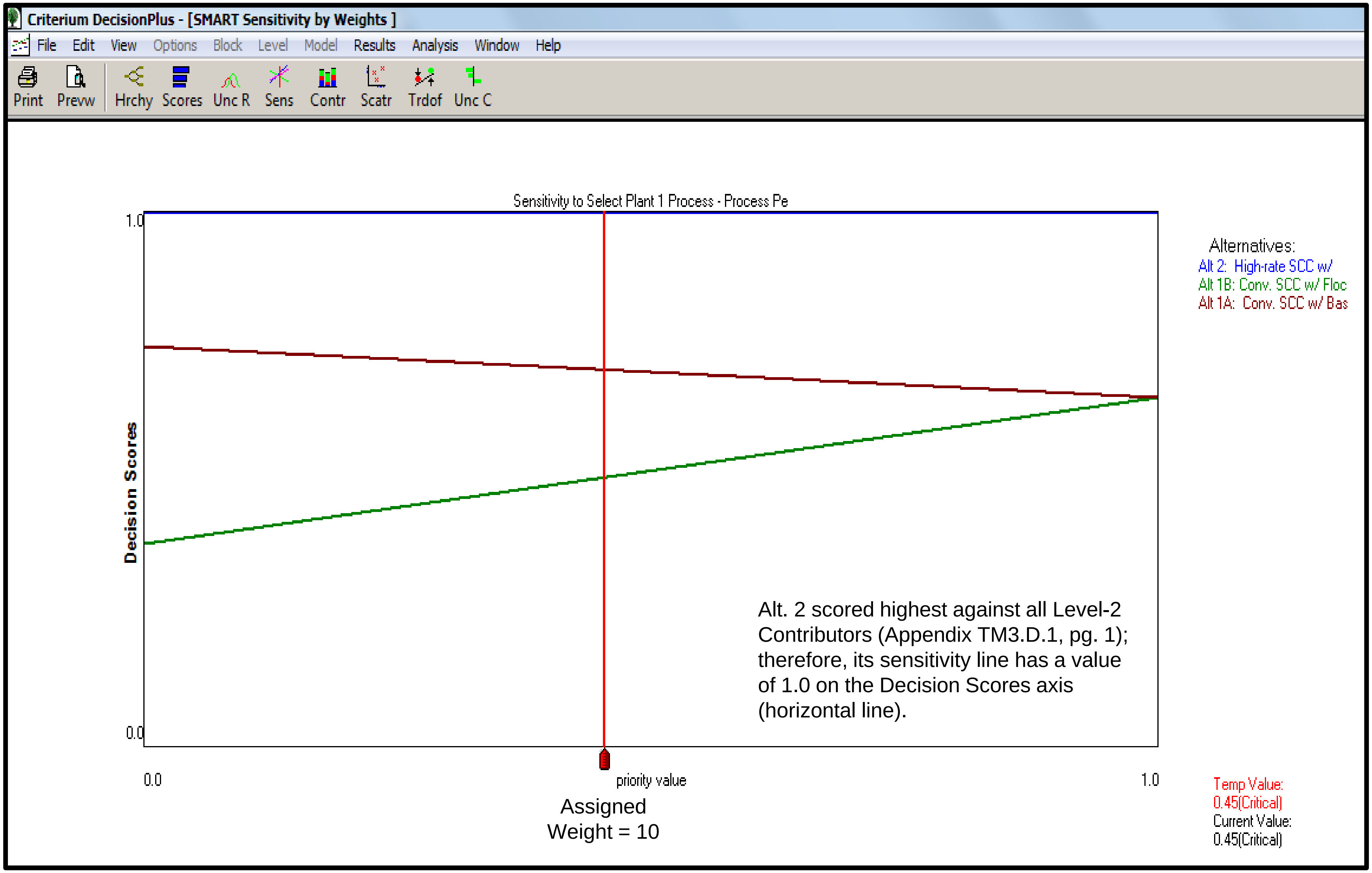
[1]Score = 10 if an alternative supports each Sustainability Framework Element considered
[1]Score = 5 if an alternative supports 2 of the 3 Sustainability Framework Element considered
[1]Score = 1 if an alternative supports 1 of the 3 Sustainability Framework Element considered



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Desires – Operational Flexibility

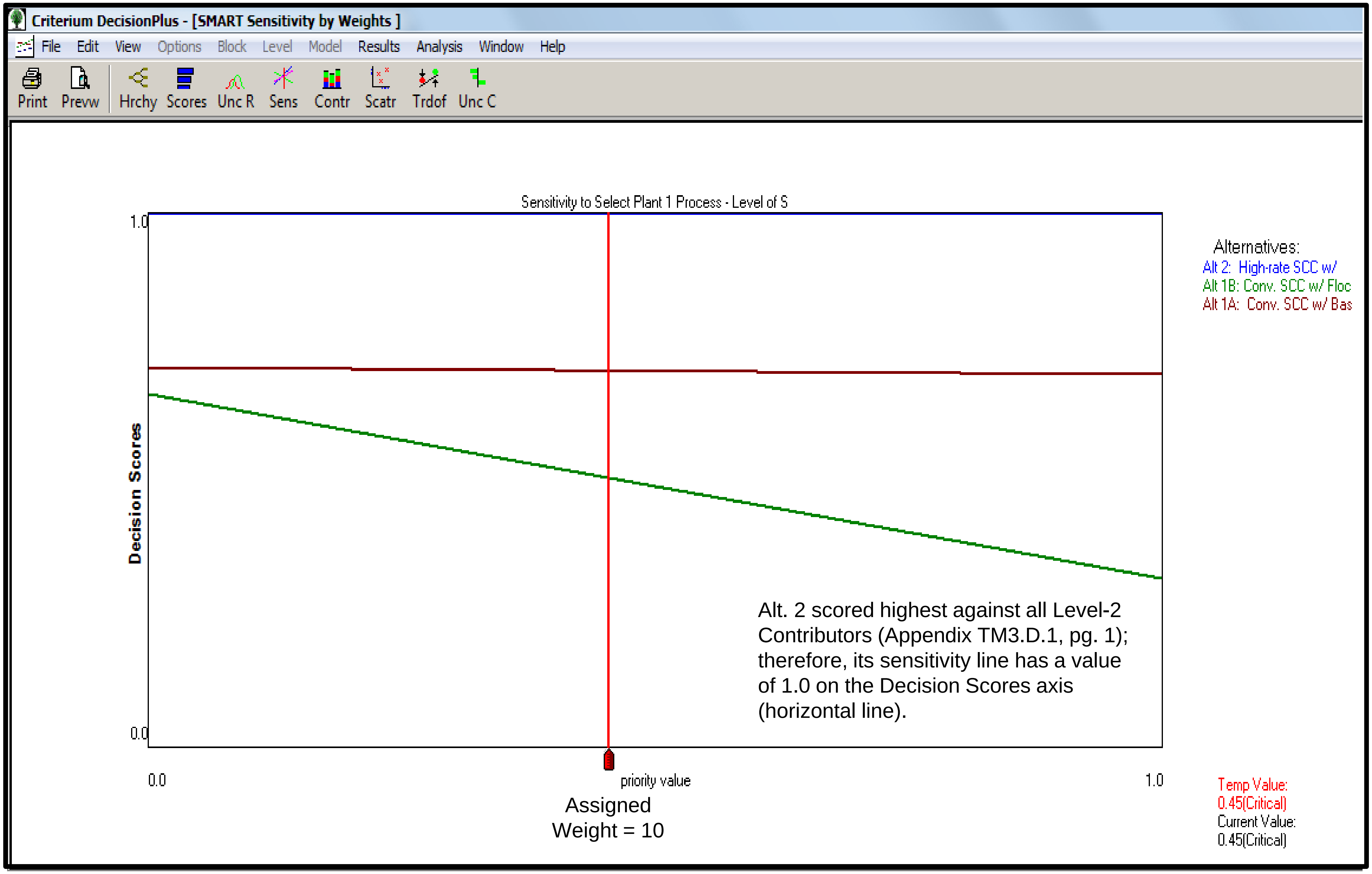
Figure TM3.D-1



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Desires – Process Performance

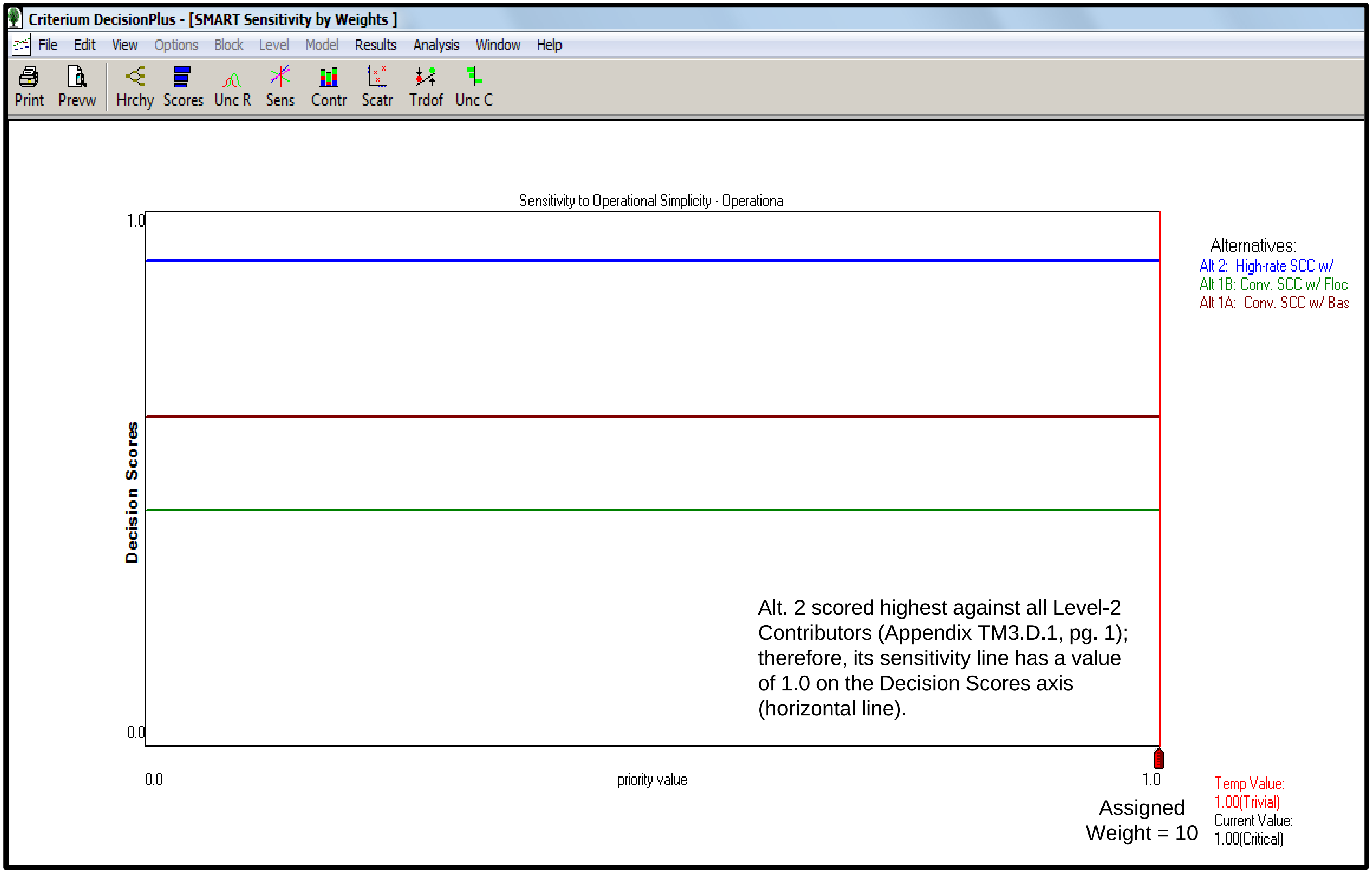
Figure TM3.D-2



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Desires – Level of Service

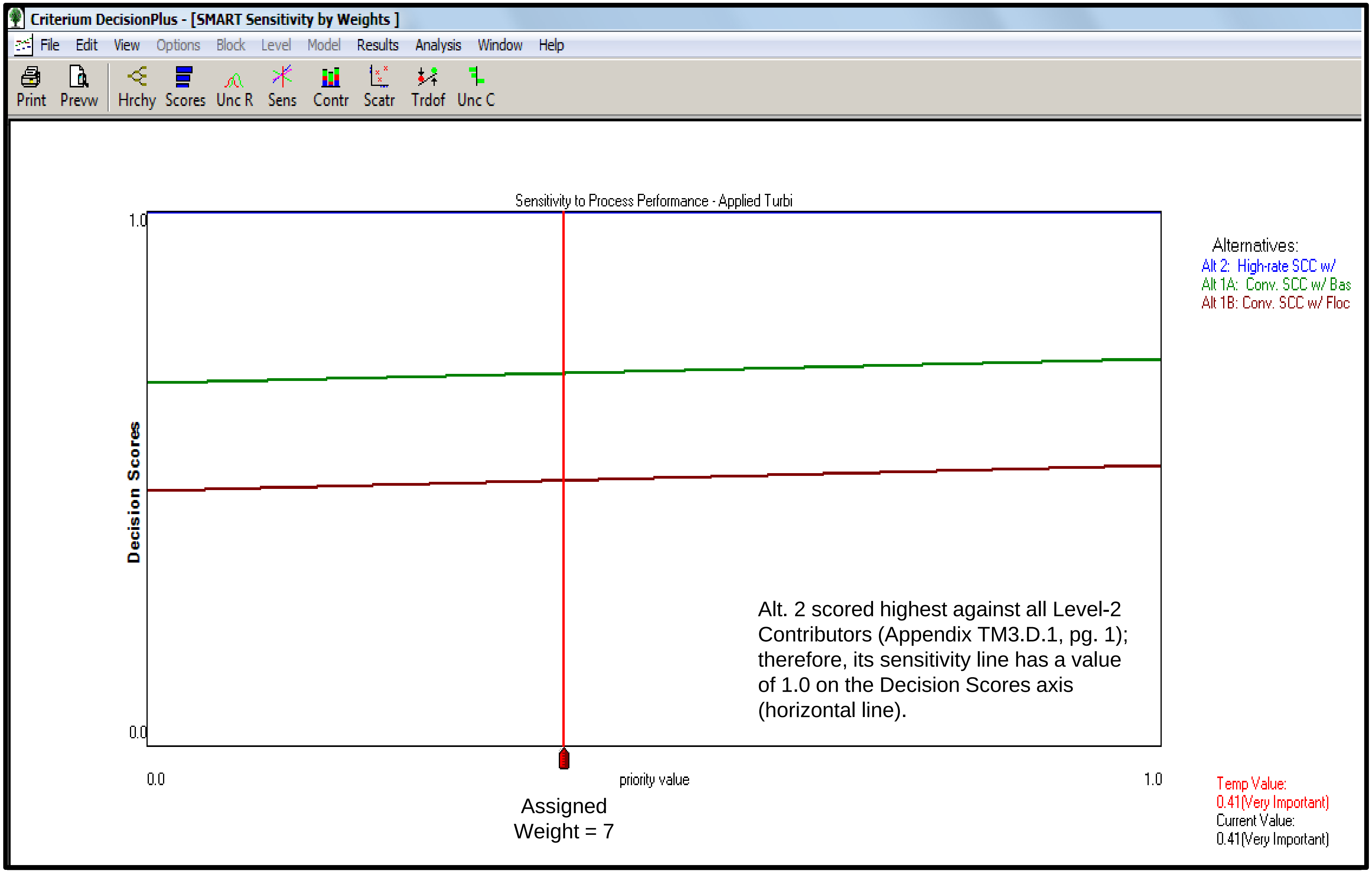
Figure TM3.D-3



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Operational Simplicity

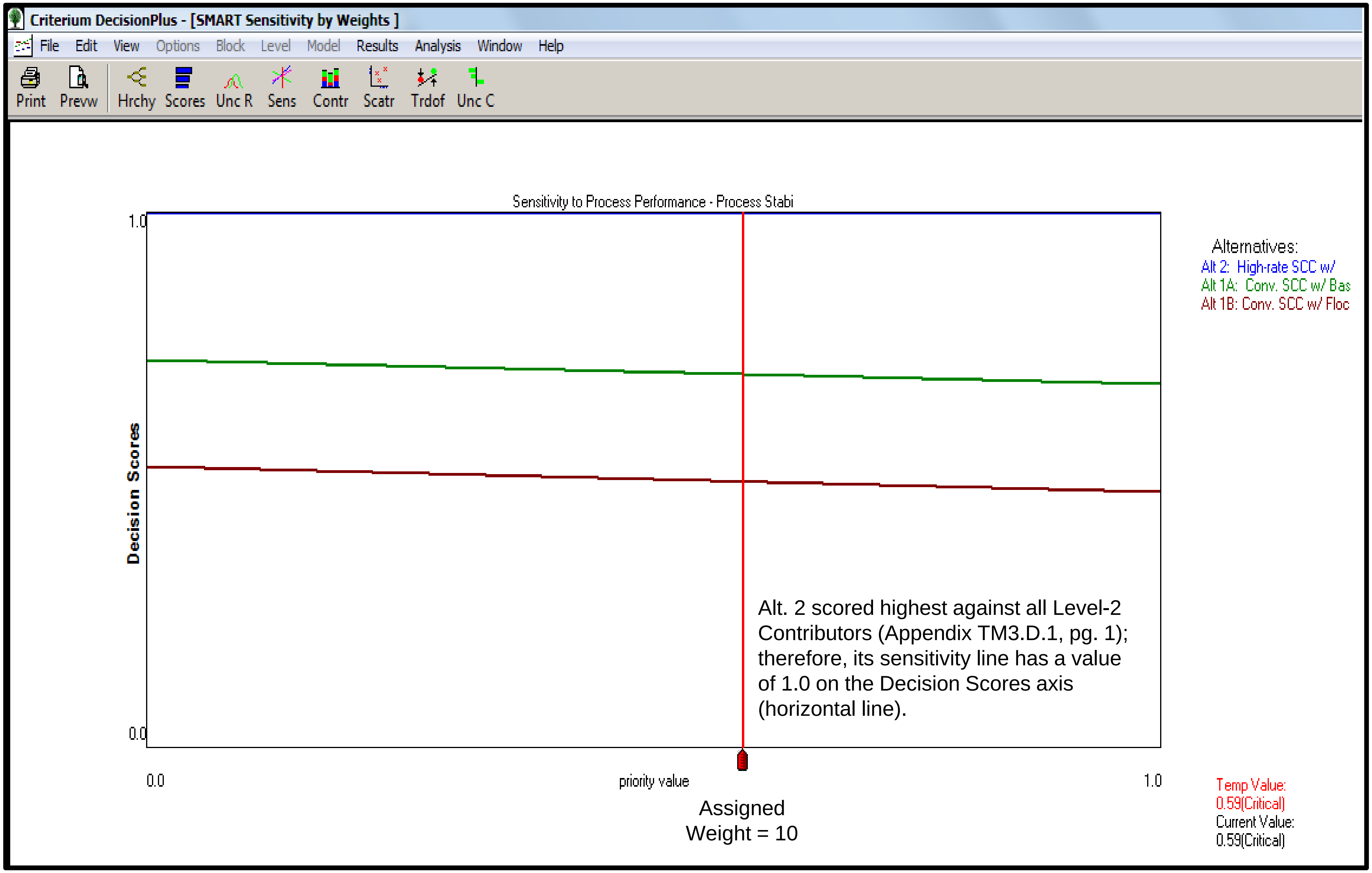
Figure TM3.D-4



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Applied Turbidity

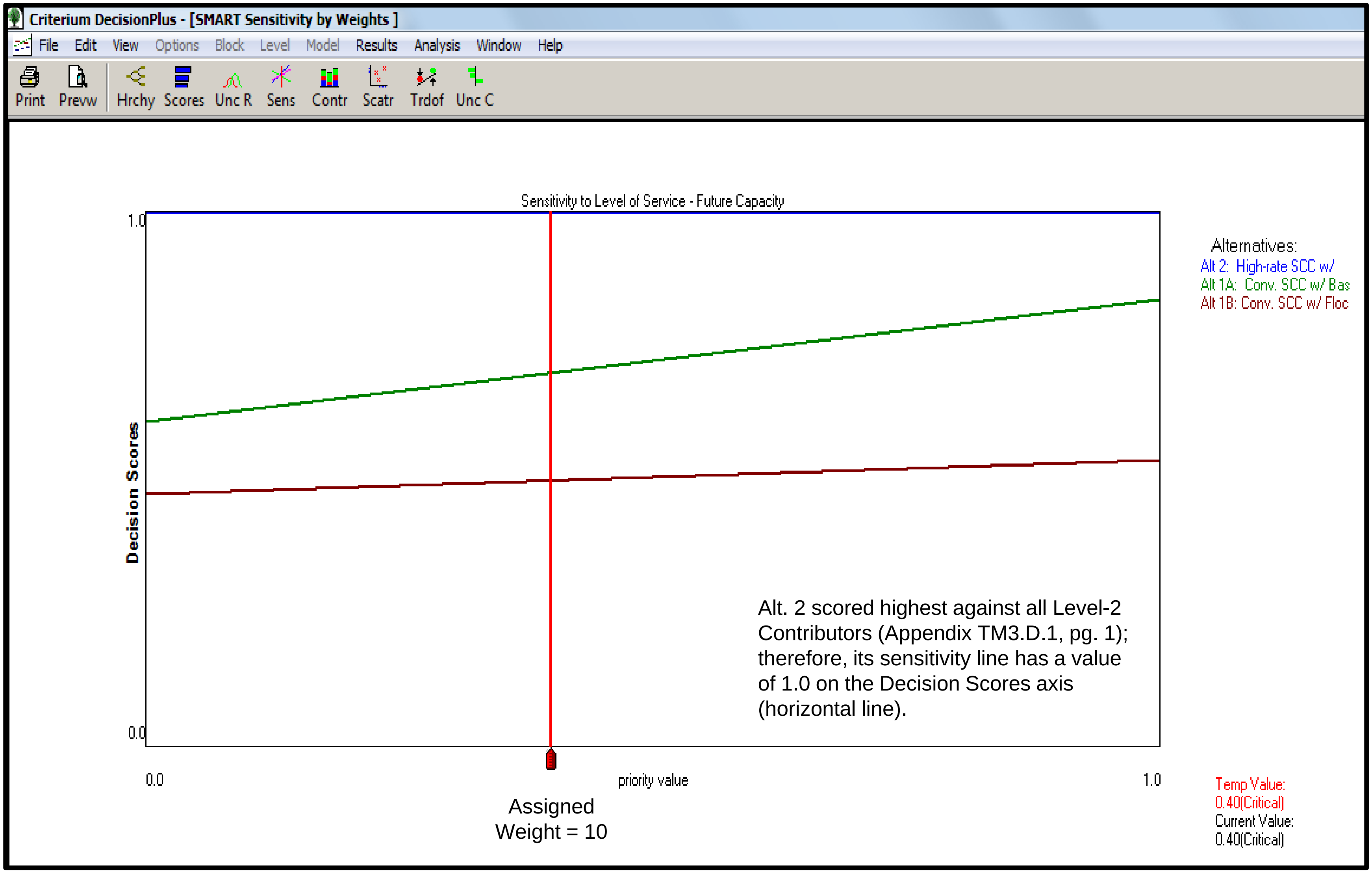
Figure TM3.D-5



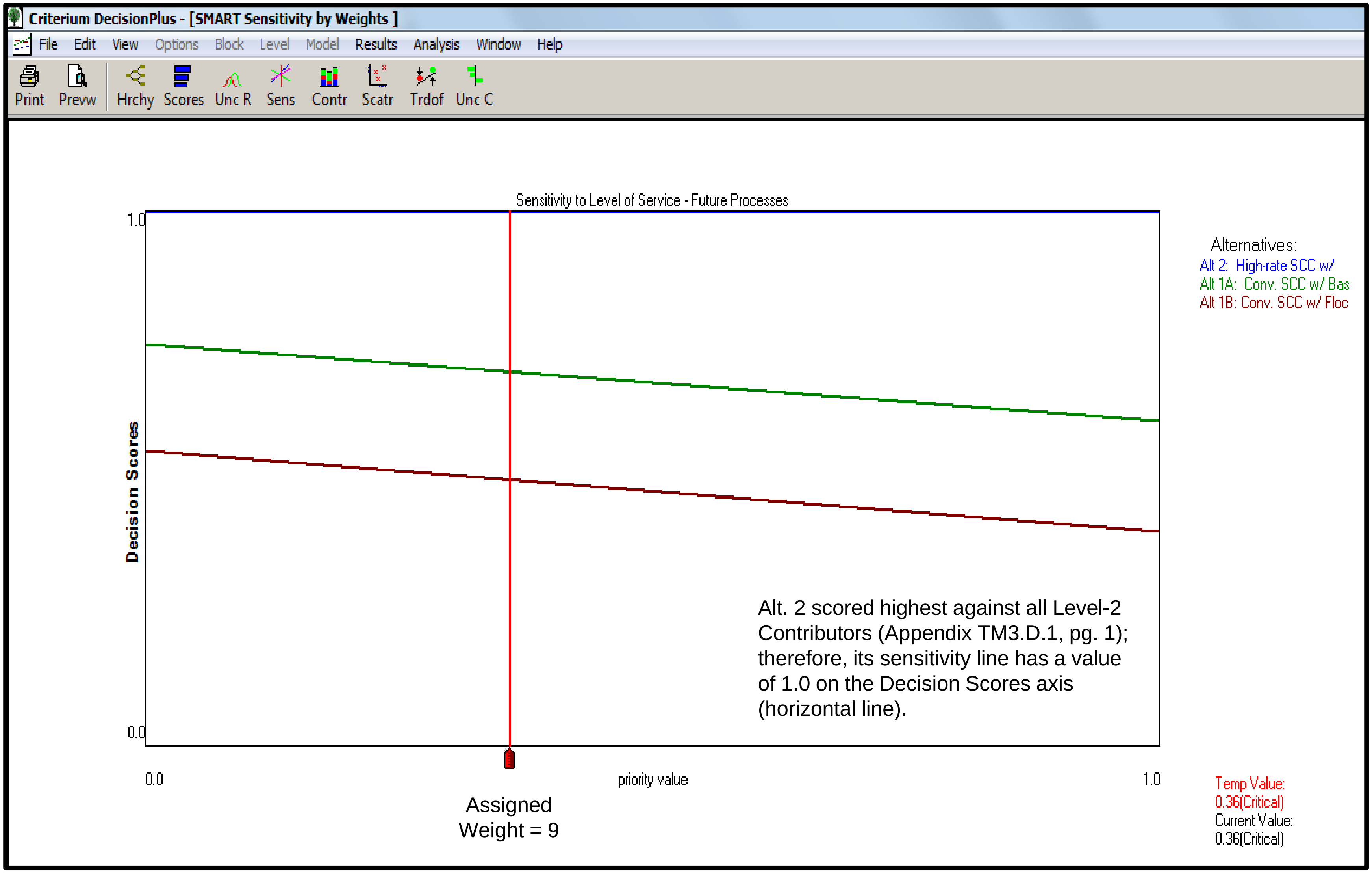
City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Process Stability

Figure TM3.D-6



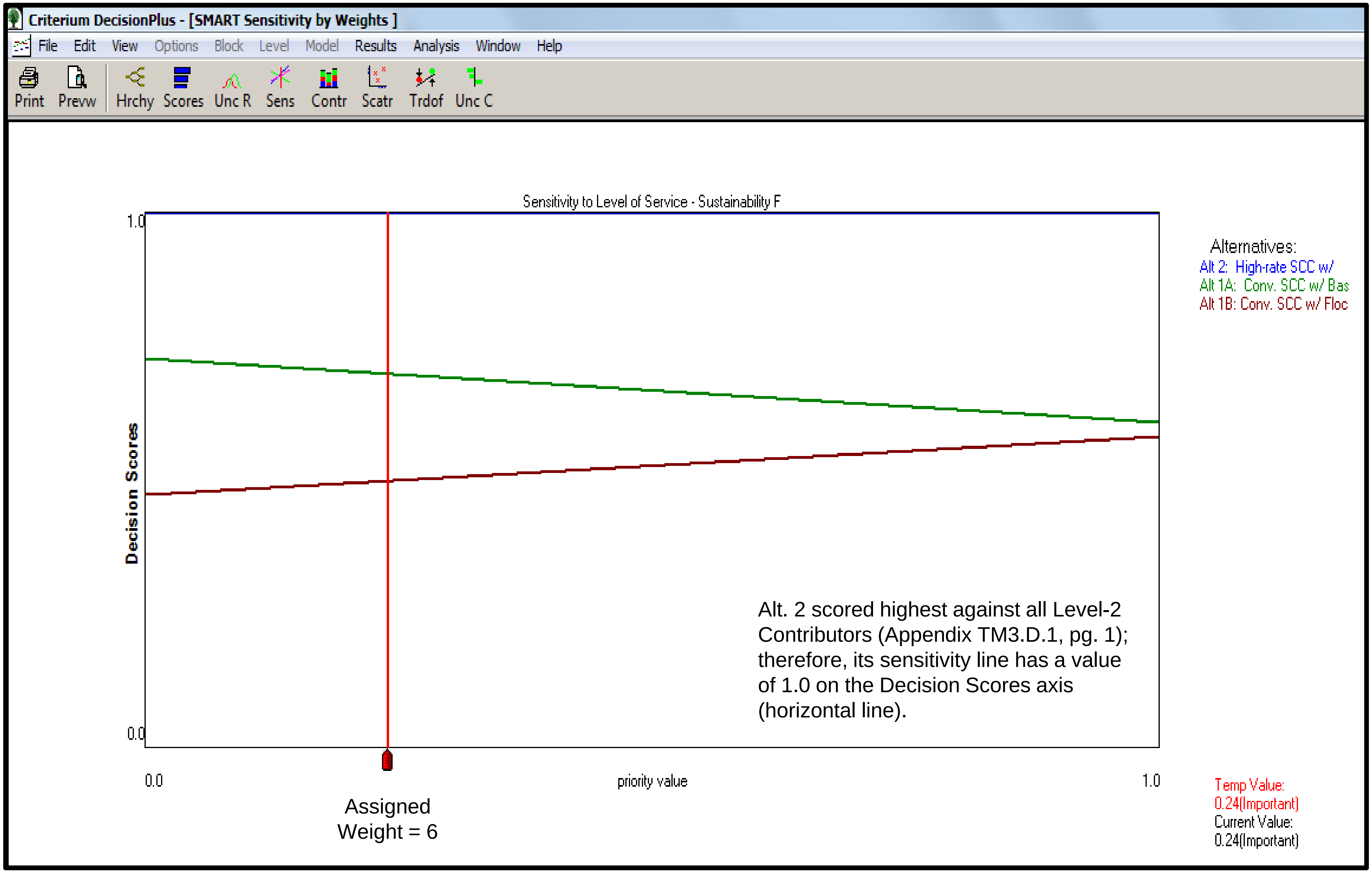
City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis		Figure TM3.D-7
Sensitivity Analysis: Contributors – Future Capacity		



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Future Processes

Figure TM3.D-8



City of Ann Arbor, Michigan – Water Treatment Plant Alternatives Analysis

Sensitivity Analysis: Contributors – Sustainability Framework

Figure TM3.D-9

FINAL

WATER TREATMENT PLANT ALTERNATIVES ANALYSIS

Technical Memorandum 4: Residuals Treatment Alternatives Analysis

B&V PROJECT NO. 183262

PREPARED FOR

City of Ann Arbor

4 MAY 2015

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Table of Contents

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APPENDICES

1 Introduction

The City of Ann Arbor (City) Water Treatment Plant (WTP) uses a filter press dewatering and contract land application management system for the lime residuals generated through the liquid stream softening process. This Technical Memorandum (TM) evaluates long term residuals handling alternatives for the plant.

1.1 PROJECT BACKGROUND

The Ann Arbor WTP has used a combination of gravity thickening and filter press dewatering to thicken and dewater its lime residuals. Dewatered cake is beneficially used through land application. The existing filter press system has exceeded its “typical” life; however, extensive rebuilds and retrofits by the plant staff have been successful in extending the useful life of the press equipment. A nearby lagoon has been used for residuals storage for decades prior to implementation of the mechanical dewatering system and is still used periodically for back-up to the mechanical dewatering system, notably during construction events that interrupt truck access to the dewatering facility and basin cleaning evolutions that produce substantial amounts of non-dewaterable solids such as zebra mussel shells. The lagoon has significant solids accumulation and will require removal of a portion of the solids for continued use.

1.2 SCOPE

The scope of this work was to evaluate the existing residuals management system and to identify alternatives for consideration for the future, with the goal of robust solids management at the plant capacity of 50 million gallons per day (mgd). Lime solids management alternatives considered herein include thickening, mechanical dewatering, and ultimate disposal components, configured in various combinations. Based on initial discussion with plant staff, the existing gravity thickening facilities are understood to perform well and are in acceptable condition for long-term continued use.

2 Basis of Design

The required solids treatment process capacity at the Ann Arbor WTP was evaluated based on historical lime softening solids production and solids production estimates at 50 mgd plant capacity. Historical plant flows and solids production quantities for the 6-year period between 2008 and 2013 used in this evaluation are given in TM 5.

2.1 SOLIDS QUANTITIES AND CHARACTERISTICS

Historical total suspended solids (TSS) production quantities are presented in **Figure TM4-1**. As shown in this figure, historical solids production peaks during summer months. Historical annual plant solids production was 57,900 pounds per day (lb/day) at an average plant flow of 14.6 mgd, equating to 3,970 pounds of dry solids per million gallons treated (lb/MG). With continued operation of the water treatment processes currently in service at the Ann Arbor WTP, future solids production rates are expected to be similar to current rates. Consequently, the 3,970 lb/MG production rate was used for future solids projections. Changes to water treatment processes or plant operations may expected to impact solids production rate.

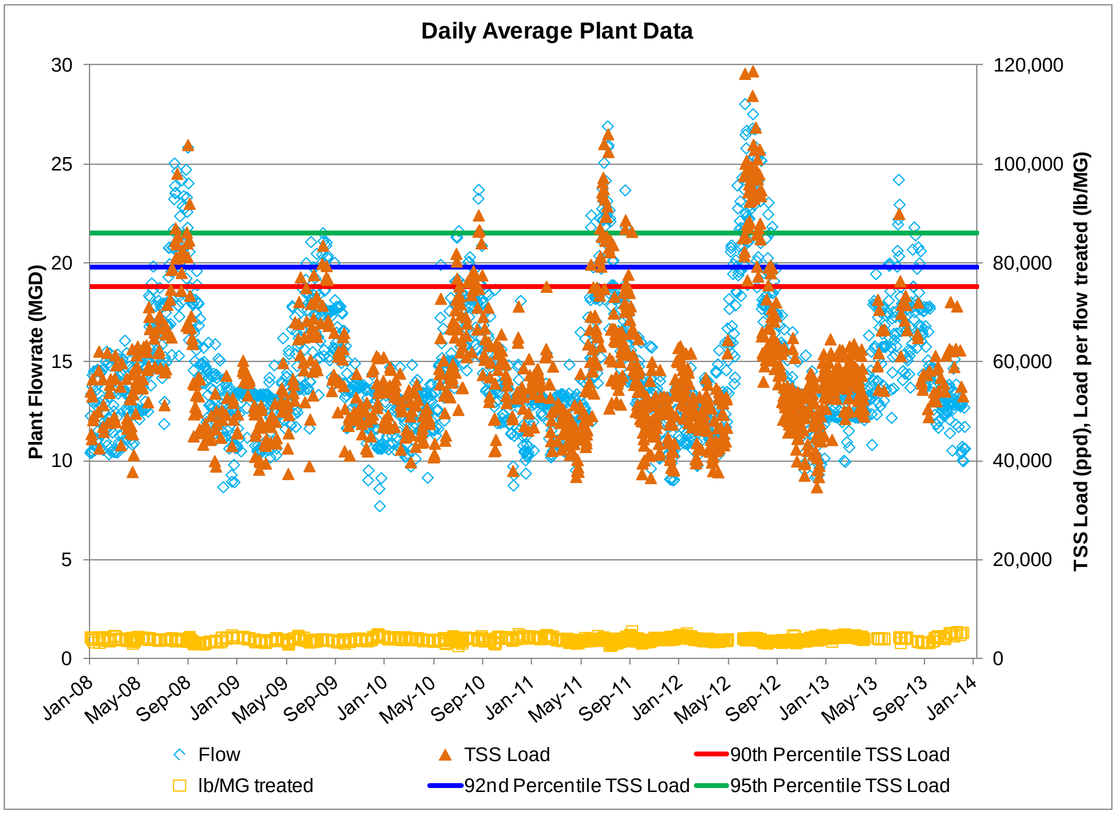

Figure TM4-1: Daily Average Residuals Production

A statistical distribution of historical residuals production is shown in **Figure TM4-2**. A solids processing rate between the 90th and 95th percentile of average daily production, rather than the maximum daily production (100th percentile value), is typically used as a design value for sizing solids processing facilities because water plants have significant solids storage capacity in their clarification basins to attenuate peak short-term solids production rates. Using a design processing value between the 90th and 95th percentile avoids oversizing facilities to accommodate infrequent high-production peaks.

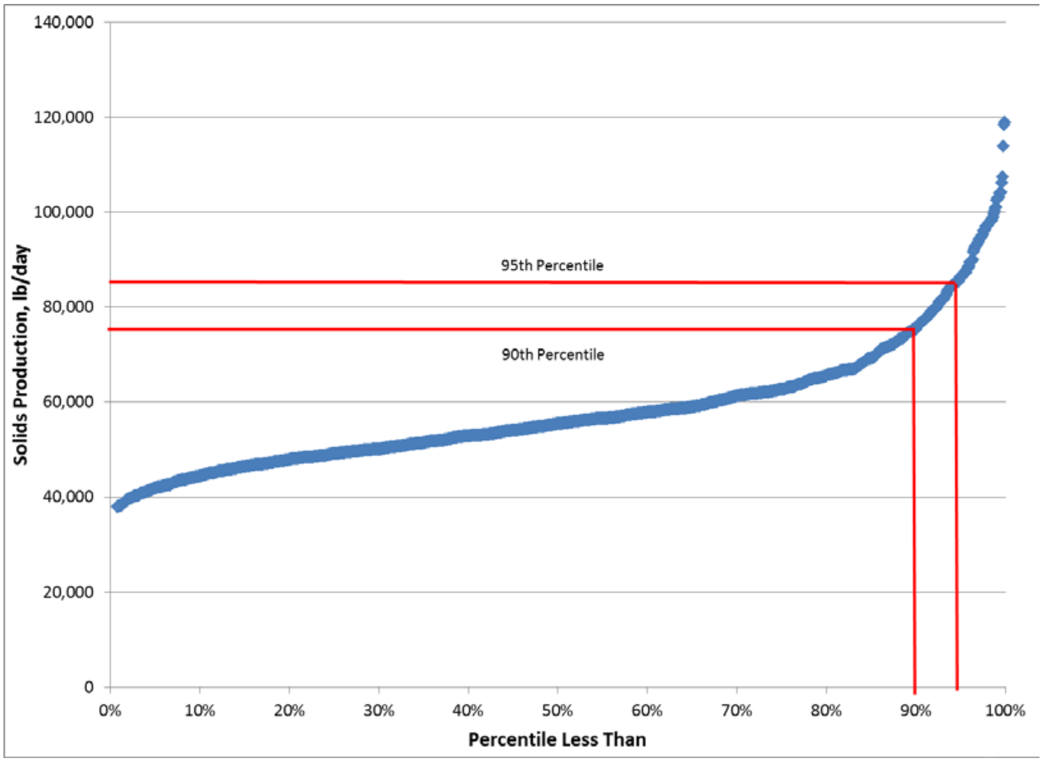

Figure TM4-2: Solids Production Distribution

When choosing the percentile used in solids process sizing, it is useful to identify the duration of solids production values that exceed the selected percentile. The number of consecutive days exceeding each of the solids production percentiles is listed in **Table TM4-1**.

Table TM4-1: Greatest Number of Days Exceeding Solids Production Percentile

PERCENTILE	HISTORICAL SOLIDS PRODUCTION RATE (LB/DAY)	CONSECUTIVE DAYS EXCEEDING
90th percentile	75,300	22
92nd percentile	79,200	9
95th percentile	86,100	5

While the number of consecutive days exceeding the 90th percentile production value is fairly high, the design basis for this evaluation is the 50 mgd plant capacity, which is significantly higher than the current average day production of 15 mgd. Because the recent trend in drinking water demand has been constant or slightly decreasing, the 90th percentile basis for residuals treatment sizing is considered conservative and was used for this evaluation.

Table TM4-2 summarizes the annual average and 90th percentile (design condition) for current and the projected 50 mgd flow conditions.

Table TM4-2: Current and Projected Solids Production

	CURRENT	FUTURE
Annual Average Flow (mgd)	14.6	26.7[2]
Design Flow (mgd)	28[1]	50
Annual Average Solids Load (lb/d)	57,900	106,100
Annual Average Solids Production Rate (lb/MG)	3,970	3,970
90th Percentile Solids Production Rate (lb/MG)	5,166	5,166
90th Percentile Solids Production (lb/d)	75,300	138,100

[1]Maximum historical plant flow
[2]Anticpated average flow at 50 mgd design condition

3 Existing Facilities Description

The current residuals treatment process at the Ann Arbor WTP is shown in **Figure TM4-4**. Lime solids blow-down from sedimentation basins are thickened in the gravity thickeners from approximately 8 percent total solids (TS) to approximately 25 percent TS. The two gravity thickeners are operated in a batch mode, with all sedimentation solids fed to a single gravity thickener until the height of the sludge blanket exceeds the desired level, at which point, the thickener is taken off line and settled solids are directed to the second thickener. One of the gravity thickeners has a double weir construction; however, the lower weir is not used. Based on WTP staff input, the double weir configuration makes measurement of sludge blanket depth difficult. Based on anecdotal information from the staff, the gravity thickener decant turbidity is approximately 10 Nephelometric Turbidity Units (NTU).

Thickened solids are transferred from the off-line thickener to the filter press feed tank (Holding Tank) using progressing cavity pumps (Moyno pumps). Thickened solids are fed from the holding tank to the two filter presses using a combination of fast feed centrifugal pumps and slow feed, high head piston pumps. Dewatered cake at approximately 65 percent TS is discharged from the filter presses to dump trucks, and then is land applied by a contractor. The existing filter presses are over 30 years old and have been rebuilt several times.

Solids dewatering facilities are operated approximately 8 hours per day, four to five days per week. The operating schedule is driven by the solids concentration in the gravity thickeners – dewatering is suspended when the thickened solids concentration drops to approximately 10 percent TS. Filtrate is returned to the water treatment process and core blow down is directed to the Sludge Transfer Tank. Solids can be diverted to an off-site lagoon for storage; however, the lagoon has little remaining available capacity. A solids storage tank can also accept solids from the sedimentation basin; however, it is not typically used and several of the tank mixers are inoperable. The thickened solids pump (Moyno No. 1) can also transfer solids from the Sludge Transfer Tank to the Holding Tank. Moyno No. 2 can transfer thickened solids from the gravity thickeners to the lagoon.

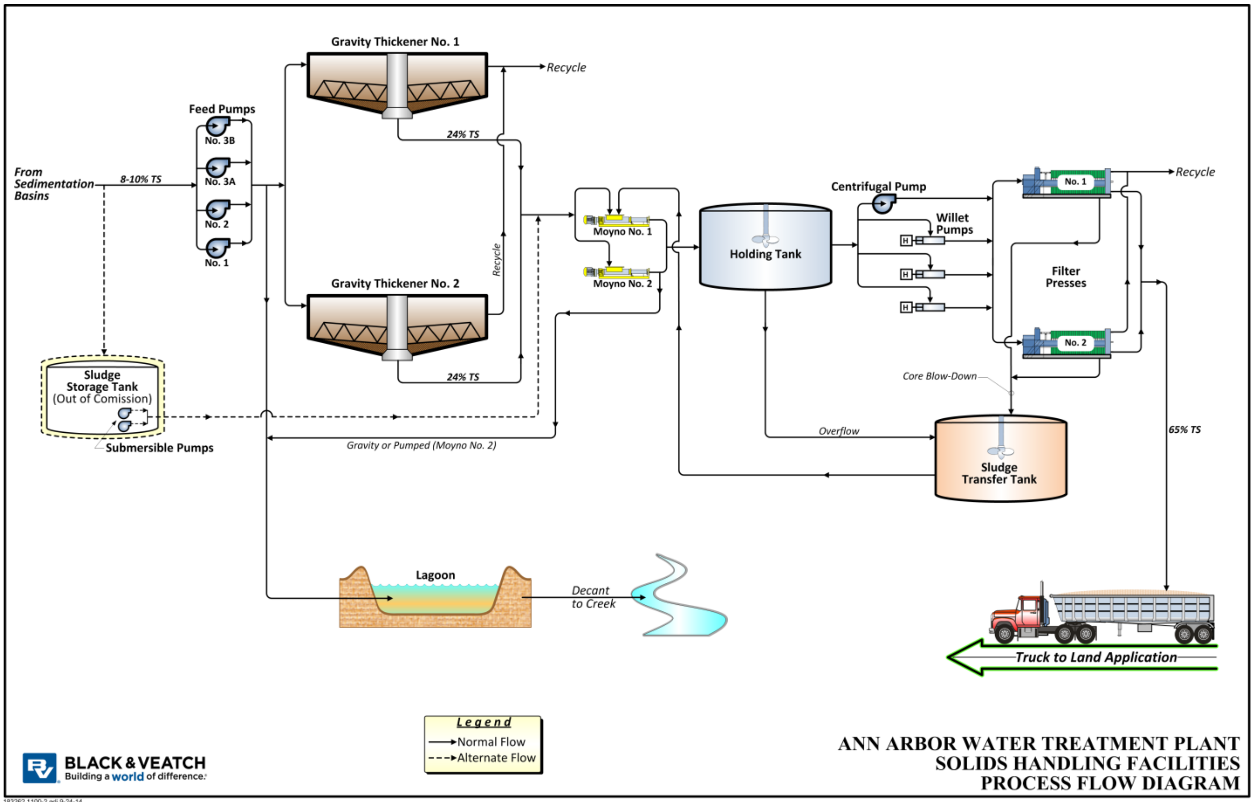

Figure TM4-3: Existing Residuals Handling Process

A partial list of the residuals treatment equipment is provided in **Table TM4-3**.

Table TM4-3: Residuals Treatment Equipment

PROCESS	EQUIPMENT	NUMBER (EA)	SIZE/CAPACITY (EA)	COMMENTS
Gravity Thickening	GT1	1	50 ft diameter	Double weir configuration
	GT2	1	40 ft diameter	Single weir configuration
	Thickened solids pumps	2	2,300 gpm	Moyno progressing cavity
Dewatering	Filter Press	2	12,500 pph	Ritterhaus & Blecher
Sludge Storage Tank	-	1	21,120 cu.ft	-
Sludge Transfer Tank	-	1	4,860 cu.ft	-

4 Treatment Technologies and Lime Solids Disposal

Conventional lime solids treatment includes thickening and dewatering processes to convert the low concentration sedimentation basin solids into a drier material suitable for disposal or beneficial use. With the exception of long term lagoon storage, all disposal and end use options require thickening as a cost effective first step in removing water from the solids. While various thickening technologies are available, gravity thickening is very effective for lime residuals and is the most commonly used thickening technology. In addition, the gravity thickening process at the Ann Arbor WTP has worked well. Consequently, continued use of existing gravity thickening facilities has been considered in this evaluation. The thickening capacity requirements and current capacity information are discussed in **Section 4.1**.

There are several alternatives commonly used for disposal or beneficial use of lime softening residuals that include discharge to the sanitary sewer, landfill, land application or other beneficial use. Based on discussion with Ann Arbor staff, the current practice of beneficial use through land application was evaluated. Alternate end uses including long term lagoon storage with periodic contract removal and disposal or lime recalcination and reuse was also be considered.

4.1 GRAVITY THICKENING

Ann Arbor WTP has two gravity thickeners to treat its lime solids. While gravity thickening is a robust process and has few maintenance requirements, many installations include a spare thickening to provide firm capacity. Loading rates vary based on settling characteristics of the solids; however, typical loading rates for lime solids are approximately 30 to 50 lb/day/sf. A solids loading rate of 40 to 50 lb/day/sf was used for this evaluation.

Table TM4-4 summarizes loading rates to the gravity thickeners under current and future conditions with both thickeners in service and with one thickener out of service. As shown in the table, the existing two thickeners can support current and future solids production with both thickeners in service. However, solids loading rates exceed the recommended rates for future conditions if either thickener is out of service. In addition, if the large gravity thickener is out of service at current 90th percentile conditions, loading rates exceed the design value by a considerable margin. It should be noted that the thickeners are currently operated in a quasi-batch mode, alternating between thickeners. Consequently, the current loading rates are likely similar to the values in **Table TM4-4** corresponding to the out-of-service conditions.

Table TM4-4: Gravity Thickener Loading Rates

	CURRENT(1)		FUTURE(1)	
	Annual Average	90th Percentile	Annual Average	90th Percentile
Total Surface Area, 2 thickeners in service, sf	3,217	3,217	3,217	3,217
Hydraulic loading rate, gpd/sf	27	35	50	64
Solids loading rate, ppd/sf	18	24	33	43
Solids loading rate, ppd/sf, large thickener out of service	46	***60***	***85***	***110***
Solids loading rate, ppd/sf, small thickener out of service	30	38	***54***	***71***

(1)Based on current and future conditions as given in TableTM4-2.

At current plant flows, the existing gravity thickeners provide adequate capacity. As plant flow increases towards 50 mgd, the addition of a third thickener may be considered to support operation with a thickener out of service. The area of the existing sludge storage basin should be reserved for construction of an additional gravity thickener in the future, if required.

4.2 MECHANICAL DEWATERING

There are several mechanical dewatering technologies available for lime residuals, including centrifuge, belt filter press and pressure filter press (plate and frame press) dewatering. Based on discussion with the Ann Arbor staff during Workshop 2 (July 9, 2014), centrifuge dewatering and filter press dewatering were evaluated.

4.2.1 Centrifuge Dewatering

Centrifugation of residuals is basically a shallow depth settling process enhanced by applying a centrifugal force. While several types are available, the scroll-discharge, solid bowl centrifuge is most often used for lime solids dewatering. The combined solids (slurry) are pumped into the centrifuge, where the high speed spinning action of the bowl forces the solids against the bowl surface. The heavier solids are conveyed by the scroll along the bowl to the solids discharge point (**Figure TM4-4**). The separated liquid (centrate) flows to the opposite end of the centrifuge and is discharged. An example of an installed centrifuge is shown in **Figure TM4-5**.

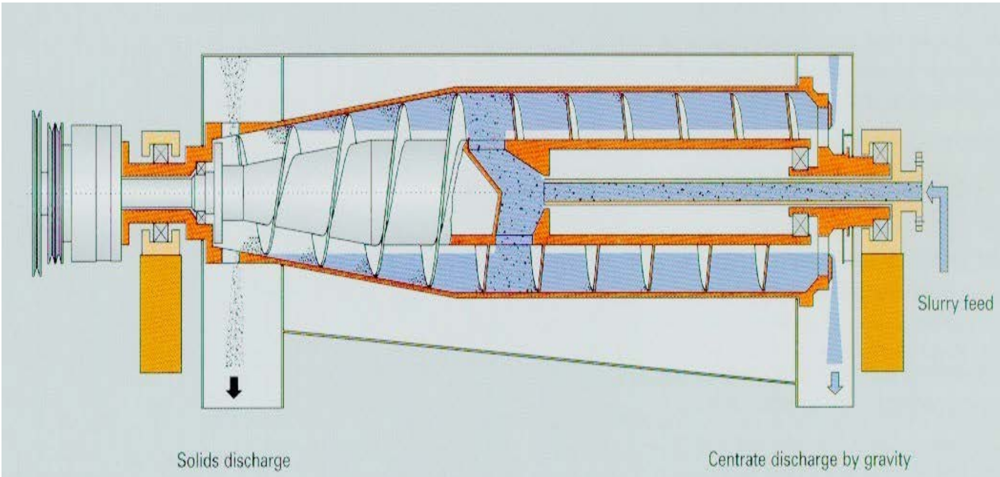

Figure TM4-4: Centrifuge Dewatering

Figure TM4-5: Installed Centrifuge

Centrifuge equipment is sensitive to damage from debris (trash or metal) in the feed stream and in wastewater installations typically requires macerators upstream of each centrifuge to protect the machines. Macerators are not usually required for water treatment solids dewatering installations.

Centrifuge performance is affected by applied water characteristics and water treatment chemical types and dosages. Typical cake concentrations range from 45 to 55 percent for lime solids, with a solids recovery ranging from 90 to 95 percent. Since centrifuge capacity is affected by the solids concentration of the feed, thickening is typically installed upstream of centrifuge dewatering to reduce the hydraulic loading on the machines. A wide range of centrifuge capacities is available from a number of manufacturers.

While centrifuges can be operated on either a batch or continuous basis, they are most economical if operated on a continuous basis. Centrifuges can be operated with less operator attention than other dewatering processes; however, centrifuge maintenance is often complex; consequently, major maintenance is typically performed by the vendor or through a service contract.

4.2.2 Filter Press Dewatering

The pressure filter press (also known as a plate and frame press) is a batch process used for dewatering residuals. Thickened residuals are pumped by high-pressure pumps into the closed press at the start of the dewatering cycle. The feed process can use a single variable speed pump or multiple pumps to support a fast fill for the initial portion of the dewatering cycle, followed by a slow, higher-pressure fill. As more solids are forced between the plates, the increased pressure forces out liquid, which passes out of the cake through the cloths covering each plate, and out of the press through discharge ports. After dewatering is complete, the plates are separated and the dewatered cake drops from the plates to a conveyor or dump truck below the machine.

The cake discharge process typically requires assistance from an operator to ensure that the plates separate correctly. Dewatering cycle times vary based on feed rates. The current filter presses at the Ann Arbor WTP have a cycle time of approximately 20 minutes to fill the press and 10 to 15 minutes to discharge the dewatered cake. Lime solids can typically be dewatered to 55 to 65 percent TS using a filter press. A filter press installation is shown in **Figure TM4-6**.

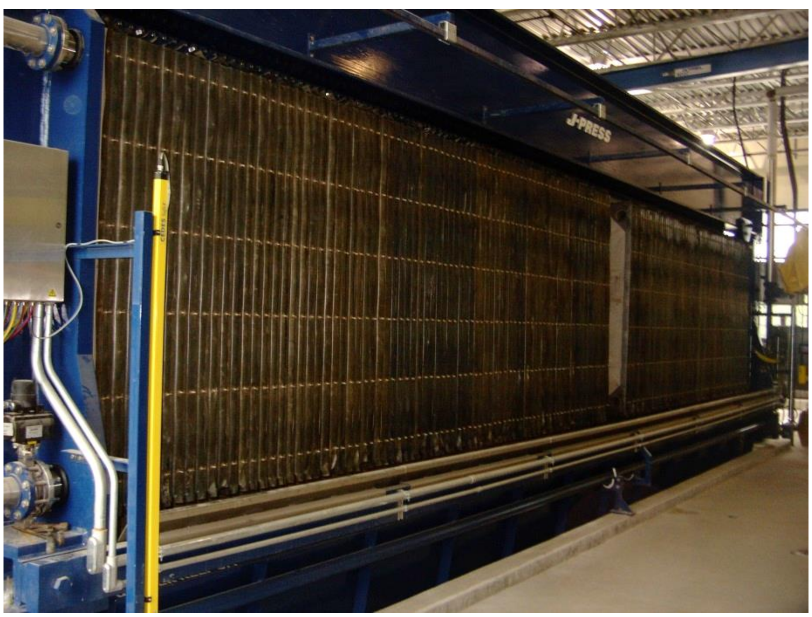

Figure TM4-6: Filter Press Installation

4.3 LIME SOLIDS DISPOSAL

Alternatives commonly used for disposal or beneficial use of lime softening residuals that include discharge to the sanitary sewer, landfill, land application or other beneficial use. Based on the City's desire to promote sustainability in its planning and operations, some form of beneficial use of dewatered lime solids is preferred. Therefore, discharge to the sanitary sewer or landfill of lime solids were not considered in this evaluation. Land application and recalcination were evaluated as beneficial disposal options for lime solids. Storage of lime solids in the City's existing WTP sludge lagoons, either short-term or long-term, was also considered a beneficial use option, as these solids will ultimately be either land applied or processed by recalcination for recovery of lime for reuse in water softening.

5 Lime Solids Management Alternatives

A side-by-side comparison of five different residuals management alternatives was performed. Each alternative included necessary processing steps and an acceptable solids end use to form an integrated lime solids management solution. Use of existing solids thickening and storage systems without modification or improvement was assumed where required. The description, advantages and disadvantages of each alternative is presented in the following sections.

5.1 ALTERNATIVE 1: MECHANICAL DEWATERING WITH LAND APPLICATION – EXISTING PRESSURE FILTER PRESSES

This lime solids management alternative would continue existing gravity thickening, mechanical dewatering, and land application practices. Existing gravity thickening and dewatering equipment would be used over the project life, with maintenance and refurbishment as necessary. **Figure TM4-7** shows the process flow diagram for Alternative 1. As shown in the figure, the existing lagoon will continue to be used for storage of solids that cannot be processed through the existing system. Lagoon discharge occurs infrequently, but provides additional redundancy for mechanical dewatering and land application.

This option includes one duty and one spare filter press, as shown in **Table TM4-3**. The presses will be operated 8 hours per day, 5 days per week at average conditions and design conditions. At current average conditions, approximately 15,000 cubic yards (cy) of dewatered cake will be generated annually. **Table TM4-5** lists the various components and their rebuild frequency of the existing filter presses, based on information from City staff.

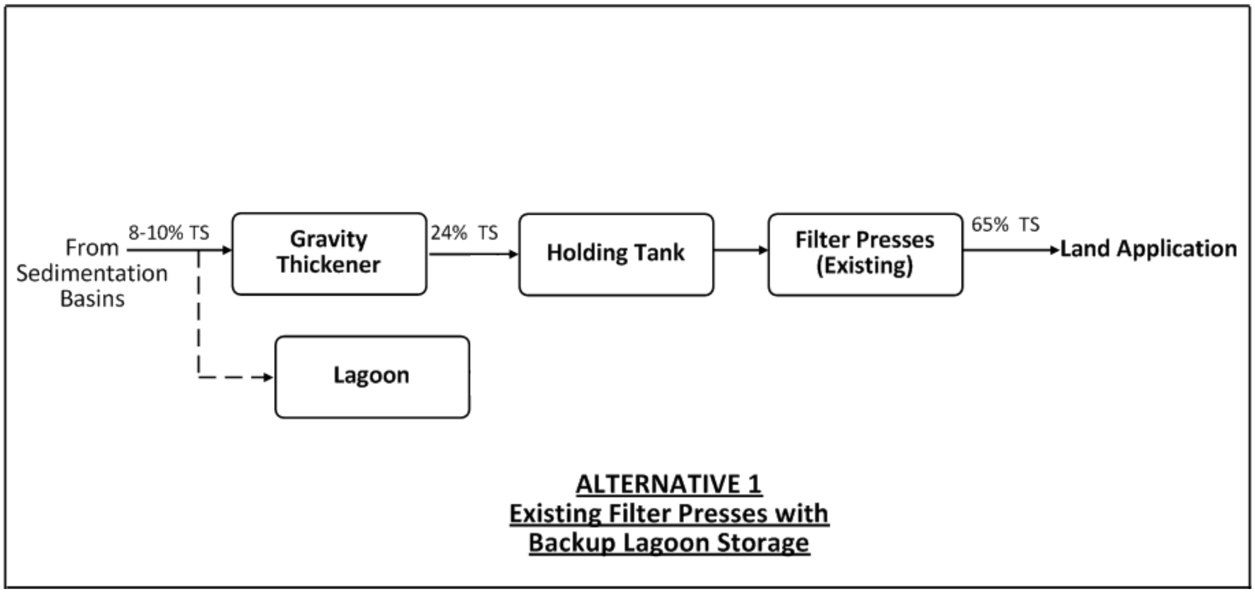

Figure TM4-7: Alternative 1 Process Flow Diagram

Table TM4-5: Alternative 1 Equipment List

COMPONENTS	NUMBER	REPLACEMENT PERIOD (YEARS)
Filter Press rebuild (rollers/seals/hydraulic oil)	N/A	5
Filter Cloth	178	5
Plate Replacement	178	15
Fast feed pumps (centrifugal)	1	15
Slow feed pumps (piston)	3	15
Filtrate pumps	2	15

This alternative requires no modification to the existing system other than long term maintenance. However, based on staff input, the age of the equipment, especially the feed pumps, has presented some challenges in obtaining replacement parts.

Additional options for the lagoon back-up system are discussed in **Appendix TM4.A**.

5.2 ALTERNATIVE 2: MECHANICAL DEWATERING WITH LAND APPLICATION – NEW PRESSURE FILTER PRESSES

This lime solids management alternative would continue existing gravity thickening, mechanical dewatering, and land application practices. However, Alternative 2 provides new filter presses and pumps to replace the existing equipment. As shown in **Figure TM4-8**, the process is essentially the same as the existing system and performance and labor requirements are expected to be similar to existing equipment. As shown in the figure, the existing lagoon will continue to be used for storage of solids that cannot be processed through the existing system. Lagoon discharge occurs infrequently, but provides additional redundancy for mechanical dewatering and land application. The presses will be operated 8 hours per day, 5 days per week at average conditions and design conditions. Equipment requirements were based on using filter presses manufactured by Pacific Press Company.

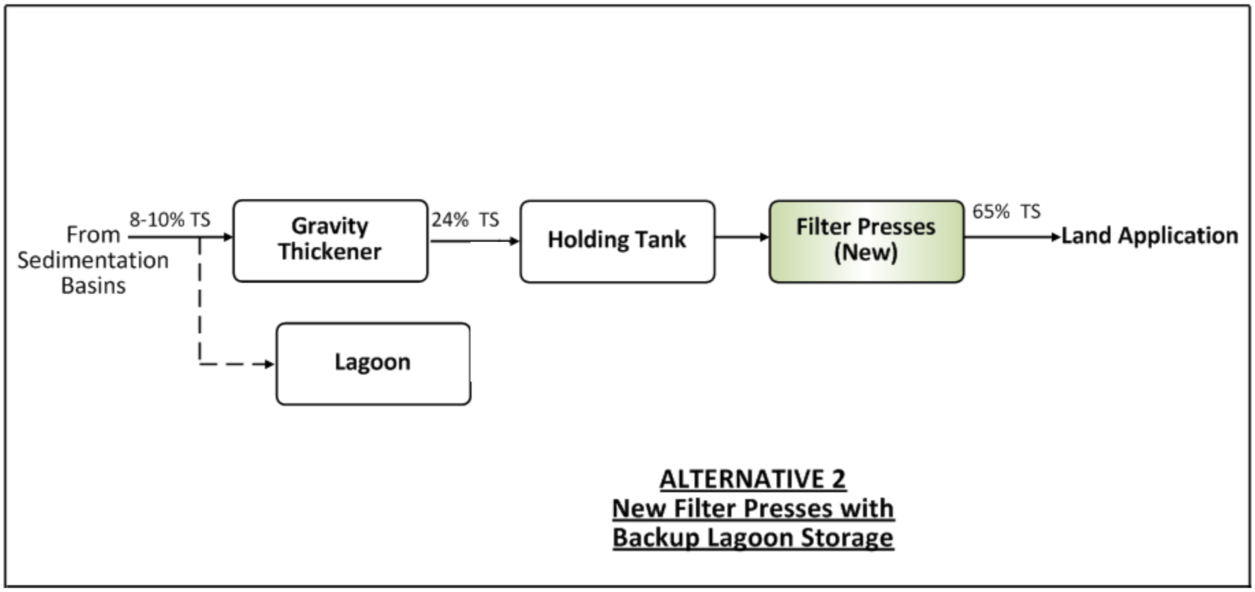

Figure TM4-8: Alternative 2 Process Flow Diagram

As shown in **Figure TM4-9**, the new filter presses would be installed in the existing solids building, with the core blow dropping into the hauling trucks through bomb bay doors.

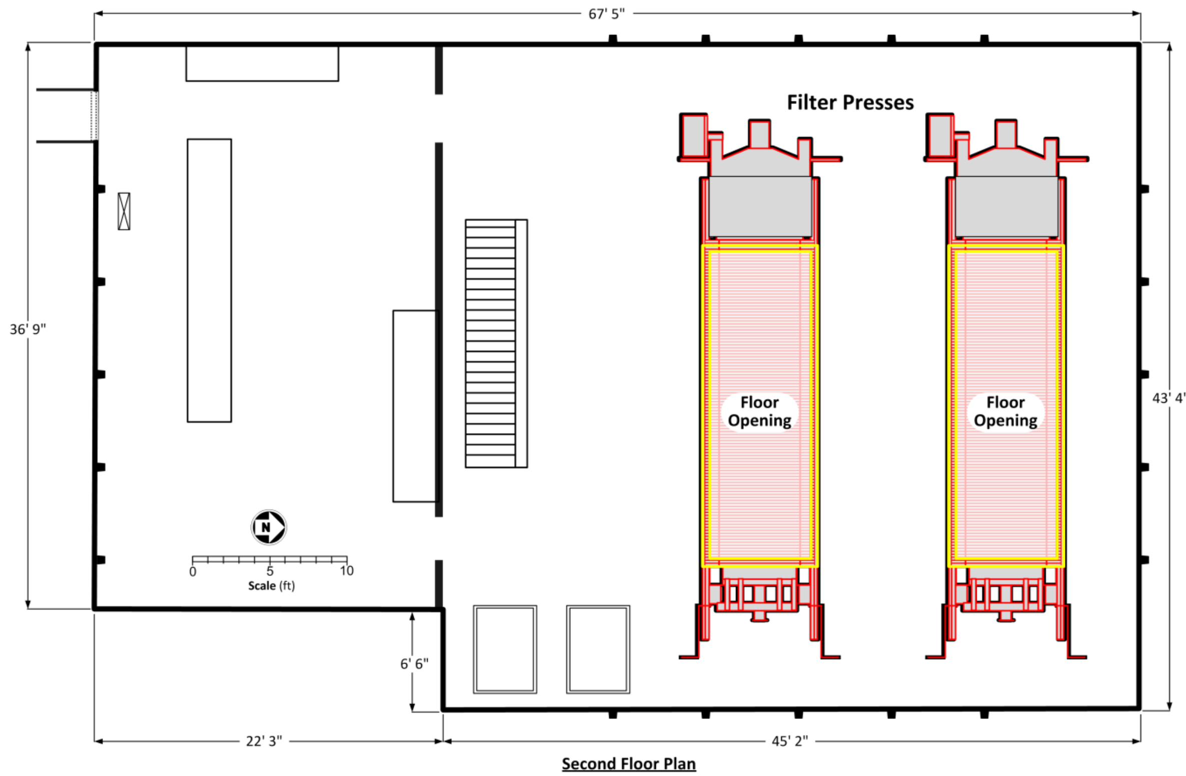

Figure TM4-9: Alternative 2 Suggested Filter Press Layout

Table TM4-6 lists the required equipment and replacement frequency for the dewatering system. While the filter press equipment would typically be expected to have a 20 year life, the City can rebuild the equipment (similar to the maintenance program for their current filter presses) to extend the press life to 30 years. Consequently, costs have been included to rebuild the presses after 15 years, but no costs are included to replace the presses.

Table TM4-6: Alternative 2 Equipment List

COMPONENTS	NUMBER	REPLACEMENT PERIOD (YEARS)
Filter Press	2 (one duty/one standby)	30
Filter Cloths	162	5
Plastic Plate Replacement	162	15
Roller/seal Replacement	2	5 (starting in year 20)
Fast feed pump (centrifugal)	2 (one duty/one standby)	15
Slow feed pumps (progressive cavity)	2 (one duty/one standby)	15
Filtrate pumps	2	15

Additional options for the lagoon back-up system are discussed in **Appendix TM4.A**.

5.3 ALTERNATIVE 3: MECHANICAL DEWATERING WITH LAND APPLICATION – NEW CENTRIFUGE UNITS

This lime solids management alternative would continue existing gravity thickening, mechanical dewatering, and land application practices. However, Alternative 3 replaces the current filter press dewatering equipment with centrifuge dewatering equipment (**Figure TM4-10**). As shown in the figure, the existing lagoon will continue to be used for storage of solids that cannot be processed through the existing system. Lagoon discharge occurs infrequently, but provides additional redundancy for mechanical dewatering and land application.

Two new dewatering centrifuges will be installed on platforms in the area currently housing the pressure filters. New screw conveyors will be added to distribute dewatered cake across the existing truck loading openings in the floor below. The centrifuges will be operated 8 hours per day, 5 days per week at average conditions and 15 hours per day, 5 days per week at design conditions. Samples of the Ann Arbor solids were tested to identify performance and equipment requirements, with test results indicating cake solids of approximately 45 to 55 percent TS. A value of 50 percent TS was used for this evaluation. The dewatered cake from centrifuges has a higher moisture content compared to cake from filter presses; consequently, solids hauling requirements will be greater. At current average conditions, approximately 19,000 cy of cake will be generated annually.

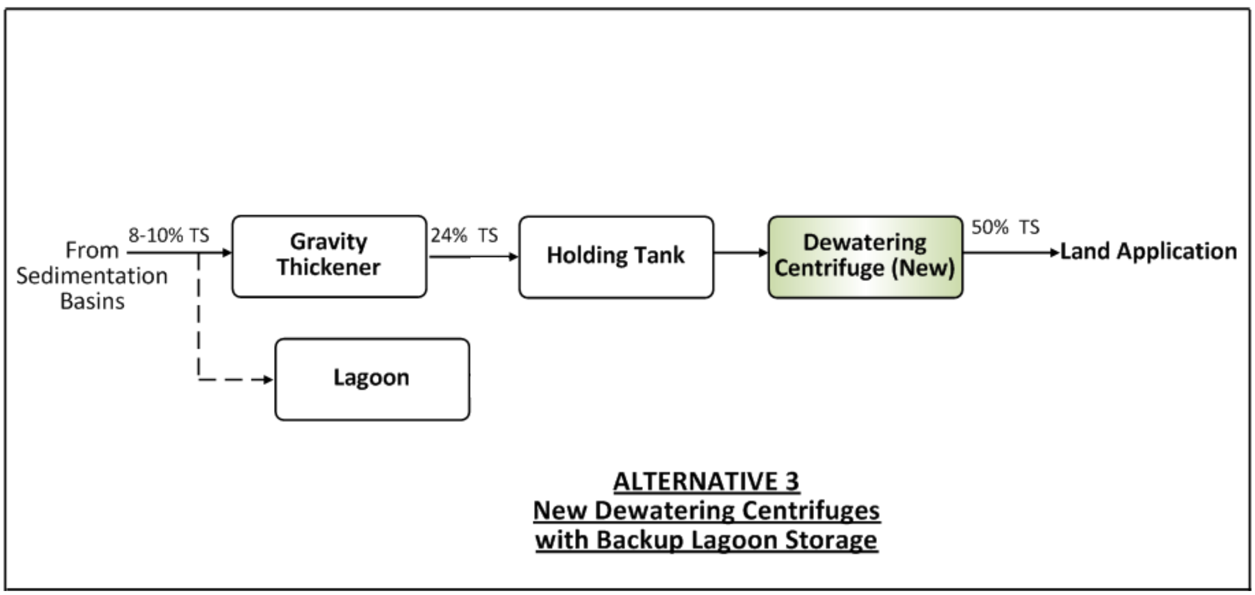

Figure TM4-10: Alternative 3 Process Flow Diagram

A suggested layout for the dewatering centrifuges within the existing solids dewatering building is shown in **Figure TM4-11**. In order to fit within the existing dewatering space, the centrifuges will be elevated on a platform over a portion of the truck loading openings. Costs have been included for the platforms, but a structural evaluation of the building and platform requirements will need to be performed to confirm constructability. As part of this option, the existing feed pumps will be replaced with progressing cavity pumps. Polymer is not expected to be required for the lime solids dewatering process with centrifuges.

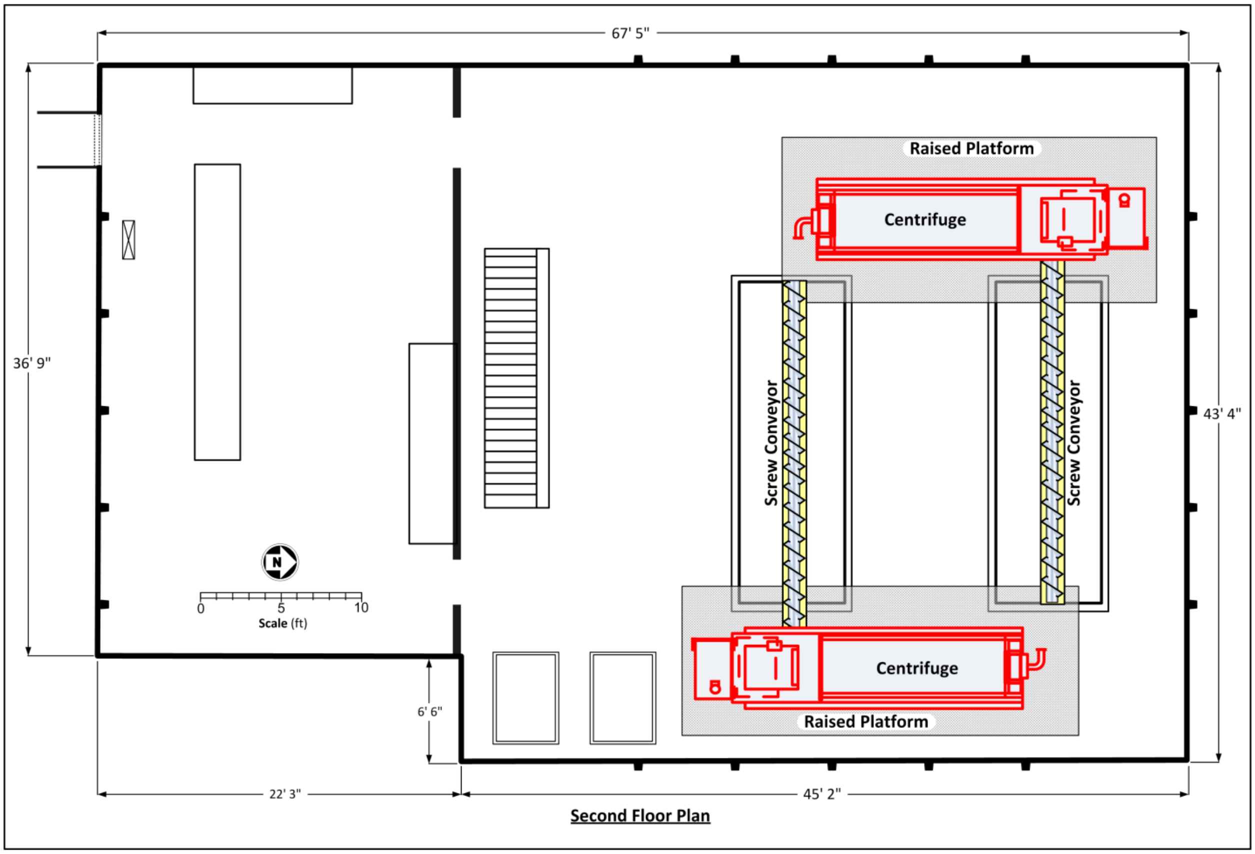

Figure TM4-11: Alternative 3 Dewatering Centrifuge Layout

Table TM4-7 lists the equipment requirements and replacement frequency for centrifuge dewatering. While centrifuges can be rebuilt with new or refurbished bowls and scroll equipment, a typical centrifuge life is 15 to 20 years. If the City pursues centrifuge dewatering, staff may be able to increase the centrifuge life beyond the 15 year period used in this evaluation, resulting in lower replacement costs.

Table TM4-7: Alternative 3 Equipment List

COMPONENTS	NUMBER	REPLACEMENT PERIOD (YEARS)
Centrifuge	2 (one duty/1 standby)	15
Feed Pump (progressing cavity)	2 (one duty/1 standby)	15
Filtrate Pump (centrifugal)	2 (one duty/1 standby)	15

Additional options for the lagoon back-up system are discussed in **Appendix TM4.A**.

5.4 ALTERNATIVE 4: LONG-TERM LAGOON STORAGE

This lime solids management alternative would replace existing gravity thickening and mechanical dewatering with long-term storage in the existing Sludge Lagoons (**Figure TM4-12**). Removal and disposal of dewatered solids would be required when the lagoon storage capacity is reached. Lagoon storage capacity is a function of solids production and the settled solids concentration in the lagoon. Lagoon solids concentration information was not available; however, a value of 50 percent was used to reflect the combination of fairly dry solids at the southern portion of the lagoon and the more dilute solids in the northern portion of the lagoon. At current average conditions, the plant generates approximately 53 cy per day of residuals at 50 percent TS.

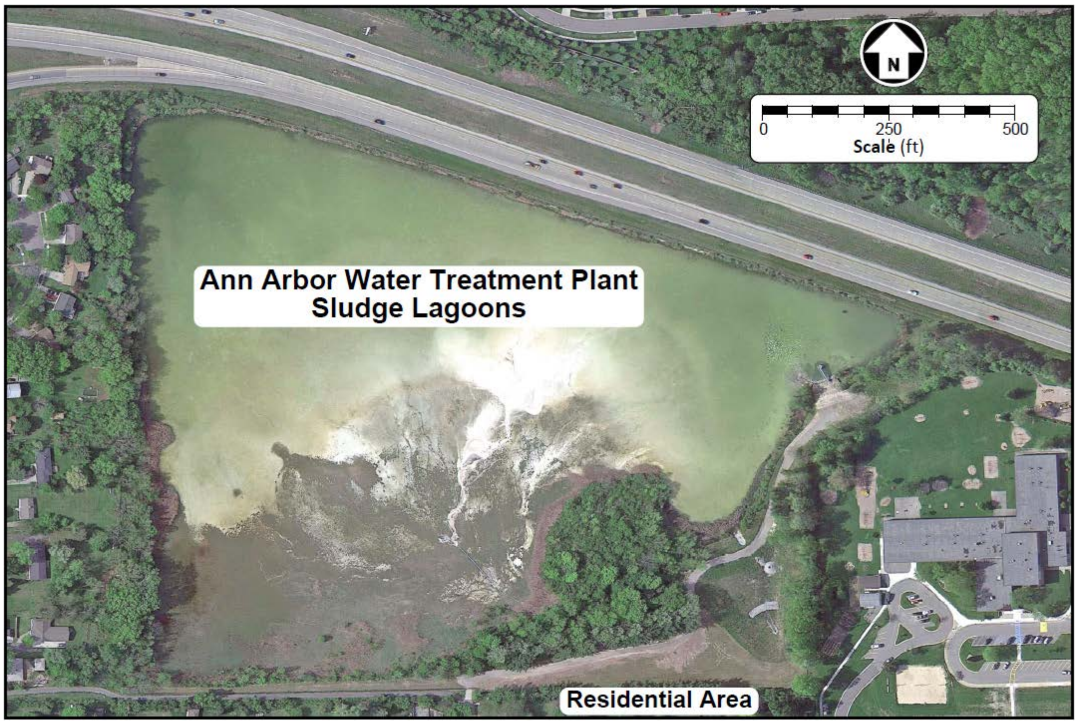

Figure TM4-12: Alternative 4 Existing Solids Storage Lagoon

Evaluation of the lagoon (based on 1972 drawings) indicated a total empty lagoon volume of 738,000 cubic yards. The lagoon has been in use for several decades and currently is almost full. Consequently, a portion of the lagoon would need to be dewatered and cleaned to provide storage volume for future solids production. To minimize contractor mobilization and hauling issues, a minimum operating period of 10 years is recommended, which corresponds to a lagoon volume of approximately 193,000 cy. Assuming a truck volume of 20 cy, this would require 9,650 trucks per cleaning event. Access to the lagoon site is limited and requires travel through a residential district. To limit the impact on residents, cleaning would be limited to summer months, when trucks can travel through an adjacent elementary school parking lot. As a result of the high number of trucks and the limited hauling period, the viability of this alternative is in question. Options for short-term storage of lime solids in the lagoons as a back-up to other management alternatives are discussed in **Appendix TM4.A**.

5.5 ALTERNATIVE 5: RECALCINATION FOR LIME RECOVERY

Recalcination is a thermal process used to convert lime residuals, which are primarily calcium carbonate ($CaCO_3$) to calcium oxide or quicklime (CaO) for reuse in the lime softening process. In the recalcination process (**Figure TM4-13**), dewatered lime residuals are treated with a binder prior to drying to achieve 97 percent TS required for recalcination. The binder is made of a starch compound and prevents the agglomerate from disintegrating in the dryer or the kiln. Heating in the rotary kiln converts the $CaCO_3$ to CaO and carbon dioxide. After recalcination, the resulting CaO solids are cooled using a counter-flow air-swept rotary cooler.

Because the Ann Arbor WTP practices magnesium removal during softening operations, additional pre-processing of lime residuals would be required prior to recalcination. Magnesium hydroxide solids must be separated from calcium carbonate solids to prevent re-introduction to the raw water stream with recovered lime. Magnesium precipitates are typically dissolved by lowering the pH of lime solids prior to mechanical dewatering, and magnesium removed with excess water. In this application the liquid residual stream from mechanical dewatering has high magnesium content, requiring further processing before recycling or disposal by other means.

Recalcination technology is available from two rotary kiln manufacturers: A-C Equipment of Milwaukee, WI and Feeco International of Green Bay, WI – however, only Feeco International offers equipment matching the Ann Arbor capacity requirements. Equipment required for the recalcination process is listed in **Table TM4-8**.

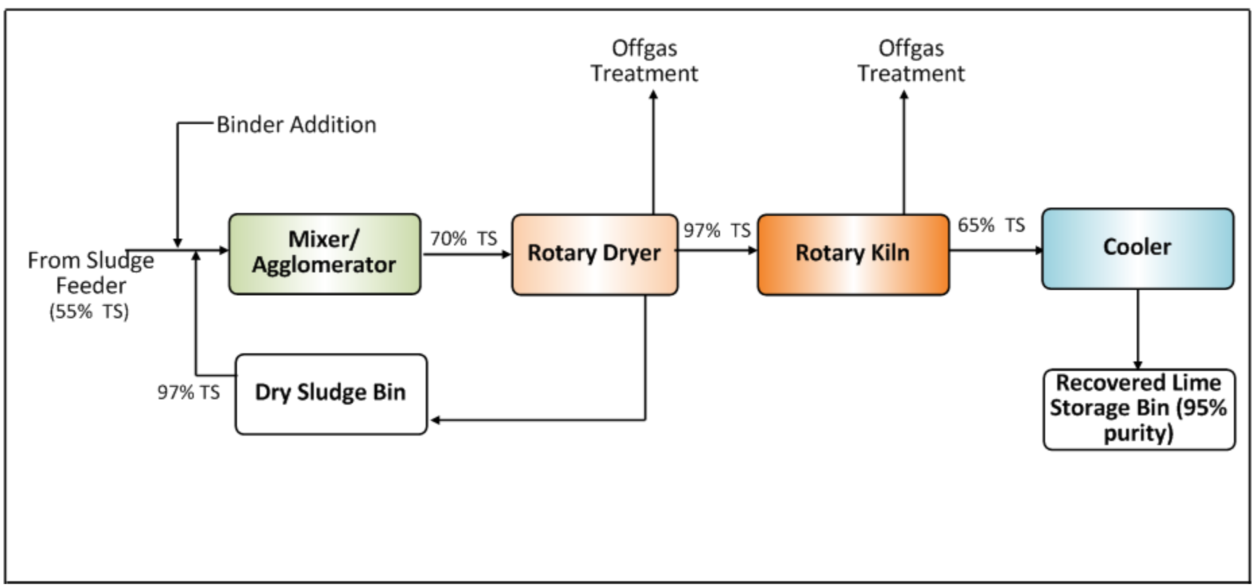

Figure TM4-13: Recalcination Process Flow Diagram

The recalcination system will also require construction of a new building to house the equipment. At the time of this writing, installation requirements and building size information was not available from equipment vendors. Consequently, building costs are not included in the recalcination equipment costs.

Table TM4-8: Alternative 5 Equipment List

COMPONENTS	NUMBER	REPLACEMENT PERIOD (YEARS)
Mixer/Agglomerator	1	15
Rotary Dryer	1	15
Rotary Kiln	1	15
Storage Bin	1	15
Cooler	1	15
Odor Control	1	15

Based on discussion during the August 21, 2014 workshop, City staff indicated that implementation of a recalcination facility solely for the City's lime residuals is unlikely. In the event that other nearby water treatment utilities using lime softening were interested in jointly operating a recalcination facility at another site, a regional facility could become attractive.

Additional options for the lagoon back-up system are discussed in **Appendix TM4.A**.

6 Opinions of Probable Cost

Conceptual level opinions of probable cost (OPCs) were developed for the five lime solids management alternatives described in **Section 5**. Conceptual level OPCs were also developed for lagoon back-up storage options, as given in **Appendix TM4.A.**

The conceptual level OPCs presented here were developed using a common set of capital and operations, maintenance, repair, and replacement (OMR&R) unit costs. The Class 4 planning level cost opinions presented here reflect use of standard engineering practices and were prepared without the benefit of detailed engineering designs. As defined by The Association for the Advancement of Cost Engineering (AACE), Class 4 cost opinions of this type are generally considered to have an accuracy range of plus 50 to minus 30 percent. Any actual project cost would depend on current labor and material costs, competitive market conditions, final project scope, bid date, and other variable factors. The opinions of probable cost presented here are most appropriately used to compare the relative costs of various Lime Solids Management Alternatives, rather than as estimates of actual project costs for detailed budgeting purposes.

A detailed breakdown of cost assumptions for each evaluated component is provided in **Appendix TM4.B.** The following sections summarize key cost considerations used in the development of component costs. Financial and capital cost factors used in this evaluation are listed in **Table TM4-9**.

Table TM4-9: Financial and Capital Cost Factors

COMPONENTS	UNITS	VALUE
Project Life	Years	30
Interest Rate	%	2
Escalation Rate	%	5
Electrical & Instrumentation	% of total capital cost	13
HVAC & Plumbing	% of total capital cost	10
Contingencies	% of total capital cost	30
Engineering, Legal & Administration	% of total construction cost	20
General Requirement	% of total construction cost	26

6.1 OPINIONS OF PROBABLE CAPITAL COSTS

The opinions of probable capital cost for each alternative are listed in **Table TM4-10**. Opinions of probable cost (OPCs) include equipment and installation, contractor General Requirements, engineering, and contingencies for all alternatives with the exception of Alternative 5 (recalcination). As stated in Section 5.5, limited information was available for recalcination installation and facility requirements and consequently, only equipment costs are included. The OPCs for Alternative 1 (continued use of existing filter press dewatering) include only initial feed pump and filtrate pump replacement. Other rebuild costs for Alternative 1 are included as O&M costs.

OPCs for periodic lagoon cleaning are included in the capital costs for Alternative 4, based on information provided by a local contractor (Dunigan Brothers, Jackson, MI). With the exception of Alternative 5 (recalcination), no additional buildings are required. As noted in Section 5.5, building size requirements were not available from the recalcination vendor and consequently, building costs have not been included in the Alternative 5 OPCs. Costs for continued maintenance on existing pressure filter presses were also not included in Alternative 5 OPCs. Detailed information used to develop Capital OPCs is provided in **Appendix TM4.B**.

Table TM4-10: Opinions of Probable Capital Costs for Lime Solids Management Alternatives

	ALTERNATIVE 1- CONTINUED FILTER PRESS DEWATERING	ALTERNATIVE 2- NEW FILTER PRESS DEWATERING	ALTERNATIVE 3- NEW CENTRIFUGE DEWATERING	ALTERNATIVE 4 - LAGOON DISPOSAL	ALTERNATIVE 5- RECALCINATION
Equipment and Facility Cost	$370,000	$2,060,000	$2,010,000	$84,000	$3,320,000
Lagoon Cleaning	-	-	-	$ 8,460,000[1]	-

	ALTERNATIVE 1- CONTINUED FILTER PRESS DEWATERING	ALTERNATIVE 2- NEW FILTER PRESS DEWATERING	ALTERNATIVE 3- NEW CENTRIFUGE DEWATERING	ALTERNATIVE 4 - LAGOON DISPOSAL	ALTERNATIVE 5- RECALCINATION
General Requirements	$110,000	$658,000	$642,000	$22,000	
Contingencies	$159,000	$954,000	$930,000	$11,000	
Engineering, Legal & Administration	$134,000	$806,000	$786,000	$23,000	
Total Project Cost	$820,000	$4,940,000	$4,820,000	$8,590,000	$3,320,000[2]

[1]Cleaning costs for about ten years of solids deposited in the lagoon. Cost re-occurs at 10 year frequency.
[2]Costs reflect only the purchase costs for the recalcination equipment.

6.2 OPINIONS OF PROBABLE ANNUAL OPERATIONS AND MAINTENANCE COSTS

Opinions of probable annual operations and maintenance (O&M) costs are based on the current average solids production (57,900 lb/day dry solids). The O&M OPCs include power consumption, contract hauling and land application of dewatered lime residuals, maintenance and operating labor, and equipment maintenance, as listed in **Table TM4-11**. Costs for equipment maintenance were obtained from vendors for specific equipment or based on an annual rate of 2 percent of the equipment cost. All other O&M costs were based on information provided by City staff. All O&M costs and repair and replacement costs were escalated at a rate of 5 percent per year. Annual O&M OPCs for lime solids management alternatives are listed in **Table TM4-12**.

At the time of this writing, information on O&M requirements for recalcination (labor, energy use, and equipment maintenance) were not available. Consequently, no O&M costs were developed for Alternative 5, Recalcination.

Table TM4-11: Project Operations and Maintenance Unit Costs

COMPONENTS	UNITS	CURRENT COSTS
Electricity	$/kwh	0.089
Hauling/Land Application	$/wt	17.46
Labor- Operations	$/hr	48
Labor- Maintenance	$/hr	55
Equipment Maintenance	% of equipment cost	2

Table TM4-12: Opinions of Annual O&M Costs for Lime Solids Management Alternatives

	ALTERNATIVE 1-CONTINUED FILTER PRESS DEWATERING	ALTERNATIVE 2-NEW FILTER PRESS DEWATERING	ALTERNATIVE 3-NEW CENTRIFUGE DEWATERING	ALTERNATIVE 4 - LAGOON DISPOSAL	ALTERNATIVE 5-RECALCINATION
Power	$ 8,000	$19,000	$17,000	$25,000	n/a[1]
Labor Operations	$217,000	$217,000	$109,000	$0	n/a[1]
Labor Maintenance	$273,000	$249,000	$124,000	$18,700	n/a[1]
Equipment Maintenance	$6,000	$32,000	$27,000	$1,000	n/a[1]
Hauling and Disposal	$615,000	$615,000	$799,000		n/a[1]
Total Annual O&M OPC	$1,110,000	$1,132,000	$1,076,000	$45,000	n/a[1]

[1]Annual O&M costs for recalcination not available from equipment manufacturers

6.3 OPINIONS OF PROBABLE LIFE-CYCLE COSTS

Opinions of probable life-cycle net present value were developed based on capital OPCs (**Table TM4-10**)and annual O&M OPCs (**Table TM4-12**) using the financial factors listed in **Table TM4-9**, and are presented in **Table TM4-13.** The annualized unit cost was based on an annual solids production of 10,560 dt.

Table TM4-13: Opinions of Probable Life-Cycle Costs for Lime Solids Management Alternatives

	ALTERNATIVE 1-CONTINUED FILTER PRESS DEWATERING	ALTERNATIVE 2-NEW FILTER PRESS DEWATERING	ALTERNATIVE 3-NEW CENTRIFUGE DEWATERING	ALTERNATIVE 4-LAGOON DISPOSAL	ALTERNATIVE 5-RECALCIN-ATION
Capital Cost ($)	$820,000	$4,940,000	$4,820,000	$8,590,000	$8,500,000
Annual O&M Cost ($)	$1,119,000	$1,132,000	$1,076,000	$45,000	n/a[1]
PW Repair & Replacement ($)	$1,860,000	$3,380,000	$2,310,000	$23,193,000[2]	n/a[1]
PW Costs of Annual O&M ($)	$25,410,000	$25,705,000	$24,433,000	$1,022,000	n/a[1]
Total Lifecycle Cost ($)	$28,090,000	$34,030,000	$31,560,000	$32,810,000	n/a[1]
Annualized Unit Cost ($/dt)	$117	$142	$132	$137	n/a[1]

[1]O&M requirements from vendor not available
[2]Includes costs for two 10-year lagoon clean out events (2025 and 2035) at $8.4 million per event (2014 dollars)

7 Recommendations

Based on the evaluated equipment requirements, opinions of probable cost, and discussions with City staff, the recommended lime solids management alternative is to continue to use the existing filter press equipment, with periodic rebuilds. If rebuild frequency or costs increase or parts become more difficult to obtain, consideration should be given to replacing the filter presses with new filter presses.

Because the existing lagoon has little remaining storage capacity, plans should be made to remove a portion of the stored residuals, freeing up volume for future dewatering back-up capability. It is recommended that 16,000 cy of stored solids be removed from the lagoons to permit continued use as a back-up to mechanical dewatering and land application. At current annual average solids production, removing this volume of solids would permit the lagoons to be used for back-up solids disposal for 30 days per year for a period of 10 years.

Appendix TM4.A

Existing Lagoons as a Back-up for Mechanical Dewatering

The City desires to maintain the capability to use the existing lagoons as a back-up method for lime solids storage when the mechanical dewatering units are overloaded or out of service. This scenario is based on using the lagoon approximately 30 days per year, with a lagoon storage requirement of 53 cy per day at 50 percent TS. Periodic lagoon cleaning would be required to remove accumulated solids. Based on cleaning events every ten years, approximately 16,000 cy of solids at 50 percent TS would need to be removed per cleaning event, which corresponds to 80 truck loads at 20 cy per truck. Lagoon cleaning would be performed only during summer months, on a ten year cycle, to minimize noise and traffic impacts on neighbors.

A second option for using the lagoon system as "back-up" for the mechanical dewatering is to dewater through permeable geotextile fabric tubes or "Geotubes" installed at the lagoon. These tubes, manufactured by TenCate, would be placed near the bank of the lagoons, so that the feed to lagoon will flow through the Geotubes, with permeate filtering through the tubes and into the lagoons. **Figure TM4-14** illustrates the use of Geotubes as a dewatering technology.

Figure TM4-14: TenCate Geotube Dewatering Technology

The lime solids are retained in the tubes. When the tube is full of solids, it taken out of service and is allowed to dry further, and eventually removed by a contractor for disposal. While the final solids concentration is a function of the drying time, solids concentrations can range from 30 percent to 45 percent total solids. The approximate area required for Geotubes alternative is presented in **Figure TM4- 15**.

Figure TM4- 15: Suggested TenCate Geotube Layout

The most common installation configuration for Geotubes is to place them along the lagoon berm and allow the filtrate to drain into the lagoon. However, because of the limited available berm area and the proximity of residences, the elementary school, and the highway, the most likely location for the Geotubes is in the wooded area west of the elementary school. At current average conditions, around 2,700 cy of dewatered cake will be generated annually, at 30 percent TS concentration. Between two and three tubes would be filled each year and would require removal and replacement. **Table TM4-14** lists the equipment requirement and replacement frequency for the Geotube alternative**.**

Table TM4-14: Geotube Equipment List

COMPONENTS	VALUE	UNITS	REPLACEMENT PERIOD (YEARS)
TenCate Geotubes	550	ft	1
Custom liner	55,000	ft^2	5
Geotube Filtration Fabric	23	rolls	1

Use of the existing lagoon for periodic back-up provides additional flexibility for the plant dewatering process and can support extended dewatering downtime as a result of construction or unanticipated system outages. Based on conversations with local excavation contractors, the lagoon cleaning and solids hauling can be performed within a summer season, allowing use of the elementary school parking lot for truck travel.

The life-cycle costs for lagoon back-up, through conventional lagoon storage or through Geotube dewatering are listed in **Table TM4- 15.** Costs for lagoon back-up are based on a 10-year cleaning frequency. Costs for the Geotube back-up are based on annual solids removal and Geotube replacement.

Table TM4- 15: Opinions of Probable Cost for Lagoon Back-up

	LAGOON BACK-UP	GEOTUBE BACK-UP
Initial Excavation/Installation ($)	$830,000	$330,000
Annual O&M Cost ($)	$42,000	$79,000
Present Worth 10 Year Excavation	$830,000	-
Present Worth Repair & Replacement ($)	$1,901,000	$3,053,000
Present Worth Costs of Annual O&M ($)	$954,000	$1,794,000
Total Lifecycle Cost ($)	$3,680,000	$5,180,000

Appendix TM4.B

Lime Solids Alternatives Cost Calculations

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Existing Filter Press Dewatering**	Date:	November 6, 2014

Alternative 1 - Existing Filter Press Dewatering

CAPITAL COST

Item Description	No. of Units		Unit Cost	2014 Cost	SV at 2030
Dewatering					
P&F Press (no cost - rebuild only)		ea		$0	
Installation Costs		LS		$0	
Fast Feed Pumps	1	ea	$63,000	$63,000	
Slow Feed Pumps	3	ea	$63,000	$189,000	
Pump Installation Costs @ 40%		LS		$100,800	
Filtrate Pumps	2	ea	$7,000	$14,000	
Pump Installation Costs @ 40%		LS		$5,600	
Subtotal				**$370,000**	**$0**

Total Capital Costs		**$370,000**
Electrical & Instrumentation	8%	$30,000
HVAC & Plumbing	5%	$19,000
Subtotal		**$420,000**
Sitework	0%	$0
General Requirements	26%	$110,000
Construction Subtotal		**$530,000**
Contingencies	30%	$159,000
Engineering, Legal & Administration	20%	$134,000
Total Project Cost		**$820,000**

ANNUAL OPERATING COSTS

Item Description	Units	Unit Cost	$/per year
Power	kWh	$0.089	$8,000
Labor			
Operations	hr	$48.00	$217,000
Maintenance	hr	$55.00	$273,000
Equipment Maintenance	LS	$0	$6,000
Disposal and Hauling	LS		$615,000
Total Operating Cost			**$1,119,000**

PRESENT WORTH & ANNUALIZED UNIT COST

Period, years	30
Interest Rate	2%
P/A Factor, Operations	22.71
P/F Salvage in 2030	(0.569)
Year 0 Capital Costs	$820,000
PW of Salvage Value (Buildings)	$0
Total Present Worth Capital Costs	$820,000
Present Worth Cost of Annual O&M	**$25,410,000**
Present Worth Repair and Replacement	**$1,860,000**
Total Present Worth Costs	**$28,090,000**
Annualized Present Worth Costs	$1,237,000
Annual Average Solids Production (dt/yr	10,561
Annualized Unit Cost ($/dt)	**$117**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**New Filter Press Dewatering**	Date:	November 6, 2014

Alternative 2 - New Filter Press Dewatering

CAPITAL COST

Item Description	No. of Units		Unit Cost	2014 Cost	SV at 2030
Dewatering					
P&F Press	2	ea	$648,500	$1,297,000	
Installation Costs @ 30%		LS		$389,100	
Fast Feed Pumps	2	ea	$63,000	$126,000	
Slow Feed Pumps	2	ea	$63,000	$126,000	
Pump Installation Costs @ 40%		LS		$100,800	
Filtrate Pumps	2	ea	$7,000	$14,000	
Pump Installation Costs @ 40%		LS		$5,600	
Subtotal				**$2,060,000**	**$0**

Total Capital Costs		**$2,060,000**
Electrical & Instrumentation	13%	$258,000
HVAC & Plumbing	10%	$206,000
Subtotal		**$2,520,000**
Sitework	0%	$0
General Requirements	26%	$658,000
Construction Subtotal		**$3,180,000**
Contingencies	30%	$954,000
Engineering, Legal & Administration	20%	$806,000
Total Project Cost		**$4,940,000**

ANNUAL OPERATING COSTS

Item Description	Units	Unit Cost	$/per year
Power	kWh	$0.089	$19,000
Labor			
Operations	hr	$48.00	$217,000
Maintenance	hr	$55.00	$249,000
Equipment Maintenance	LS	$0	$32,000
Disposal and Hauling	LS		$615,000
Total Operating Cost			**$1,132,000**

PRESENT WORTH & ANNUALIZED UNIT COST

Period, years	30
Interest Rate	2%
P/A Factor, Operations	22.71
P/F Salvage in 2030	(0.569)
Year 0 Capital Costs	$4,940,000
PW of Salvage Value (Buildings)	$0
Total Present Worth Capital Costs	$4,940,000
Present Worth Cost of Annual O&M	**$25,705,000**
Present Worth of Repair and Replacement	**$3,380,000**
Total Present Worth Costs	**$34,030,000**
Annualized Present Worth Costs	$1,499,000
Annual Average Solids Production (dt/yr	10,561
Annualized Unit Cost ($/dt)	**$142**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**New Centrifuge Dewatering**	Date:	November 6, 2014

Alternative 3 - New Dewatering Centrifuges

CAPITAL COST

Item Description	No. of Units		Unit Cost	2014 Cost	SV at 2030
Dewatering					
Centrifuge- ALDEC G2 125	2	ea	$625,000	$1,250,000	
Installation Costs @ 30%		LS		$375,000	
Feed Pumps	2	ea	$20,000	$40,000	
Filtrate Pumps	2	ea	$7,000	$14,000	
Pump Installation Costs @ 40%		LS		$21,600	
Conveyor Costs (Screw)	50	LF	$4,200	$210,000	
Installation Costs				$100,000	
Subtotal				**$2,010,000**	**$0**

Total Capital Costs		**$2,010,000**
Electrical & Instrumentation	13%	$251,000
HVAC & Plumbing	10%	$201,000
Subtotal		**$2,460,000**
Sitework	0%	$0
General Requirements	26%	$642,000
Construction Subtotal		**$3,100,000**
Contingencies	30%	$930,000
Engineering, Legal & Administration	20%	$786,000
Total Project Cost		**$4,820,000**

ANNUAL OPERATING COSTS

Item Description	Units	Unit Cost	$/per year
Power	kWh	$0.089	$17,000
Labor			
Operations	hr	$48.00	$109,000
Maintenance	hr	$55.00	$124,000
Equipment Maintenance	LS	$0	$27,000
Disposal and Hauling	LS		$799,000
Total Operating Cost			**$1,076,000**

PRESENT WORTH & ANNUALIZED UNIT COST

Period, years	30
Interest Rate	2%
P/A Factor, Operations	22.71
P/F Salvage in 2030	(0.569)
Year 0 Capital Costs	$4,820,000
PW of Salvage Value (Buildings)	$0
Total Present Worth Capital Costs	$4,820,000
Present Worth Cost of Annual O&M	**$24,433,000**
Present Worth Repair and Replacement	**$2,310,000**
Total Present Worth Costs	**$31,560,000**
Annualized Present Worth Costs	$1,390,000
Annual Average Solids Production (dt/yr	10,561
Annualized Unit Cost ($/dt)	**$132**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Lagoon Storage for all Residuals**	Date:	November 6, 2014

Alternative 4 - Lagoon Storage

CAPITAL COST

Item Description	No. of Units		Unit Cost	2014 Cost	SV at 2030
Dewatering					
Lagoon Cleaning	1	ea	$8,460,000	$8,460,000	
Transfer pumps	2	ea	$30,000	$60,000	
Pump installation @ 40%				$24,000	
Subtotal				**$8,540,000**	**$0**
Total Capital Costs				**$8,540,000**	
Electrical & Instrumentation				$0	
HVAC & Plumbing				$0	
Subtotal				**$8,540,000**	
Sitework	0%			$0	
General Requirements	26%			$22,000	
Construction Subtotal				**$8,560,000**	
Contingencies	10%			$11,000	
Engineering, Legal & Administration	20%			$23,000	
Total Project Cost				**$8,590,000**	

ANNUAL OPERATING COSTS

Item Description	Units	Unit Cost	$/per year
Power	kWh	$0.089	$25,000
Labor			
Operations	hr	$48.00	$0
Maintenance	hr	$55.00	$18,700
Lagoon Maintenance	LS		$1,000
Disposal and Hauling	LS		
Total Operating Cost			**$45,000**

PRESENT WORTH & ANNUALIZED UNIT COST

Period, years	30
Interest Rate	2%
P/A Factor, Operations	22.71
P/F Salvage in 2030	(0.569)
Year 0 Capital Costs	$8,590,000
PW of Salvage Value (Buildings)	$0
Total Present Worth Capital Costs	$8,590,000
Present Worth Cost of Annual O&M	**$1,022,000**
Present Worth of Repair and Replacement, 10 and 20 yr lagoon cleaning	**$23,193,000**
Total Present Worth Costs	**$32,810,000**
Annualized Present Worth Costs	$1,445,000
Annual Average Solids Production (dt/yr	10,561
Annualized Unit Cost ($/dt)	**$137**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Cost Summary of Recalcination**	Date:	November 6, 2014

Alternative 5 - Recalcination Process- FEECO - Capital Costs Only

CAPITAL COST

Item Description	No. of Units		Unit Cost	2014 Cost	SV at 2030
Dewatering					
Rotary kiln	1	ea	$950,000	$950,000	
Agglomerator+dryer+cooler	1	ea	$1,100,000	$1,100,000	
sludge feeder+odor control+screen+cr	1	ea	$500,000	$500,000	
Installation Costs @ 30%		LS		$765,000	
Filtrate Pumps	1	ea	$7,000	$7,000	
Pump Installation Costs @ 40%		LS		$2,800	
Subtotal				**$3,320,000**	**$0**

Total Capital Costs		**$3,320,000**
Electrical & Instrumentation	13%	
HVAC & Plumbing	10%	
Subtotal		**$3,320,000**
Sitework	8%	
General Requirements	26%	
Construction Subtotal		**$3,320,000**
Contingencies	30%	
Engineering, Legal & Administration	20%	
Total Project Cost		**$3,320,000**

ANNUAL OPERATING COSTS - NOT AVAILABLE

Item Description	Units	Unit Cost	$/per year
Power	kWh	$0.089	
Labor			
Operations	hr	$48.00	
Maintenance	hr	$55.00	
Equipment Maintenance	LS	$0	
Disposal and Hauling	LS		
Total Operating Cost			**$0**

PRESENT WORTH & ANNUALIZED UNIT COST

Period, years	30
Interest Rate	2%
P/A Factor, Operations	22.71
P/F Salvage in 2030	(0.569)
Year 0 Capital Costs	$3,320,000
PW of Salvage Value (Buildings)	$0
Total Present Worth Capital Costs	$3,320,000
Present Worth Cost of Annual O&M	**$0**
Present Worth Repair and Replacement	
Total Present Worth Costs	**$3,320,000**
Annualized Present Worth Costs	$146,000
Annual Average Solids Production (dt/yr	10,561
Annualized Unit Cost ($/dt)	**$14**

Owner:	City of Ann Arbor		Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant		Date:	August 13, 2014
PN:	183262.110	File No.	Checked By:	PAS
Title:	**Geotube dewatering at Lagoon**		Date:	November 6, 2014
	Backup Dewatering Only (30 day/yr)			

Lagoon Dewatering - Tencate GeoTubes - Costs do not include clearing, berming or pipeline to the geotubes

CAPITAL COST

Item Description	No. of Units		Unit Cost	2014 Cost	SV at 2030
Dewatering					
Geotube GT500 container	1000	ft	$59	$58,600	
Geotube filtration fabric	23	rolls	$475	$10,925	
Polymer make-down unit	1	LS	$5,200	$5,200	
Custom liner	55,000	sq. ft	$0.29	$15,950	
Training	3	days	$1,250	$3,750	
Subtotal				**$90,000**	**$0**
Total Capital Costs				**$90,000**	
Electrical & Instrumentation	13%			$11,000	
HVAC & Plumbing	15%			$14,000	
Subtotal				**$120,000**	
Sitework		sq.ft	$0.80	$44,000	
General Requirements	26%			$43,000	
Construction Subtotal				**$210,000**	
Contingencies	30%			$63,000	
Engineering, Legal & Administration	20%			$53,000	
Total Project Cost				**$330,000**	

ANNUAL OPERATING COSTS

Item Description	Units	Unit Cost	$/per year
Power	kWh	$0.089	$13,000
Chemical	tote	$3,845	$17,000
Labor			
Operations	hr	$48.00	$13,000
Maintenance	hr	$55.00	$14,346
Geotube Maintenance	LS		$22,000
Disposal and Hauling	LS		
Total Operating Cost			**$79,000**

PRESENT WORTH & ANNUALIZED UNIT COST

Period, years	30
Interest Rate	2%
P/A Factor, Operations	22.71
P/F Salvage in 2030	(0.569)
Year 0 Capital Costs	$330,000
PW of Salvage Value (Buildings)	$0
Total Present Worth Capital Costs	$330,000
Present Worth Cost of Annual O&M	**$1,794,000**
Present Worth of Repair and Replacement	**$3,053,000**
Total Present Worth Costs	**$5,180,000**
Annualized Present Worth Costs	$228,000
Annual Average Solids Production (dt/yr	10,561
Annualized Unit Cost ($/dt)	**$21.59**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Lagoon Dewatering**	Date:	November 6, 2014
	Backup Dewatering Only (30 days/yr)		

Lagoon Dewatering - Lagoon Backup

CAPITAL COST

Item Description	No. of Units		Unit Cost	2014 Cost	SV at 2030
Dewatering					
Lagoon Cleaning	1	ea	$696,000	$696,000	
Transfer pumps	2	ea	$30,000	$60,000	
Pump installation @ 40%				$24,000	
Subtotal				**$780,000**	**$0**
Total Capital Costs				**$780,000**	
Electrical & Instrumentation				$0	
HVAC & Plumbing				$0	
Subtotal				**$780,000**	
Sitework	0%			$0	
General Requirements	26%			$22,000	
Construction Subtotal				**$800,000**	
Contingencies	10%			$11,000	
Engineering, Legal & Administration	20%			$23,000	
Total Project Cost				**$830,000**	

ANNUAL OPERATING COSTS

Item Description	Units	Unit Cost	$/per year
Power	kWh	$0.089	$22,000
Labor			
Operations	hr	$48.00	$0
Maintenance	hr	$55.00	$18,700
Lagoon Maintenance	LS		$1,000
Disposal and Hauling	LS		
Total Operating Cost			**$42,000**

PRESENT WORTH & ANNUALIZED UNIT COST

Period, years	30
Interest Rate	2%
P/A Factor, Operations	22.71
P/F Salvage in 2030	(0.569)
Year 0 Capital Costs	$830,000
PW of Salvage Value (Buildings)	$0
Total Present Worth Capital Costs	$830,000
Present Worth Cost of Annual O&M	**$954,000**
Present Worth Lagoon Cleaning Year 10 and Year 20	**$1,901,000**
Total Present Worth Costs	**$3,690,000**
Annualized Present Worth Costs	$163,000
Annual Average Solids Production (dt/yr	10,561
Annualized Unit Cost ($/dt)	**$15**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Power Costs**	Date:	November 6, 2014

POWER USE AND COST

Alt 1 **Unit Cost for Power (per kWh)** $0.193

Alternative 1 - Existing Filter Press Dewatering

Equipment List	No. of Units	Installed HP	Operating HP	Hr/Day	Day/Wk	Wk/Yr	kWh/Yr	Cost $/yr
Dewatering								
P&F Press	0		0.0	0	5	52	0	$0
Pre-Fill Pump	1	20	16.0	1.07	5	52	4,138	$799
Fast Feed Pump	1	50	40.0	1.60	5	52	15,517	$2,995
Slow Feed Pump	1	20	16.0	2.67	5	52	10,345	$1,997
Filtrate Pump	1	8	6.4	8	5	52	12,413	$2,396
Subtotal							**42,413**	**$8,000**

Ann Arbor Water Treatment Plant

Total	**42,000**	**$8,000**

Alt 2 **Unit Cost for Power (per kWh)** $0.193

Alternative 2 - New Filter Press Dewatering

Equipment List	No. of Units	Installed HP	Operating HP	Hr/Day	Day/Wk	Wk/Yr	kWh/Yr	Cost $/yr
Dewatering								
P&F Press	1	0	0.0	0	5	52	0	$0
Fast Feed Pump	1	150	120.0	2	5	52	46,550	$8,985
Slow Feed Pump	1	75	60.0	3	5	52	38,792	$7,488
Filtrate Pump	1	8	6.4	8	5	52	12,413	$2,396
Subtotal							**97,756**	**$19,000**

Ann Arbor Water Treatment Plant

Total	**98,000**	**$19,000**

Alt 3 **Unit Cost for Power (per kWh)** $0.193

Alternative 3 - New Dewatering Centrifuges

Equipment List	No. of Units	Installed HP	Operating HP	Hr/Day	Day/Wk	Wk/Yr	kWh/Yr	Cost $/yr
Dewatering								
Centrifuge- ALDEC G2 125	1		0.0	8	5	52	43,850	$8,464
Feed Pumps	1	10	8.0	8	5	52	15,517	$2,995
Filtrate Pumps	1	8	6.4	8	5	52	12,413	$2,396
Conveyors	1	10	8.0	8	5	52	15,517	$2,995
Subtotal							**87,297**	**$17,000**

Ann Arbor Water Treatment Plant

Total	**87,000**	**$17,000**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Power Costs**	Date:	November 6, 2014

Alt 4 **Unit Cost for Power (per kWh)** $0.193

Alternative 4 - Lagoon Storage

Ann Arbor Water Treatment Plant								
Equipment List	**No. of Units**	**Installed HP**	**Operating HP**	**Hr/Day**	**Day/Wk**	**Wk/Yr**	**kWh/Yr**	**Cost $/yr**
Dewatering								
Transfer pump to lagoon	1	20	16.0	24	7	52	130,341	$25,159
Subtotal							**130,341**	**$25,000**
Total							**130,000**	**$25,000**

Sub Alt "A" **Unit Cost for Power (per kWh)** $0.193

Lagoon Dewatering - Tencate GeoTubes - Costs do not include clearing, berming or pipeline to the geotubes

Alt 2								
Equipment List	**No. of Units**	**Installed HP**	**Operating HP**	**Hr/Day**	**Day/Wk**	**Wk/Yr**	**kWh/Yr**	**Cost $/yr**
Dewatering								
Transfer pump to lagoon	1	10	8.0	24	7	52	65,171	$12,580
Subtotal							**65,171**	**$13,000**
Total							**65,000**	**$13,000**

Sub Alt "1" **Unit Cost for Power (per kWh)** $0.193

Lagoon Dewatering - Lagoon Backup

Equipment List	**No. of Units**	**Installed HP**	**Operating HP**	**Hr/Day**	**Day/Wk**	**Wk/Yr**	**kWh/Yr**	**Cost $/yr**
Dewatering								
Transfer pump to lagoon	1	20	16.0	24	7	4	10,741	$2,073
Subtotal							**10,741**	**$2,000**
Total							**11,000**	**$2,000**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Chemical Costs**	Date:	November 6, 2014

CHEMICAL USE AND COST

Sub Alt "A" **Unit chemical cost** **$/tote** $8,358

Lagoon Dewatering - Tencate GeoTubes - Costs do not include clearing, berming or

Ann Arbor Water Treatment Plant						
Chemical	**Dose**	**Solids (dtpd)**	**Solids (dtpy)**	**Chemical Used (tote/yr)**	**Chemical Cost ($/tote)**	**Cost $/yr**
Dewatering						
Polymer- Solive 162				2	8,358	$16,716
Subtotal						**$17,000**

Total	**$17,000**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Labor Costs**	Date:	November 6, 2014

LABOR REQUIREMENT AND COSTS

Alt 1
Alternative 1 - Existing Filter Press Dewatering

Ann Arbor Water Treatment Plant								
Labor Category	**Number**	**Hr/Shift**	**Shift/Day**	**Day/Wk**	**Wk/Yr**	**Total Hours**	**Hourly Rate**	**Cost, $/yr**
Filter Press								
Operation	1	8	1.0	5	52	2,080	$ 104.34	217,000
Maintenance	1	8	1.0	5	52	2,080	$ 119.55	249,000
Rebuild Labor	0	0	0.0	0	0	203	$ 119.55	24,000

OperationTotal	**2,100**	**$217,000**
Maintenance Total	**2,300**	**$273,000**
Total	**4,400**	**$466,000**

Alt 2
Alternative 2 - New Filter Press Dewatering

Ann Arbor Water Treatment Plant								
Labor Category	**Number**	**Hr/Shift**	**Shift/Day**	**Day/Wk**	**Wk/Yr**	**Total Hours**	**Hourly Rate**	**Cost, $/yr**
Filter Press								
Operation	1	8	1.0	5	52	2,080	$ 104.34	217,000
Maintenance	1	8	1.0	5	52	2,080	$ 119.55	249,000

OperationTotal	**2,100**	**$217,000**
Maintenance Total	**2,100**	**$249,000**
Total	**4,200**	**$466,000**

Alt 3
Alternative 3 - New Dewatering Centrifuges

Ann Arbor Water Treatment Plant								
Labor Category	**Number**	**Hr/Shift**	**Shift/Day**	**Day/Wk**	**Wk/Yr**	**Total Hours**	**Hourly Rate**	**Cost, $/yr**
Dewatering Centrifuges								
Operation	0.5	8	1.0	5	52	1,040	$ 104.34	109,000
Maintenance	0.5	8	1.0	5	52	1,040	$ 119.55	124,000

OperationTotal	**1,000**	**$109,000**
Maintenance Total	**1,000**	**$124,000**
Total	**2,000**	**$233,000**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Labor Costs**	Date:	November 6, 2014

Alt 4

Alternative 4 - Lagoon Storage

Ann Arbor Water Treatment Plant								
Labor Category	**Number**	**Hr/Shift**	**Shift/Day**	**Day/Wk**	**Wk/Yr**	**Total Hours**	**Hourly Rate**	**Cost, $/yr**
Lagoon Storage								
Operation	0	8	1.0	5	52	0	$ 104.34	0
Maintenance	1	3	1.0	1	52	156	$ 119.55	18,700

OperationTotal	**0**	**$0**
Maintenance Total	**200**	**$18,700**
Total	**200**	**$18,700**

Sub Alt "A"

Lagoon Dewatering - Tencate GeoTubes - Costs do not include clearing, berming or pipeline to the geotubes

Operation								
Labor Category	**Number**	**Hr/Shift**	**Shift/Day**	**Day/Wk**	**Wk/Yr**	**Total Hours**	**Hourly Rate**	**Cost, $/yr**
Lagoon Storage								
Operation	1	8	1.0	15	1	120.0	$ 104.34	12,521
Maintenance	1	8	1.0	15	1	120.0	$ 119.55	14,346

OperationTotal	**100**	**$13,000**
Maintenance Total	**100**	**$14,300**
Total	**200**	**$26,900**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Equipment Maintenance Costs**	Date:	November 6, 2014

EQUIPMENT MAINTENANCE COSTS

2%	**of equipment cost**
1%	**of equipment cost for polymer system**

Alt 1

Alternative 1 - Existing Filter Press Dewatering

Ann Arbor Water Treatment Plant					
Equipment List	**No. of Units**	**Equip. Cost/unit**	**Total Equip. Cost**	**Maintenance %**	**Cost $/yr**
Dewatering					
P&F Press (no cost - rebui	0	$0	0	2%	$0
Fast Feed Pumps	1	$63,000	63,000	2%	$1,260
Slow Feed Pumps	3	$63,000	189,000	2%	$3,780
Mixer- Holding tank, Trans	2	$25,000	50,000	2%	$1,000
Subtotal					**$6,000**

Total	**$6,000**

Alt 2

Alternative 2 - New Filter Press Dewatering

Ann Arbor Water Treatment Plant					
Equipment List	**No. of Units**	**Equip. Cost/unit**	**Total Equip. Cost**	**Maintenance %**	**Cost $/yr**
Dewatering					
P&F Press	2	$648,500	1,297,000	2%	$25,940
Fast Feed Pumps	2	$63,000	126,000	2%	$2,520
Slow Feed Pumps	2	$63,000	126,000	2%	$2,520
Mixer- Holding tank, Trans	2	$25,000	50,000	2%	$1,000
Subtotal					**$32,000**

Total	**$32,000**

Alt 3

Alternative 3 - New Dewatering Centrifuges

Ann Arbor Water Treatment Plant					
Equipment List	**No. of Units**	**Equip. Cost/unit**	**Total Equip. Cost**	**Maintenance %**	**Cost $/yr**
Dewatering					
Centrifuge- ALDEC G2 125	2	$625,000	1,250,000	2%	$25,000
Feed Pumps	2	$20,000	40,000	2%	$800
Filtrate Pumps	2	$7,000	14,000	2%	$280
Mixer- Holding tank, Trans	2	$25,000	50,000	2%	$1,000
Subtotal					**$27,000**

Total	**$27,000**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Equipment Maintenance Costs**	Date:	November 6, 2014

Alt 4

Alternative 4 - Lagoon Storage

Ann Arbor Water Treatment Plant					
Equipment List	**Total Sludge Volume cy**	**Dredging Cost/cy**	**Total Costs over storage period $/10yr**	**Storage Period yr**	**Cost $/yr**
Lagoon					
Dredging	194,681	$43	$8,463,568	10	$846,357
Subtotal					**$846,000**
Dewatering					
Transfer pump to lagoon	2	$30,000	$60,000	2%	$1,200
Subtotal					**$1,000**
Total					**$846,000**

Alt 1, 2, 3

Lagoon Backup Option

Alternative 1 - Existing Filter Press Dewatering					
Equipment List	**Total Sludge Volume cy**	**Dredging Cost/cy**	**Total Costs over storage period $/10yr**	**Storage Period yr**	**Cost $/yr**
Lagoon					
Dredging	16,001	$43	$695,636	10	$69,564
Subtotal					**$70,000**
Total			**$696,000**		**$70,000**

Sub Alt "A"

Geotubes for Lagoon Backup Option

Equipment List	**Annual Sludge Volume cy**	**Excavation Cost/cy**			**Annual Excavation Cost $/yr**
Lagoon					
Excavation	500	$43			$21,737
Subtotal					**$22,000**
Total					**$22,000**

Owner:	City of Ann Arbor	Computed By:	A. Kadava
Plant:	Ann Arbor Water Treatment Plant	Date:	August 13, 2014
PN:	183262.110 File No.	Checked By:	PAS
Title:	**Disposal and Hauling**	Date:	November 6, 2014

HAULING AND DISPOSAL COST - Based on Current AA Solids Production

Landfill Disposal Fee ($/wet ton)	$37.95
Hauling Fee ($/wet ton)	

Alt 1
Existing Filter Press

Category	dtpd	wtpd	Day/Wk	Wk/Yr	Quantity (wtpy)	Cost ($/wt)	Cost $/yr
Land application	28.9	45	7	52	16,204	37.95	614,982
Subtotal							**$615,000**

Alt 2
New Filter Press

Category	dtpd	wtpd	Day/Wk	Wk/Yr	Quantity (wtpy)	Cost ($/wt)	Cost $/yr
Land application	28.9	45	7	52	16,204	37.95	614,982
Subtotal							**$615,000**

Alt 3
New Centrifuges

Category	dtpd	wtpd	Day/Wk	Wk/Yr	Quantity (wtpy)	Cost ($/wt)	Cost $/yr
Land application	28.9	58	7	52	21,065	37.95	799,477
Subtotal							**$799,000**

FINAL

WATER TREATMENT PLANT ALTERNATIVES ANALYSIS

Technical Memorandum 5: Applied Turbidity Evaluation

B&V PROJECT NO. 183262

PREPARED FOR

City of Ann Arbor

4 MAY 2015

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LIST OF TABLES

LIST OF FIGURES

APPENDICES

1 Introduction

This technical memorandum (TM) summarizes results of an assessment of current treatment practices at the Ann Arbor Water Treatment Plant (WTP) and recent plant performance with regard to turbidity of softened water applied to filters, and its impact on ability to maintain compliance with regulatory requirements. This assessment included discussions with plant operating staff, detailed review of historical plant operating data, and comparison of plant performance with that of other precipitative softening facilities.

2 Current Treatment Practices

Current treatment consists of two-stage split-treatment softening of the City's surface water and ground water supplies, ozone disinfection, granular media filtration, and residual disinfection with combined-chlorine. All surface water and a portion of the ground water supply pumped to the WTP site undergoes excess lime treatment at pH 11.0 to 11.3 s.u. in the primary flocculation/settling basins to precipitate calcium and magnesium hardness as calcium carbonate ($CaCO_3$) and magnesium hydroxide ($Mg(OH)_2$), respectively. Settled water from the primary basins is blended with untreated ground water prior to entering the secondary flocculation/settling basins on a seasonal basis. Blending of softened water from the primary basins with ground water at the secondary basin influent, along with supplemental addition of carbon dioxide (CO_2) if necessary, reduces pH of blended water to levels that promote precipitation of excess lime as $CaCO_3$within the secondary settling basins.

While the relative amount of ground water conveyed to the plant can be as much as 50 percent of the total water treated at times, ground water typically comprises approximately 20 percent of the blended raw water treated. The amount of ground water bypassed around the primary softening basins is typically limited to about 10 percent of the total plant flow treated; any additional ground water is blended with surface water and treated in the primary softening basins. Cationic polymer is added to the blended water at the secondary flocculation basin influent at an average dose of approximately 0.60 mg/L to promote agglomeration and settling of the calcium carbonate particles. Following secondary settling, additional carbon dioxide is applied to reduce settled water pH to approximately 7.5 to 8.0 s.u. at the ozone disinfection process inlet. Sodium hydroxide is added at the ozone contactor discharge to maintain a pH of approximately 9.3 in finished water leaving the plant.

As is typical for two-stage excess lime softening facilities practicing either split-treatment or conventional two-stage recarbonation (addition of CO_2 at the primary basin discharge to remove the excess lime in the secondary basins, with additional CO_2 fed at the secondary basin discharge to achieve desired finished water pH conditions), the turbidity of settled water at the secondary basin discharge is generally higher than at the primary basin discharge. This can be attributed to the following:

- Magnesium hydroxide precipitate formed in the primary softening basin as a result of high-pH excess lime treatment functions as a highly-effective coagulant that enhances removal of calcium carbonate precipitates, thereby producing settled water with low turbidity (less than 5 to 10 NTU).

- Reduction of pH to precipitate excess lime added in the primary basins results in formation of up to 50 to 70 mg/L of pure $CaCO_3$ in the secondary basin, which precipitates from solution as very finely dispersed particles which are difficult to flocculate and settle.

While difficulties in achieving good agglomeration and settling of $CaCO_3$ particles generated in precipitative softening applications have been well-documented, it should also be noted that $CaCO_3$ is readily removed by granular media filtration, particularly in the presence of filter aid polymers applied at low doses. This characteristic of $CaCO_3$ particles explains why utilities practicing precipitative softening can consistently maintain compliance with filtered water standards even when filter influent turbidity is as high as 40 to 50 NTU.

A summary of daily turbidity monitoring data at various points within the treatment facilities for the period of 2008 through 2013 is presented in **Table TM5-1**. Softening basin effluent samples are manually collected once per shift and turbidity measured, whereas filter influent turbidity is measured continuously. The frequency distribution of filter influent turbidity is shown graphically on **Figure TM5-1**. This figure illustrates that settled water turbidity during the period evaluated was less than 15 NTU approximately 88 percent of the time, and less than 10 NTU approximately 56 percent of the time.

Table TM5-1: Daily Turbidity Monitoring Results (2008 to 2013)

LOCATION	TURBIDITY, NTU	
	Average	Range
Plant 1:		
Primary Settling Basin[1]	5.0	0.2 to 64
Secondary Settling Basin	12.3	0.4 to 49
Plant 2:		
Primary Settling Basin	15.4	0.4 to 88
Secondary Settling Basin	13.7	0.5 to 78
Filter Influent	10.3	2.7 to 44
Filtered Water Clearwells[2]:		
Clearwell 1	0.05	0.03 to 0.19
Clearwell 2	0.05	0.02 to 0.24
Finished Water (Plant Discharge)	0.04	0.02 to 0.23

[1]Average of results for primary settling basins 1 and 2
[2]Average of 6 daily samples collected at 4 hour intervals

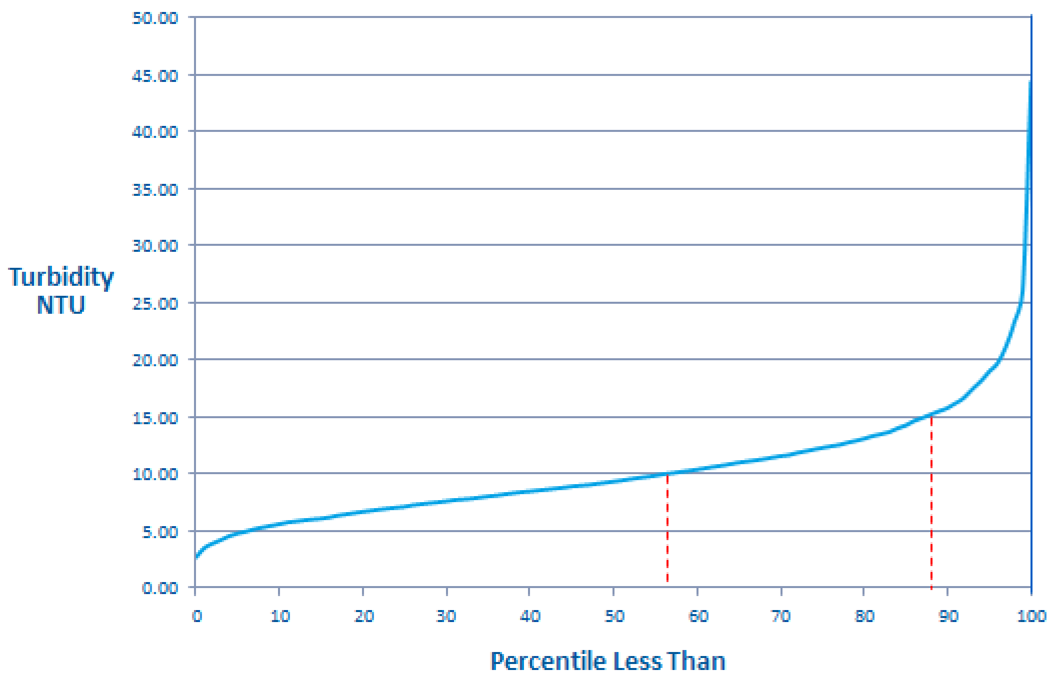

Figure TM5-1: Filter Influent Turbidity 2008 to 2013 – Frequency Occurrence Plot

3 Recent MDEQ Sanitary Survey Comments

There are currently no specific state or federal regulatory requirements that address the turbidity of settled water applied to granular media filters. However, settled water turbidity must be maintained at levels that will not negatively impact the ability to maintain compliance with state and federally-mandated filtered water turbidity standards. In addition, it is desirable to maintain settled water turbidity at levels that preclude rapid development of hydraulic head loss across the filters, and that produce acceptable filter fun times between backwashes and high filter productivities.

In its most recent sanitary survey of the Ann Arbor water treatment facilities, the Michigan Department of Environmental Quality (MDEQ) states that "effluent turbidity from both secondary clarifiers is in the 5 – 10 NTU range", and that this turbidity "is high even for facilities that practice lime softening". MDEQ notes that "it is not uncommon for turbidities following secondary treatment to exceed primary effluent turbidities". The report cites a recommendation presented in a USEPA publication (Optimizing Water Treatment Plant Performance Using the Composite Correction Program, EPA/625/6-91/027, revised August 1998) that settled water turbidity be maintained at "less than 1 NTU 95 percent of the time when the average raw water turbidity is less than or equal to 10 NTU", with a comment that this "should be considered by Ann Arbor WTP staff". Finally, the sanitary survey report includes a recommendation for "Long Term Implementation (>12 months)" that the City should "Continue to investigate methods to reduce turbidity carryover onto filters".

Additional comments relative to these observations and recommendations are summarized later in this memorandum. The following points should be considered with regard to comments presented in the MDEQ sanitary survey report:

- The recommendations presented in the USEPA report cited were developed considering typical treatment and performance capabilities for systems practicing conventional clarification/turbidity removal, rather than for systems practicing precipitative softening.
- Our extensive experience in the design and operation of precipitative softening plants throughout the United States suggests that a settled water goal of 1 NTU for treatment facilities practicing lime softening is neither practical from a technical feasibility standpoint nor necessary to maintain compliance with applicable regulations governing filtered water turbidity.

4 Discussions with Plant Operations Staff

Discussions with plant operating staff were conducted to solicit their thoughts and observations regarding historical treatment process performance as it relates to turbidity typically observed at the filter influent. The primary focus of these discussions was to obtain detailed responses to the following questions:

- Are filtered water turbidity goals being achieved?
- Is ability to consistently achieve compliance with regulatory requirements for the filtered water a concern?
- Are filter run times and productivities acceptable?
- Does hydraulic head loss limit filter run time?
- Does turbidity breakthrough limit filter run time?
- Are there significant differences in performance between Plants 1 and 2?
- Are there notable differences in seasonal performance with respect to filter influent turbidity?

Discussions with plant operations staff were conducted during Project Workshop 1 (July 7, 2014 through July 9, 2014) and Project Workshop 2 (August 21, 2014 through August 22, 2014). A summary of comments provided during these discussions is presented below.

4.1 FILTER OPERATING PRACTICES

- Filters are routinely backwashed after 96 hours of operation.
- During summer months when elevated wash water temperatures (and correspondingly lower wash water densities) result in the need for increased filter backwashing time to meet backwash water turbidity goals at termination of backwashing, maximum filter run times are reduced to approximately 72 hours to maintain ability to conduct backwashes during off-peak electrical charge periods.

- Total filtered water production of up to 5 million gallons per filter between backwashes was reported as typical. At an average area of approximately 456 square foot per filter, 5 MG of filtered water production corresponds to a unit filter productivity of approximately 11,000 gallons per square foot per filter run. This level of filter productivity is well within ranges generally considered as acceptable for well-operated systems.

4.2 IMPACT OF COAGULANT ADDITION AT SECONDARY BASIN INFLUENT

- WTP staff indicated that while they've evaluated use of polyaluminum chloride, sodium aluminate, and ferric chloride as coagulants within the secondary basins to reduce settled turbidity, the current cationic polymer has demonstrated best overall results. This conclusion is consistent with B&V's experience at other facilities treating similar source waters and practicing precipitative lime softening; cationic polymer generally works best in most cases when lime softening is practiced.
- Plant staff suggested that cationic polymer residual carried over to the filters may be functioning as a filter aid and improving overall filter performance.
- Ferric chloride addition reportedly resulted in low settled turbidity, but problems were experienced with downstream filter performance due to interaction of ferric iron in settled water from the secondary basins.
- Polyphosphate is fed at the filter influent to form soluble complexes with hardness ions and minimize precipitation on filter media grains. This practice has been successful at preventing cementing of filter media.

4.3 SETTLED WATER TURBIDITY VERSUS FILTERED WATER TURBIDITY

- Filtered water turbidity is typically very low (0.04 to 0.05 NTU). Staff reported that turbidity excursions, while rare, have occurred occasionally. It is believed that these elevated turbidity excursions were caused by inadvertent opening of filter effluent valves caused by SCADA system malfunctions. Resulting hydraulic surges produced spikes in individual filter effluent turbidity, abnormal treatment conditions and/or elevated filter influent turbidity were not noted.
- Direct correlations between elevated filter influent turbidity levels and filter performance with regard to turbidity removal, filter productivities and run times, and rates of head loss accumulation have not been observed.

4.4 REGULATORY COMPLIANCE

- Based on consistently low filtered water turbidity under varying filter influent turbidity conditions, there are no specific concerns with regard to compliance with filtered water turbidity standards.
- However, staff agreed that treatment options being considered for future replacement of Plant 1 pretreatment/softening basins that could potentially lower settled water turbidity levels should be ranked higher than other options that would provide treatment performance similar to that of the existing Plant 1 facilities.

4.5 SEASONAL/PLANT PERFORMANCE VARIATIONS

- No significant seasonal differences in settling behavior or turbidity removal have been noted. (Note: blending significant amounts of relatively warm well water with the Huron River surface water supply likely mitigates reduction in treatment performance associated with cold weather operation).
- There appeared to be a perception that Plant 1 performed less effectively than Plant 2 with respect to settled water/filter influent turbidity. However, as discussed below, review of historical plant operating data suggests that settled water turbidity performance for Plant 1 may actually be superior to that of Plant 2.

5 Plant Operating Data Review

Daily plant operating records for 2008 through 2013 were provided for review. These records include detailed information on source water and finished water quality, water quality at several intermediate points within the treatment process, plant production rates, filter operations, and chemical feed rates. These data were tabulated and evaluated to identify potential impacts of settled water turbidity on various filter performance criteria; results of these evaluations are shown graphically on **Figures TM5-2, TM5-3, and TM5-4**.

If elevated settled water turbidity were having a significant negative impact on filter run times and productivities, the trend lines for the data plotted on Figure TM5-2 and Figure TM5-3 should exhibit an exponentially declining trend with increasing settled water turbidity. Similarly, if settled turbidity were having significant negative impact on filtered water turbidity, the trend line for the data plotted on Figure TM5-4 should exhibit an exponentially increasing trend with increasing settled turbidity. However, historical operating data show no clear negative impact of increasing settled water turbidity on filter run times, filter productivities, or filtered water turbidity. This suggests that while factors other than settled turbidity may influence filter performance, there is no clear indication that elevated settled water turbidity is negatively impacting filter performance and/or ability to consistently comply with filtered water turbidity regulatory standards.

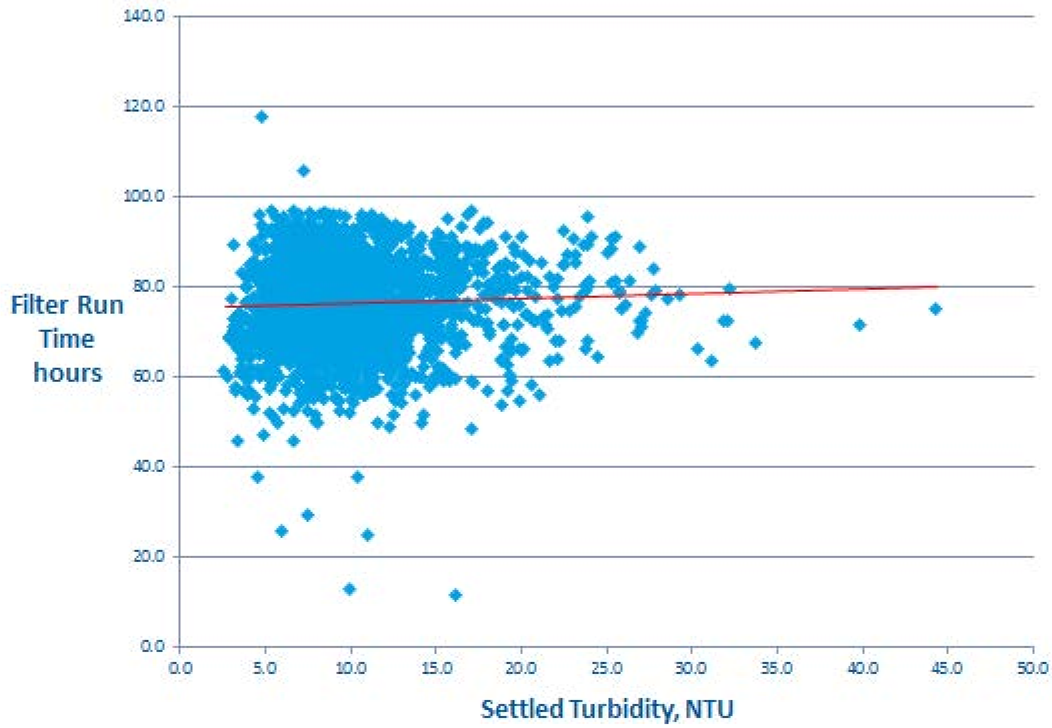

Figure TM5-2: Settled Turbidity versus Average Filter Run Time (2008 to 2013)

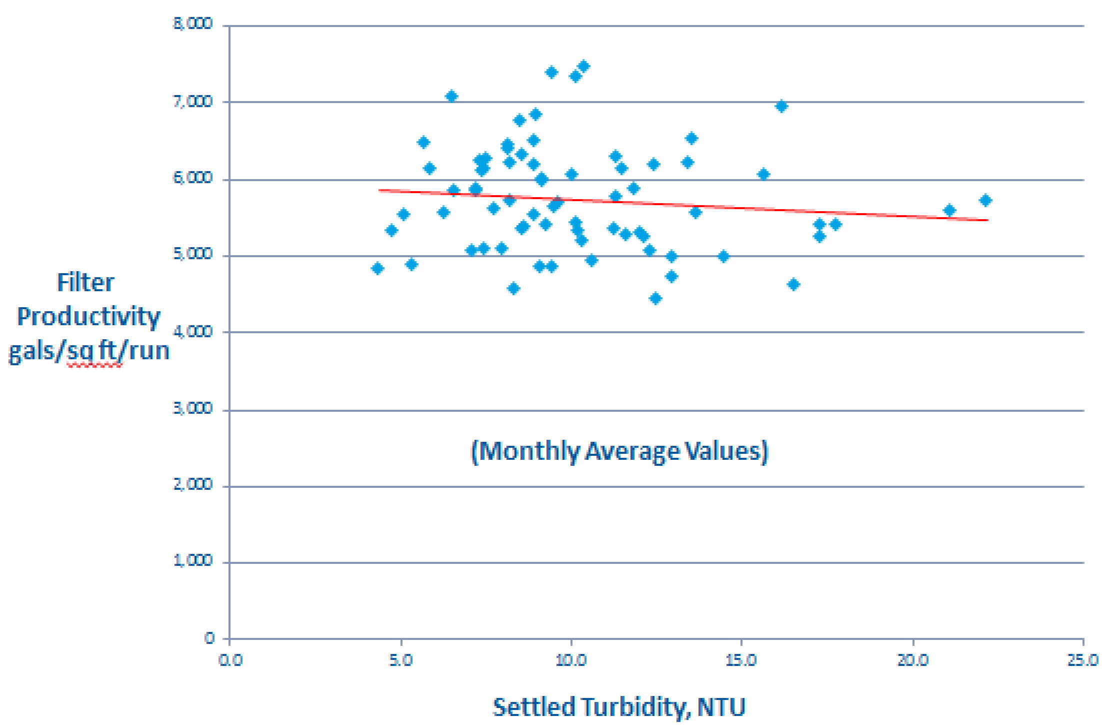

Figure TM5-3: Settled Turbidity versus Average Filter Productivity (2008 to 2013)

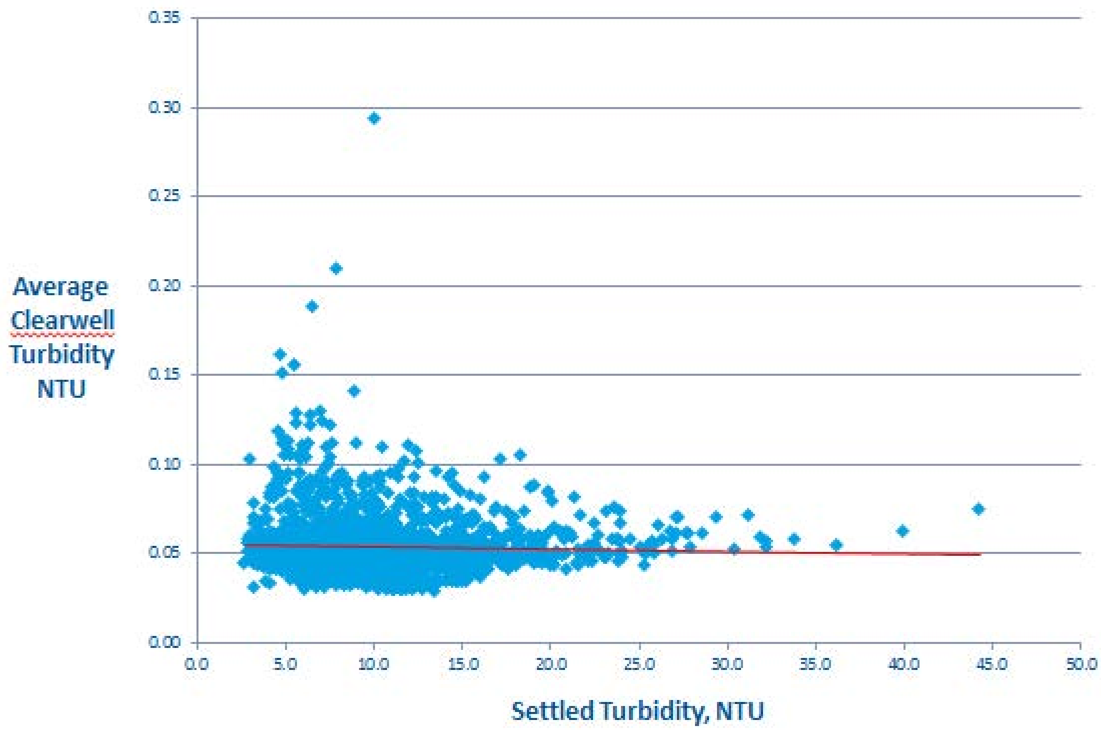

Figure TM5-4: Settled Turbidity versus Clearwell Turbidity (2008 to 2013)

Seasonal variations in settled water turbidity are summarized in **Table TM5-2**. Review of this data suggests that significant seasonal variations in settled water turbidity due to water temperature variations, changes in plant production rate, or other factors do not typically occur.

Table TM5-2: Settled Water Turbidity – Seasonal Variation

SEASON	MONTHS	SETTLED TURBIDITY, NTU	
		Average	Range
Spring	March to May	10.6	4.7 to 36.3
Summer	June to August	9.2	2.7 to 44.4
Fall	September to November	9.5	2.9 to 23.3
Winter	December to February	12.4	4.6 to 26.9

Our experience with other facilities practicing lime softening of low-turbidity surface supplies or ground water supplies suggests that the majority of particles typically present in settled water is generated during the softening process. To illustrate the relative impact of precipitated softening solids ($CaCO_3$ and/or $Mg(OH)_2$) carryover on settled turbidity at the Ann Arbor treatment plant, settled water samples collected at the discharge of secondary settling basin 5 were dosed with hydrochloric acid. Turbidity of these samples was measured prior to and approximately 15 to 20 minutes after acidification. Substantial reductions in turbidity were achieved following acidification, as shown in Table TM5-3. This suggests that the majority of particles that contribute to settled water turbidity are softening precipitates generated within and carried over from the sedimentation basins, and that the plant is achieving excellent removal of source water turbidity prior to filtration.

Table TM5-3: Acidification of Settled Water Samples

SAMPLE DATE	SAMPLE PH		SAMPLE TURBIDITY, NTU	
	Settled	Acidified	Settled	Acidified
08/27/2014	-	~2	5.01	0.10
09/03/2014	9.57	1.70	13.2	0.18
*Samples collected at Basin 5 discharge				

Plant performance with regard to settled water turbidity was evaluated for a 2-month period during 2012 when Plant 1 and Plant 2 were both operating in parallel in two-stage split treatment softening mode to determine if any significant difference in performance exists between the two trains. Data for this period are summarized in **Table TM5-4**. As is evident from review of data presented in **Table TM5-4**, significant differences in settled water turbidity existed for water produced by Plants 1 and 2 during the period evaluated, with settled water turbidity from Plant 1 averaging only 23 percent of that produced by Plant 2. However, hydraulic surface loading rates for the secondary basins over the period evaluated were approximately 53 percent higher for Plant 2 (Basin 5) than for Plant 1 (Basin 3), and average secondary flocculation basin detention times for Plant 2 were approximately 76 percent of those for Plant 1.

Operating data for Plant 1 and Plant 2 during this period when secondary basins in both plants were operating at comparable hydraulic surface loading rates were compared. As shown in **Table TM5-5**, with the secondary basins operating at equivalent hydraulic surface loading rates, settled turbidity for water produced by Plant 1 was still significantly lower than for water produced by Plant 2. Average secondary flocculation basin detention time during this period was approximately 28 percent less for Plant 2 than for Plant 1. While this difference in flocculation basin detention times may have had some impact on the relative sizes of the floc particles formed within the basins and their ability to readily settle, the significant difference in settled turbidity between Plant 1 and Plant 2 at comparable secondary basin hydraulic loading rates suggests that other factors, such as lower flocculation energy levels and/or mal-distribution of flow within Basin 5, may also be contributing to the apparent performance difference between Plant 1 and Plant 2.

Table TM5-4: Turbidity versus Location (06/30/2012 through 08/27/2012)

PLANT	BASIN NO.	SETTLED TURBIDITY, NTU*		FLOW MGD*	SLR GPM/SQ FT*	FLOC BASIN DT, MINUTES*
		Average	Range			
Plant 1	2 (primary)	2.5	0.9 to 6.4	7.60	0.71	49
	3 (secondary)	5.9	2.1 to 30		0.44	42
Plant 2	4 (primary)	19.9	9.1 to 87	14.61	0.78	39
	5 (secondary)	26.2	8.7 to 61		0.67	32
Filter Influent	-	14.4	7.5 to 32	22.21	-	-

*Average values over period evaluated

Table TM5-5: Settled Turbidity at Comparable Hydraulic Surface Loading Rates (06/30/2012 through 08/27/2012)

PARAMETER	BASIN 3 (PLANT 1 SECONDARY)	BASIN 5 (PLANT 2 SECONDARY)
Surface Loading Rate, gpm/sq ft		
Average	0.47	0.45
Range	0.38 to 0.56	0.38 to 0.58
Flocculation Detention Time, minutes		
Average	39	28
Range	32 to 54	24 to 35
Settled Turbidity, NTU		
Average	6.2	20.8
Range	2.1 to 30	8.7 to 40

6 Review of Previous Bench-Scale Testing

Results of previous bench-scale evaluations of various softening process options conducted between mid-November 2004 and mid-March 2005 were reviewed with regard to settled water turbidity. It is emphasized that while bench-scale/jar testing can provide relative indications of softening process performance, achieving consistent/reproducible results when conducting bench-scale assessments of precipitative softening is often problematic. Thus results should be regarded as preliminary, with additional bench-scale and (potentially) full-scale testing required for confirmation. Notable results from this testing are as follows:

- Single-stage softening using a combination of lime and sodium hydroxide achieved settled turbidity of 2 to 5 NTU.

- Addition of ferric chloride at 4 to 10 mg/L during simulated two-stage softening yielded settled turbidity of approximately 1 NTU.
- Addition of anionic and nonionic polymers did not significantly reduce settled water turbidity.

Results of bench-scale testing led to development of a two-stage softening process option consisting of lime addition in the primary basins to achieve pH conditions that are optimal for removal of calcium hardness, followed by addition of sodium hydroxide at the secondary basin inlet to increase pH sufficiently to removal of a portion of the magnesium hardness. A full-scale trial of this process option was conducted over a one-week period during mid-March 2005. Softened water turbidity was reportedly reduced from an initial value of approximately 9 NTU prior to implementing full-scale testing to approximately 3 NTU during the modified two-stage operational testing period. Plant operations staff report that while this process modification worked well overall, it was not adopted for full-scale implementation due to chemical feed system capacity limitations and higher chemical treatment costs as compared to current practices.

7 Experience of Other Utilities Practicing Precipitative Softening

A summary of design and operational characteristics for precipitative softening plants for which Black & Veatch maintains recent performance results is presented in **Table TM5-6**. Typical settled water turbidity results for these treatment facilities are included in this summary. The following observations can be derived from review of the information summarized in **Table TM5-6** and from discussions with operations staff for the utilities listed in **Table TM5-6**:

Table TM5-6: Settled Turbidity for Precipitative Softening Plants

UTILITY LOCATION (CAPACITY)	SOURCE WATER	TYPICAL SETTLED TURBIDITY NTU	BASIN TYPE	SOFTENING FACILITIES	OPERATING AS 2-STAGE OR SPLIT TREATMENT ?	MGH REMOVED?	SECONDARY COAGULANT ADDED?
Ann Arbor MI (50 mgd)	SW/GW	10 to 15	Conv	2-Stage	Yes	Yes	Cationic Polymer
Kansas City MO (240 mgd)	SW/GW	15 to 20	Conv	2-Stage	No	Yes	None
Nebraska City NE (6 mgd)	GWUDI	10 to 15	SCC	SS	No	No	-
St. Charles MO (22 mgd)	GWUDI	~15	SCC	SS	No	No	-
Owensboro KY (30 mgd)	GW	8 to 10	Conv/ SCC	2-Stage	No	Yes	None
Ft. Wayne IN (72 mgd)	SW	5 to 7	Conv	2-Stage	No	Yes	None
WaterOne KS (180 mgd)	SW/GW	3 to 5	SCC	2-Stage	No	Yes	Cationic Polymer

UTILITY LOCATION (CAPACITY)	SOURCE WATER	TYPICAL SETTLED TURBIDITY NTU	BASIN TYPE	SOFTENING FACILITIES	OPERATING AS 2-STAGE OR SPLIT TREATMENT ?	MGH REMOVED?	SECONDARY COAGULANT ADDED?
Topeka KS (62 mgd)	SW	2 to 4	SCC	2-Stage	No	Yes	None
Elgin IL (32 mgd)	SW	~2	SCC	2-Stage	No	Yes	Ferric Sulfate
Decatur IL (36 mgd)	SW	~2	SCC	2-Stage	No	Yes	Cationic Polymer
Troy OH (16 mgd)	GWUDI	1 to 2	SCC	2-Stage	No	Yes	None
Fargo ND (30 mgd)	SW	~1	SCC	2-Stage	No	Yes	None

Abbreviations:
Conv: Conventional circular or rectangular basins
GW: Ground water
GWUDI: Ground water under direct surface water influence
MgH: Magnesium hardness
SCC: Solids contact clarifier basin
SS: Single-stage softening
SW: Surface water

- With the exception of the Ann Arbor WTP, essentially all of the facilities listed in **Table TM5-6** that have 2-stage recarbonation and/or split-treatment capability are currently not operating in that manner. These facilities are essentially operated in a single-stage excess-lime softening mode, with secondary basins used only to provide additional detention time for stabilization reactions to occur and for additional settling prior to filtration. Because the lower finished water hardness production capability provided by operation in true two-stage recarbonation mode is not needed to achieve current finished water hardness goals adopted by the utilities included in **Table TM5-6**, two-stage treatment is not practiced.
- Several of these utilities have attempted to operate in split-treatment mode in the past, and indicate their experience has been that chemical cost savings and reduced residual solids production achieved through use of split-treatment softening do not offset the increased operator attention required to maintain consistent finished water quality.
- Operation in single-stage softening mode with removal of significant amounts of magnesium hardness assists in achieving low settled water turbidity, often reducing or eliminating the need for supplemental coagulant addition at the secondary basins.
- Systems with treatment facilities that only provide ability to practice single-stage softening, and which are not operating at pH levels that result in significant removal of magnesium hardness, generally report higher settled turbidity than do utilities operating in single-stage mode with

removal of magnesium hardness. These utilities do not benefit from magnesium hydroxide's ability to function as an effective coagulant and to facilitate maintenance of low settled water turbidity.

- Several of the utilities with two-stage treatment capability feed a coagulant (cationic polymer or ferric sulfate) at low dosages at the secondary basin inlet to assist in maintaining settled turbidity of in the range of 2 to 5 NTU.
- Systems using upflow solids contact clarifier equipment generally report lower settled water turbidity than systems with conventional flocculation/sedimentation basins.
- None of the utilities included in **Table TM5-6** report any significant filtration performance problems attributable to elevated settled water turbidity levels.

8 Conclusions

Discussions with plant operating staff, review of historical plant performance data, and the experience of other utilities practicing precipitative softening suggest that there is no compelling evidence to reduce current settled water turbidity, nor of potential benefits that may be derived from reductions in settled turbidity. The Ann Arbor WTP consistently complies with all applicable regulatory requirements governing filtered water turbidity. Furthermore, it achieves more stringent internal goals with respect to finished water turbidity. As discussed here, operations staff has not observed direct correlations between elevated settled water turbidity and filter performance. Filter productivity and filter run time appear to be well within ranges generally considered as acceptable for well-operated systems, and continued compliance with applicable filtered water regulatory standards is anticipated. Potential modifications that could significantly improve the settled water turbidity performance of Plant 2 (ex., primary and/or secondary basin modifications to reduce weir loading rates, or retrofitting of Basin 4 with conventional upflow solids contact equipment) would likely not be cost-effective and may yield only minor improvements in overall performance.

With regard to potential future treatment modifications and/or replacement of existing facilities, the current split-treatment excess-lime softening process employed by the City, may not be the optimal approach to consistently produce softened water with low settled turbidity (i.e., less than 5 NTU). Although two-stage split-treatment is considered optimal with respect to minimizing both chemical costs and residual solids production during treatment of the City's current surface water and ground water supplies, other process configurations currently being considered for replacement of aging Plant 1 basin facilities, such as single-stage or two-stage treatment with lime/caustic softening and/or use of conventional or high-rate solids contact clarification equipment, are capable of routinely producing water with settled turbidity lower than currently produced by existing Plant 1 and Plant 2 facilities.

Appendix TM5.A

City of Ann Arbor Source Water Quality

Table TM5.A-1: Source Water Quality

CONSTITUENT	HURON RIVER		STEERE FARM WELLS	
	Average	Range	Average	Range
Turbidity, NTU	2.0	0.2 to 34	-	-
pH, units	8.2	7.3 to 8.7	7.3	6.9 to 8.0
Hardness, mg/L as $CaCO_3$				
Total	273	162 to 396	548	246 to 788
Calcium	198	100 to 322	404	184 to 656
Magnesium	75	4 to 176	145	32 to 374
Noncarbonate	54	0 to 179	224	56 to 433
Alkalinity, mg/L as $CaCO_3$	216	112 to 278	324	226 to 524
Color, units	21	2 to 70	-	-
Temperature, degrees C	14.4	1.5 to 27.8	14.4	7.1 to 25.0
Odor, units	1.4	0 to 14	-	-

Appendix TM5.B

City of Ann Arbor Lime Solids Production

Table TM5.B-1: Lime Solids Production

PARAMETER	VALUE
2008 – 2013 Historical Ann Arbor WTP Solids Production	
TSS Production, lbs/day[1]	
Average	57,900
Range	34,800 to 118,800
90% Less Than Value	75,300
95% Less Than Value	86,100
TSS Production, lbs/MG treated	
Average	3,970
Range	2,630 to 5,630
90% Less Than Value	4,500
95% Less Than Value	4,620
Treatment of 100% Well Water (120 mg/L Finished Water Hardness)	
TSS Production, lbs/MG treated	
Split Treatment (Lime + NaOH)	5,525
Single-Stage Treatment (Lime + NaOH)	6,380
Single-Stage Treatment of Surface Water/Well Water Blend (120 mg/L Finished Water Hardness)	
TSS Production, lbs/MG treated	
100% Surface Water (Lime Only)	3,520
80% Surface Water / 20% Well Water (Lime + NaOH)	3,770

[1]**TSS Projection Assumptions:**
Lime purity (average) = 93%
50% of lime inerts removed as grit in slakers
Coagulant contribution to solids production is negligible
TSS/NTU ratio = 1.5

FINAL

WATER TREATMENT PLANT ALTERNATIVES ANALYSIS

Technical Memorandum 6: Regulatory Compliance and Future Treatment Alternatives

B&V PROJECT NO. 183262

PREPARED FOR

City of Ann Arbor

4 MAY 2015

BLACK & VEATCH
Building a world of difference.

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APPENDICES

1 Introduction

High quality drinking water produced and delivered by a safe and reliable system is central to the health and wellbeing of the residents of Ann Arbor. Compliance with state and federal regulations and standards requires extensive monitoring, reporting, and recordkeeping for a wide range of diverse biological, chemical, and radiological contaminants that may be present in natural waters used as drinking water supplies. There are currently 88 contaminants that have enforceable maximum contaminant levels, and ongoing regulatory actions will add to the list of regulated contaminants in drinking water. Continuing evaluation of contaminant occurrence in drinking water supplies in conjunction with research related to their potential adverse health effects will undoubtedly identify previously unrecognized targets for future regulation.

This technical memorandum provides an overview of the regulatory process as it relates to drinking water produced and distributed by public water systems and presents a brief summary of existing regulations and standards. Contaminants known to be on the regulatory horizon are also discussed. Multi-barrier treatment schemes in place at the Ann Arbor Water Treatment Plant (WTP) for various classifications of biological, chemical, and radiological contaminants are identified, and their likely effectiveness for continued compliance with existing regulations and standards is assessed. Several advanced treatment processes that could be implemented in response to potential future changes in source water quality or drinking water regulations are described, and conceptual level opinions of probable capital, annual operations and maintenance, and life-cycle cost are provided. The approximate footprint for each advanced treatment process considered here is also given; however, potential integration of these processes within the layout of existing treatment facilities at the Ann Arbor WTP is beyond the scope of this evaluation.

2 Regulatory Review

This review is intended to provide an overview of the structure and key provisions drinking water regulations; the actual regulations and their associated guidance documents should be carefully reviewed to ensure that both general and system-specific requirements are thoroughly understood.

2.1 THE REGULATORY PROCESS

Drinking water quality in the United States is governed by legislation enacted by the federal and state governments. *Statutes*, more commonly known as *laws*, direct the appropriate government agency to develop and publish *regulations* or *rules* to implement the requirements of the law. *Standards* specify the amount or concentration of a particular constituent that is legally allowed in drinking water. At the federal level, the United States Environmental Protection Agency (EPA) is primarily responsible for developing and enforcing drinking water regulations, whereas state health departments typically regulate drinking water quality at the state level. Any drinking water regulations promulgated by a state are required to include standards that are at least as stringent as those imposed by comparable federal regulations; however, states may implement regulations in addition to those mandated by federal statutes, or standards that are more restrictive than federal ones. Federal regulations specify requirements and the process by which states may assume major responsibility, or *primacy,* for implementing and enforcing drinking water regulations. Although drinking water regulations implemented and enforced by states generally adhere to requirements specified in federal regulations, state regulations do contain unique provisions in some instances.

The Safe Drinking Water Act (SDWA) of 1974 and its amendments (1986 and 1996) provide a regulatory framework that specifies how National Primary Drinking Water Regulations (NPDWR) are developed, promulgated, and implemented. Elements of this regulatory framework require that existing NPDWRs are reviewed periodically for continued protection of public health, evaluate potential risks associated with unregulated contaminants that are known to occur in drinking water supplies, and monitor the occurrence of contaminants in drinking water supplies. Revisions to existing regulations and new regulations are promulgated under procedures established by the 1996 SDWA Amendments. The EPA administrator is required to establish standards that are protective of public health; however, he/she is also required to consider technological feasibility, economics, and competing risks when setting drinking water standards.

The 1996 SDWA Amendments established the regulatory timeline associated with new or revised drinking water standards. If EPA makes a determination that regulation of a contaminant is warranted, the Agency has 24 months to publish a proposed Maximum Contaminant Level Goal (MCLG) and a proposed NPDWR. After proposal, the Agency has 18 months to publish a final MCLG and promulgate a final NPDWR. The requirements of an NPDWR take effect three years after promulgation, unless the primacy agency determines that an earlier date is practicable. The compliance date of an NPDWR may be extended by up to two additional years if capital improvements are required.

Other provisions of these amendments include source water assessment and protection and operator certification programs, establishment of a State Drinking Water Revolving Fund to support infrastructure improvements, and a requirement for utilities to distribute annual consumer confidence reports to their customers.

2.1.1 Six Year Review

The Safe Drinking Water Act requires EPA to review each existing NPDWR at least once every six years, and to develop and promulgate revisions if appropriate. The purpose of the review, referred to as the Six-Year Review, is to identify those contaminants regulated by NPDWRs for which current health effects assessments, changes in technology, and/or other factors provide a health or technical basis to support a regulatory revision that will maintain or strengthen public health protection. Announcement that EPA intends to revise an NPDWR is not a regulatory determination, but rather, initiates a review process that ultimately determines whether a revision is appropriate. The Six-Year Review does not obligate EPA to revise an NPDWR should it be determined during the review process that revision is not warranted or appropriate.

In July, 2003 EPA announced the review results for the Agency's first Six-Year Review (Six-Year Review 1). EPA reviewed 69 NPDWRs that were established prior to 1997, including 68 NPDWRs for chemical contaminants and the Total Coliform Rule (TCR). Based on the Agency's preliminary review, as well as public comments received and other new information, EPA determined that revision of the Total Coliform Rule was appropriate. The Agency also determined that revision of the 68 chemical NPDWRs reviewed was not appropriate at that time.

In March 2010, EPA announced the review results for the Agency's second Six-Year Review (Six-Year Review 2). After detailed review of 71 NPDWRs, the Agency determined that 67 NPDWRs remain appropriate and four NPDWRs were candidates for regulatory revision. These four NPDWRs include acrylamide, epichlorohydrin, tetrachloroethylene, and trichloroethylene. In addition to the 71 NPDWRs reviewed in detail for the Six-Year Review 2, 14 other NPDWRs were included in the review but were not given detailed consideration because of other recent or ongoing regulatory actions (e.g., disinfection byproducts, lead and copper and microbial pathogens).

On January 7, 2011, EPA announced its intent to review the national primary and secondary drinking water regulations for fluoride. This review follows up on a commitment made in the second Six-Year Review to reevaluate fluoride after the Office of Water completed its updates of health and exposure assessments, and that when the Agency finalized these studies it would review the existing drinking water regulation to determine whether revisions are appropriate.

2.1.2 Drinking Water Candidate Contaminant List

The SDWA requires EPA to publish a Contaminant Candidate List (CCL) every five years identifying contaminants that are currently not subject to any proposed or promulgated national primary drinking water regulations, but that are known or anticipated to occur in public water systems. EPA is required to determine whether to regulate at least five contaminants on the CCL every five years, a process termed *regulatory determination*. The regulatory determination process considers available health effects and drinking water occurrence data, as well as availability of suitable analytical protocols. Contaminants for which sufficient data or methods are not available to support a regulatory determination may be carried forward from the current CCL to the next. CCLs are used to set regulatory, research, and occurrence-investigation priorities within EPA.

The SDWA specifies that contaminants on the CCL shall be regulated if the EPA Administrator determines that:

- The contaminant may have an adverse effect on the health of persons;
- The contaminant is known to occur, or there is a substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern; and
- In the sole judgment of the Administrator, regulation of such contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems.

If EPA makes a determination that regulation of a contaminant in the CCL is warranted, the Agency must develop and promulgate a NPDWR based on the timeline established by the 1996 SDWA Amendments.

2.1.2.1 Contaminant Candidate List 1

The first Contaminant Candidate List (CCL 1) was published in draft form in March 1998, and consisted of 50 chemical contaminants and 10 microbial contaminants. EPA subsequently narrowed this list to include 19 chemicals and one microbial contaminant the Agency considered as "high priority" with respect to determination of the need to regulate, and ultimately reduced the list to a total of nine. In June 2003, the Agency announced its decision that no regulatory action was needed for these nine contaminants, as they were determined not to present a significant public health risk. Contaminants from the CCL 1 for which regulatory determinations not to regulate were issued include:

- Acanthamoeba (guidance for contact lens wearers)
- Naphthalene
- Hexachlorobutadiene
- Aldrin
- Dieldrin
- Metribuzin
- Sodium (guidance)
- Manganese
- Sulfate

2.1.2.2 Candidate Contaminant List 2

The second Contaminant Candidate List (CCL 2) was finalized in February 2005. CCL 2 contained the 51 contaminants (42 chemical and 9 microbial) from CCL 1 for which regulatory determinations were not issued. Regulatory determinations indicating no regulatory action was appropriate for 11 of the contaminants listed in CCL 2 were published in the Federal Register in July 2008. Contaminants from the CCL 2 for which regulatory determinations not to regulate were issued include:

- Boron
- Dacthal Mono- and Di-Acid Degradates
- 1,1-Dichloro-2,2-bis(p-chlorophenyl)ethylene
- 1,3-Dichloropropene
- 2,4-Dinitrotoluene and 2,6-Dinitrotoluene
- s-Ethyl dipropylthiocarbamate
- Fonofos

2.1.2.3 Candidate Contaminant List 3

EPA implemented a different process to develop CCL 3 than was used for CCL 1 and CCL 2. This new process considered evaluations from previous CCLs and included substantial expert input and recommendations from various groups, including the National Academy of Science's National Research Council, the National Drinking Water Advisory Council, and the Science Advisory Board. Contaminants of emerging concern contained in CCL 3 (September, 2009) include 116 microbial pathogens, inorganic compounds, synthetic organic chemicals, disinfection byproducts, hormones, and pharmaceuticals.

Preliminary regulatory determinations for contaminants on CCL 3 were published in the Federal Register on October 20, 2014. With this action EPA made regulatory determinations for five unregulated compounds. A positive determination was made to regulate strontium and negative determinations were made for dimethoate, 1,3-dinitrobenzene, terbufos, and turbufos sulfone. Regulatory determinations for other contaminants listed on CCL 3 were not made because they did not meet one or more of several criteria including availability of nationally representative finished water occurrence data, a completed health assessment, or a widely available analytical method for analysis.

Current regulatory schedules call for final determinations regarding the need to regulate at least five of the contaminants listed in the CCL 3 by to late 2015, which may include one or more of the microbial pathogens listed.

2.1.3 Unregulated Contaminant Monitoring Rules

The Unregulated Contaminants Monitoring Rule (UCMR) program was developed in coordination with the Contaminant Candidate List regulations. The data collected by the UCMR process is used to support analysis and review of contaminant occurrence, to guide the CCL process, and to support determination of whether to regulate a contaminant to protect public health. The Safe Drinking Water Act Amendments of 1996 required EPA to establish criteria for a program to monitor unregulated contaminants and to identify not more than 30 contaminants to be monitored every 5 years. EPA published a list of unregulated contaminants for the first UCMR cycle (UCMR1) in September 1999. UCMR1 established a tiered monitoring approach, and required all large public water systems and some systems serving fewer than 10,000 consumers to monitor for unregulated contaminants from 2001 to 2005.

Monitoring under the second cycle of unregulated contaminants monitoring (UCMR2), as outlined in the January 2007 Final Rule, was conducted between 2007 and 2010. UCMR2 included 25 contaminants and five associated analytical methods. All systems serving more than 10,000 consumers (based on retail population directly served plus the population served by any consecutive systems), and 800 selected systems serving 10,000 or fewer consumers were required to conduct first tier assessment monitoring for 10 contaminants (List 1 contaminants). A second tier screening survey of 15 additional contaminants (List 2 contaminants) was conducted by 400 systems serving more than 100,000 consumers, 320 systems serving between 10,001 and 100,000 consumers, and 480 systems serving 10,000 or fewer consumers. Consecutive systems that purchase all of their water from another system were not subject to the UCMR2 monitoring requirements.

Samples were collected during one continuous 12-month period beginning no earlier than January 2008 and concluding no later than December 2010. For systems with surface water sources, monitoring was required at 3-month intervals for 4 consecutive quarters, while groundwater systems monitored twice at 6-month monitoring intervals. Monitoring for most contaminants was conducted at the entry point to the distribution system; however, monitoring for the six List 2 nitrosamine compounds was conducted at both the system entry point and at a point that reflects maximum system residence time. Monitoring requirements for systems with blended surface and groundwater sources, or with multiple groundwater wells, were more complex.

EPA published the final UCMR3 in May 2012. The structure of UCMR3 is similar to previous UCMRs. UCMR3 requires all systems serving greater than 10,000 people to monitor for 21 List 1 contaminants and systems serving greater than 100,000 people to monitor for the seven List 2 contaminants. One notable difference between UCMR3 and previous rules is that consecutive systems are required to conduct monitoring. Participating systems will conduct UCMR3 monitoring during one consecutive 12-month period between 2013 and 2015.

2.1.4 Drinking Water Strategy

In March 2010, EPA announced its intention to implement a new approach to expand public health protection for drinking water through modification of the traditional regulatory framework which addresses contaminants one at a time. The Agency's new Drinking Water Strategy (DWS) is intended to find ways to strengthen public health protection from contaminants in drinking water by streamlining decision-making, expanding protection under existing laws, and promoting cost-effective new technologies to meet the needs of rural, urban, and other water-stressed communities. This new strategy focuses on four principles that EPA believes provide for greater public protection:

- Address contaminants as groups rather than one at a time so that enhancement of drinking water protection can be achieved cost-effectively.
- Foster development of new drinking water technologies to address public health risks posed by a broad array of contaminants.
- Use the authority of multiple statutes to help protect drinking water.
- Partner with states to share more complete data from monitoring of public water systems.

In February 2011, the Agency announced that carcinogenic VOCs would be the first group of compounds to be regulated as part of its new strategy to regulate contaminants as groups rather than as individual constituents and that in the near-term nitrosamine disinfection byproducts would also be evaluated for regulation as a group (see **Section 2.4.2.1**). Details on how contaminant groups will be regulated under the new Drinking Water Strategy have not been formally developed. However, there is precedence for regulation of similar chemical compounds as a group, including rules for a group of five haloacetic acids and total trihalomethane disinfection byproducts as well as gross alpha and gross beta radionuclides.

2.2 DRINKING WATER STANDARDS

Contaminants that pose a risk to public health if present in drinking water include microbial pathogens, toxic organic compounds, toxic inorganic elements and compounds, and radionuclides. These contaminants are regulated by NPDWR and have enforceable standards based on various health-related endpoints. Other contaminants may cause non-health related effects such as skin or dental discoloration or objectionable taste, odor, or color in drinking water. These contaminants are regulated by National Secondary Drinking Water Regulations (NSDWR) and have non-enforceable guidelines based on cosmetic or aesthetic effects. Contaminant standards typically have defined numerical values known as Maximum Contaminant Levels (MCLs); however, several are regulated with non-numerical Treatment Technique (TT) requirements.

There are currently 88 contaminants that have enforceable MCL or TT standards including 8 microbial pathogens, 53 organic compounds, 16 inorganic elements and compounds, 3 disinfectants, 4 disinfection byproducts, and 4 radionuclides. There are also 15 contaminants and chemical attributes that have non-enforceable standards. Regulated contaminants and their associated MCL and TT standards are listed in **Appendix A**.

2.3 CURRENT DRINKING WATER REGULATIONS

The following sections provide a brief overview of current drinking water regulations adopted by the Michigan Department of Environment Quality (MDEQ), organized by contaminant class.

2.3.1 Microbials and Disinfection Byproduct Rules

Over the past two decades EPA has promulgated a series of increasingly complex drinking water regulations intended to protect the public from microbial pathogens such as viruses, Giardia, and Cryptosporidium that may be present in surface water supplies, and from DBPs formed by chemical disinfection. The family of regulations that focuses on microbial pathogen control includes:

- Surface Water Treatment Rule (SWTR, 1989),
- Total Coliform Rule (TCR, 1989),
- Interim Enhance Surface Water Treatment Rule (IESWTR, 1998),
- Filter Backwash Recycling Rule (FBRR, 2001),
- Long-Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR, 2002),
- Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR, 2006), and
- Ground Water Rule (GWR, 2006).

Regulations intended to minimize disinfection byproduct (DBP) formation in drinking water include:

- Total Trihalomethane Rule (TTHMR, 1979),
- Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR, 1998), and
- Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR, 2006).

Collectively, these regulations have come to be known as the Microbials and Disinfection Byproducts (MDBP) Rules, and are intended to balance the risk-risk tradeoff between health concerns related to exposure to pathogenic microorganisms and disinfection byproducts.

The monitoring and compliance requirements of the MDBP Rules are complex and to a large extent system-specific. Based on recognition that simultaneous compliance with the provisions of the MDBP Rules requires a well-planned and highly-coordinated approach, EPA has developed a series of guidance manuals to help drinking water providers manage the often conflicting objectives of these rules.

2.3.2 Chemical Contaminants Regulations

Chemical contaminants have been regulated in drinking water for nearly four decades, including a variety of organic compounds with industrial, commercial, and agricultural uses, as well as inorganic elements and compounds of natural and human origin. Although these compounds typically occur at low concentrations in source waters, and at trace levels in drinking water supplies, many of these compounds are highly toxic or carcinogenic and therefore pose a health risk if present in drinking water. Rules that regulate chemical contaminants in drinking water include:

- National Interim Primary Drinking Water Regulations (NIPDWR – 1975, 1976),
- Phase I VOCs (Phase I, 1987),
- Phase II SOCs (Phase II, 1991),
- Lead and Copper Rule (LCR, 1991),
- Phase V SOCs (Phase V, 1992),
- Arsenic Rule (2001).

2.3.3 Radionuclide Contaminant Regulations

Radionuclides have also been regulated in drinking water for nearly four decades, including elements and compounds that emit alpha-, beta-, gamma-, and neutron-radiation due to spontaneous radioactive decay. Radionuclides may occur in drinking water supplies due to dissolution of native minerals or through commercial and industrial discharges or as the result of other human activities. Although these elements and compounds typically occur at low concentrations in source waters, and at trace levels in drinking water supplies, low-level exposure to radionuclides in drinking water poses a health risk due to the combined effects of radiation damage and chemical toxicity on susceptible tissues and organs. Rules that regulate radionuclides in drinking water include:

- National Interim Primary Drinking Water Regulations (NIPDWR – 1975, 1976), and
- Radionuclides Rule (2000).

2.4 POTENTIAL FUTURE DRINKING WATER REGULATIONS

The Safe Drinking Water Act and its amendments require that the EPA reevaluate existing drinking water regulations on a periodic basis, and develop and promulgate new standards and regulations as necessary to protect public health.

2.4.1 Proposed Rules

Several regulations have been proposed by EPA and are in various stages of development, review, and approval.

2.4.1.1 Radon

EPA proposed new regulations for radon during October 1999. Two alternative compliance approaches were included in the proposed radon rule:

- States can elect to develop programs to address the health risks from radon in indoor air through adoption and implementation of a multimedia mitigation program. Under this approach, individual water systems would be required to reduce radon levels in the treated water to 4,000 pCi/L or lower. EPA will encourage states to adopt this approach, as it considered the most cost-effective way to achieve the greatest reduction in radon exposure risk.

- If the State elects not to develop a multimedia radon mitigation program, individual water systems will be required to reduce radon levels in their system's treated water to 300 pCi/L, or to develop local multimedia mitigation programs and to reduce radon levels in drinking water to 4,000 pCi/L.

Systems with radon levels at or below 300 pCi/L would not be required to treat their water to remove radon. States will likely be granted fairly wide latitude in developing and implementing the multimedia programs, and it is expected that the programs will differ significantly from state to state. The need for radon treatment will be based on results of quarterly monitoring. If the state regulatory agency commits to the multimedia mitigation and alternative MCL compliance approach within 90 days of final promulgation of the rule, it will be granted an additional 18 months to achieve compliance. Considerable controversy currently surrounds the regulation of radon in drinking water supplies, and modification of this regulation as currently proposed could significantly alter the requirements contained in the final rule. There is no recent information on the status of this proposed regulation, and no revised timeline for its implementation has been issued by EPA.

2.4.1.2 Revised Total Coliform Rule

Proposed revisions to the Total Coliform Rule (TCR) were published by EPA in July 2010. The intent of the Revised Total Coliform Rule (RTCR) is to increase public health protection through the reduction of potential pathways of entry for fecal contamination into the distribution system. As E. coli is considered to be a more specific indicator of fecal contamination and the potential presence of harmful pathogens than total coliform bacteria, the proposed RTCR reflects a shift in compliance requirements that focuses more on the presence/absence of E. coli in the distribution system. As with the current TCR, provisions of the RTCR will apply to all public water systems. Provisions of the Final RTCR were published in the Federal Register on February 13, 2013.

2.4.2 Contaminants on the Regulatory Horizon

In June 2011, EPA held a stakeholder meeting to discuss the health effects and occurrence data for the subset of contaminants from the Third Contaminant Candidate List (CCL 3) that were being investigated further for the third regulatory determination. Based on the discussions at that meeting and subsequent discussions, AWWA expects that positive regulatory determinations for several contaminants on CCL 3 will be issued. Preliminary regulatory determinations for contaminants on CCL 3 were published on October 20, 2014, with final determinations scheduled to be completed by 2015. In addition, several new or revised regulations are expected based on positive regulatory determinations for contaminants listed on CCL 2 or reviewed under Six-Year Review 3.

2.4.2.1 Nitrosamines

Five organic nitrogen-containing compounds (4 nitrosamines and nitrosopyrrolidine) that have been detected in treated drinking water are listed on CCL 3. Formation of these compounds is associated with disinfection with free chlorine in the presence of naturally occurring ammonia in the source water or ammonia added to treated water to form a combined-chlorine residual. Formation of these nitroso-compounds requires a nitrogenous organic precursor. Dimethylamine has been shown to be particularly reactive in formation of N-nitrosodimethylamine (NDMA) in drinking water, with formation from several other less reactive precursors possible.

Regulation of nitrosamines in drinking water remains controversial for several reasons. Recent research on human exposure to nitrosamines indicates that drinking water contributes a very small percentage (less than 0.01 percent) of total exposure compared with natural formation in the body and consumption in certain foods. Therefore, it is unclear whether or not a regulation for nitrosamines would meet the SDWA criteria for "a meaningful opportunity for health risk reduction for persons served by public water systems". Likely strategies for reducing nitrosamine formation in drinking water, such as limiting or discontinuing use of polyDADMAC polymers or chloramine disinfectant residual, would also present simultaneous compliance issues with other currently regulated contaminants.

MCLs for individual nitrosamines or as a chemically similar group of several compounds would be established during the rulemaking process. The body of research on animal and human responses to nitrosamine exposure indicates the MCLs for nitrosamines in drinking water would be at the nanogram per liter (ng/L) level. NDMA and other nitrosamines have been classified as either probable or known human carcinogens by several public health organizations, with a relatively wide range of non-enforceable guidelines or enforceable standards. The World Health Organization has set a guideline for NDMA in drinking water of 100 ng/L, whereas Health Canada has established a Maximum Allowable Concentration for NDMA in drinking water of 40 ng/L. Massachusetts has set a guideline level of 10 ng/L for NDMA in drinking water, and Arizona requires monitoring for NDMA as part of its state administered National Pollution Discharge Elimination System permit program and has set a water quality criterion of 30 ng/L. The State of California has set a notification level of 10 ng/L for NDMA in drinking water and a public health goal of 3 ng/L. EPA Regions 3 and 6 have calculated 0.42 ng/L as the nonenforceable screening level for NDMA in drinking water based on a 1 in 10^{-6} lifetime excess cancer risk.

The American Water Works Association Governmental Affairs Office recommends that a utility consider sampling for nitrosamines if it did not participate in UCMR2, to develop an understanding of nitrosamine occurrence and formation patterns within its system (AWWA, 2012). Potential sampling points the City should consider include the combined raw water influent to The Ann Arbor WTP, finished water at the point of entry to the distribution system, and several locations in the distribution system. One location should be representative of the highest likely residence time in the distribution system. All samples should be analyzed using EPA Method 521.

A decision not to regulate nitrosamines as part of the preliminary regulatory determinations for contaminants on CCL3 was published in the Federal Register on October 20, 2014. However, EPA plans to review existing MDBP regulations as part of Six-Year Review 3. Because nitrosamines are DBPs that may be introduced or formed in public water systems related to disinfection practices, EPA believes it is important to evaluate these DBPs in the context of the review of existing MDBP regulations. EPA expects to complete this review by the end of 2015.

2.4.2.2 Strontium

Strontium occurs in drinking water supplies due to dissolution of naturally-occurring mineral deposits, and due to its commercial and industrial uses in pyrotechnics, steel production, as a catalyst, and as a lead scavenger. A decision to regulate strontium as part of the preliminary regulatory determinations for contaminants on CCL3 was published in the Federal Register on October 20, 2014.

2.4.2.3 Chlorate

Chlorate compounds are used in agriculture as defoliants or desiccants and may occur in drinking water related to use of disinfectants such as chlorine dioxide. A decision not to regulate chlorate as part of the preliminary regulatory determinations for contaminants on CCL3 was published in the Federal Register on October 20, 2014. However, EPA plans to review existing MDBP regulations as part of Six-Year Review 3. Because chlorate is a DBP that may be introduced or formed in public water systems related to disinfection practices, EPA believes it is important to evaluate this DBP in the context of the review of existing MDBP regulations. EPA expects to complete this review by the end of 2015

2.4.2.4 Perchlorate

On February 11th 2011, EPA published its decision to move forward with the development of a regulation for perchlorate, a contaminant evaluated under CCL 2. Under the current regulatory schedule, a proposed MCL for perchlorate would have been expected sometime in 2014, and a final MCL no later than 2016, with compliance required by 2019. However, EPA is still finalizing the modeling research recommended by a Science Advisory Board in conjunction with the Food and Drug Administration. This research is anticipated to be complete in 2015, followed by a proposed regulation in 2016 or later.

2.4.2.5 Fluoride

In January 2011, the United States Department of Health and Human Services (HHS) announced a proposed recommendation that fluoride levels in drinking water be set at an optimal level of 0.7 mg/L. Concurrent with the HHS announcement, EPA announced plans to initiate a review of the current MCL and maximum contaminant level goal (MCLG) for fluoride. HHS's proposed recommendation would replace the 1962 US Public Health Standard of 0.7 to 1.2 mg/L, under which the optimal fluoride level is determined based upon the ambient air temperature of the geographic region. HHS believes that this revised optimal concentration will provide the best balance of public protection from dental caries (tooth decay) and the desire to limit the risk of dental fluorosis (spotting/pitting damage to tooth enamel), particularly in children.

HHS implementation of the proposed revision to its recommended optimal fluoridation level of drinking water is still pending as of November 2014. While the HHS guidance is advisory rather than regulatory, EPA could elect to modify current regulations governing maximum fluoride levels in response to HSS recommendations and to the agency's review of recent research results.

On January 7, 2011, EPA announced its intent to review the national primary and secondary drinking water regulations for fluoride. This review follows up on a commitment made in the second Six-Year Review to reevaluate fluoride after the Office of Water completed its updates of health and exposure assessments, and that when the Agency finalized these studies it would review the existing drinking water regulation to determine whether revisions are appropriate.

2.4.2.6 Hexavalent Chromium

The existing regulation for total chromium in drinking water was reevaluated by EPA as part of Six-Year Review 2, the results of which were announced in March 2010. The Agency noted that it had initiated a reassessment of the health risks associated with chromium exposure and that it did not believe it was appropriate to revise the national primary drinking water regulation while that effort was in process. EPA began a rigorous and comprehensive review of hexavalent chromium health effects following the release of the toxicity studies by the National Toxicology Program in 2008. In September, 2010, EPA released a draft scientific assessment for public comment and external peer review.

Hexavalent chromium (Cr^{6+}) has come under increased scrutiny recently with the release of an Environmental Working Group study in December 2010 that found levels of hexavalent chromium exceeding the non-enforceable public health goal set by the California Department of Health in the tap water of 25 of 35 US cities tested. Based on additional recent research, the schedule for the hexavalent chromium human health assessment was revised by EPA in Feb 2012, with the final version now expected to be approved and posted in the first quarter of 2015. When this human health assessment is finalized, EPA will carefully review the conclusions and consider all relevant information to determine if a new standard needs to be set. Hexavalent chromium levels in public drinking water supplies are currently being monitored as part of UCMR 3. EPA may incorporate a standard for hexavalent chromium as a revision to the existing regulation for total chromium as part of Six-Year Review 3, scheduled for completion in 2016, or as a separate regulatory action.

In a separate regulatory action, the California Department of Public Health (CDPH) adopted a drinking water MCL for hexavalent chromium of 10 μg/L, which became effective July 1, 2014. The regulations adopted by CDPH specify initial monitoring requirements, approved analytical methods and detection limits, and best available technologies for treatment (coagulation/filtration, ion exchange, and reverse osmosis). Compliance with the MCL is based on a running annual average of hexavalent chromium measurements averaged quarterly.

2.4.2.7 Volatile Organic Compounds

In January 2011 the EPA Administrator announced that Carcinogenic Organic Compounds (cVOCs) will be the first contaminants regulated as a group rather than as individual compounds under the Agency's new Drinking Water Strategy. Eight currently regulated cVOCs and eight currently unregulated cVOCs have been proposed for regulation as a group. The cVOCs group will include trichloroethylene and tetrachloroethylene, for which a rulemaking effort to revise existing standards is underway. The ultimate form of this regulation remains to be determined. A proposed cVOC regulation is anticipated during 2015, but could slip to 2016 due to resource limitations at EPA.

2.4.2.8 Methyl Tertiary Butyl Ether

Methyl tertiary butyl ether (MTBE) is an oxygenate additive used in gasoline to increase the octane number. It has been used widely used in gasoline in the United States as a replacement for lead; however, its use has declined in recent years due incorporation of ethanol in fuels. MTBE is very soluble and has been detected in numerous water supplies but is most commonly found in ground water supplies.

In 1997, EPA issue a drinking water advisory for MTBE of 20 to 40 µg/L based on taste and odor. MTBE was included in CCL 1 and CCL 2 for evaluation, with negative regulatory determinations because its regulation would not present a meaningful opportunity for health risk reduction for persons served by public water systems. Because of several prominent cases of drinking water contamination with MTBE in the past, public interest related to MTBE regulation remains active. Therefore, MTBE was carried over to CCL 3 for further evaluation; however, no schedule for revision of the health risk assessment for MTBE has been set.

2.4.2.9 Long-Term Lead and Copper Rule

Revision of the Lead and Copper Rule is currently in progress to address several long-term issues including partial lead service line replacement, sample site selection, tap sampling, measures to ensure optimal corrosion control, and public education for copper. EPA has convened a Work Group under guidance of the National Drinking Water Advisory Council (NDWAC) to review and make recommendations on some of the more complex issues related to the Lead and Copper Rule Long Term Revisions (LCR-LTR) under consideration. Work Group recommendations anticipated in early 2015 will be reviewed by the full NDWAC and forwarded to EPA, which will decide how to incorporate them into a proposed rule. A proposed LCR-LTR rule may be expected sometime in 2016 or 2017.

3 Treatment Assessment

A wide variety of chemical, physical, and biological processes are available to treat natural waters and produce safe and palatable drinking water. Contaminants that pose potential health concerns include microbial pathogens, organic and inorganic chemicals, and radionuclides. Other contaminants pose only aesthetic concerns such as objectionable tastes and odors, color, cloudiness, scaling on household fixtures and in boilers, and staining of fixtures and laundry. For the purpose of evaluating treatment process performance and regulatory compliance, contaminants may be grouped into several discrete categories based on their physical, chemical and biological properties including turbidity, microbial pathogens, disinfection byproduct precursors and disinfection byproducts (DBPs), inorganic macro-contaminants, trace inorganic contaminants, trace organic contaminants, and objectionable tastes and odors.

Drinking water treatment must be capable of reliably lowering contaminant concentrations to acceptable levels before water enters the distribution system. However, no single treatment process provides adequate public health protection against all categories of drinking water contaminants that may be present in drinking water sources at different times and under different conditions. Barriers to different contaminant categories are provided by incorporating several processes into an integrated treatment train. Furthermore, it is desirable to provide multiple barriers for contaminant categories of greatest public health concern, particularly microbial pathogens. Thus, drinking water treatment in and of itself is considered a multi-barrier activity.

The following sections provide an assessment of the technological capabilities of processes currently in place at the Ann Arbor WTP for continued compliance with currently implemented drinking water regulations. This technology assessment is based on information developed in other Technical Memoranda completed as part of this project, discussions with City staff related to historical regulatory compliance at the Ann Arbor WTP, and typical performance of treatment processes in place at the Ann Arbor WTP. Additional treatment that may be needed in the future based on changes in source water quality or regulatory requirements is also discussed. Treatment technology options that could be implemented to meet these potential future treatment needs are considered, and planning level opinions of probable cost are provided for options that most effectively address these areas of need.

3.1 CURRENT TREATMENT PROCESSES

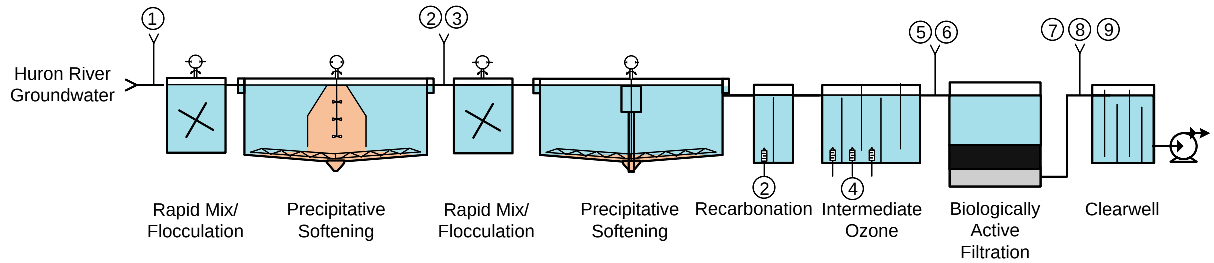
The treatment process train at the Ann Arbor WTP includes two-stage precipitative softening, intermediate ozonation, biologically active filtration (BAF), and residual disinfection with monochloramine. This process train and its associated chemical addition points are shown schematically on **Figure TM6-1**. Pre-treatment is divided among two independent treatment trains termed Plant 1 and Plant 2. Both Plants have two stages of treatment, each of which includes rapid mixing, horizontal-shaft flocculation, and clarification. Primary clarification is accomplished in Plant 1 in two rectangular basins (Basin 1 and Basin 2), and in one circular basin (Basin 4) in Plant 2. Secondary clarification is accomplished in circular basins in both trains, Basin 3 in Plant 1 and Basin 5 in Plant 2. The hydraulic capacities of Plant 1 and Plant 2 are 22 mgd and 28 mgd, respectively.

Softening operations are normally configured as two-stage split-treatment with two-stage recarbonation. Groundwater is typically introduced to the secondary basins during warmer months and to both the primary and secondary basins during periods when the Huron River surface water supply temperature is below 10 °C. Lime is added during first-stage rapid mix and a cationic coagulant aid polymer is added during second-stage rapid mix. Recarbonation is accomplished through groundwater addition and carbon dioxide application at secondary rapid mix and in a dedicated contactor following secondary clarification.

Ozone is applied following softening and recarbonation to meet several treatment objectives including primary disinfection, removal of objectionable tastes and odors, and reduction of potentially harmful chlorinated disinfection byproducts. Sodium hydroxide (NaOH) and sodium hexametaphosphate are added following ozonation to raise pH for corrosion control during distribution and to prevent calcium precipitation on the filter media, respectively.

Filtration is divided among 26 granular media filters with a design hydraulic capacity of 50 mgd with one filter out of service for backwashing (design loading rate of 3 gpm/ft^2). Each dual-media filter bed contains 18 to 24 inches of granular activated carbon (GAC) over 6 inches of silica sand. Filter backwash water is recovered, clarified, equalized, and recycled by blending with surface and groundwater entering the WTP.

Following filtration sodium hypochlorite and aqueous ammonia are added to form a monochloramine residual that provides continued disinfection during distribution. Fluoride is also added to filtered water for dental health protection.



Baseline Treatment Operation

Treatment Processes

Process	Number
Rapid Max/Flocculation	2
Softening, First-Stage (Basins 1, 2 ,4)	3
Rapid Mix/Flocculation (Basins 3, 5)	2
Recarbonation	2
Ozonation	1
Biologically Active Carbon Filtration	26
Clearwell	2

Treatment Chemicals

1. Lime
2. Carbon Dioxide
3. Polymer
4. Ozone
5. Sodium Hydroxide
6. Polyphosphate
7. Sodium Hypochlorite
8. Ammonia
9. Fluoride

Figure TM6-1: Simplified Process Schematic of Existing Facilities – 50 mgd

The contributions of processes incorporated in the Ann Arbor WTP treatment train to a multi-barrier approach for control of key contaminant categories are identified qualitatively on **Figure TM6-2**. The following sub-sections provide a general description of the combined effectiveness of treatment processes currently installed at the Ann Arbor WTP and provide qualitative assessments of their potential for continued compliance with current enforceable regulatory standards, non-enforceable regulatory guidelines, and internal City water quality goals.

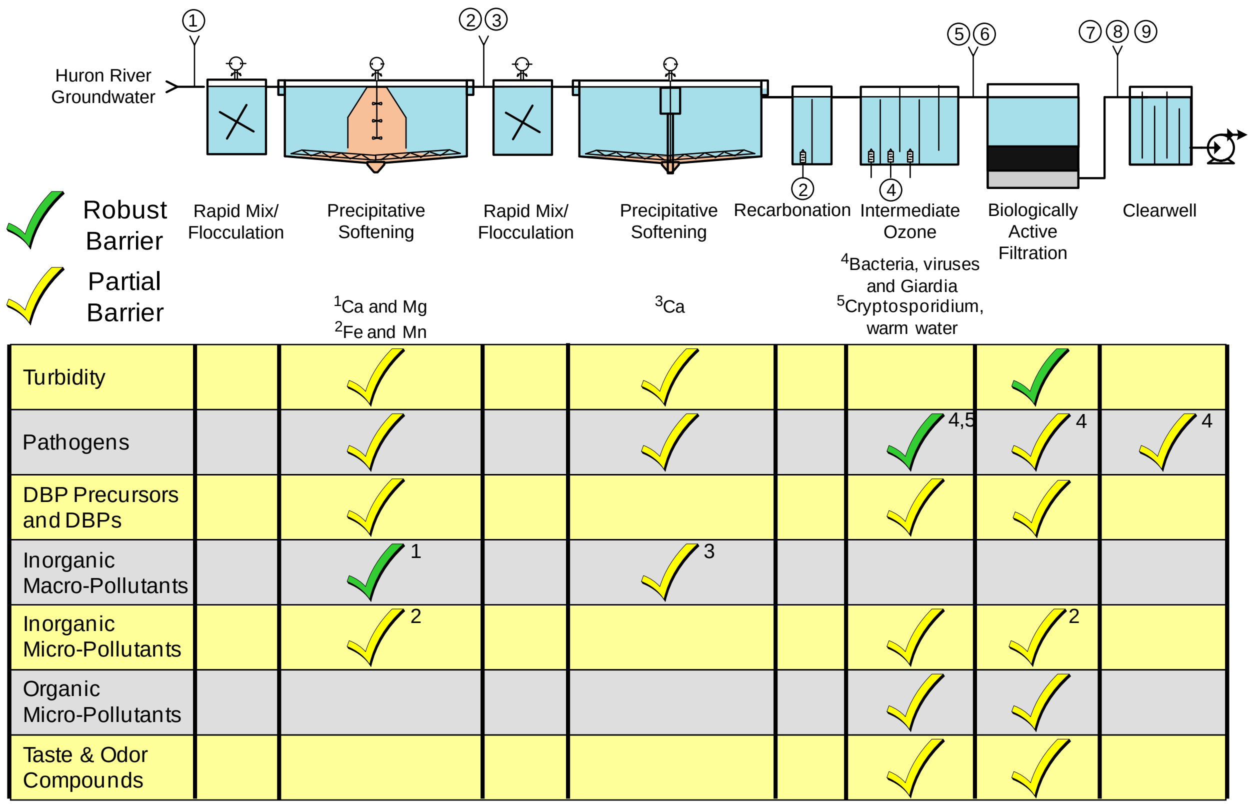


Figure TM6-2: Contaminant Barriers Provided by Existing Treatment Processes

3.1.1 Turbidity

Turbidity in drinking water is perceived as the most obvious indication of poor water quality, and has health-related and aesthetic impacts that depend on the physical, chemical, and biological properties of the particles present. Suspended particles absorb or scatter incident light to varying degrees reducing water clarity, and may impart objectionable tastes. Because of their small size and relatively high numbers in many natural waters, particles may present a large surface area for adsorption of toxic chemicals. Pathogenic microorganisms may be present as individual particles in natural waters, or may be incorporated in particulates formed through aggregation of organic and mineral matter.

Turbidity removal was the earliest form of drinking water treatment practiced, traditionally relying on settling and filtration, and has become the cornerstone of modern drinking water treatment. Standard practice now includes chemical pre-treatment through coagulant addition, which modifies particle surface chemistry to improve removal through subsequent clarification and filtration processes. The Ann Arbor WTP utilizes pre-treatment (precipitative softening) and filtration to provide multiple barriers for turbidity removal.

Raw water delivered to the Ann Arbor WTP generally has turbidity less than 5 NTU with occasional recorded values as high 34 NTU. Finished water turbidity is typically less than 0.1 NTU. Collectively, the processes incorporated in the Ann Arbor WTP are appropriate for treating a consistently low turbidity source water. When appropriately operated and maintained, full conventional treatment (precipitative softening, flocculation, clarification and granular media filtration) provides a robust multi-barrier approach for turbidity control. Continued compliance with existing turbidity standards is anticipated.

3.1.2 Microbial Pathogens

Disease caused by pathogenic microorganisms (pathogens) has historically posed the single largest public health threat associated with drinking water. Microbial pathogen control in drinking water is achieved through a combination of physical removal by pre-treatment and filtration and disinfection by chemical or physical treatment processes. Physical removal of microorganisms through pre-treatment and filtration is discussed in conjunction with turbidity control in **Section 3.1.1**. The following paragraphs describe microbial pathogen control through disinfection.

Disinfection of drinking water is the final treatment barrier to transmission of waterborne disease by microorganisms. Drinking water disinfection produces inactivation of pathogens, rendering them unable to infect or reproduce. Disinfection differs from sterilization in which all microorganisms, not only pathogens, are inactivated. Chemical disinfection has been standard practice in the drinking water industry; however, ultraviolet (UV) light disinfection has been widely implemented in recent years. In order to maintain the human health benefits provided by primary disinfection performed during drinking water treatment, a chemical disinfectant residual must be maintained during drinking water distribution. Disinfection provides a large measure of public health protection at a relatively low cost compared with many other water treatment processes.

Chemical disinfection is assessed in terms of the composite parameter CT, in which C is disinfectant residual concentration in mg/L, and T is disinfectant contact time in minutes. Because the flow through treatment basins is non-uniform to varying degrees (flow short-circuiting), the effective contact time for chemical disinfection is typically less than basin hydraulic residence time. To account for short-circuiting during disinfectant contact, the detention time at which at least 90 percent of the water flowing through a basin has been in contact with the disinfectant, T_{10}, is used in CT calculations. T_{10} may be determined using a tracer study, by applying mathematical models of disinfection effectiveness, or by applying an empirical basin baffling factor to basin hydraulic detention time.

The Ann Arbor WTP uses a combination of pre-treatment, filtration, and chemical disinfection to provide a robust multi-barrier strategy for microbial pathogen control. Precipitative softening, clarification, and filtration constitute an integrated approach for physical removal of pathogens. The disinfection CT requirements of the *Surface Water Treatment Rules* are met using ozone contact. Residual disinfection of finished water is provided by chloramine addition. Collectively, the physical removal and chemical disinfection technologies incorporated in the Ann Arbor WTP are appropriate for removal/inactivation of bacterial, viral, protozoan, and algal pathogens that may be present in raw water, and provide a robust multi-barrier approach for microbial pathogen control. Continued compliance with existing microbial pathogen standards is anticipated.

3.1.3 DBP Precursors and Regulated DBPs

Disinfection byproducts (DBPs) are compounds formed during drinking water treatment through reaction of chemical disinfectants with either organic or inorganic constituents present in the source water. The most widespread and well documented class of DBPs is halogenated organic compounds formed by reaction of free-chlorine and natural organic matter (NOM). Typically, only 30 to 60 percent of halogenated organic DBPs are chemically identifiable, with trihalomethanes and haloacetic acids occurring in the highest concentrations. The Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR) standards for total trihalomethanes (TTHM) and haloacetic acids (HAA5) are 80 and 60 micrograms per liter (μg/L), respectively, measured as locational running annual averages (LRAAs) at each distribution system monitoring site.

Treatment technologies that seek to minimize DBP formation follow one of three strategies related to the reactions between chemical disinfectants and organic or inorganic source water constituents: 1) reduce or remove one of the byproduct precursors, 2) alter reaction conditions so as to reduce byproduct formation, or 3) remove undesirable byproducts once formed. However, for compelling operational and economic reasons, minimizing DBP formation during drinking water treatment has largely focused on reducing or removing DBP precursors, and has governed development of the interrelated set of microbial pathogen and DBP regulations over the past decade.

The Ann Arbor WTP uses a multi-barrier strategy to minimize the formation of regulated DBPs that integrates pre-treatment, filtration, and disinfection with ozone and chloramines. Pre-treatment (precipitative softening and clarification) and filtration provide multiple treatment barriers that remove selected DBP precursor NOM fractions. Ozonation oxidizes NOM DBP precursors, reducing their reactivity when chlorine is subsequently applied. Use of a combined-chlorine disinfectant residual removes contact between NOM DBP precursors and free-chlorine during finished water distribution, thereby reducing TTHM and HAA5 formation.

The multi-barrier strategy to control TTHM and HAA5 formation at the Ann Arbor WTP has maintained compliance with regulated DBP standards of the Stage 1 DBPR and Stage 2 DBPR Rules. Continued compliance with existing DBP precursor removal and DBP formation standards is anticipated.

3.1.4 Inorganic Macro-Contaminants

Inorganic macro-contaminants may be present in drinking water supplies as suspended and colloidal solids or as dissolved species. Suspended silt and clay particles are removed through pre-treatment and filtration, whereas dissolved inorganic species require additional precipitative, adsorptive, or high-pressure membrane treatment for removal. Inorganic species that are typically present in drinking water supplies at concentrations greater than 1 mg/L are considered macro-contaminants, and include positively charged sodium, potassium, calcium, and magnesium ions, as well as negatively charged bicarbonate, carbonate, chloride, sulfate, nitrate, and silicate ions. Although numerous other inorganic ionic species may be present at very low concentrations, these macro-contaminants constitute the vast majority of total dissolved solids (TDS) in drinking water supplies. Among the inorganic macro-contaminants commonly present in drinking water supplies, nitrate (NO_3) has an enforceable primary MCL of 10 mg/L NO_3 as N and chloride and sulfate each have non-enforceable secondary MCLs of 250 mg/L.

The Ann Arbor WTP source water supplies are classified as very-hard (greater than 300 mg/L as $CaCO_3$) based on calcium and magnesium ion concentrations. Precipitative softening provides an effective treatment barrier for hardness control, with the degree of hardness removal determined by process operating parameters such as pH, chemical doses, and treatment configuration.

Historical operational practice at the Ann Arbor WTP has generally met the City's seasonally adjusted finished water hardness goal of 120 to 140 mg/L as $CaCO_3$. Precipitative softening does not remove other inorganic macro-contaminants such as sodium, potassium, chloride, sulfate, or nitrate to any great extent. Continued compliance with existing inorganic macro-contaminant standards is anticipated.

3.1.5 Trace Inorganic Contaminants

There are 16 alkaline-earth metal, transition metal, and nonmetallic elements and compounds, as well as 4 radionuclides, which may be classified as trace inorganic contaminants (TInCs) and have enforceable national primary drinking water standards. There are also 6 metals and the halogen fluoride that have non-enforceable secondary drinking water standards. Trace inorganic contaminants typically, although not universally, occur in drinking water supplies at concentrations less than 1 mg/L. Notable exceptions to this broad classification include iron, and occasionally manganese, which may be present at up to several mg/L in drinking water supplies.

Trace inorganic contaminants may be present in drinking water supplies as elemental ions or as colloidal and particulate oxides. They may occur naturally due to dissolution of contaminant-bearing minerals or due to commercial, industrial, and municipal discharges. If incorporated in or adsorbed on suspended and colloidal particles trace inorganic contaminants are removed through pre-treatment and filtration, whereas those in dissolved form require additional precipitative, adsorptive, or high-pressure membrane treatment for removal.

Nuisance metals such as iron and manganese may be present in ground and surface waters that are in contact with iron and manganese containing minerals, occurring as either soluble reduced ions (Fe^{2+} and Mn^{2+}) or precipitated oxides ($Fe(OH)_3$ or MnO_2), depending on pH and oxygen concentration. Aesthetic issues associated with iron and manganese in drinking water include staining of laundry and fixtures and unpleasant taste. Iron or manganese concentrations less than 0.5 milligrams per liter (mg/L) may promote bacterial regrowth in reservoirs and drinking water distribution systems. Consumer complaints regarding aesthetic issues associated with iron or manganese in drinking water have been documented at concentrations as low as 0.02 mg/L. There are presently no known adverse health effects of iron or manganese in drinking water, but the EPA has set secondary maximum contaminant levels for iron and manganese at 0.3 mg/L and 0.05 mg/L, respectively, based on aesthetic concerns.

The Ann Arbor WTP uses pre-treatment (precipitative softening), ozonation, and filtration to provide multiple barriers for trace inorganic contaminants. Ozonation oxidizes trace inorganic contaminants including arsenic, selenium, iron, and manganese that may be present in reduced form, promoting their precipitation and subsequent removal by filtration. Currently installed processes provide very effective barriers for trace inorganic contaminants, with greater than 90 percent removal commonly observed in facilities that utilize similar treatment schemes. Continued compliance with existing trace inorganic contaminant standards is anticipated.

3.1.6 Trace Organic Contaminants

Trace organic contaminants (TOrCs) enter source waters from industrial and municipal effluents, agricultural runoff, and unregulated waste discharge. These contaminants encompass a wide range of volatile organic compounds (VOCs) and synthetic organic compounds (SOCs) with diverse physical and chemical properties. Trace organic contaminants may be present in water supplies as dissolved species, or may be adsorbed onto or contained within suspended particulate matter. Due to typically low solubility, organic contaminants are often associated with natural organic matter (NOM) in aquatic and sedimentary environments. However, both dissolved and particulate organic contaminants are relevant from a regulatory point of view, as drinking water primary MCLs are based on total contaminant concentrations.

Trace organic contaminant control in drinking water supplies utilizes watershed management to limit effluent discharges, as well as treatment processes including air stripping, chemical oxidation, coagulation, activated carbon adsorption, reverse osmosis, and advanced oxidation for removal during treatment. Chemical characteristics such as volatility, polarity, charge, molecular weight, and solubility, determine which processes are appropriate for trace organic contaminant removal during drinking water treatment.

3.1.6.1 Regulated Trace Organic Contaminants

Historically important classes of VOCs and SOCs that may be present as trace contaminants in drinking water sources include solvents, plasticizers, propellants, petroleum additives, chemical intermediates, herbicides, and pesticides. Although these compounds typically occur at low concentrations in source waters, and at trace levels in drinking water supplies, many of these compounds are highly toxic or carcinogenic and therefore pose a health risk if present in drinking water. There are currently national primary drinking water standards for 53 organic compounds. Candidate Contaminant List 3 lists an additional 86 organic compounds for which regulatory determinations are forthcoming from the EPA.

3.1.6.2 Contaminants of Emerging Concern

Over the past several decades, improved extraction, concentration, and analytical techniques used to measure trace organic compounds in natural waters has led to recognition of a wide range of previously undetected contaminants in drinking water supplies. These contaminants of emerging concern (CECs) typically occur at extremely low concentrations (ng/L or less), and have health effects that are not fully understood. However, many CECs have been shown to disrupt the normal functioning of human and animal endocrine systems that regulate many aspects of organ and tissue activity and function. The human endocrine system transmits regulatory signals to specific receptor cells throughout the body by controlling the concentrations of endogenous (native) hormones. The term endocrine disrupting compounds (EDCs) has been used to describe a wide variety of structurally diverse chemicals that interfere with the synthesis, secretion, transport, binding, action, or elimination of natural hormones that are responsible for maintenance of homeostasis (stable cellular activity), reproduction, development, and behavior.

Organic compounds that are of emerging concern in drinking water supplies include hormones, human and veterinary pharmaceuticals (PhACs), personal care products (PCPs), pesticides, and industrial chemicals; however, only certain chemicals in each of these classes display endocrine disrupting properties. Personal care products such as detergents, antimicrobials, over-the-counter medicines, and common household chemicals have been implicated as potential EDCs. Although the majority of EDCs identified to date are organic compounds, inorganic chemicals such as perchlorate have also been identified as potential EDCs.

Emerging contaminants enter natural waters through several pathways including treated municipal and industrial effluents, agricultural and urban runoff, and uncontrolled discharges. Pharmaceuticals and personal care products primarily enter natural waters through municipal wastewater effluent discharges. The predominant pathway for pesticide introduction to natural waters is surface runoff. Effluent discharges from manufacturing and chemical processing operations are largely responsible for industrial chemicals present in natural waters; although, inappropriate disposal practices may also be a significant source.

Toxins produced by many common cyanobacteria, formerly known as blue-green algae, also pose a public health threat when present in drinking water supplies. Nuisance cyanobacteria blooms attributed to nitrogen and phosphorus pollution of lakes and rivers used as drinking water supplies has increased public awareness and concern about the health risks posed by cyanotoxins. These trace organic contaminants have been widely detected at low levels in drinking water supplies, notably in the Toledo, Ohio public water system in the summer of 2014. Although there are currently no federal drinking water regulations for cyanotoxins, several are listed on CCL3 for evaluation.

A chemically diverse group of over 100 cyanobacterial metabolites have been identified as cyanotoxins, which have been variously classified as neurotoxins, hepatoxins, and contact irritants. Neurotoxins affect neuromuscular function and have the potential to be lethal at high doses. Hepatoxins cause liver damage and in extreme cases liver failure. All cyanobacteria cells contain a cell wall layer made of lipopolysaccharides (LPS), which have been shown to cause skin irritation in humans and animals, as well as fever and gastroenteritis. Neurotoxins produced by common cyanobacteria genera such as *Anabaena, Cylindrospermopsis,* and *Oscillatoria* include anatoxin-a, saxitoxin, and β-N-methylamino-L-alanine (BMAA). Hepatoxins produced by common cyanobacteria genera such as *Microcystis, Cylindrospermopsis*, *Anabaena, Plantothrix,* and *Nodularia* include microcystins, cylindrospermopsins, and nodularin.

3.1.6.3 Trace Organic Contaminant Barriers at the Ann Arbor WTP

Treatment barriers for trace organic contaminants currently implemented in the Ann Arbor WTP process train include ozone oxidation and biologically active granular activated carbon (BAC) filtration. Molecular ozone oxidizes organic compounds by attacking specific reactive functional groups within their structures, resulting in a wide variety of oxidized products. Ozone is a particularly effective oxidant for organic compounds that contain aromatic functional groups in their structures; however, its reactivity with compounds that contain aliphatic (straight carbon chain) and heterocyclic (non-aromatic carbon ring) structures is generally much lower. Ozone oxidation of NOM commonly produces low molecular weight organic compounds including aldehydes, ketoacids, and carboxylic acids, which are not currently believed to pose a health hazard and are therefore not regulated in drinking water. These reactive organic byproducts may be effectively removed by adsorption and biological degradation in BAC filtration. Based on the multi-barrier approach to trace organic contaminant control currently in place at the Ann Arbor WTP, and historically low concentrations of regulated trace organic contaminants is raw water supplies, continued compliance with existing standards for these contaminants is anticipated.

3.1.7 Taste and Odor Compounds

Objectionable tastes and odors in drinking water may occur due to the presence of anthropogenic (man-made) organic and inorganic compounds, which may enter source waters through industrial discharges including pulp and paper making, food processing, and petrochemical manufacturing. Medicinal, petrochemical or solvent-like, and fragrant off-tastes and odors are often associated with drinking water supplies developed from source waters that receive organic solvents, pesticides, and petroleum products from industrial effluent, agricultural runoff, and liquid waste disposal. Often, these chemicals produce tastes and odors that are not directly attributable to a parent organic compound, but rather to chlorinated disinfection byproducts that occur in discharged waste effluents or finished drinking water.

Inorganic compounds including metals, salts, and disinfectants may also impart objectionable tastes to drinking water. Metals may be present in drinking water through industrial and municipal discharges to source waters, or through corrosion of distribution system and plumbing materials. Metals typically do not impart objectionable odors to drinking water, but have been associated with metallic, salty, or sour tastes. Anthropogenic sources of salts in drinking water include industrial and municipal discharges and urban run-off to surface waters as well as artificial recharge to groundwater. Salts are also not typically associated with objectionable odors in drinking water, but may produce salty or bitter tastes. Residual disinfectants applied to prevent bacterial regrowth during drinking water distribution may impart chlorinous tastes and odors.

Naturally occurring organic and inorganic compounds may also produce objectionable tastes and odors in drinking water. Taste and odor compounds in natural waters are usually either directly or indirectly associated with the growth and decay of microorganisms, either in the water column or bottom sediments of surface waters or near-surface layers in soils. Numerous photosynthetic microorganisms belonging to cyanobacteria, green algae, diatom, and flagellate groups that may be present in surface waters produce odors variously described as sweet, fragrant, grassy, musty, earthy, swampy, fishy, and septic. Actinomycetes (Gram-positive bacteria), the primary decomposers of organic matter in freshwater and soil environments, also produce metabolites and degradation products that cause objectionable tastes and odors in drinking water supplies. Geosmin and 2-methylisoborneol (MIB) are the most well known microbial odor-causing metabolites found in drinking water supplies, producing earthy and musty odors, respectively. Other relatively common microbial metabolites responsible for objectionable tastes and odors in water supplies include mucidone (musty) and several sulfur containing mercaptan (rotten egg) compounds.

Treatment barriers for taste and odor compounds such as geosmin and MIB currently implemented in the Ann Arbor WTP process train include ozone oxidation and BAC filtration. Ozonation followed by BAC filtration has proven to be an effective control strategy for common taste and odor compounds such as geosmin and MIB. Removal efficiency of 80 percent or greater is typically achieved in all but the most severe seasonal taste and odor episodes. Unless water quality in Barton Pond declines significantly due to extensive eutrophication, the multi-barrier approach for taste and odor control currently in place at the Ann Arbor WTP is anticipated to provide continued satisfactory control of taste and odor compounds such as geosmin and MIB.

3.2 POTENTIAL FUTURE TREATMENT NEEDS

Compliance with potential future drinking water standards for contaminants not currently regulated will depend on the chemical properties and concentrations of the particular contaminants involved. CCL 3 lists 104 chemical contaminants and 12 microbial pathogens that are currently under review for potential future regulation. Several new or revised regulations are expected based on positive regulatory determinations for contaminants listed on CCL 3 or reviewed under Six-Year Review 3 (see **Section 2.4**).

Treatment processes as currently implemented at the Ann Arbor WTP may be sufficient to adequately control some of the contaminants on the regulatory horizon, whereas modifications of current processes or additional treatment process may be required for others. Because of the relatively large number of contaminants on the regulatory horizon, and uncertainty regarding actual numerical standards or treatment technique requirements that may be promulgated, potential future regulatory compliance was evaluated by grouping contaminants into several discrete categories based on their physical, chemical and biological properties. Contaminant categories considered here include turbidity, microbial pathogens, disinfection byproduct precursors and disinfection byproducts (DBPs), inorganic macro-contaminants, trace inorganic contaminants, trace organic contaminants, and objectionable tastes and odors.

3.2.1 Turbidity

Existing facilities at the Ann Arbor WTP including pre-treatment (precipitative softening) and granular media filtration provide a robust multi-barrier approach for turbidity control. There are currently no new regulations related to turbidity on the regulatory horizon. Therefore, no additional treatment barriers for future compliance with turbidity standards are anticipated at this time. Use of riverbank filtration (RBF) could potentially be implemented for the City's Huron River supply to buffer seasonal turbidity variations and to filter out zebra and quagga mussel veligers and algal cells.

3.2.2 Microbial Pathogens

There are 12 microbial pathogens listed in CCL 3 under consideration for potential future regulation. The types and extent of treatment that may be required to provide effective control for these pathogens has not been established. Treatment barriers for Cryptosporidium may need to be reevaluated if future monitoring places the City's Huron River water supply above its current LT2ESWTR Bin 1 classification. Treatment processes that could provide an additional barrier for microbial pathogens include replacing existing granular media filtration capacity with low-pressure membrane filtration, installing UV light disinfection, or adding an advanced oxidation process. Riverbank filtration may also provide an additional barrier for Giardia, Cryptosporidium, and other microbial pathogens.

3.2.3 DBP Precursors and Regulated DBPs

There are no new standards on the regulatory horizon for regulated DBP precursors, and additional barriers for currently regulated DBP precursor removal are not anticipated at this time. Five organic nitrogen-containing compounds (4 nitrosamines and nitrosopyrrolidine) associated with chloramination are listed on CCL 3 for regulatory consideration. The DBP chlorate, which may be formed during onsite hypochlorite or chlorine dioxide generation or through decay of bulkdelivered hypochlorite, is also listed on CCL 3 for regulatory consideration. Additional barriers for these potentially regulated DBPs may include high-pressure membrane (nanofiltration or reverse osmosis – NF/RO), advanced oxidation, or UV light treatment processes.

3.2.4 Inorganic Macro-Contaminants

Nitrate is currently the only inorganic macro-contaminant with an enforceable primary drinking water standard; there are non-enforceable secondary guidelines for chloride, sulfate, and TDS (**Table TM6.A-2**). There are currently no new regulations related to inorganic macro-contaminants on the regulatory horizon. The Ann Arbor WTP currently provides a robust barrier for calcium and magnesium by precipitative softening, but does not have effective barriers for other inorganic macro-contaminants. Finished water concentrations of regulated inorganic macro-contaminants are typically well below their respective enforceable primary standards or non-enforceable secondary guidelines. Barring dramatic and unforeseen changes in source water quality, additional barriers for inorganic macro-contaminants are not anticipated at this time.

3.2.5 Trace Inorganic Contaminants

There are 8 trace inorganic contaminants listed on CCL 3 that are under review for possible future regulation in drinking water. In addition, potential revisions to current fluoride and chromium standards are being considered under separate regulatory actions. Existing facilities at the Ann Arbor WTP including pre-treatment (precipitative softening), intermediate ozonation, and granular media filtration provide a robust multi-barrier approach for iron and manganese control. However, the effectiveness of these processes as implemented at the Ann Arbor WTP for control of other metals and currently or potentially regulated anionic contaminants such as arsenic, selenium, perchlorate, hexavalent chromium, and fluoride has not been demonstrated. Additional adsorptive or high-pressure membrane (NF/RO) processes may be required in response to changes in source water quality or to comply with future drinking water standards.

3.2.6 Trace Organic Contaminants

There are 96 trace organic contaminants listed on CCL 3 that are under review for possible future regulation in drinking water. Ozone oxidation followed by BAC filtration is an effective multi-barrier control strategy for a wide range of trace organic contaminants. However, there are a number of chemically diverse organic compounds that are not effectively removed from drinking water by these treatment technologies. The cyclic ether compound 1,4-Dioxane is of particular concern because of known contamination in a groundwater aquifer adjacent to the City's Huron River surface water supply. Additional advanced oxidation or high-pressure membrane (NF/RO) processes may be required in response to changes in source water quality or to comply with future drinking water standards.

3.2.7 Taste and Odor Compounds

There are currently no drinking water regulatory standards for objectionable tastes and odors, and none are anticipated in the near future. The Ann Arbor WTP has not historically experienced severe objectionable taste and odor episodes in its source water supplies. Ozonation followed by BAC filtration provide an effective multi-barrier strategy for modest to moderate levels of taste and odor compounds such as geosmin and MIB. Barring dramatic and unforeseen changes in source water quality, additional barriers for control of objectionable taste and odor episodes are not anticipated at this time.

3.3 FUTURE TREATMENT ALTERNATIVES

As discussed in the previous section, additional treatment barriers for microbial pathogens, DBPs, trace inorganic contaminants, and trace organic contaminants may be required at the Ann Arbor WTP in the future in response to changes in source water quality or to comply with future drinking water standards. Barring dramatic and unforeseen changes in source water quality, additional barriers for turbidity, DBP precursors, inorganic macro-contaminants, and objectionable taste and odor compounds are not anticipated at this time.

Typical treatment effectiveness of several processes that could be implemented at the Ann Arbor WTP to meet future source water quality and/or regulatory changes is listed in **Table TM6-1**. No single treatment process provides adequate public health protection against all categories of drinking water contaminants that may be present in drinking water sources at different times and under different conditions. Advanced oxidation, UV light disinfection, low-pressure membrane filtration, and high-pressure membrane processes each provide effective treatment of several contaminant classes of interest here. Potential application of these processes at the Ann Arbor WTP is described in the following sections.

Table TM6-1: Typical Performance of Selected Treatment Processes

	ADVANCED OXIDATION	UV DISINFECTION	ACTIVATED CARBON	ACTIVATED ALUMINA	IRON-BASED SORBENTS	MIEX	PACKED COLUMN IX	LOW-PRESSURE MEMBRANES	HIGH-PRESSURE MEMBRANES	ELECTRODIALYSIS REVERSAL (EDR)
Turbidity	P	P	F-G	F-G	F-G	P	P	E	E	P
Microbial Pathogens	G-E	G-E	P-F	P-F	P-F	P	P	G-E	E	P
DBP Precursors and DBPs	P-G	P-VG	P-VG	P	P	F-G	P-F	F-VG	E	P-F
Inorganic Macro-Contaminants	P	P	P	P	P	P	F-G	P	E	VG-E
Trace Inorganic Contaminants	P	P	P	P-G	P-G	P-G	G-E	P	E	VG-E
Trace Organic Contaminants	E	P-VG	G-E	P	P	P	P	P	G-E	P
Objectionable Tastes and Odors	E	P	G-E	P	P	P	P	P	E	P

Abbreviations:

P – Poor (0 to 20 percent removal), F – Fair (20 to 40 percent removal), G – Good (40 to 60 percent removal), VG – Very Good (60 to 80 percent removal), E – Excellent (80 to 100 percent removal)

Future treatment goals for target pathogens or chemical contaminants are difficult to predict based on the current regulatory environment and uncertainty regarding potential degradation of the Ann Arbor WTP source water supply. Bench-scale and pilot-scale testing required to establish treatment performance parameters including chemical doses, UV dose, or high-pressure membrane system recovery were beyond the scope of this evaluation. Therefore, typical process parameters often utilized for the additional treatment processes evaluated here were assumed, as described in the following sections.

3.3.1 Advanced Oxidation Processes

Advanced oxidation processes (AOPs) that generate highly reactive hydroxyl radicals (·OH) at ambient temperatures have become more widely used in recent years. Unlike conventional oxidants such as free chlorine, which exhibit very selective reactivity with organic compounds, hydroxyl radicals produced by AOPs are capable of completely oxidizing organic compounds to carbon dioxide and mineral acids. Advanced oxidation is the preferred treatment process for low molecular weight non-polar trace organic contaminants such as 1,4-Dioxane, which are not effectively removed by other advanced treatment processes. AOPs have several inherent advantages over other trace organic contaminant control measures such as air-stripping or GAC adsorption including:

- Contaminant can be completely destroyed,
- Contaminants that are not volatile or adsorbable can be destroyed,
- Processes such as air-stripping and GAC adsorption merely transfer contaminants to another phase, generating a residual that may require further treatment or disposal,
- Liquid or solid residuals are not produced by AOPs.

Several methods of hydroxyl radical formation for AOP use in drinking water treatment are possible including ozone contact at alkaline pH, ozone contact with hydrogen peroxide addition, ozone contact with UV irradiation, and hydrogen peroxide contact with UV irradiation.

Ozonation with hydrogen peroxide addition was selected as the baseline advanced oxidation process for evaluation here. Design and average ozone doses of 6 mg/L and 3 mg/L, respectively, were assumed. New ozone generators with capacity sufficient to meet this design dose were specified. The existing ozone building and contact facilities were utilized in this evaluation. A hydrogen peroxide to ozone dose mass ratio of 0.3 mg H_2O_2/mg O_3 was also assumed. Hydrogen peroxide storage and feed equipment would be housed in a separate building with a footprint of approximately 650 sq. ft.

3.3.2 Ultraviolet Light Disinfection

Ultraviolet (UV) light wavelengths range from 200 nm to 400 nm, but the germicidal range is typically between 230 and 260 nm. Major UV system components include a flow chamber, UV lamps, quartz sleeves, UV sensors, cleaning system, ballasts, and a control system. UV lamps are housed in quartz sleeves for protection from encrustation and breakage. Post-filtration UV disinfection with medium pressure (MP) lamp technology was evaluated here.

UV dose requirements for Cryptosporidium, *Giardia lamblia*, and virus inactivation credit are specified by the LT2ESWTR. For the purpose of sizing UV reactor equipment a design dose of 12

mJ/cm^2 was assumed, which would provide 3-log inactivation of Cryptosporidium. The ability of a given UV disinfection system to provide the desired dose depends on the reactor/lamp arrangement, lamp output, flow rate, and water quality. Three 48-inch MP reactors were specified (2 duty and 1 standby), with a hydraulic capacity of 25 mgd each. Each reactor would be equipped with nine 20 kW MP lamps. Filtered water UV transmittance was assumed to be 85 percent. A new 5,000 sq. ft. building would house all UV system equipment.

3.3.3 Low-Pressure Membrane Filtration

Membrane treatment technologies may be used for particulate or dissolved constituent removal from drinking water, depending on the membrane pore size and material used. Microfiltration (MF) and ultrafiltration (UF) membrane systems, which have pore sizes in the range of 0.1 μm and 0.01 μm respectively, are used for particulate removal, but do not remove dissolved constituents such as TOC, hardness, salts, taste and odor compounds, and organic chemicals. MF and UF systems typically operate at trans-membrane pressures of 8 psig to 30 psig and are thus classified as low-pressure technologies. Typical average flux rates are in the range of 30 to 70 gallons per square foot of membrane surface per day (gfd) for polymer-based membrane systems; however, ceramic membrane systems may have flux rates of 100 $gal/ft^2 \cdot d$ or more.

Pretreatment of low-pressure membrane feed-water is required for source waters that commonly have elevated turbidity or total organic carbon levels. Pretreatment may involve a precipitative process to reduce the organic loading or cartridge filters upstream of MF or UF membranes to capture larger sized particles. Overall recovery from low-pressure membrane systems is typically 90 to 95 percent, depending on membrane material and configuration and source water quality. Because low-pressure membrane filtration provides an absolute barrier to particulates based on membrane pore size and integrity, filtered water turbidity of less than 0.1 NTU is readily achieved by this technology.

Low-pressure membrane filtration of softened water was considered as an additional barrier for removal of pathogenic microorganisms at the Ann Arbor WTP. An encased system with polymeric membranes was evaluated, assuming an average membrane flux of 35 gfd and an overall system recovery of 95 percent. MF/UF membrane skids (18 duty and 2 standby trains) and ancillary chemical feed and clean-in-place equipment would be housed in a new building with a footprint of approximately 36,000 sq. ft.

3.3.4 High-Pressure Membrane Filtration

High-pressure membrane processes remove dissolved constituents from drinking water based on membrane-specific electrochemical repulsion rather than mechanical straining. Rejection of dissolved constituents at the membrane surface produces a concentration difference between the feedwater (concentrate) and treated water (permeate), resulting in an osmotic pressure difference that must be overcome by pressurizing the feedwater. Reverse osmosis (RO) membrane systems have relatively high solute rejection and typically operate at trans-membrane pressures in excess of 100 psig, whereas nanofiltration (NF) membrane systems have comparatively lower solute rejection and operate at trans-membrane pressures between 70 psig and 100 psig.

Membrane material properties and pore size determine the extent to which various dissolved ions and molecules including inorganic salts and metals, NOM, and trace organic contaminants are rejected by high-pressure membranes. Reverse osmosis membranes typically have rejection coefficients for charged inorganic contaminants (salts and metals) in excess of 95 percent, whereas NF membranes reject these solutes over a much broader range (10 percent to 90 percent) depending on species charge and polarity. Most organic compounds are also strongly rejected (greater than 80 percent) by RO membranes, although some low molecular-weight (less than 200 amu) non-polar compounds such as 1,4-Dioxane are poorly rejected. Rejection of most organic compounds by NF membranes is substantially lower than that of RO membranes.

Reverse osmosis of filtered water was evaluated for removal of trace inorganic and organic contaminants. Membrane rejection for the target organic contaminant was assumed to be 90 percent at an RO system recovery of 85 percent, which would generate a brine concentrate liquid waste stream approximately of approximately 7.5 mgd requiring disposal. For the purpose of this evaluation, concentrate disposal was assumed to be by discharge to a sanitary sewer. After accounting for RO brine disposal, overall finished water production would be 42.5 mgd.

Finished water stabilization with lime and caustic soda addition was incorporated due to the relatively low bypass flow required to achieve high target contaminant removal. RO membrane skids (18 duty and 2 standby trains) and ancillary chemical feed and clean-in-place equipment would be housed in a new building with a footprint of approximately 50,000 sq. ft.

3.4 FUTURE TREATMENT ALTERNATIVE COSTS

The conceptual level opinions of probable cost presented here were developed using a common set of capital and operations and maintenance (O&M) unit process costs. The Class 4 planning level cost opinions presented here reflect use of standard engineering practices and were prepared without the benefit of detailed engineering designs. As defined by The Association for the Advancement of Cost Engineering (AACE), Class 4 cost opinions of this type are generally considered to have an accuracy range of plus 50 to minus 30 percent. Any actual project cost would depend on current labor and material costs, competitive market conditions, final project scope, bid date, and other variable factors. The opinions of probable cost presented here are most appropriately used to compare the relative costs of various water treatment alternatives, rather than as an estimate of actual project costs for detailed budgeting purposes.

3.4.1 Opinions of Probable Capital Cost

The opinions of probable capital cost for advanced treatment components provided here include unit process costs, additional project costs, contractor mark-up costs, and non-construction costs. Unit process costs include process equipment and basins, structures needed to house process equipment, and any additional structures required for office, laboratory, and maintenance spaces. Items included in additional project costs, contractor mark-ups, and non-construction costs, as well as the unit multipliers for each, are listed in **Table TM6-2**. The opinions of probable capital cost for treatment components were developed as follows: additional project costs were added to the unit process costs subtotal to give the *facility cost* subtotal, contractor mark-up unit costs were then applied cumulatively to the facility cost subtotal to give the *construction cost* subtotal, and non-construction costs calculated and added to the construction cost subtotal to give the *total project capital cost* sub-total.

Development of facility layouts for the advanced treatment processes was beyond the scope of this evaluation. For the purpose of evaluating potential capital costs, it was assumed that all facilities associated with these processes would be contained within the existing Ann Arbor WTP site. Advanced treatment facilities could be located in portions of the site that may be made available after replacement of Plant 1 pretreatment facilities (see TM 3) or after completion of projects related to Plant 2 pretreatment facilities that may be considered in the future. Because of the relatively large footprint associated with some of the advanced treatment processes considered here and limited space available on the existing site, multi-level structures may be an option to adequately house some additional facilities.

Due to the uncertainty associated with major rehabilitation and reconstruction projects within the confines of an existing water treatment facility, a rehabilitation adjustment factor was included in the non-construction costs category. This factor is intended to cover extraordinary costs that often occur associated with maintaining service of existing facilities throughout demolition and construction, incomplete knowledge of existing facility and site conditions, and difficulties related to restricted access and movement on the site. For the current level of definition of the City's Water Treatment Plant Alternatives Analysis Project, industry standard construction costing guidelines recommend using an adjustment factor in the range of 25 percent to 75 percent (CIC, 2011). A rehabilitation adjustment factor of 50 percent was applied during development of the opinions of probable capital cost for advanced treatment alternatives evaluated here.

Table TM6-2: Capital Cost Markups

CATEGORY	UNIT COST
Additional Project Costs	**Percent of Unit Process Costs [(1)]**
Site Work	8 %
Yard Piping	20 %
Electrical Service	15 %
Instrumentation and Controls	5 %
Contractor Mark-Ups	**Percent of Facility Costs[(2)]**
Overhead	7 %
Profit	10 %
General Requirements[(3)]	3 %
Contingency	4 %
Non-Construction Costs	**Percent of Construction Costs[(4)]**
Permitting	1 %
Engineering	8 %
Construction Services	7 %
Commissioning	3 %

CATEGORY	UNIT COST
Legal/Administration	0.5 %
Contingency	30 %
Rehabilitation Adjustment Factor	50 %

(1)Additional project costs are applied to the unit process costs subtotal additively.
(2)Facility cost is the sum of the unit process cost subtotal and the additional project cost subtotal. Contractor mark-up costs are applied cumulatively to the facility cost.
(3)Mobilization, bonding, and insurance.
(4)Construction cost is the sum of facility cost subtotal and the contractor mark-ups subtotal. Non construction costs are applied to the construction costs subtotal additively.

Total project capital cost opinions for the advanced treatment alternatives evaluated here are listed in **Table TM6-3**. Capital cost opinions are expressed using a cost basis of July 2014.

Table TM6-3: Total Project Opinions of Probable Capital Cost(1)

TREATMENT ALTERNATIVE	OPC CAPITAL COST
Advanced Oxidation(2)	$40,840,000
UV Disinfection	$11,350,000
Low-Pressure Membrane Filtration	$114,800,000
Reverse Osmosis	$294,490,000

(1)Cost basis is July 2014.
(2)New Ozone equipment installed in existing ozone building.

3.4.2 Opinions of Probable Annual OMR&R Cost

Annual operation, maintenance, and repair (OM&R) opinions of probable cost include treatment chemicals, process, pumping, and building HVAC energy costs, and maintenance related labor. Maintenance costs were calculated as 1.5 percent of installed equipment cost and 1.0 percent of associated building construction cost, respectively. Costs associated with RO brine concentrate were not included in annual OM&R opinions of probable costs developed here. Labor costs associated with staffing for routine treatment facility operations were not included in these annual O&M opinions of probable cost. Annual OM&R opinions of probable cost were based on an annual average daily production of 15 mgd.

Annual OM&R cost opinions for the advanced treatment alternatives evaluated here are listed in **Table TM6-4**. Annual OM&R cost opinions are expressed using a cost basis of July 2014.

Table TM6-4: Annual OM&R Opinions of Probable Cost[1]

TREATMENT ALTERNATIVE	ANNUAL OM&R COST
Advanced Oxidation	$437,000
UV Disinfection	$204,000
Low-Pressure Membrane Filtration	$874,000
Reverse Osmosis[2]	$4,730,000

[1]Cost basis is July 2014.
[2]Brine concentrate costs not included.

3.4.3 Opinions of Probable Life-Cycle Net Present Value

A 30 year life-cycle was assumed for the net present value (NPV) analysis performed here, consistent with industry standard expected service lives for major drinking water treatment equipment. The net present values calculated here are based on the opinions of probable capital cost (**Section 3.4.1**) and opinions of probable annual OMR&R cost (**Section 3.4.2**) previously presented, and are given in 2014 dollars. Economic parameters used to calculate the net present values of advanced treatment alternatives are listed in **Table TM6-5**. The 30-year life-cycle net present values that include all treatment components of each advanced treatment alternative are listed in **Table TM6-6**.

Table TM6-5: Net Present Value Economic Parameters

PARAMETER	VALUE
Base Year	2014
General Inflation Rate	4 %
OMR&R Inflation Rate	5 %
Loan Interest Rate[1]	3.9 %
Discount Rate[1]	1.9 %
Loan Duration	30 years

[1]Guidelines and Discount Rates for Benefit-Cost Analyses of Federal Programs, Circular A-94, Office of Management and Budget.

Table TM6-6: Opinions of Life-Cycle Net Present Value for Advanced Treatment Alternatives

TREATMENT ALTERNATIVE	OPC NET PRESENT VALUE ($)
Advanced Oxidation	$74,600,000
UV Disinfection	$24,820,000
Low-Pressure Membrane Filtration	$192,000,000
Reverse Osmosis(2)	$615,500,000

(1)Cost basis is July 2014.
(2)Brine concentrate costs not included.

4 References

CIC (2011), *Global Construction Cost and Reference Yearbook, 11th Annual Addition*, Compass International Consultants Inc., Morrisville, Pennsylvania, USA, 2011.

Appendix TM6.A

National Primary and Secondary Drinking Water Standards

Table TM6.A-1: National Primary Drinking Water Standards (as of 11/2014)

CONTAMINANT	REGULATION	MCL, MG/L	MCLG, MG/L
Organic Substances			
Acrylamide	Phase II	(TT)	Zero
Alachlor	Phase II	0.002	Zero
Atrazine	Phase II	0.003	0.003
Benzene	Phase I	0.005	Zero
Benzo(a)pyrene (PAHs)	Phase V	0.0002	Zero
Carbofuran	Phase II	0.04	0.04
Carbon tetrachloride	Phase I	0.005	Zero
Chlordane	Phase II	0.002	Zero
Chlorobenzene	Phase II	0.1	0.1
2,4-D	Phase II	0.07	0.07
Dalapon	Phase V	0.2	0.2
Dibromochloropropane (DBCP)	Phase II	0.0002	Zero
o-Dichlorobenzene	Phase II	0.6	0.6
p-Dichlorobenzene	Phase I	0.075	0.075
1,2-Dichloroethane	Phase I	0.005	Zero
1,1-Dichloroethylene	Phase I	0.007	0.007
cis-1,2-Dichloroethylene	Phase II	0.07	0.07
trans-1,2-Dichloroethylene	Phase II	0.1	0.1
Dichloromethane	Phase V	0.005	Zero
1,2-Dichloropropane	Phase II	0.005	Zero
Di(2-ethylhexyl) adipate	Phase V	0.4	0.4
Di(2-ethylhexyl) phthalate	Phase V	0.006	Zero
Dinoseb	Phase V	0.007	0.007
Dioxin (2,3,7,8-TCDD)	Phase V	0.00000003	Zero
Diquat	Phase V	0.02	0.02
Endothall	Phase V	0.1	0.1
Endrin	Phase V	0.002	0.002
Epichlorohydrin	Phase II	(TT)	Zero

CONTAMINANT	REGULATION	MCL, MG/L	MCLG, MG/L
Ethylbenzene	Phase II	0.7	0.7
Ethylene dibromide	Phase II	0.00005	Zero
Glyphosate	Phase V	0.7	0.7
Heptachlor	Phase II	0.0004	Zero
Heptachlor epoxide	Phase II	0.0002	Zero
Hexachlorobenzene	Phase V	0.001	Zero
Hexachlorocyclopentadiene	Phase V	0.05	0.05
Lindane	Phase II	0.0002	0.0002
Methoxychlor	Phase II	0.04	0.04
Oxamyl (Vydate)	Phase V	0.2	0.2
Pentachlorophenol	Phase II	0.001	Zero
Picloram	Phase V	0.5	0.5
Polychlorinated biphenyls (PCBs)	Phase II	0.0005	Zero
Simazine	Phase V	0.004	0.004
Styrene	Phase II	0.1	0.1
Tetrachloroethylene	Phase II	0.005	Zero
Toluene	Phase II	1	1
Toxaphene	Phase II	0.003	Zero
2,4,5-TP (Silvex)	Phase II	0.05	0.05
1,2,4-Trichlorobenzene	Phase V	0.07	0.07
1,1,1-Trichloroethane	Phase I	0.2	0.2
1,1,2-Trichloroethane	Phase V	0.005	0.003
Trichloroethylene	Phase I	0.005	Zero
Vinyl chloride	Phase I	0.002	Zero
Xylenes (total)	Phase II	10	10
Inorganic Substances			
Antimony	Phase V	0.006	0.006
Arsenic	Arsenic Rule	0.010	Zero
Asbestos (fibers/L > 10 um)	Phase II	7 million fibers/L	7 million fibers/L

CONTAMINANT	REGULATION	MCL, MG/L	MCLG, MG/L
Barium	Phase II	2	2
Beryllium	Phase V	0.004	0.004
Cadmium	Phase II	0.005	0.005
Chromium (total)	Phase II	0.1	0.1
Copper	LCR	(TT) AL=1.3	1.3
Cyanide	Phase V	0.2 (as free cyanide)	0.2
Fluoride	NIPDWR	4.0	4.0
Lead	LCR	(TT) AL = 0.015	Zero
Mercury (inorganic)	Phase II	0.002	0.002
Nitrate (as N)	Phase II	10	10
Nitrite (as N)	Phase II	1	1
Nitrate + Nitrite (both as N)	Phase II	10	10
Selenium	Phase II	0.05	0.05
Thallium	Phase V	0.002	0.0005
Radionuclides			
Gross Alpha	Radionuclides Rule	15 pCi/L	Zero
Beta and photon radioactivity	Radionuclides Rule	4 mrem/yr	Zero
Radium-226 + Radium-228	Radionuclides Rule	5 pCi/L	Zero
Uranium	Radionuclides Rule	30 ug/L	Zero
Microorganisms			
Cryptosporidium	LT2ESWTR	(TT)	Zero
Escherichia coli	TCR	(TT)	Zero
Fecal coliforms	TCR	(TT)	Zero
Giardia lamblia	SWTR	(TT)	Zero
Heterotrophic plate count (HPC)	SWTR	(TT)	NA
Legionella	SWTR	(TT)	Zero
Total coliforms	TCR	5.0 percent[2]	Zero
Turbidity	SWTR	0.3[3]	NA

CONTAMINANT	REGULATION	MCL, MG/L	MCLG, MG/L
Viruses	SWTR	(TT)	Zero
Disinfectant Byproducts			
Bromate	Stage 1 DBPR	0.010	Zero
Chlorite	Stage 1 DBPR	1.0	0.8
Haloacetic Acids (HAA5[4])	Stage 2 DBPR	0.060[5]	NA
Trihalomethanes (total)	Stage 2 DBPR	0.080[5]	NA
Bromodichloromethane	Stage 1 DBPR	-	Zero
Bromoform	Stage 1 DBPR	-	Zero
Chloroform	Stage 2 DBPR	-	0.07
Dibromochloromethane	Stage 1 DBPR	-	0.06
Dichloroacetic acid	Stage 1 DBPR	-	Zero
Monochloroacetic acid	Stage 2 DBPR	-	0.07
Trichloroacetic acid	Stage 2 DBPR	-	0.02
Disinfectant Residuals			
Chlorine (as Cl_2)	Stage 1 DBPR	4.0[6]	4[7]
Chloramines (as Cl_2)	Stage 1 DBPR	4.0[6]	4[7]
Chlorine dioxide (as ClO_2)	Stage 1 DBPR	0.8[6]	0.8[7]

[1]No more than 5 percent of monthly samples may be positive for presence of coliforms.
[2]Performance standard; no more than 5 percent of monthly samples may exceed 0.3 NTU.
[3]No more than 5 percent of samples total coliform-positive in a month.
[4]Sum of concentrations of five haloacetic acid species (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, dibromoacetic acid).
[5]Measured as locational running annual average at each monitoring site.
[6]Maximum Residual Disinfectant Level.
[7]Maximum Residual Disinfectant Level Goal.

AL = Action Level.
DBPR = Disinfection Byproducts Rule.
IESWTR = Interim Enhanced Surface Water Treatment Rule.
NIPDWR = National Interim Primary Drinking Water Regulations
LCR = Lead and Copper Rule.
LT2ESWTR = Long-Term 2 Enhanced Surface Water Treatment Rule
SWTR = Surface Water Treatment Rule.
TCR = Total Coliform Rule.
TT = Treatment technique.

Table TM6.A-2: National Secondary Drinking Water Regulation Standards (as of 11/2014)

CONTAMINANT	SMCL
Aluminum	0.05 - 0.2 mg/L
Chloride	250 mg/L
Color	15 Color Units
Copper	1.0 mg/L
Corrosivity	Non-corrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 Threshold Odor Units
pH	6.5 – 8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L