City of Columbia, Missouri Water and Light Department
McBaine Water Treatment Plant

# 2017-2018 Drinking Water Planning Work Group Recommendations Update to 2011 Preliminary Design Report

FINAL | March 2018

City of Columbia, Missouri Water and Light Department
McBaine Water Treatment Plant

# 2017-2018 Drinking Water Planning Work Group Recommendations
# Update to 2011 Preliminary Design Report

FINAL | March 2018

# Contents

## Appendices

## Tables



## Figures

# Abbreviations

| | |
|---|---|
| AACE | American Association of Cost Estimators |
| $CaCO_3$ | calcium carbonate |
| Carollo | Carollo Engineers, Inc. |
| CDP | Criterium Decision Plus |
| CEC | Contaminants of Emerging Concern |
| City | City of Columbia |
| DBP | Disinfection By-Product |
| D/DBPR | Disinfectants/Disinfection By-Products Rule |
| DWPWG | Drinking Water Planning Work Group |
| ft | feet |
| GAC | Granular Activated Carbon |
| gpm/sf | gallons per minute per square foot |
| GWUDI | groundwater under the direct influence |
| IDSE | Initial Distribution System Evaluation |
| IWRP | Integrated Water Resource Plan |
| *LRWSS* | *Long Range Water System Study (Jacobs, 2015)* |
| µg/L | micrograms per liter |
| MG | million gallons |
| µg/L | micrograms per liter |
| mg/L | milligrams per liter |
| mgd | million gallons per day |
| MIEX | Magnetic Ion Exchange |
| NTU | nephelometric turbidity unit |
| PDR | 2012 Preliminary Design Report for the McBaine WTP |
| ppd | pounds per day |
| RO | reverse osmosis |
| SDA | Structured Decision Analysis |
| S.U. | Standard Units |
| TTHM | Total Trihalomethane |
| UF | Ultrafiltration |
| UV | ultraviolet |
| WTP | water treatment plant |

# EXECUTIVE SUMMARY

## Goals

The main goal of this project is to update the recommendations of the 2012 Preliminary Design Report (PDR) for the McBaine WTP. This update is based on the conclusions and recommendations of the 2016 Condition Assessment Report and the updated demand projections from the 2017 Integrated Water Resources Plan (IWRP).

## Mission of Drinking Water Planning Workgroup

Provide planning recommendations to the Water and Light Advisory Board and the City Council regarding the expansion of the water treatment system by establishing water quality goals, determining assessment criteria; and, conducting a thorough, objective, assessment of industry accepted treatment technologies to determine the process or processes that best meet these criteria.

## Methodology

Similar to the 2012 PDR, the Drinking Water Planning Workgroup (DWPWG) utilized a series or workshops, facilitated by Carollo Engineers, Inc., (Carollo), in which a structured decision analysis (See Figure ES-1) was employed to provide these planning recommendations. A total of eight (8) workshops were held between May 2017 and February 26, 2018.

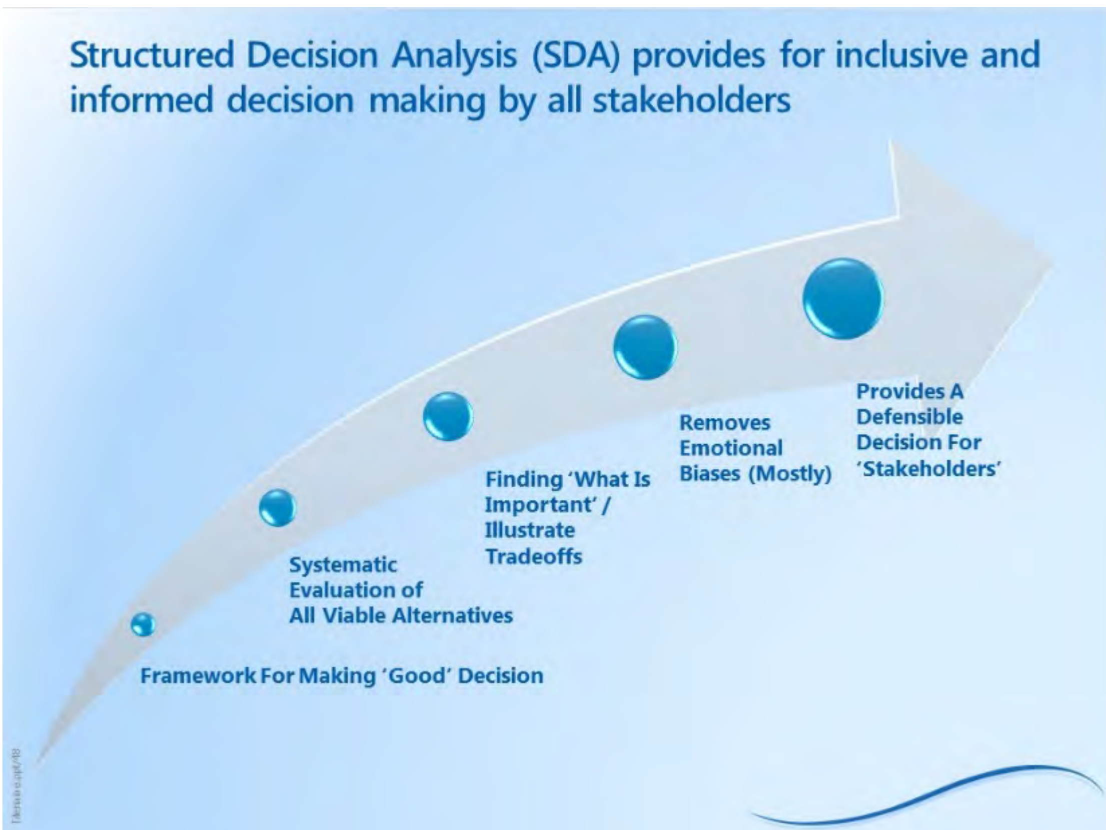



Figure ES-1 Structured Decision Analysis Benefits

The major steps associated with the structured decision analysis are as follows:

- Project Visioning: A process in which the framework and boundaries for the decision are established. A fatal flaw list is developed.
- Alternatives Identification and Screening: A process in which potential alternatives are identified and screened. Any alternatives with fatal flaws are eliminated from further consideration.
- Criteria Selection and Ranking: A process in which the criteria upon which particular alternatives associated with the decision process are to be evaluated and the relative importance of these criteria to the decision are established through a "pairwise" comparison.
- Alternative Development and Shortlist: A process in which potential alternatives are sufficiently developed to eliminate those that provide the lowest benefit (non-economic scores): i Cost (Economic scores) ratio when examined with the weighted criteria.
- Alternative Re-Ranking and Sensitivity Analysis: A process in which data gaps identified as relevant to the decision process are identified and resolved; the alternatives reranked with respect to the evaluation criteria; a sensitivity analysis conducted to determine the robustness of a potential decision; and a final decision statement and recommendation statement is generated.

## Cost Development

Table 5 presents the cost classification system as applied in Engineering, Procurement, and construction for the Process Industries as developed by the American Association of Cost Estimators (AACE). It is important to note that the level of estimates (Class 4) provided in the alternatives development and selection process are utilized to provide a relative comparison between alternatives and **should not be utilized for budgetary purposes.**

Table ES-1 AACE Cost Classification System

| Estimate Class | Primary Characteristic | Secondary Characteristic | | |
|---|---|---|---|---|
| | Maturity Level of Project Definition Deliverables (as % of definition) | End Usage – Typical Purpose of Estimate | Methodology – Typical Estimating Method | Expected Range of Accuracy Typical variation in low to high |
| Class 5 | 0% to 2% | Concept Screening | Capacity factored Parametric models Judgement or analogy | L: -20% to +50%<br>H: +30% to +100% |
| **Class 4** | **1% to 15%** | **Study or Feasibility** | **Equipment factored Parametric models** | **L: -15% to +30%**<br>**H: +20% to +50%** |
| Class 3 | 10% to 40% | Budget Authorization or Control | Semi-detailed unit costs with assembly level line items | L: -10% to -20%<br>H: +10% to +30% |
| Class 2 | 30% to 70% | Control or bid/tender | Detailed unit costs with forced detail take-off | L: -5% to -15%<br>H: +5% to +20% |
| Class 1 | 65% to 100% | Check estimate or bid/tender | Detailed unit costs with detailed take-off | L: -3% to -10%<br>H: +3% to +15% |

Notes:
(1) Taken from 18R-97 Cost Estimate Classification System Published by AACE.

## Final Recommendations

The findings and recommendations of the DWPWG are as follows:

1. DWPWG Findings:
   a. The McBaine WTP should consider processes that meet the requirements for a GWUDI Facility.
   b. The McBaine WTP should utilize treatment technologies to achieve Disinfection By Products (DBP) compliance without the need for chloramines and to also assist in removal of Contaminants of Emerging Concern (CEC's).
2. DWPWG Recommendations:
   a. Priority should be given to first restoring the plant to its 32 MGD capacity prior to increasing capacity to 48 MGD.
   b. The base alternatives of B1.1, B1.2, and B2 should be evaluated with the supplemental processes to achieve improved water quality through a phased approach.
   c. The design on the selected alternative should begin no later than 2020, as indicated in Carollo's analysis, to be in operation no later than 2024, unless design and construction are able to be accomplished sooner.
   d. In order to improve water quality while the new process train is in design, and construction, repair and/or enhancement of the current filters and pilot testing done to make every effort to return to free chlorine disinfection.
   e. The rehabilitation and/or enhancement initiatives outlined in the Condition Assessment will address deficiencies in the facility and system and request an updated timeline for these initiatives be produced by Water and Light.

Section 1

# INTRODUCTION

## 1.1 Background

The City of Columbia (City) owns and operates a municipal water treatment utility that supplies water to domestic, commercial, institutional, and industrial customers in and around the City. The water supply and treatment system consists of a 15 well ground water well field, one water treatment plant rated for 24 million gallons per day (mgd) capacity, a transmission network, and several water storage tanks/reservoirs. Originally constructed in 1970, the facility has gone through a number of upgrades and expansions with the latest occurring in 2008.

### 1.1.1 2012 McBaine Water Treatment Plant (WTP) Expansion Preliminary Design Report

Following the last plant expansion, the City completed the *McBaine WTP Expansion Preliminary Design Report (Carollo, 2012)*. The purpose of this report was to provide recommendations to expand the existing facilities in order to meet future demands and achieve compliance with current and anticipated future regulatory requirements. The decision making process that was established considered three (3) primary criteria, thirteen (13) sub-criteria, and incorporated relative cost comparisons.

The recommended treatment alternative from this report involved rehabilitation of the existing filters to increase filtration rate to 6 gallons per minute per square foot (gpm/sf) along with installation of high rate deep bed rapid rate multimedia filters as part of any filtration expansion. This recommendation resulted in a treatment alternative that not only met future demands, but also provided a facility that was groundwater under direct influence compliant. It should be noted that treatment alternatives that provided removal of contaminants of emerging concern (CECs) were also evaluated. Although these higher cost alternatives resulted in a lower benefit/cost ratio, the decision to implement these is a matter of public policy rather than determination through any engineering evaluation.

### 1.1.2 2016 Condition Assessment Report

In 2016, the City worked with Black & Veatch to complete a condition assessment of the McBaine WTP, as well as the Well Field and West Ash Booster Pump Station. The goal of the condition assessment was to assess the condition of the existing equipment to determine which components need to be replaced to meet current critical demands and water quality, identify potential improvements that will enhance performance and reliability, and address future capacity increases.

Because the ultimate capacity of the plant was uncertain at the time of the condition assessment, the report that was developed evaluated alternatives for expanding the plant to 45 or 60 mgd. In addition, the associated impact if the groundwater is reclassified as groundwater under the direct influence (GWUDI) was also considered in some of the alternatives. All in all, three (3) 45 mgd alternatives were considered, three (3) 60 mgd alternatives were considered, and two (2) of the 60 mgd alternatives were evaluated considering the impact of GWUDI.

Selection of the recommended alternatives was based on a number of factors, including capital costs, operation costs, constructability, regulatory, and operational. Based on this evaluation, the initial expansion alternative (45 mgd expansion) that was recommended in the Condition Assessment Report was construction of a new process train. This alternative consists of building an additional treatment train on the north side of the plant that includes two new aerators, one solids contact unit, one recarbonation basin, and a new filter complex. Although the costs associated with this alternative were higher than re-rating the existing plant, it was selected due to its ease of constructability and regulatory approval.

Another notable result of the condition assessment that should be mentioned here was the derating of plant capacity. As previously mentioned, the last plant expansion occurred in 2008 and included, among other things, a fourth Primary Basin and a fourth Secondary Basin. The four sets of basins each provided a capacity of 8 mgd, for a total plant capacity of 32 mgd. Because of the age and condition of the equipment in Primary Basins No. 1 and 2, these basins were derated to 4 mgd each, resulting in a total plant capacity of 24 mgd. It should be noted that the replacement of equipment in Primary Basins No. 1 and 2 should occur regardless of any expansion alternative recommended in this report.

### 1.1.3 2017 Integrated Water Resource Plan

In 2017, the City completed their Integrated *Water Resource Plan (Black & Veatch, 2017)*. This report focused on a number of issues associated with managing water resources and included the following:

- The City's current water source and supply capacity.
- Projected population growth and water needs.
- Potential future sources of water.
- Development of water alternatives considering:
  - Water Demand Trends.
  - Water Conservation.
  - Potable Water Supply.
  - Non-Potable Water Supply.
  - Regulatory Requirements.
  - Community Involvement.

There were multiple notable recommendations from the Integrated Water Resource Plan (IWRP) that directly affect the development of recommendations in this report. The IWRP established specific demand projections by user class, which included residential, commercial, large commercial, and irrigation users to better understand the impact if alternative water supply or conservation measures were implemented. This evaluation included a review of known historical data along with expected growths typical of this type of community to establish supply requirements to year 2040. The demand projections derived from the evaluation were also compared to previous projections from the *Long Range Water System Study (LRWSS) (Jacobs, 2015)* and are presented in Figure 1.

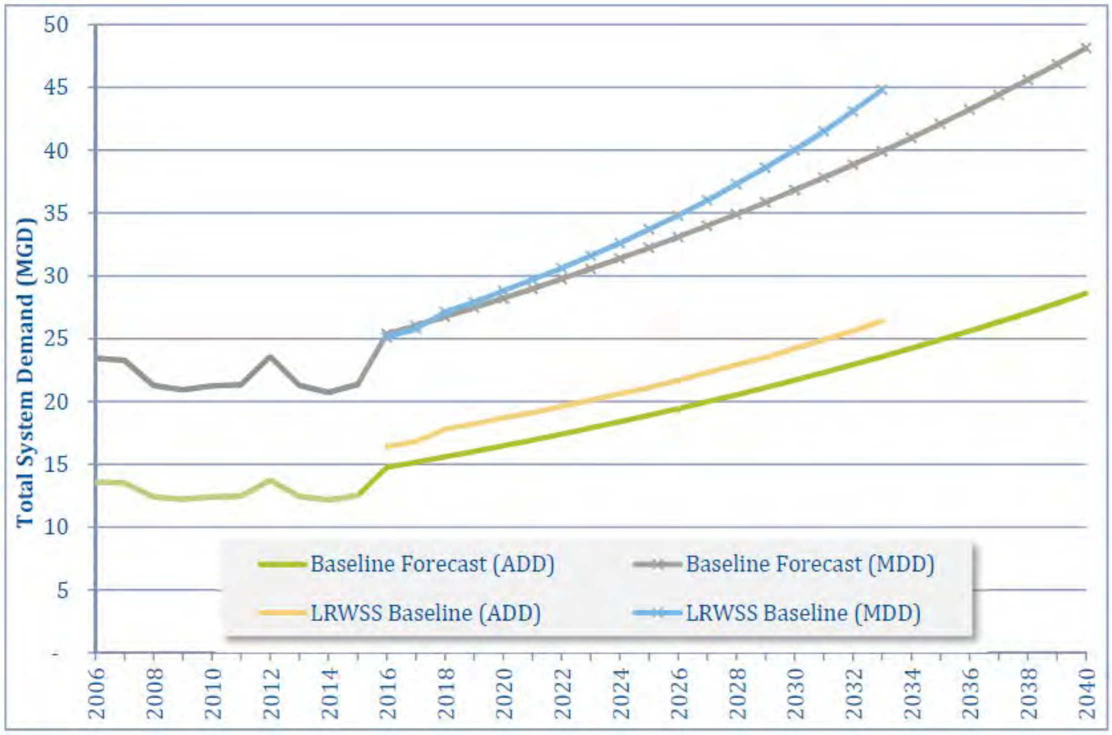



Figure 1 Average Daily and Maximum Daily Demand Forecasts from the Integrated Water Resource Plan (Black & Veatch, 2017)

In addition to the updated demand projections, the IWRP also evaluated current and potential future water supply sources. The alternatives that were evaluated included the continued use of the McBaine Bottoms Aquifer using vertical wells, installation of horizontal collector wells along the Missouri River bank, and the potential use of the Missouri River as a supply source. The evaluation did not include potable water supplies beyond the general area of the plant due to the requirement for a new treatment facility and additional transmission piping. A conceptual model indicated that the aquifer could yield a total of 65 mgd with 32 wells for 30 days with groundwater levels at each well approaching, but not dropping below the tops of the well screens. In summary, the evaluation concluded that the McBaine Bottoms Aquifer could produce the desired demands for the planning period.

## 1.2 Scope

The main goal of this project is to update the recommendations of the 2012 Preliminary Design Report (PDR) for the McBaine WTP. This update is based on the conclusions and recommendations of the 2016 Condition Assessment and the updated demand projections from the 2017 IWRP.

In order to facilitate the process of updating the Water Treatment Plant Expansion PDR, the City Council established the Drinking Water Planning Work Group (DWPWG). The group consists of seven (7) voting members and three (3) non-voting members. The voting members include one (1) member from the City Council and six (6) members appointed by City Utilities from several drinking water customer user groups. The resolution signed by the Mayor is provided in Appendix A.

A series of workshops were conducted that included direct input and participation from the DWPWG. These workshops utilized a decision analysis model to identify and screen potential alternatives and ultimately come up with a recommendation. By using the decision analysis model, the team was able to provide a defensible decision for stakeholders by providing a systematic approach for evaluation of all viable alternatives.

Project visioning was utilized to review existing information, discuss the results of previous studies, and discuss potential boundaries for the project. Input was solicited from the DWPWG to establish a set of water quality goals as well as any additional goals for the project. These goals were then used to develop a set of viable base and supplemental alternatives for the project. Following project visioning, a potential set of viable base and supplemental alternatives were developed.

Similar to what was done in the 2012 PDR, the decision making process considered several primary criteria along with sub-criteria. The primary criteria that were agreed upon included constructability, water quality, operability, project cost, and GWUDI facility. Each of the primary criteria and sub-criteria were assigned weighted values based on input from the DWPWG. Using computer based software, the viable alternatives were then scored against the criteria, and a preliminary ranking of alternatives was developed. The rankings were reviewed with the DWPWG and a shortlisted set of alternatives was created.

To further refine the alternatives, data gaps were identified, layouts were created, and costs were refined. The shortlisted alternatives were then re-ranked and a sensitivity analysis was conducted on the results. Using these results, along with input from the DWPWG, a final recommendation was developed.

Section 2

# PROJECT VISIONING

## 2.1 Purpose

The purpose of the project visioning phase of the project was to establish the boundaries or framework for the decision. This included the following:

- Establish/refine the mission statement and goals for the project.
- Development of questionnaire to assess preferences of DWPWG.
- Determine the water quality goals for the treatment plant effluent.

## 2.2 Meetings and Workshops

The following public meetings were held during the project visioning phase of the project:

- Visioning Workshop I – July 10, 2017.
- Visioning Workshop II – August 14, 2017.
- Water Quality Goals Workshop – September 11, 2017.

## 2.3 Mission and Goals Statement

The DWPWG met over the three visioning meetings and developed the following mission statement:

"Provide planning recommendations to the Water and Light Advisory Board and the City Council regarding the expansion of the water treatment system by establishing water quality goals, determining assessment criteria; and, conducting a thorough, objective, assessment of industry accepted treatment technologies to determine the process or processes that best meet these criteria."

The **Goals** of the DWPWG are as follows:

- Review current planning strategies for water supply and verify current goals and planning horizon for water treatment capacity expansion.
- Considering current regulations, potential future regulations, and potential enhancements; review and recommend potential long term water quality goals.
- Assess the state of the industry and shortlist potential treatment strategies that meet or exceed some or all of the potential long term water quality goals based upon industry acceptance and long term (present worth) costs.
- Formulate a set of criteria upon which potential treatment strategies to meet or exceed potential goals will be evaluated.
- Objectively evaluate and rank potential treatment strategies that meet planning horizon goals using a structured decision analysis model.
- Conduct a sensitivity analysis of decisions to review robustness and defensibility of decisions to potential changes in criterion assessments.

- Through this objective process, develop planning recommendations to guide the Water and Light Advisory Board and City Council regarding the water treatment system.

## 2.4 Visioning Questionnaire and Results

Appendix C presents the questionnaire and a summary of the results. The questionnaire was issued as a vehicle to allow the group to provide feedback on the development of the direction for the planning group.

## 2.5 Establishing Project Boundaries

The following boundaries were established by the DWPWG for the investigations:

1. Retain/Expand Current Well Field per IWRP: The DWPWG accepts all of the recommendations of the IWRP. This includes retaining the existing groundwater wells and well field as the water supply source for the Citizens of Columbia.
2. Retain Existing WTP infrastructure: The existing plant infrastructure and plant site will be retained. As a result, the investigations into the treatment strategies to be employed will be limited to expansion and integration of processes at the existing WTP site.
3. Water Treatment Expansion Needs/Timeline: Figure 2 presents a summary of the projected demands and the WTP expansion capacity and timeline recommended by the IWRP reviewed and accepted by the DWPWG. The IWRP recommended an expansion of the water treatment plant capacity from 32 mgd to 48 mgd by the planning year 2024.

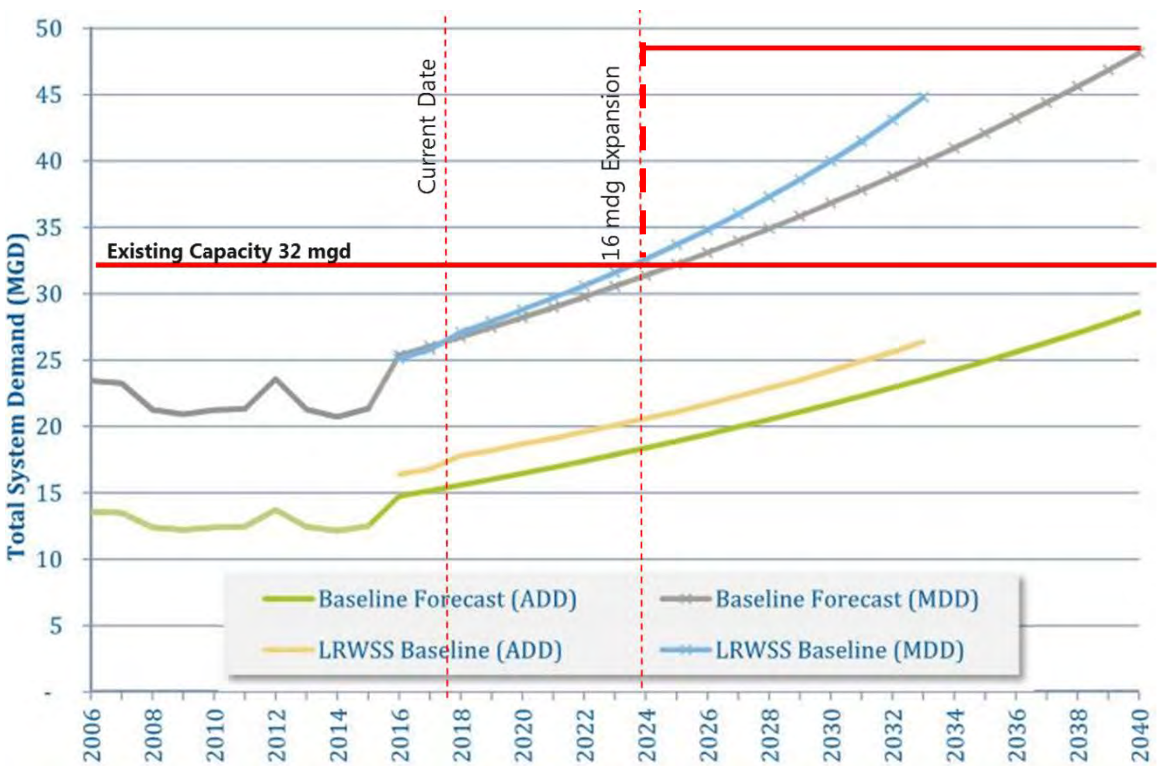



Figure 2 WTP Expansion Recommendations of IWRP

4. Accept WTP Capacity Restoration Project: Figure 3 presents a summary of the recommendations of the 2017 *Condition Assessment Report Well Field, McBaine Water Treatment Plant, and West Ash Booster Pump Station.* The findings and recommendations of these report to conduct a project to restore the capacity of the existing plant 32 mgd from its current derated capacity of 24 mgd in 2018-2019.
5. Softening: Following an examination of the benefits and drawbacks of the softening process in water treatment, the DWPWG concluded that softening would be continued with the targeted plant expansion project.

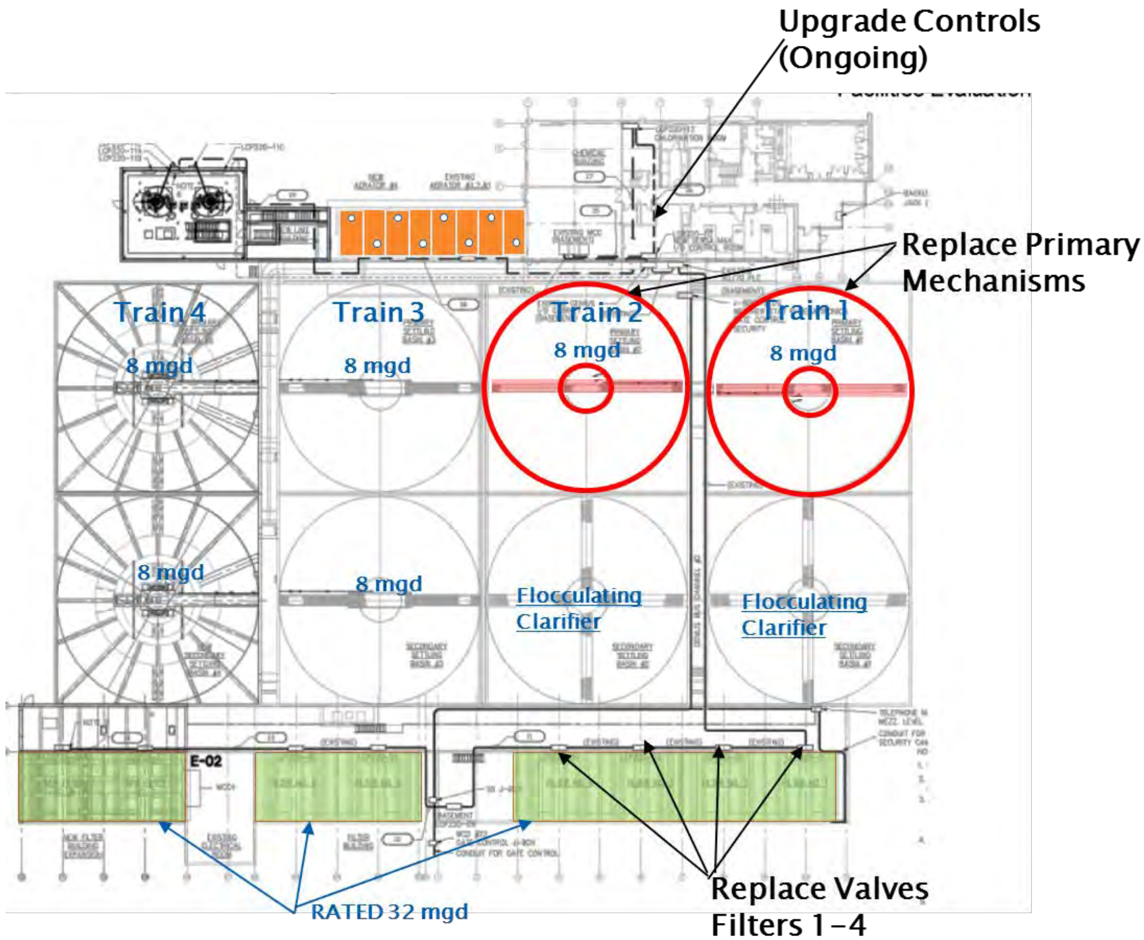



Figure 3 Summary of Capacity Restoration Project as Recommended by 2017 Condition Assessment Report Well Field, McBaine Water Treatment Plant, and West Ash Booster Pump Station

## 2.6 Regulatory Review and Water Quality Goals

The visioning process included an assessment of the current and anticipated future drinking water regulations. A differentiation was made between the primary drinking water regulations which establish strict compliance levels for certain health related parameters and secondary standards which provide treatment goals for mainly Aesthetic reasons (i.e. taste and odor, salinity, manganese, etc.). From this discussion a tiered water quality goal sheet presented in Table 1 was compiled that provided the following tiered levels of water quality goals:

**Groundwater Only:** The first tier of water quality goals were related to the current primary and secondary standards achieved by the existing WTP facility.

**Groundwater Under the Direct Influence:** The next tier of water quality goals were related to achieving compliance with a facility supply source classified by the state as a Groundwater Under the Direct Influence of a Surface Water (GWUDI).

**Enhanced WQ Goal:** The final tier of water quality goals were related to achieve additional level of treatment not required by the regulations but included levels of treatment to achieve specific water quality goals based upon the results of the survey. This final tier specifically includes the best available technologies to maximize removal of CEC and additional treatment requirements to maintain a free chlorine residual within the distribution system while maintaining water quality goals for disinfection by-products.

Table 1 DWPWG – Summary of Tiered Finished Water Quality Goals

| Regulation | Teir 1 Goal Groundwater Only | Tier 2 Goal GWUDI Facility | Tier 3 Goal Enhanced WQ Goal | Regulatory Limit | |
|---|---|---|---|---|---|
| | | | | GW | GWUDI |
| **Microbial Removal/Inactivation Performance** | | | | | |
| Filter Effluent Turbidity | < 1 NTU of 95% of CFE<br>< 5 NTU of CFE | < 0.3 NTU for 95% of individual Filter Readings<br>< 1.0 NTU in 100% of individual Filter Readings | < 0.1 NTU for 95% of individual Filter Readings<br>< 0.3 NTU in 100% of individual Filter Readings | None | < 0.3 NTU for 95% of individual Filter Readings<br>< 1.0 NTU in 100% of individual Filter Readings |
| *Giardia* Inactivation | None | >2.5 log removal through filters<br>>0.5 log inactivation through Disinfection<br>>3.0 total | None | None | 3-log removal/ inactivation |

Table 1 DWPWG – Summary of Tiered Finished Water Quality Goals (cont.)

| Regulation | Teir 1 Goal Groundwater Only | Tier 2 Goal GWUDI Facility | Tier 3 Goal Enhanced WQ Goal | Regulatory Limit | |
|---|---|---|---|---|---|
| | | | | GW | GWUDI |
| Virus Inactivation | 4 log removal /inactivation | $\geq$ 2.0 log removal through filters<br>$\geq$ 2.0 log inactivation through Disinfection<br>$\geq$ 4.0 log removal (total) | None | 4-log Removal/ Inactivation | 4 log removal/ inactivation |
| Cryptosporidium Inactivation | None | 2-long removal/ inactivation | None | none | None- Bin 0 |
| TOC Removal Through Process | None | 25% Removal | 25% Removal | As necessary to achieve goals | 25% |
| **Disinfection By-Products** | | | | | |
| TTHM[1] | $\leq$ 64 µg/L | $\leq$ 64 µg/L | $\leq$ 50 µg/L | $\leq$ 80 µg/L | $\leq$ 80 µg/L |
| HAA5[1] | $\leq$ 48 µg/L | $\leq$ 48 µg/L | $\leq$ 50 µg/L | $\leq$ 60 µg/L | $\leq$ 60 µg/L |
| Total Chlorine | 1.2-1.5 mg/L | 1.2-1.5 mg/L | < 4.0 mg/L | >0.2 mg/L and < 4.0 mg/L | > 0.2 mg/L and < 4.0 mg/L |
| Bromate ($BrO_3^-$) | $\leq$10 µg/L | $\leq$10 µg/L | $\leq$ 5 µg/L | $\leq$ 10 µg/L | $\leq$ 10 µg/L |
| Chlorite ($ClO_2^-$) | <0.4 mg/L | < 0.4 mg/L | $\leq$ 1.0 mg/L | $\leq$ 1.0 mg/L | $\leq$ 1.0 mg/L |
| **Finished Water Stability** | | | | | |
| pH | 8.5 to 9.0 S.U. | 8.5 to 9.0 S.U. | 7.5 to 8.5 S.U. | | Sufficient to retain effectiveness of disinfectant and high enough to limit nitrification. |
| Total Hardness | 150 mg/L as $CaCO_3$ | 150 mg/L as $CaCO_3$ | NA | NA- Internal Goal | NA- Internal Goal |

Notes:

(1) Running annual average of locations selected in accordance with IDSE (typically long duration time) required by Stage II D/DBPR.

(2) California became the first state in the nation in 2014 to issue a drinking water standard for chrome 6, setting a maximum concentration of 10 parts per billion. However, in August 2017, the State Water Resources Control Board removed the cap in response to a Sacramento judge's ruling that said the regulation was invalid. Based upon current research, a national standard of 20 ppd is much more likely in the distant future.

The workshops conducted as part of the visioning process included a comprehensive review and discussion of the potential regulations and anticipated impacts (if any) on any potential decisions regarding treatment process. The workshops associated with the visioning portion of the project are provided in Appendix D. The DWPWG provided this tiered approach to aid in evaluating the benefit:cost ratios associated with progressively higher levels of treatment than required by current regulations.

## 2.7 Treatment Concept Development

Based upon the visioning process, the DWPWG developed a list distinguishing the "must haves" with the "may haves" for the treatment alternatives development and evaluation. These are presented in Table 2.

Table 2 Summary of Must Haves and May Haves for Treatment Plant Expansion Alternatives

| Element | Definition | Components |
|---|---|---|
| Must Include | Elements that must be included in the development of the treatment plant expansion alternative that satisfy the Tier 1 water quality goals. | 1. Expansion must be performed on existing site.<br>2. Continued use and expansion of the existing wellfield per the recommendations of the IWRP.<br>3. Meets all current regulations for a Groundwater Treatment facility.<br>4. Continue satisfying secondary standard MCLG's and soften to a finished water hardness of 150 mg/L as $CaCO_3$. |
| May Include | Elements that contribute to enhancements of the treatment process to achieve advancement of the process to satisfy one or more of the goals specifically to achieve one or more of the Tier 2 or Tier 3 water quality goals. | 1. Allow entire facility (existing and expanded capacity) to satisfy the regulatory requirements of a GWUDI facility.<br>2. Will enable the City of Columbia to utilize free chlorine as a secondary disinfectant in the distribution system during the entire year.(1)<br>3. Will include technologies and operational techniques that include the best available control technologies for contaminants of emerging concern (CEC). |

Notes:
(1) Currently the city utilizes a periodic "free chlorine burn" to control nitrification within the distribution system. However, this is performed at lower temperatures to ensure compliance with the stage II Disinfection by Product rule.

Figure 4 presents a summary of the concept for examination of treatment alternatives by the DWPWG. The concept is to provide a "base" treatment alternative which, at a minimum, is designed to satisfy all of the "must have" criteria provided in Table 2. Other unit processes or groups of processes would be provided as a "supplement" to provide all or some of the tiered water quality goals associated with the "may have" criteria provided in Table 2.

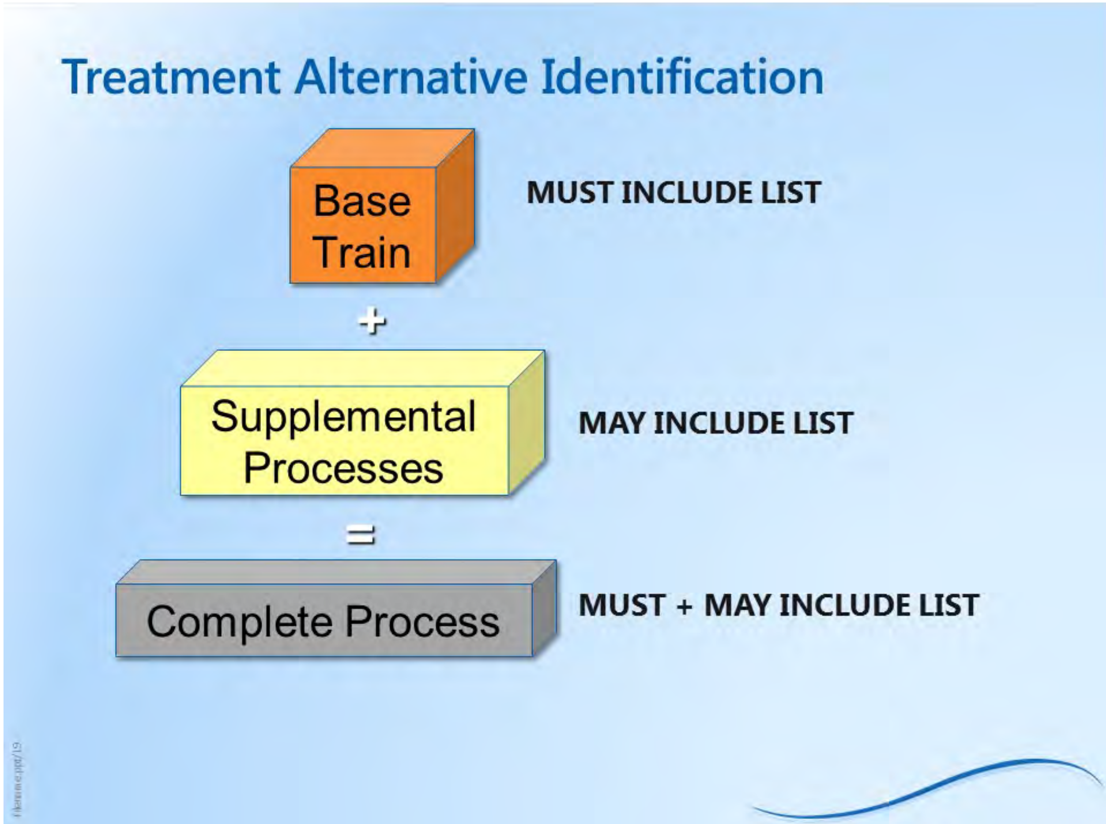



Figure 4 Summary of Treatment Train Alternative Development

## 2.8 Treatment Train Identification and Fatal Flaw Analysis

Once the boundaries and goals for the treatment process have been established, the final phase of the visioning process is to examine the suite of potential "base" and "alternative" treatment processes that potentially be included as part of a treatment alternative and examine each of these potential processes for a "fatal flaw" that would eliminate this process from further consideration. In this manner, the visioning process can take an almost unlimited combination of treatment alternatives into a shortlist of those that, in the opinion of the DWPWG, are suitable for further examination and evaluation as part of the structured decision analysis approach described in the next section.

### 2.8.1 Treatment Technology Identification

Figure 5 below summarizes the potential technologies examined for the base and supplemental unit processes for the McBaine WTP. These were grouped based upon the following characteristics:

1. Softening Treatment Technologies: The implementation of these technologies will, among other elements, enable the McBaine WTP to satisfy the base treatment goal of providing a finished water hardness of 150 mg/L. In addition if paired with the appropriate technologies will allow the continued use of the well field and provide treatment that would, at a minimum, satisfy the requirements of a groundwater treatment facility.

2. Filtration Technologies: The implementation of these technologies will enable the McBaine WTP to provide a physical filtration element as part of the base or supplemental alternative. This is particularly important for a facility to meet the requirements of a groundwater under direct influence of a surface water.
3. Oxidation/Disinfection Technologies: The implementation of these technologies either by themselves or as part of another system will provide disinfection and/or oxidation within the treatment process. This becomes increasingly important as the tier levels of water quality increase. The lowest tier, only requires disinfection/oxidation to remove viruses and iron/manganese, respectively. The second tier or GWUDI tier, will require a higher level of disinfection to satisfy these standards. The third tier may require a much stronger level of disinfection/oxidation involving the generation of a hydroxyl radical to provide sufficient oxidation to satisfy the goal of providing a technology that maximizes the reduction of CEC compounds.
4. DBP/DBP Precursor Removal Technologies: The implementation of these technologies either by themselves or in combination with another treatment technologies will provide removal of either disinfection by-products (DBPs) themselves or DBP precursors to provide the enhanced level of treatment required to eliminate the need of chloramines as a secondary disinfectant.

**Hardness Removal Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| | Conventional Softening |
| | High Rate Softening |
| | Enhanced Softening |
| | Softening with Caustic |
| | Anion Exchange |
| | Split Treatment |
| | Nanofiltration/RO |
| | Pelletized Lime Reactor |
| | Electromagnetic |
| | Home POU devices |

**CEC Removal/Oxidation Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| | Ferrate |
| | Free Chlorine |
| | Chlorine Dioxide |
| | Ozone or Ozone/Peroxide |
| | Wet Air Oxidation |
| | UV/Peroxide |
| | UV/Titanium Dioxide |
| | UV/Peracetic Acid |
| | Permanganate |
| | Peracetic Acid |

**Filtration Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| | Conventional Filtration – Constant Rate |
| | Ultrafiltration Membranes |
| | Deep bed filtration – Constant Rate |
| | Alternative (Slow Sand Diatomaceous Earth) |
| | MnO2 Coated Media Filtration |
| | Manganese Greensand |
| | Nanofiltration/RO |
| | Cartridge Filtration |
| | Declining Rate Filtration |

**DBP Precursor Removal Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| | GAC Filter Contactors |
| | PAC Contactors (Actiflow CARBtm) |
| | Post Filter GAC Contactors |
| | NanoFiltration/RO |
| | Enhanced Coagulation |
| | Ozone Biofiltration |
| | Chlorine Dose Control |
| | Anion Exchange Beds |
| | Chloramination (w/ Nitrification Action Plan) |
| | MIEX (magnetic Ion Exchange) |
| | Air Stripping |
| | Electrodialysis |

Figure 5 Potential Treatment Technologies Identified for Fatal Flaw Analysis

### 2.8.2 Fatal Flaw Analysis

The final step in the visioning process is to select for a group of technologies that have a high potential of being incorporated as part of the "Base" or "Base+Supplimental" treatment alternatives. The selection is based upon a "fatal flaw" analysis to eliminate the process or processes that possess one or more of these fatal flaws.

Table 3 presents a summary of the fatal flaws applied to the treatment technologies.

Table 3 Summary of Fatal Flaws

| Fatal Flaw | Description | Comment |
|---|---|---|
| Scale | Technology has never been constructed at this scale. This can either be measured by mgd or by another parameter such as ppd or other capacity element. | Historically there have been significant issues with trying to apply a higher scale for some treatment technologies. |
| Inappropriate Technology | Technology will not be capable of achieving the goals either by itself or as part of a treatment ensemble. | |
| Extremely Inflated Costs | Technology is appropriate and can achieve goals but because of specific conditions (geographical, energy costs, operational costs, etc.) the costs to install, operate and maintain can be magnitudes higher than other technologies. | Because of antidegradation issues with the Missouri River and the inability to locate a diffuser in the river, disposal of reject becomes an issue with RO systems. |
| Not Acceptable to the Community | This relates to the acceptance of the technologies by the community. For example, there are some communities that have taken the stance that anything that contributes significantly to increasing the carbon footprint of the utility will not be allowed. | The DWPWG was expected to provide guidance during the fatal flaw analysis. |

Figure 6 below presents a summary of the fatal flaw analysis for the softening processes to be evaluated as part of the "base" treatment train. It evaluating this it was understood that these were to be incorporated or integrated as part of the existing infrastructure at the treatment facility and that that infrastructure was modified to the extent recommended by the 2017 Condition Assessment Report.

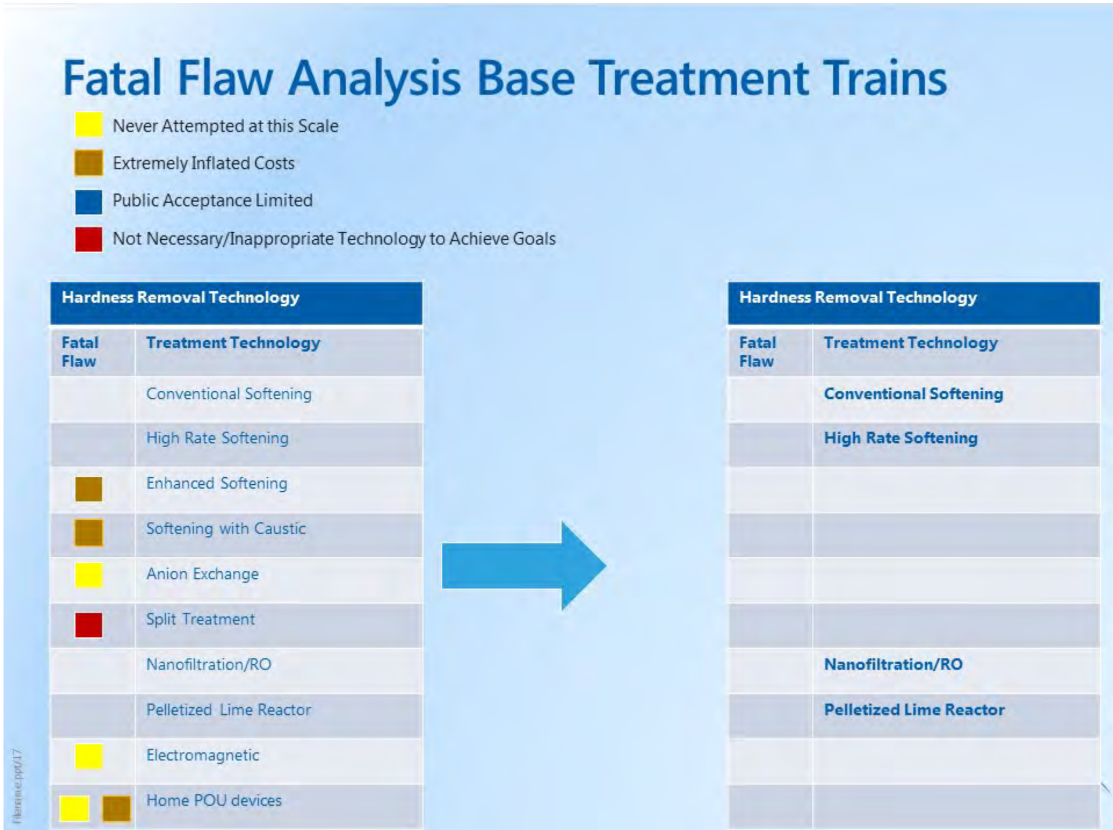



Figure 6 Fatal Flaw Analysis – Hardness Removal Technologies

Figure 7 presents the fatal flaw analysis for the filtration technologies to be employed as part of the base or as part of an advanced treatment technology. Normally, in these cases it would be appropriate to eliminate reverse osmosis because of its typically high cost. However, because reverse osmosis (RO) offers potential significant benefits to all of the tiered water supply goals, it will be evaluated further as a base alternative.

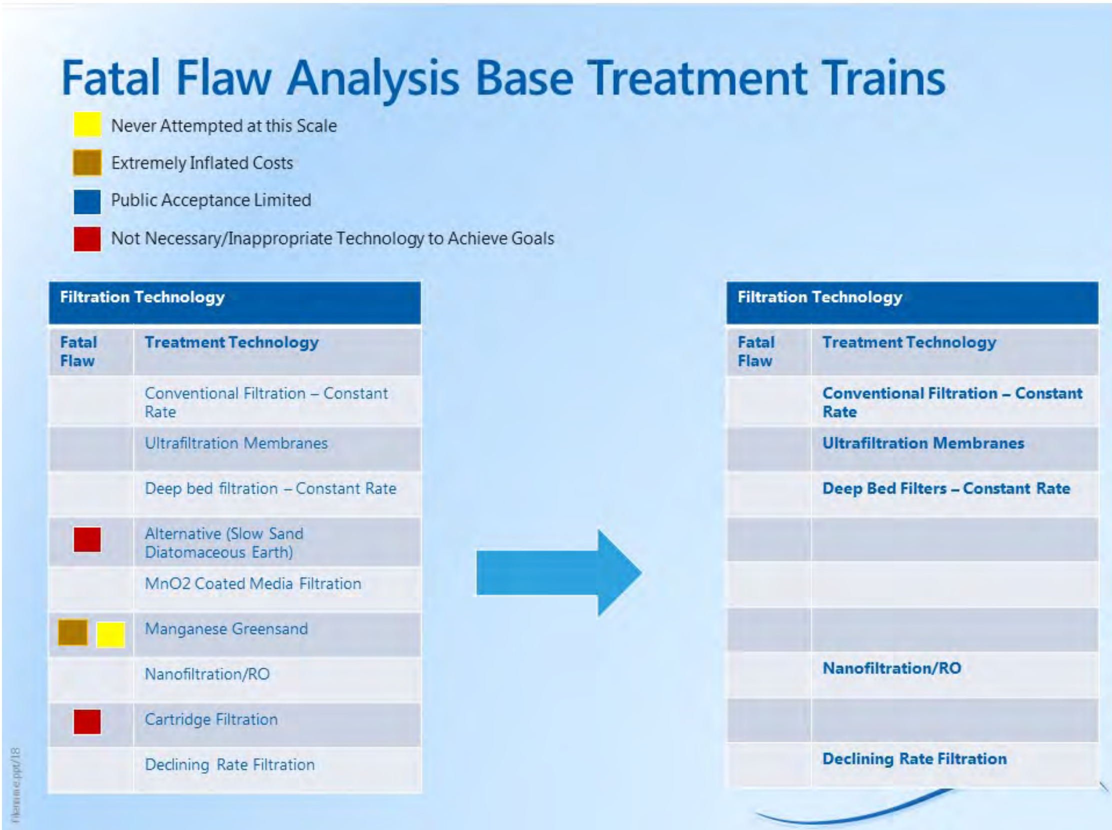



Figure 7 Fatal Flaw Analysis – Filtration Technologies

Figure 8 presents the fatal flaw analysis of the advanced oxidation and disinfection technologies. The technologies were selected based upon historical performance as part of a multi-barrier process involving oxidation to form hydroxyl radicals followed by biofiltration commonly employed in drinking water for disinfection and oxidation, as in the case of ozone or ultraviolet (UV); or advanced oxidation processes (UV peroxide) employed in wastewater reuse applications specifically for the reduction of contaminants of emerging concern.

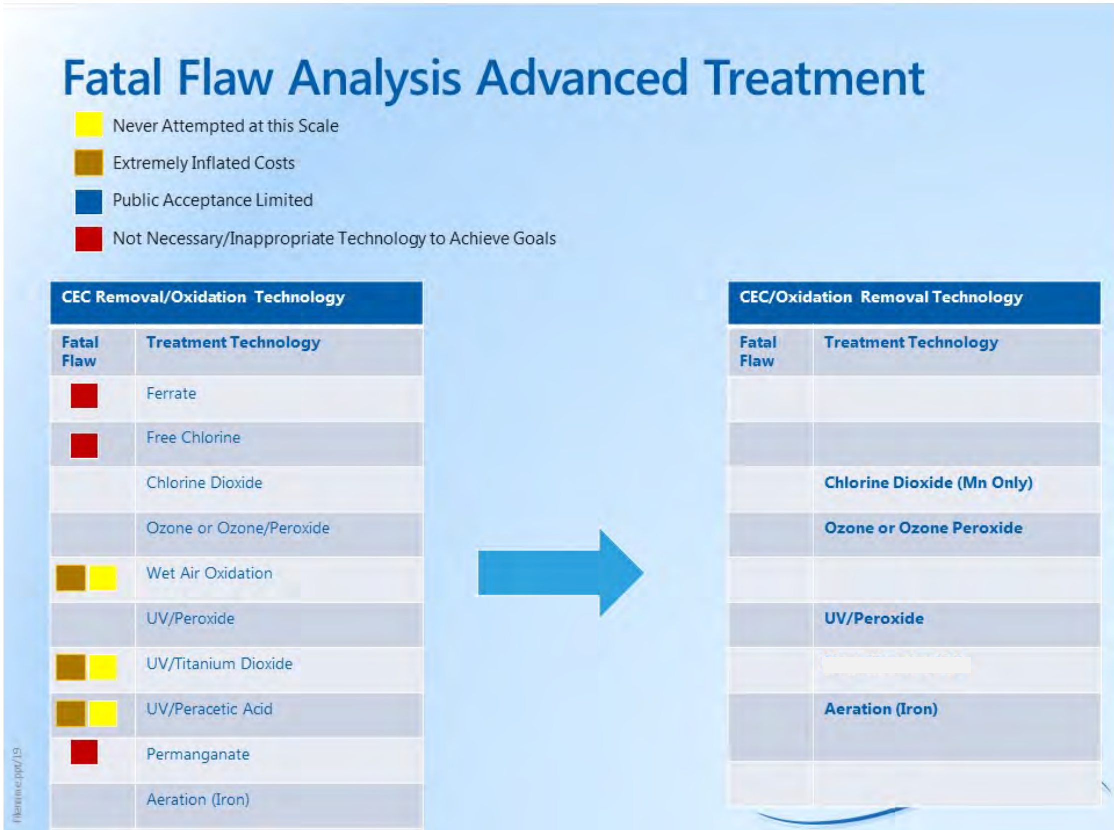



Figure 8 Fatal Flaw Analysis – CEC Removal/Oxidation Technologies

Figure 9 provides a summary of the fatal flaw analysis for the DBP/DBP by-product precursor removal technologies for the advanced treatment processes as part of the supplemental treatment process. These have been shortlisted to technologies and processes commonly employed in the drinking water field to reduce the potential for disinfection by product formation when using free chlorine by removing the precursors that react to form disinfection byproducts (total organic carbon) due to the nature of the disinfection by products formed, it was found during the previous studies that removal of disinfection by-products after formation by physical unit processes (such as air stripping) were impractical because some of the compounds formed required a sufficiently high number of aerators that it became too costly to employ with in the distribution system.

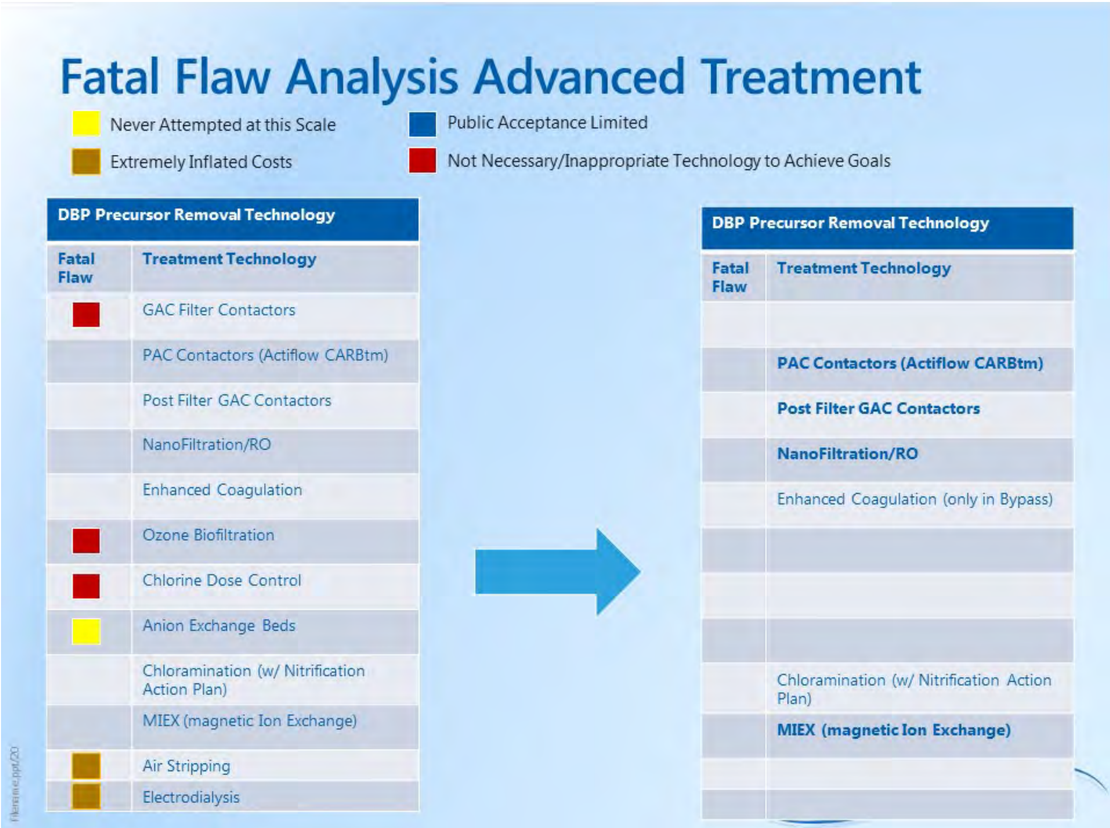



Figure 9 Fatal Flaw Analysis – DBP/DBP precursor Removal Technologies

The development of a shortlist of treatment technologies within the framework of the established boundaries completed the visioning phase of the DWPWG process. The next phase involves the assembly of viable alternatives that includes a base treatment process with and without the supplemental processes to achieve a particular tiered water quality goal and the incorporation of the structured decision analysis process to shortlist, analyze, and select the recommended treatment alternative from this suite of viable alternatives.

Section 3

# ALTERNATIVE EVALUATION

## 3.1 Purpose

The purpose of the evaluation phase of the project was to establish a shortlisted set of viable base and supplemental alternatives that could be evaluated in additional detail. This included the following:

- Establish a set of viable base and supplemental alternatives.
- Screen the alternatives using a level 5 cost estimate.
- Select criteria that will be used to evaluate the alternatives.
- Establish weighting of the criteria and assign scores for each alternative.
- Rank the alternatives with respect to the criteria weighting and scoring and establish a shortlist of alternatives for further evaluation.

## 3.2 Meetings and Workshops

The following public meetings were held during the evaluation phase of the project:

- Criteria Selection Workshop –October 11, 2017.
- Pairwise Comparison and Ranking Workshop I –November 13, 2017.
- Pairwise Comparison and Ranking Workshop II –January 8, 2018.

A summary of the workshop materials are provided in Appendix E.

## 3.3 Establish Viable Set of Treatment (Base and Supplemental) Alternatives

### 3.3.1 Establish Potential Combination of Base and Supplemental Alternatives to Achieve Treatment Goals

At the completion of the visioning process, the boundaries of the investigations were established and potentially viable Treatment Technologies were identified following a fatal flaw analysis. The next step in the process employed by the DWPWG was to assemble a viable set of base and supplemental alternatives from these treatment technologies. As previously discussed these would consist of a base treatment alternative that accomplished, at a minimum the first tier of water quality goals with supplemental alternatives that would permit achievement of all or some of the advanced tier water quality goals. Table 4 provides a summary of the preliminary alternatives assembled for the "base and Supplemental" treatment technologies established from the visioning process.

Table 4 Summary of Preliminary Alternatives

| Tier 1 Water Quality Goals: Base Alternatives | Tier 2 – GWUDI Compliance | Tier 3 Water Quality Goals | |
|---|---|---|---|
| | | DBP Control | CEC Removal |
| B1.1 - Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, S2.2, S2.3, or S2.4 | Add S3.1, or S3.2 |
| B1.2 - Expand Existing Plant w/Conventional Softening (New 15 mgd Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, S2.3, or S2.4 | Add S3.1, or S3.2 |
| B2 - New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, S2.3, or S2.4 | Add S3.1, or S3.2 |
| B3 - Replace Filters w/UF Membranes | ● | ○ | ○ |
| | | Add S2.1, S2.2, S2.3, or S2.4 | Add S3.1, or S3.2 |
| B4 - Replace Plant w/RO Facility | ● | ● | ◐ |
| | | Add S2.1, S2.2, S2.3, or S2.4 | Add S3.1, or S3.2 |
| B5 - Replace Conventional Softening w/Pellet Softening | ● | ○ | ○ |
| | | Add S2.1, S2.2, S2.3, or S2.4 | Add S3.1, or S3.2 |

Key:

● Yes ◐ Partial ○ No

- S1.1 - Expansion to GWUDI
- S2.1 - Granular Activated Carbon (GAC)
- S2.2 - Magnetic Ion Exchange (MIEX)
- S2.3 - Actiflo™ CARB
- S2.4 - Ozone/Biofiltration
- S3.1 - UV Disinfection/Peroxide
- S3.2 - Ozone/Biofiltration

### 3.3.2 Screen Base Alternatives

Table 5 presents the cost classification system as applied in Engineering, Procurement, and construction for the Process Industries as developed by the American Association of Cost Estimators (AACE). To conduct further screening of these alternatives, level 5 cost estimates were prepared of each of the alternatives to determine if the anticipated cost range of one or more of these alternatives was substantially higher.

Table 5 AACE Cost Classification System

| Estimate Class | Primary Characteristic | Secondary Characteristic | | |
|---|---|---|---|---|
| | Maturity Level of Project Definition Deliverables (as % of definition) | End Usage – Typical Purpose of Estimate | Methodology – Typical Estimating Method | Expected Range of Accuracy Typical variation in low to high |
| Class 5 | 0% to 2% | Concept Screening | Capacity factored<br>Parametric models<br>Judgement or analogy | L: -20% to +50%<br>H: +30% to +100% |
| Class 4 | 1% to 15% | Study or Feasibility | Equipment factored<br>Parametric models | L: -15% to +30%<br>H: +20% to +50% |
| Class 3 | 10% to 40% | Budget Authorization or Control | Semi-detailed unit costs with assembly level line items | L: -10% to -20%<br>H: +10% to +30% |
| Class 2 | 30% to 70% | Control or bid/tender | Detailed unit costs with forced detail take-off | L: -5% to -15%<br>H: +5% to +20% |
| Class 1 | 65% to 100% | Check estimate or bid/tender | Detailed unit costs with detailed take-off | L: -3% to -10%<br>H: +3% to +15% |

Notes:
(1) Taken from 18R-97 Cost Estimate Classification System Published by AACE.

Based upon the comparison of the level 5 estimates for the capital and life cycle costs associated with each of the base alternatives, the following conclusions were made:

1. Eliminate Base Alternative B4 Replace Plant with RO facility: This alternative was eliminated due to a higher capital and life cycle cost of the alternative with respect to other combination of base and supplemental alternatives that accomplished the same water quality goals.
2. Eliminate Base Alternative B5 Pellet Softeners: this alternative was eliminated due to a higher life cycle cost of the alternative with respect to other base alternatives that accomplished the same water quality goals.

### 3.3.3 Screen Supplemental Alternatives

Similar to the base alternatives, the supplemental alternatives were screened for excessive costs (capital and/or life cycle) using a level 5 estimate. The conclusions of this screening process were as follows:

1. Eliminate Supplemental Alternative S2.2 (MIEX Carb) from consideration due to high operating costs (higher life cycle) than other viable DBP precursor removal technologies. Bench scale testing indicating an extremely low amount of bed volumes (number of volumes processed before resin becomes ineffective) leading to high operating costs due to resin loss during regeneration.

2. Eliminate Supplemental Alternative S2.4: An advanced oxidation process (ozone, Ozone peroxide, UV-peroxide, etc.) followed by biofiltration as a means to reduced disinfection by product precursors as results from other installations indicate this will not be sufficient to reduce disinfection by product precursors to allow complete use of free chlorine as a disinfectant in the distribution system. These options will remain, however, due to excellent ability to reduce CEC compounds.
3. Eliminate Supplemental Alternative S3.1 UV Disinfection: This alternative was eliminated due to the high costs of maintaining UV disinfection systems employing advanced oxidation facility downstream of a softening process.

Table 6 below presents a summary of the remaining viable alternatives following the preliminary screening process.

Table 6 Summary of Remaining Viable Alternatives Following Initial Screening Using AACE Level 5 Cost Estimates

| Tier 1 Water Quality Goals: Base Alternatives | Tier 2 – GWUDI Compliance | Tier 3 Water Quality Goals | |
|---|---|---|---|
| | | DBP Control | CEC Removal |
| B1.1 - Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, ~~S2.2~~, S2.3~~, or S2.4~~ | Add ~~S3.1~~, or S3.2 |
| B1.2 - Expand Existing Plant w/Conventional Softening (New 15 mgd Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2,~~ S2.3~~, or S2.4~~ | Add ~~S3.1~~, or S3.2 |
| B2 - New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2,~~ S2.3~~, or S2.4~~ | Add ~~S3.1~~, or S3.2 |
| B3 - Replace Filters w/UF Membranes | ● | ○ | ○ |
| | | Add S2.1, ~~S2.2~~, S2.3, ~~or S2.4~~ | ~~Add S3.1~~, or S3.2 |
| ~~B4 - Replace Plant w/RO Facility~~ | ~~●~~ | ~~●~~ | ~~◐~~ |
| | | ~~Add S2.1, S2.2, S2.3, or S2.4~~ | ~~Add S3.1, or S3.2~~ |
| ~~B5 - Replace Conventional Softening w/Pellet Softening~~ | ~~●~~ | ~~○~~ | ~~○~~ |
| | | ~~Add S2.1, S2.2, S2.3, or S2.4~~ | ~~Add S3.1, or S3.2~~ |

Key:

● Yes ◐ Partial ○ No

- S1.1 - Expansion to GWUDI
- S2.1 - Granular Activated Carbon (GAC)
- ~~S2.2 - Magnetic Ion Exchange (MIEX)~~
- S2.3 - Actiflo™ CARB
- ~~S2.4 - Ozone/Biofiltration~~
- ~~S3.1 - UV Disinfection/Peroxide~~
- S3.2 - Ozone/Biofiltration

## 3.4 Evaluation Criteria

The Criteria Selection Workshop was held with the DWPWG on October 11, 2017. As part of this workshop, potential evaluation criteria and sub-criteria for the various alternatives were presented and discussed. In addition, the Structured Decision Analysis process was presented.

### 3.4.1 Structured Decision Analysis

The Structured Decision Analysis (SDA) that was used for the evaluation process is an effective way of making an informed decision for a complex problem. The primary benefit of using SDA is that it's designed to deal explicitly with uncertainty, and responding transparently to public preferences or values in the decision making process. This process can be divided into three simple phases each containing helpful steps for problem solving as seen below:

- Structured Decision Analysis - Phase I:
  - Define the decision makers and a simple and clear decision statement.
  - Define a potential set of viable alternatives.
  - Select the criteria that will be used to differentiate the alternatives.
  - Assign weights to the criteria and assure there is no redundancy nor 'must haves' (pass/fail criteria).
- Structured Decision Analysis - Phase II:
  - Score each alternative against each criterion (without "weight").
  - Identify 'data gaps' or 'knowledge gaps' as a part of the scoring.
  - Fill 'data and knowledge gaps'.
  - Combine the scores and weights to rank the alternatives.
- Structured Decision Analysis - Phase III:
  - Complete final ranking of each alternative.
  - Select 'best' alternative.
  - Test sensitivity of 'best' (the gut check analysis).
  - Assign the 'devil's advocate' to assure a robust decision.

In general, the SDA model receives input from the group making the decisions (DWPWG) regarding the selection and weighting of criterion. Each alternative is then scored against the criterion. The scores and weights are then combined to develop a ranking of the alternatives. This concept is illustrated in Figure 10.

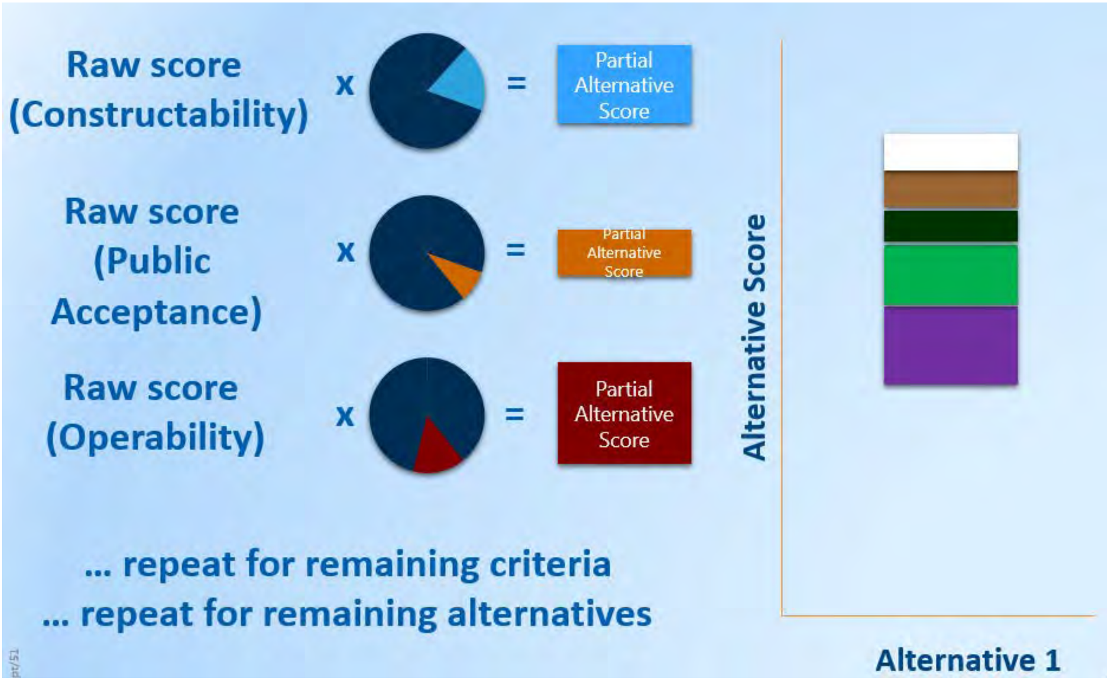



Figure 10 Alternative Weighted Scoring Process

Following the ranking of alternatives, the model can then be used to test the sensitivity of the top alternatives. Criteria weightings that were previously determined can be adjusted to determine their effect on the alternative. This concept is illustrated in Figure 11. It can be seen, that as the importance of operation and maintenance costs is adjusted, the top alternative can change.

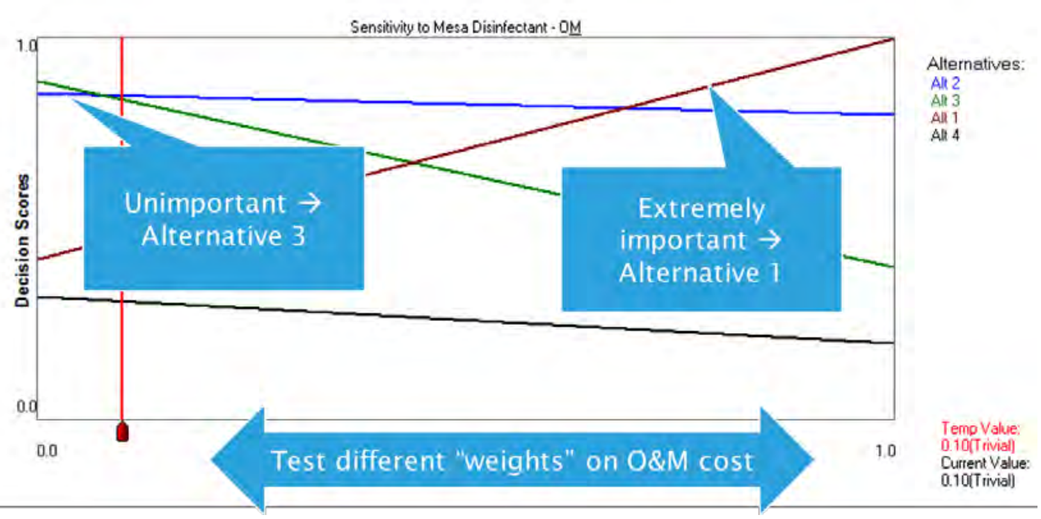



Figure 11 Sensitivity Analysis Example

### 3.4.2 Criteria Selection and Ranking

During the Criteria Selection Workshop, the DWPWG identified the criteria from which to base the alternatives screening process. Following this, the criteria were grouped into primary criteria and sub-criteria. The primary criteria that were agreed upon included constructability, water quality, operability, project cost, and GWUDI facility.

The relative importance of each primary criterion was determined by pair-wise comparison by the DWPWG members. Sixteen sub-criteria were identified and grouped with one of the five primary criteria by the DWPWG members. The relative importance of the sub-criteria associated with each primary criterion was similarly determined by pair-wise comparison by each of the DWPWG members and submitted to Carollo for analysis. A summary of the submitted criteria evaluation forms is provided in Figure 12.

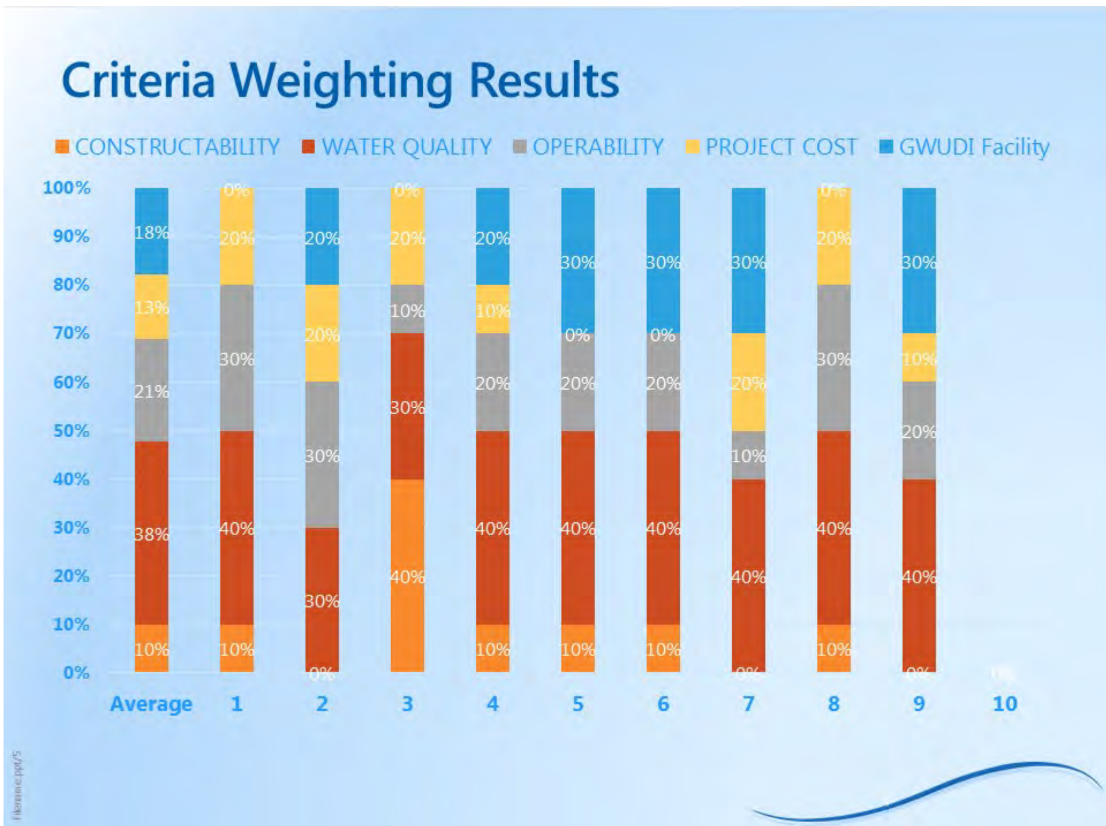



Figure 12 Summary of Pairwise Comparison from DWPWG Worksheets

Criterium Decision Plus (CDP) was used to facilitate assigning a numerical weighting (percent contribution to the total decision) to each primary and sub-criteria based on the results of the pair-wise comparisons. The ultimate numerical weighting assigned to each primary and sub-criteria was defined through an iterative process of reviewing and refining the relative weighting of each criteria. The resultant criteria, sub criteria, and associated weighting are detailed in Table 7. Water quality goals for total trihalomethanes (TTHMs) was the largest contributor to the decision with sustainability and water quality goals for CECs also determined to be significant factors.

Table 7 Summary of Primary and Sub-Criteria Ranking

| | |
|---|---|
| 0.10 | Constructability |
| 0.043 | Maintain Plant Operations |
| 0.006 | Schedule |
| 0.028 | Space Requirements |
| 0.024 | Permitting |
| 0.38E | Water Quality |
| E | Water Quality Goals - TTHMs |
| 0.098 | Sustainability |
| 0.105 | Water Quality Goals - CECs |
| 0.000 | Communication |
| 0.21 | Operability |
| 0.028 | Residuals Production |
| 0.040 | Staffing Requirements |
| 0.056 | Proven Technology |
| 0.028 | Maintenance Complexity |
| 0.059 | Source Water Quality |
| 0.13 | Project Cost |
| 0.022 | Capital Cost |
| 0.052 | Operational Cost |
| 0.037 | Maintenance Cost |
| 0.022 | Life Cycle Cost |
| 0.18 | GWUDI Facility |

### 3.4.3 Establish Criteria Scores:

Table 8 details the primary and sub-criteria used to screen alternatives. It also summarizes the associated goal/measurement and scale applied for scoring of alternatives based on each sub-criteria. A scale range of 0-5 was used in all cases, including intermediate values of 1, 2, 3, and 4. Table 8 also details the rationale associated with establishing the upper boundary (i.e., score of 5) and the lower boundary (i.e., score of 0) for each sub-criteria. Intermediate scores were assigned by relative comparison of each sub-criteria amongst alternatives. The sub-criteria scores were then multiplied by their associated weighting and totaled to result in a total score for each alternative for direct comparison.

Table 8 Evaluation Sub-Criterion for McBaine WTP Expansion

| Primary Criteria | Sub-Criteria | Goal/Measurement | Scale Range |
|---|---|---|---|
| Constructability | Maintain Plant Operations | Plant must be able to produce finished water during construction activities. | 0 - Unable to phase process with multiple plant shutdowns.<br>5 - Many options for phasing process alternative with minimal disruption to existing plant operations. |
| | Schedule | Construction duration in months, shorter duration is desired. | 0 - Very long construction period.<br>5 - Short construction period. |
| | Space Requirements | Square feet, Smaller footprint is better. | 0 - Largest footprint required to accommodate WTP structures (not including residuals handling).<br>5 - Smallest footprint required to accommodate WTP structures (not including residuals handling). |
| | Permitting | Number of permits required and difficulty to obtain. | 0 - Numerous permits needed requiring significant involvement from multiple stakeholders.<br>5 - Minimal permitting requirements with limited stakeholder involvement. |
| Water Quality | Water Quality Goals - TTHMs | A process that can remove TTHMs and other DBPs. | 0 - No removal of TTHMs or DBPs.<br>5 - Highest removal of TTHMs and DBPs based upon Best Available Control Technology. |
| | Sustainability | Minimize carbon footprint.<br>Minimize chemical usage.<br>Maximize energy efficiency.<br>Opportunities for reuse. | 0 - Process is not energy efficient and uses large quantities of chemicals for treatment. No opportunities for reusing waste materials.<br>5 - Process is efficient and uses small quantities of chemicals, uses less energy, and offers opportunities for reusing waste materials. |
| | Water Quality Goals - CECs | A process that can remove CECs. | 0 - No removal of CECs.<br>5 - Highest removal of CECs based upon Best Available Control Technology. |
| | Communication | A process that is easily communicated to and accepted by the public and the decision makers is good. | 0 - Process alternative is difficult to demonstrate to stakeholders and is difficult to obtain stakeholder and general public buy-in.<br>5 - Process alternative is easy to explain and widely acceptable to stakeholders and general public. |

Table 8 Evaluation Sub-Criterion for McBaine WTP Expansion (cont.)

| Primary Criteria | Sub-Criteria | Goal/Measurement | Scale Range |
|---|---|---|---|
| Operability | Residuals Production | Tons per year. Smaller quantities of residuals are desired. | 0 - High residuals production.<br>5 - Low residuals production. |
| | Staffing Requirements | Alternatives that do not require intensive training and large numbers of operators are desirable. | 0 - Extensive training is required and the process requires several operators at any given time.<br>5 - Training requirements are less complicated and fewer operators are required to operate the process. |
| | Proven Technology | Alternatives including processes with a proven track record score higher than newer, less proven technologies. | 0 - No full-scale installations.<br>5 - Extensive full-scale experience both in number of installations and number of years in service. |
| | Maintenance Complexity | Mechanical Intensity. Alternatives with more processes and/or a higher degree of sophistication are less desirable. | 0 - Numerous processes with extensive short- and long-term maintenance needs.<br>5 - Fewer processes with low level of sophistication resulting in easier maintenance. |
| | Source Water Quality | Alternatives include processes that can handle large variability in source water quality without impact to finished water quality is good. | 0 - Many processes sensitive to water quality changes requiring frequent operator intervention.<br>5- Fewer processes sensitive to water quality changes requiring less operator intervention. |

Table 8 Evaluation Sub-Criterion for McBaine WTP Expansion (cont.)

| Primary Criteria | Sub-Criteria | Goal/Measurement | Scale Range |
|---|---|---|---|
| Project Cost | Capital Cost | Initial capital investment necessary to design, procure, construct, and place into successful working operation improvements or process modifications recommended by a particular alternative. | 0 – Highest Capital Cost (H)<br>5 – lowest Capital Cost (L)<br>Other costs (A) will be calculated:<br>A=(10-0)*(H –A)/(H-L) |
| | Operational Cost | The operational costs over the anticipated life cycle of the process equipment recommended including labor and consumables presented in an annualized basis for assessing impact on rates. | 0 – Highest Annual Operational Cost (H)<br>5 – lowest Operational Cost (L)<br>Other costs (A) will be calculated:<br>A=(10-0)*(H –A)/(H-L) |
| | Maintenance Cost | The maintenance costs over the anticipated life cycle of the process equipment recommended including labor and consumables (oil, grease, etc.) presented in an annualized basis for assessing impact on rates. | 0 – Highest Annual Maintenance Cost (H)<br>5 – Lowest Maintenance Cost (L)<br>Other costs (A) will be calculated:<br>A=(10-0)*(H –A)/(H-L) |
| | Life Cycle Cost | The total present worth costs representing a summary of the initial capital costs, annualized maintenance costs, and annualized operational costs over a 20 year period presented in "today's dollars" using a discount rate reflective of the time value of money. | 0 – Highest Life Cycle Cost (H)<br>5 – Lowest Life Cycle Cost (L)<br>Other costs (A) will be calculated:<br>A=(10-0)*(H –A)/(H-L) |
| GWUDI Facility | | The assessment of the capability of the facility to maintain full compliance with the water quality goals and regulations associated with a source water classified by the state as a "Groundwater Under the Direct Influence of Surface Water." | 0 – Significant capital and operational/maintenance investment will be required to enable GWUDI compliance.<br>3 - Relatively minor capital investments (i.e. tweaks in process arrangement) will be required for GWUDI compliance.<br>4 – Minor operational changes will be required for GWUDI compliance.<br>5- Facilities are fully compliant with GWUDI regulations and water quality goals associated with at GWUDI facility. |

### 3.4.4 Further Screening Utilizing CDP Software – Base Alternatives

Similar to the original 2012 PDR, CDP software was used to perform the ranking and evaluation of the preliminary alternatives. Each of the remaining base alternatives were further screened with respect to the other base alternatives with respect to the established weighted criteria. Figure 13 presents a summary of the results of the preliminary screening of the base alternatives with respect to the weighted criteria using the CDP platform.

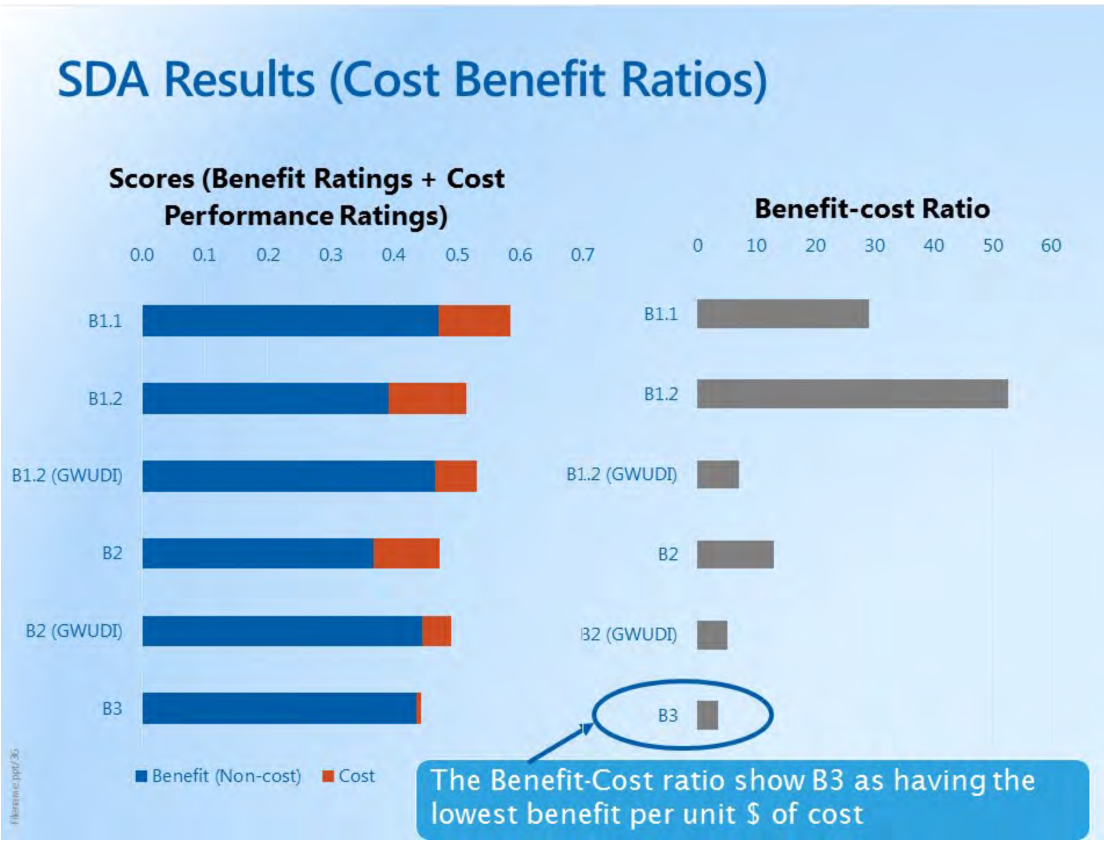



Figure 13 Summary of Base Alternative Evaluation – CDP Analysis

Figure 13 illustrates the low benefit: cost ratio of alternative B3- Ultrafiltration Membranes based upon the evaluation criteria and level 5 cost estimates. Further sensitivity analysis indicated the robustness of the evaluation and the decision to exclude Alternative B3 from further evaluation.

Table 9 presents the updated summary of viable alternatives based upon the results of the screening of the alternatives.

Table 9 Summary of Remaining Viable Alternatives Following Final Screening Using CDP Model

| Tier 1 Water Quality Goals: Base Alternatives | Tier 2 – GWUDI Compliance | Tier 3 Water Quality Goals | |
|---|---|---|---|
| | | DBP Control | CEC Removal |
| B1.1 - Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, ~~S2.2~~, S2.3~~, or S2.4~~ | Add ~~S3.1~~, or S3.2 |
| B1.2 - Expand Existing Plant w/Conventional Softening (New 15 mgd Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2,~~ S2.3~~, or S2.4~~ | Add ~~S3.1~~, or S3.2 |
| B2 - New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2,~~ S2.3~~, or S2.4~~ | Add ~~S3.1~~, or S3.2 |
| ~~B3 - Replace Filters w/UF Membranes~~ | ~~●~~ | ~~○~~ | ~~○~~ |
| | | ~~Add S2.1, S2.2, S2.3, or S2.4~~ | ~~Add S3.1, or S3.2~~ |
| ~~B4 - Replace Plant w/RO Facility~~ | ~~●~~ | ~~●~~ | ~~◐~~ |
| | | ~~Add S2.1, S2.2, S2.3, or S2.4~~ | ~~Add S3.1, or S3.2~~ |
| ~~B5 - Replace Conventional Softening w/Pellet Softening~~ | ~~●~~ | ~~○~~ | ~~○~~ |
| | | ~~Add S2.1, S2.2, S2.3, or S2.4~~ | ~~Add S3.1, or S3.2~~ |

Key:

● Yes ◐ Partial ○ No

- S1.1 - Expansion to GWUDI
- S2.1 - Granular Activated Carbon (GAC)
- ~~S2.2 - Magnetic Ion Exchange (MIEX)~~
- S2.3 - Actiflo™ CARB
- ~~S2.4 - Ozone/Biofiltration~~
- ~~S3.1 - UV Disinfection/Peroxide~~
- S3.2 - Ozone/Biofiltration

Figure 14 presents a summary of the treatment alternatives considered for detailed ranking and evaluation using the CDP model.

**Treatment Alternatives**

| Base | Supplement | Description | Comments |
|---|---|---|---|
| B1.1 | No Supplement | Only Upgrade Existing | GWUDI Compliant, Requires Chloramines |
| B1.1 | S2.1 | Upgrade Existing With GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine |
| B1.1 | S2.1, S3.2 | Upgrade Existing with Ozone/BAF and GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine |
| B1.2 | No Supplement | New Filters (15mgd) | Not fully GWUDI Compliant<br>Requires Chloramines |
| B1.2 | S1.1 | New Filters (15 mgd) with plant upgraded | GWUDI Compliant<br>Requires Chloramines |
| B1.2 | S1.1, S2.1 | New Filters (15 mgd) with GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine |
| B1.2 | S1.1, S2.1, S3.2 | New Filter (15 mgdd) with Ozone/BAF and GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine<br>Adds CEC's |
| B2 | No Supplement | New Treatment Train (15 mgd) | Not fully GWUDI Compliant<br>Requires Chloramines |
| B2 | S1.1 | New Treatment Train (15 mgd) with plant upgraded. | GWUDI Compliant<br>Requires Chloramines |
| B2 | S1.1, S.2.1 | New Treatment Train (15 mgd) and GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine |
| B2 | S1.1, S2.1, S3.2 | New Treatment Train (15 mgd) with Ozone/BAF and GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine<br>Adds CEC's |

Figure 14 Summary of Preliminary Alternatives

## 3.5 Ranking of Preliminary Alternatives

Similar to the original 2012 PDR, CDP software was used to perform the ranking and evaluation of the preliminary alternatives. Figure 15 presents a summary of the rankings that were established with respect to the non-economic and economic criterion previously indicated. The relative weight of each criterion is represented by a particular color band within the total band for each alternative. The higher the value, the stronger that particular alternative satisfies the criteria. The alternatives that best satisfy the relatively ranked criteria are represented with the highest overall bands.

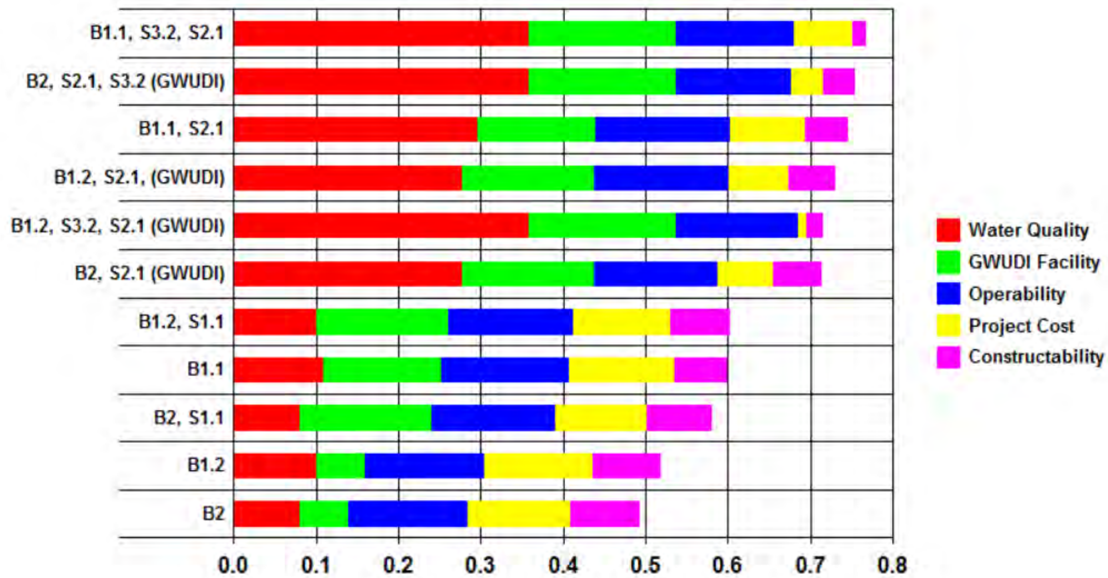



Figure 15 Results of Preliminary Alternatives Screening

On January 8, 2018, the Pairwise Comparison and Preliminary Ranking Workshop was held to discuss the results of the preliminary screening process and to develop a shortlisted set of alternatives. It can be noted from Figure 15, that because of the high weight given to Water Quality and GWUDI, it was the higher cost alternatives that scored highest and provided the most benefit. Based on the results, the team decided to eliminate the two alternatives that didn't include a GWUDI compliant facility (B1.2 and B2). In addition, it was decided to eliminate Alternative B1.2, S3.2, S2.1, S1.1 (GWUDI) due to the moderate overall score, low constructability rating, and high cost.

Further analysis of the alternatives was done by compiling the benefit/cost ratios for each alternative. This analysis indicated that some alternatives offered little additional benefit at high incremental costs. A summary of the overall ratings and benefit/cost ratios is presented in Figure 16.

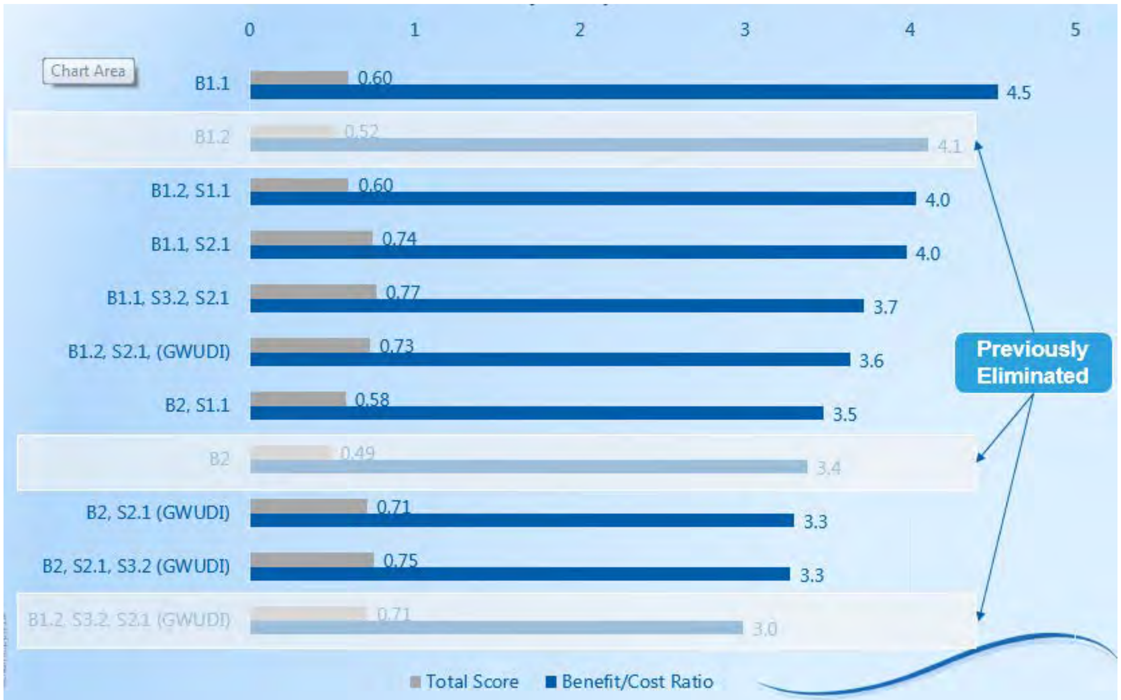



Figure 16 Total Scores and Benefit/Cost Ratios

Due to the low benefit/cost ratios presented in Figure 16, it was decided to eliminate Alternative B2, S2.1, S1.1 (GWUDI) and Alternative B2, S1.1 (GWUDI). In addition, upon further evaluation of the remaining alternatives, it was determined that due to space constraints on the site, the only viable base alternative that could implement S3.2 (Ozone/Biofiltration) in the future was B2. Because of this, regardless of benefit/cost ratio, it was decided to keep Alternative B2, S2.1, S3.2, S1.1 (GWUDI) and eliminate Alternative B1.1, S3.2, S2.1. In summary, the following alternatives were shortlisted for further evaluation:

- B1.1 - Expand existing plant (rerate existing filters).
- B1.1, S2.1 - Expand existing plant (rerate existing filters) and add post filter GAC contactors.
- B1.2, S1.1 - Expand existing plant (new filter train).
- B1.2, S1.1, S2.1 - Expand existing plant (new filter train) and add post filter GAC contactors.
- B2, S1.1, S2.1, S3.2 - Expand existing plant (new treatment train), post treatment ozone/Biofiltration and post filter GAC contactors.

Section 4

# FINAL RANKING AND RECOMMENDATIONS

## 4.1 Purpose

The purpose of the final ranking phase of the project was to further define the shortlisted alternatives and develop final rankings that can be used to establish a recommendation. This included the following:

- Identify data gaps, develop layouts, and refine cost opinions.
- Update scores and re-rank shortlisted alternatives.
- Develop final rankings and recommendations.

## 4.2 Meetings and Workshops

The following public meeting was held during the final ranking phase of the project:

- Final Ranking Workshop –January 29, 2018.

## 4.3 Data Gap Analysis

The purpose of the data gap analysis that was performed was to identify any missing information in order to further refine scores for the shortlisted alternatives. This may include modifying alternatives to address potential operability or permitting issues. Some of the concerns identified during the data gap analysis include the following:

- Due to the hydraulic capacity of existing facilities, improvements to rerate the existing filters may lead to potential problems. Alternatives that include rerating the filters should conservatively consider adding a pump station to address the concern.
- The useful life of the media in GAC contactors is unknown. Alternatives that include GAC contactors should conservatively assume a carbon life of 3 years. Pilot testing is recommended to determine useful life for DBP management.

By identifying these data gaps, the team was able to update scores for each alternative to reflect the results of the data gap analysis providing a more refined ranking.

## 4.4 Level 4 Cost Estimates

In addition to the data gap analysis, layouts and refined costs were developed for the shortlisted alternatives in order to update scores. This section presents a summary of each shortlisted alternative, along with the defined layouts and process flow diagrams. It should be noted that the cost estimates prepared for the analysis are considered Level 4 estimates by the AACE (see Figure 17) and contain a +50% to -30% level of accuracy. **The cost estimates developed for the final rankings are meant to be for relative comparison of the alternatives and are NOT to be used for budgetary purposes due to insufficient detail and lack of elements common to all alternatives (i.e. raw water pipeline, wellfield expansion, etc.).**

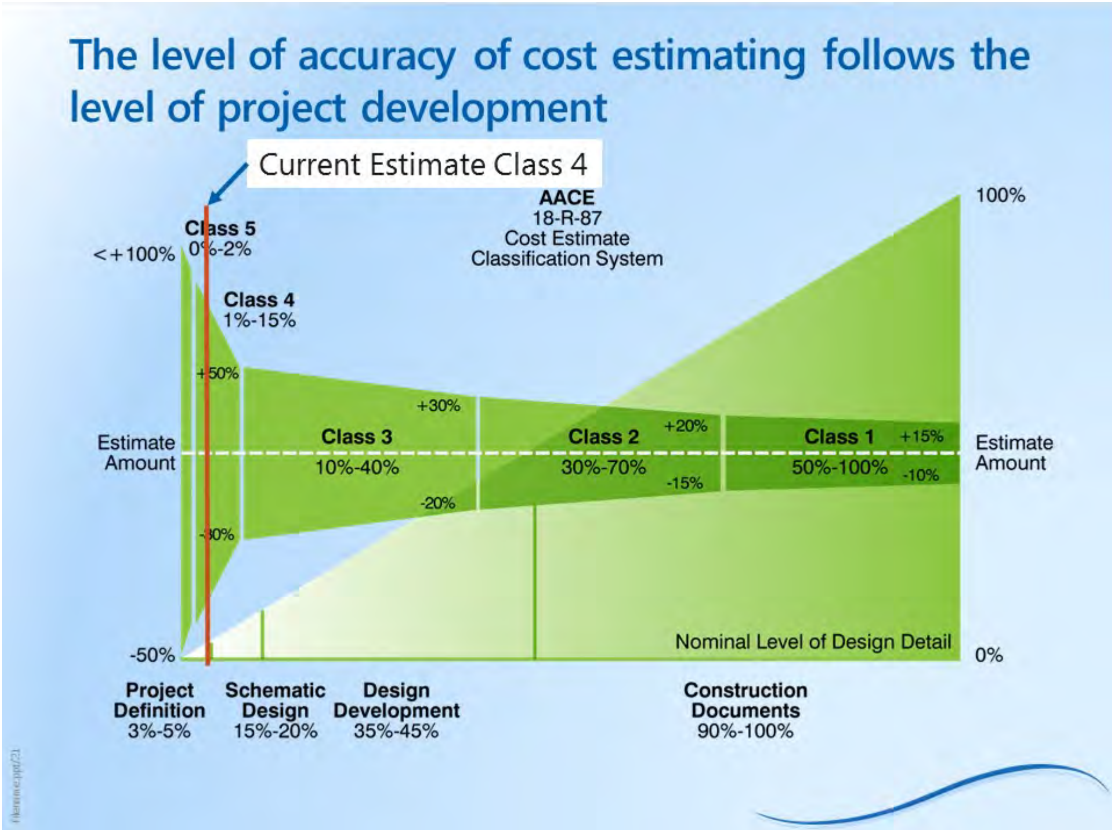



Figure 17 Level 4 Cost Estimates for Final Alternatives Ranking

## 4.5 Summary of Shortlisted Alternatives

### 4.5.1 Alternative B1.1 - Expand Existing Plant (Rerate Existing Filters)

This alternative includes construction of two new aerators, modifications to the primary basins, multiple new low lift pump stations, modifications to rerate the existing filters, new clearwells, and a new high service pump station for delivery of finished water to the distribution system. A summary of the highlights included with this alternative are presented below. An overall layout along with a process flow diagram for this alternative is presented in Figure 18 and Figure 19, respectively.

- Water Quality:
  - Likely requires chloramines to satisfy current Disinfection By-Product regulations.
  - Potential future regulatory concerns (CEC's) will need additional processes.
  - No significant improvement in overall water quality (except for GWUDI compliance).
- Operability:
  - Increased maintenance (new pumps).
  - Low lift pumps required to control filtration process and pump to clearwells, increasing complexity.
  - Most efficient use of space (easier phasing).

- Constructability:
  - Large disruption to plant operations (work on existing filters).
  - Minimal footprint of new facilities.
  - Rerating filters requires permitting variance.
- GWUDI Facility:
  - Improved filtration.
  - Disinfection to meet SWTR requirements.
- Project Costs:
  - Capital = $106 million.
  - O&M = $3.6 million.
  - Life Cycle = $160 million.

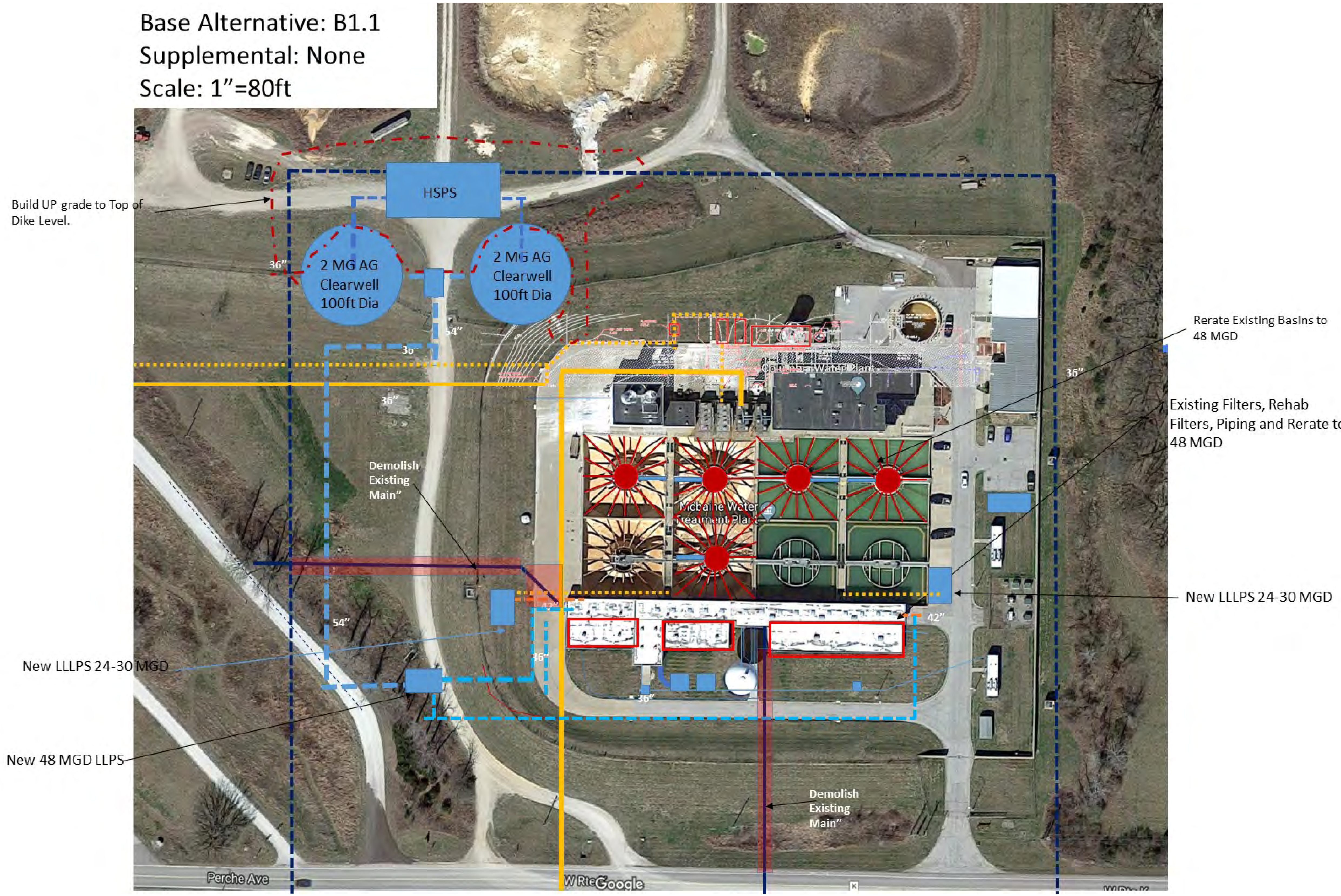



Figure 18 Alternative B1.1 Layout

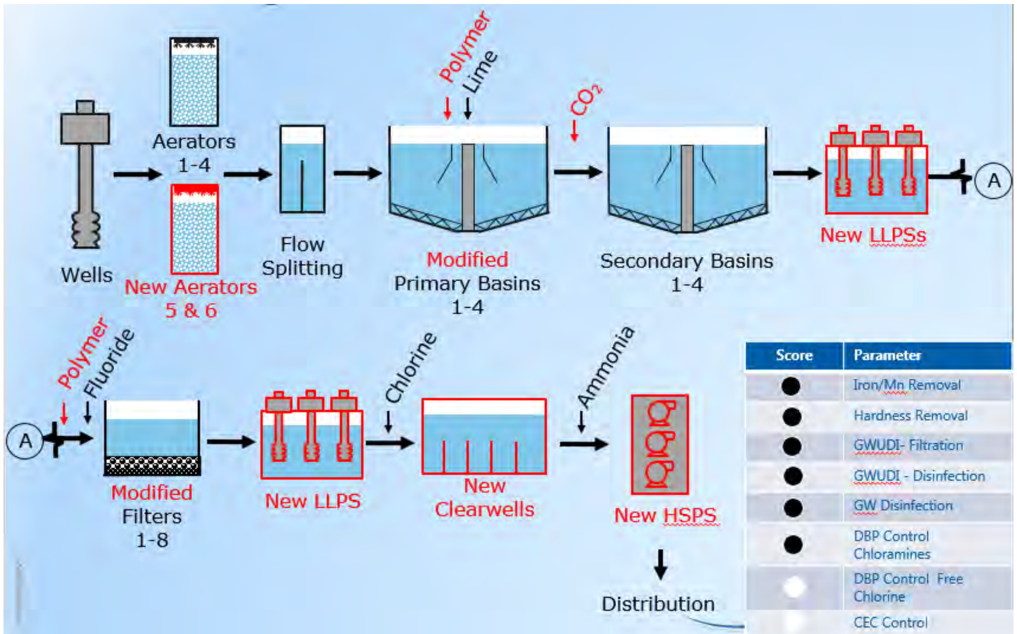



Figure 19 Alternative B1.1 Process Flow Schematic

### 4.5.2 Alternative B1.1, S2.1 - Expand Existing Plant (Rerate Existing Filters) and Add Post Filter GAC Contactors

This alternative includes the same improvements included in Alternative B1.1 with the addition of construction of GAC contactors. A summary of the highlights included with this alternative are presented below. An overall layout along with a process flow diagram for this alternative is presented in Figure 20 and Figure 21, respectively.

- Water Quality:
  - Ability to design finished water quality to meet DBP regulations without relying on chloramines.
  - Robust process that will remove some CECs. Operating cost may be impacted by future regulations due to process inefficiencies.
- Operability:
  - Additional staffing.
  - Staffing education for new processes (DBP control).
  - Increased maintenance (new pumps and process).
  - Moderate complexity.
- Constructability:
  - Large disruption to plant operations (work on existing filters).
  - Large space requirements will require some use of lagoon space.
  - Rerating filters requires permitting variance.
- GWUDI Facility:
  - Fully compliant.
- Project Costs:
  - Capital = $152 million.
  - O&M = $4.7 million.
  - Life Cycle = $221 million.

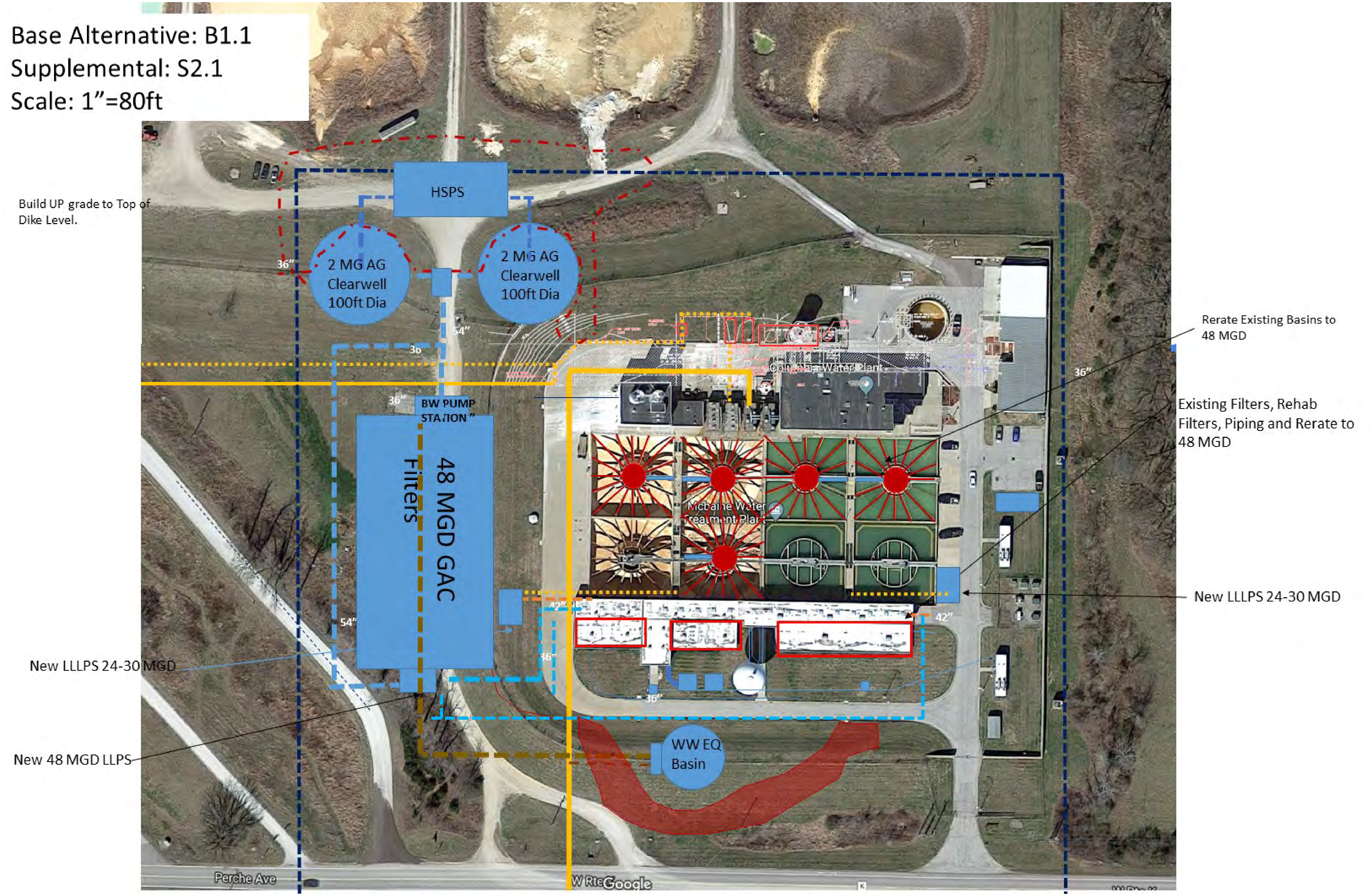



Figure 20 Alternative B1.1, S2.1 Layout

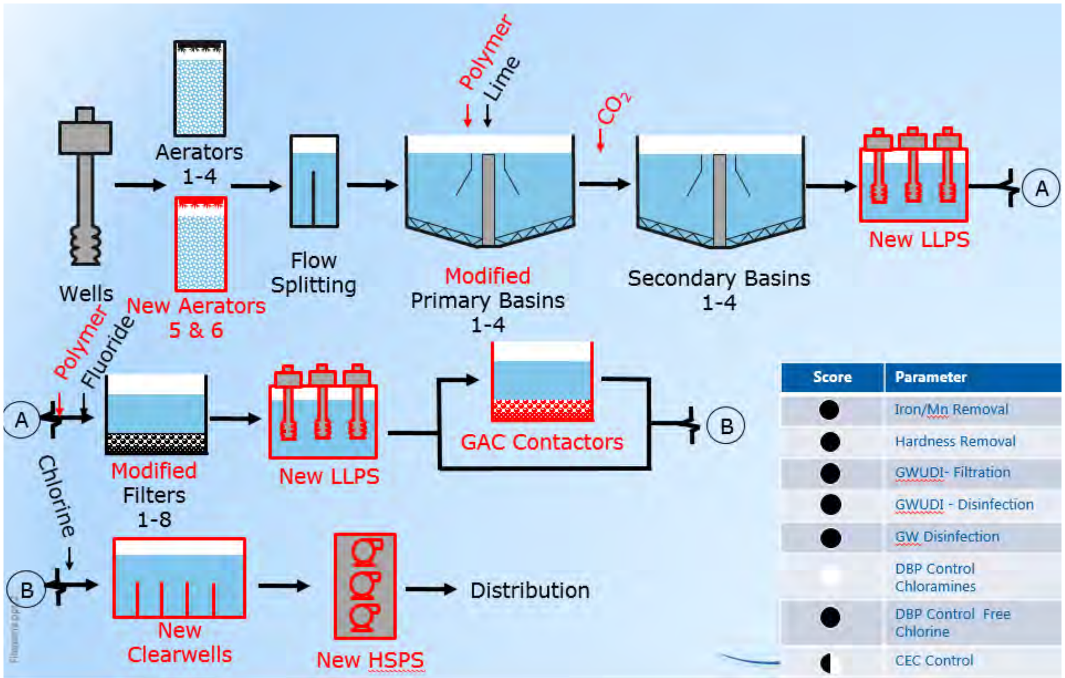



Figure 21 Alternative B1.1, S2.1 Process Flow Schematic

### 4.5.3 Alternative B1.2, S1.1 - Expand Existing Plant (New Filter Train)

This alternative includes construction of two new aerators, modifications to the primary basins, construction of a new filter train, modifications to existing filters for GWUDI compliance, multiple new low lift pump stations, new clearwells, and a new high service pump station for delivery of finished water to the distribution system. A summary of the highlights included with this alternative are presented below. An overall layout along with a process flow diagram for this alternative is presented in Figure 22 and Figure 23, respectively.

- Water Quality:
  - Likely requires chloramines to satisfy current Disinfection By-Product regulations.
  - Potential future regulatory concerns (CEC's) will need additional processes.
  - No significant improvement in overall water quality (except for GWUDI compliance).
- Operability:
  - Increased maintenance (new pumps and filters).
  - Minimal complexity.
  - Low lift pumps required for phasing and to minimize future construction costs.
  - A little more difficult to phase.
- Constructability:
  - Moderate disruption to plant operations.
  - Moderate space requirements.
- GWUDI Facility:
  - Fully compliant.
- Project Costs:
  - Capital = $124 million.
  - O&M = $3.6 million.
  - Life Cycle = $178 million.

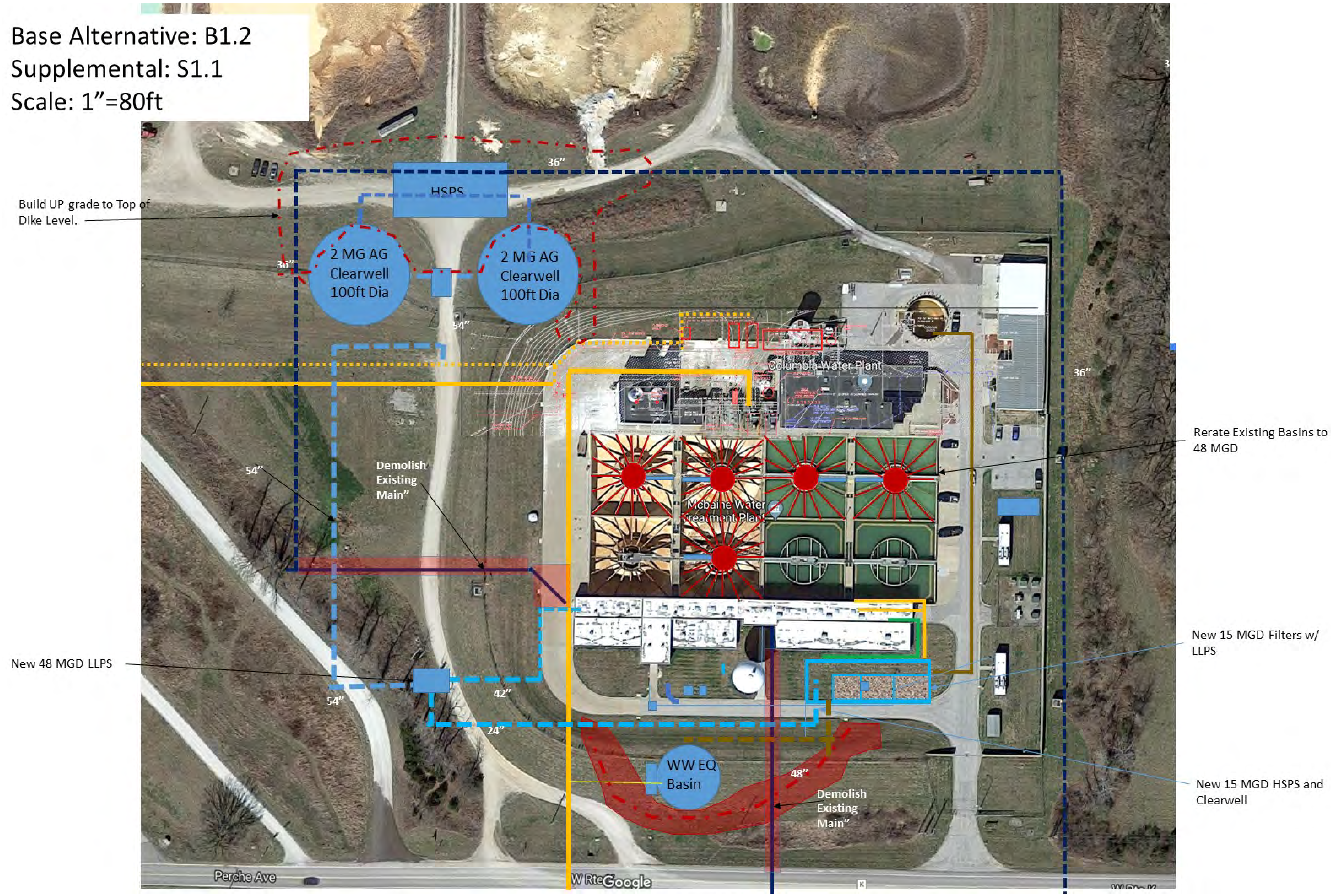



Figure 22 Alternative B1.2, S1.1 Layout

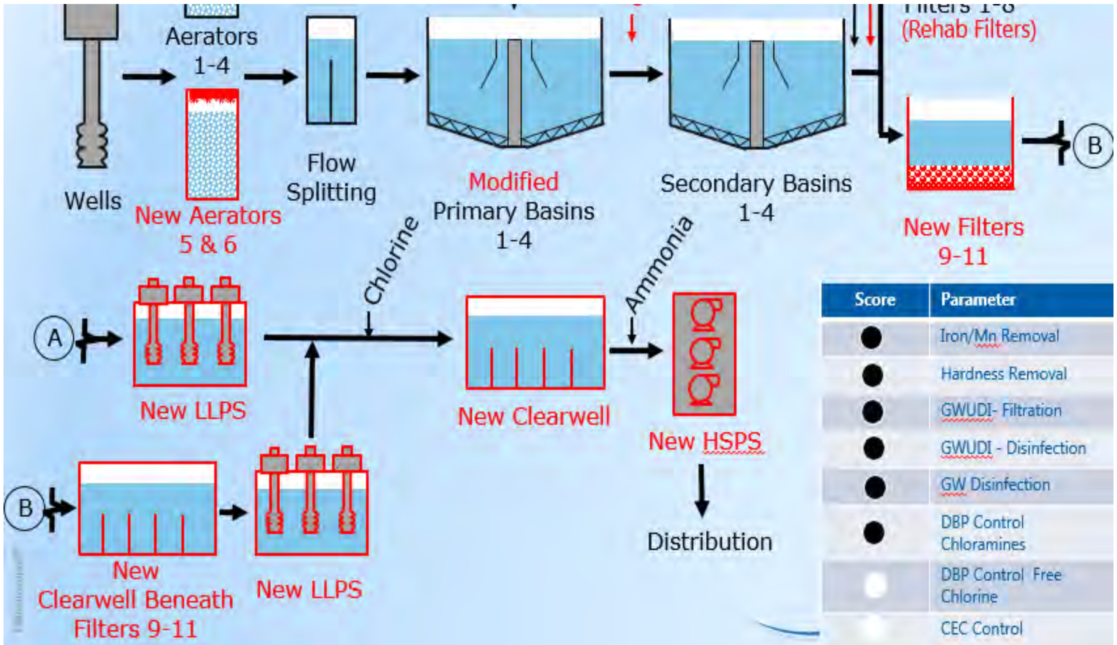



Figure 23 Alternative B1.2, S1.1 Process Flow Schematic

### 4.5.4 Alternative B1.2, S1.1, S2.1 - Expand Existing Plant (New Filter Train) and Add Post Filter GAC Contactors

This alternative includes the same improvements included in Alternative B1.2, S1.1 with the addition of construction of GAC contactors. A summary of the highlights included with this alternative are presented below. An overall layout along with a process flow diagram for this alternative is presented in Figure 24 and Figure 25, respectively.

- Water Quality:
  - Ability to design finished water quality to meet DBP regulations without relying on chloramines.
  - Robust process that will remove some CECs. Operating cost may be impacted by future regulations due to process inefficiencies.
- Operability:
  - Additional staffing.
  - Staffing education for new processes (DBP control).
  - Increased maintenance (new pumps, filters, and process).
  - Moderate complexity.
- Constructability:
  - Moderate disruption to plant operations.
  - Large space requirements.
- GWUDI Facility:
  - Fully compliant.
- Project Costs:
  - Capital = $166 million.
  - O&M = $4.7 million.
  - Life Cycle = $236 million.

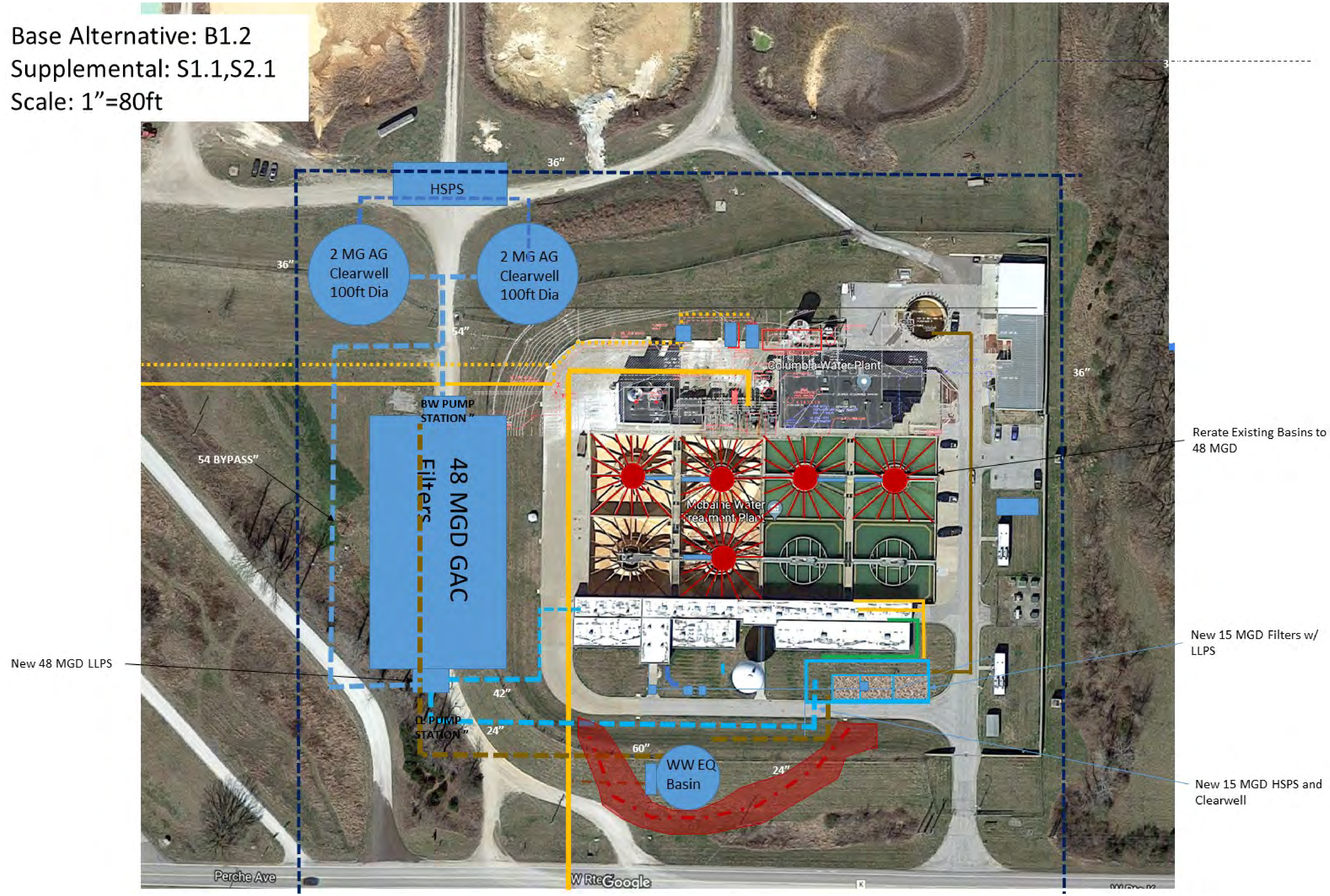



Figure 24 Alternative B1.2, S1.1, S2.1 Layout

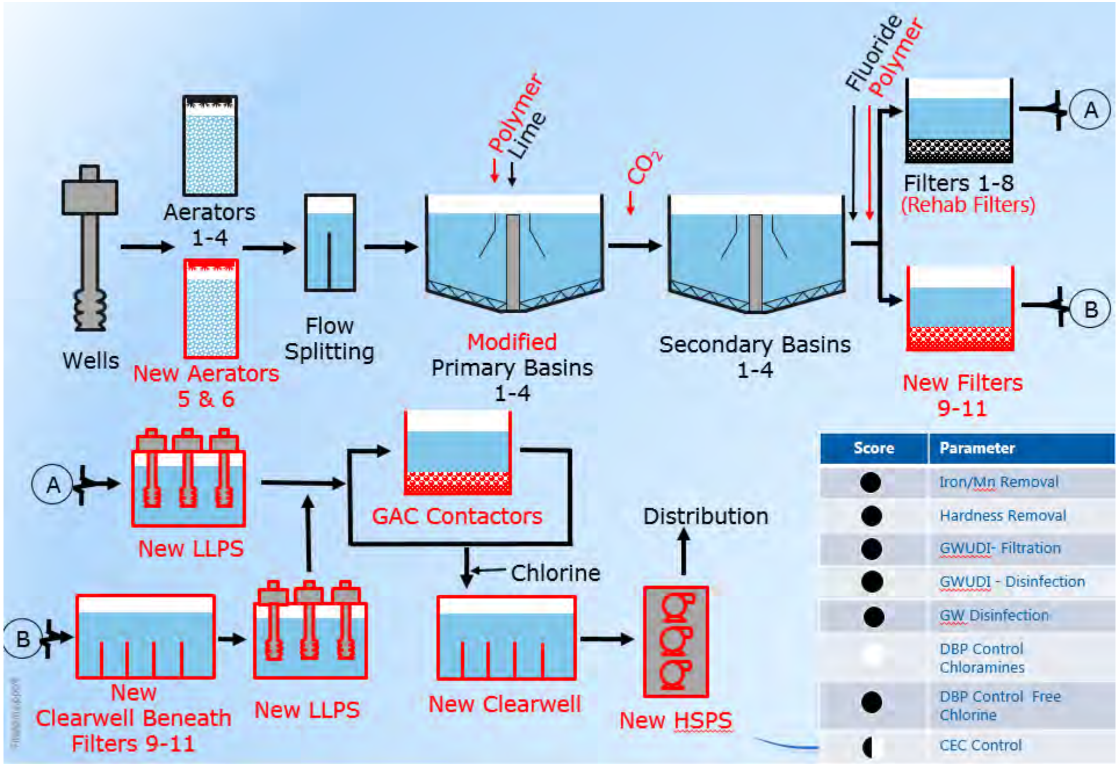



Figure 25 Alternative B1.2, S1.1, S2.1 Process Flow Schematic

### 4.5.5 Alternative B2, S1.1, S2.1, S3.2 - Expand Existing Plant (New Treatment Train), Post Treatment Ozone/Biofiltration, and Post Filter GAC Contactors

This alternative includes construction of a new treatment train consisting of two new aerators, a softening basin, a secondary basin, an ozone contactor, filters, and a low lift pump station. In addition, modifications to the existing train need to be performed, including modifications to Primary Basin No. 1 and No. 2, multiple new low lift pump stations, an ozone contactor, modifications to the filters for GWUDI compliance, new GAC contactors, new clearwells and a new high service pump station for delivery of finished water to the distribution system. A summary of the highlights included with this alternative are presented below. An overall layout along with process flow diagrams for this alternative is presented in Figure 26, Figure 27, and Figure 28, respectively.

- Water Quality:
  - Ability to design finished water quality to meet DBP regulations without relying on chloramines.
  - Best Available Technology for CEC removal. Synergistic impacts with post filter GAC.
- Operability:
  - Additional staffing.
  - Staffing education for new processes.
  - Increased maintenance (new pumps, filters, and process).
  - Most complex alternative to operate (two trains with multiple processes).

- Constructability:
  - Minimal disruption to plant operations.
  - Large space requirements.
- GWUDI Facility:
  - Fully compliant.
- Project Costs:
  - Capital = $223 million.
  - O&M = $5.1 million.
  - Life Cycle = $298 million.

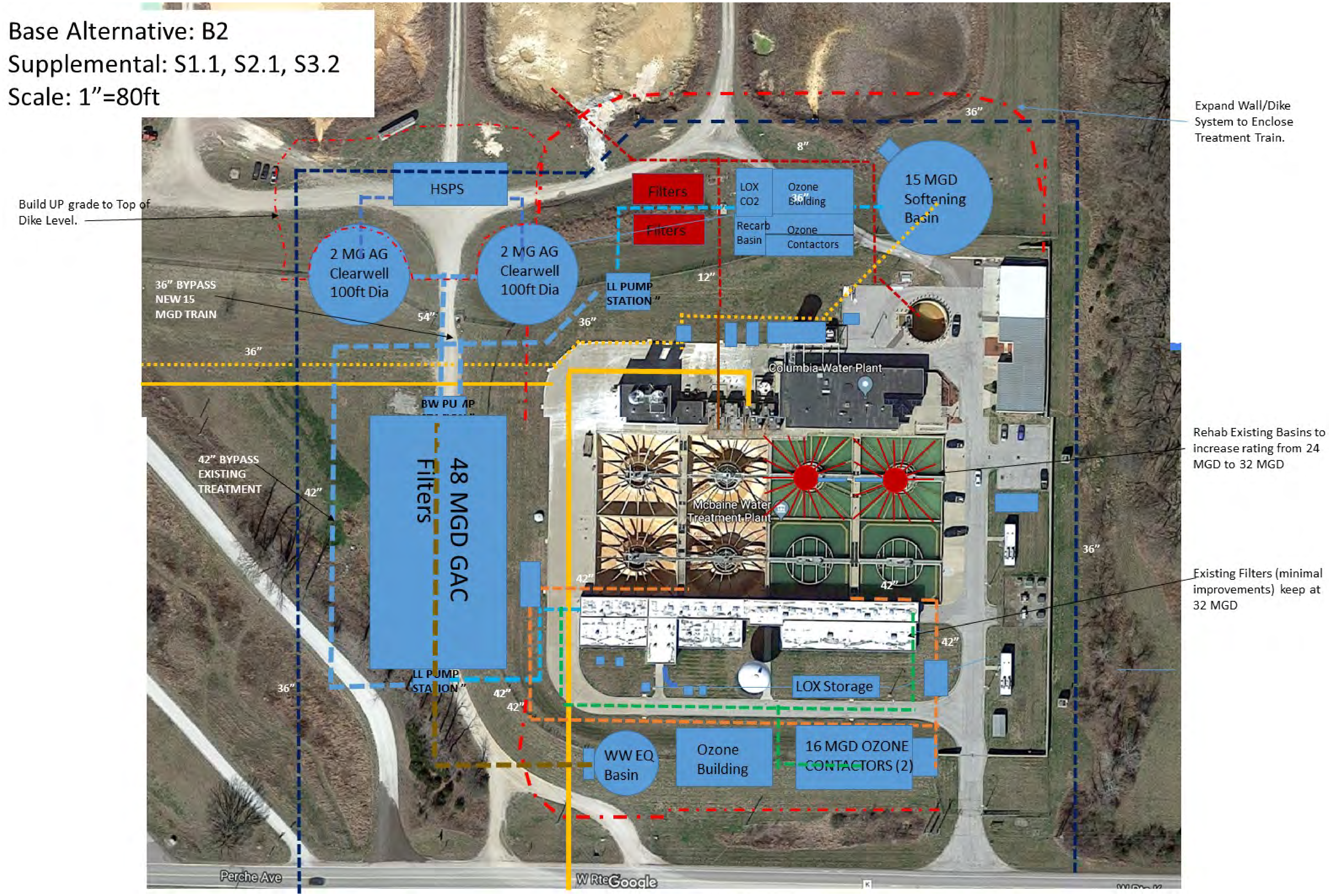



Figure 26 Alternative B2, S1.1, S2.1, S3.2 Layout

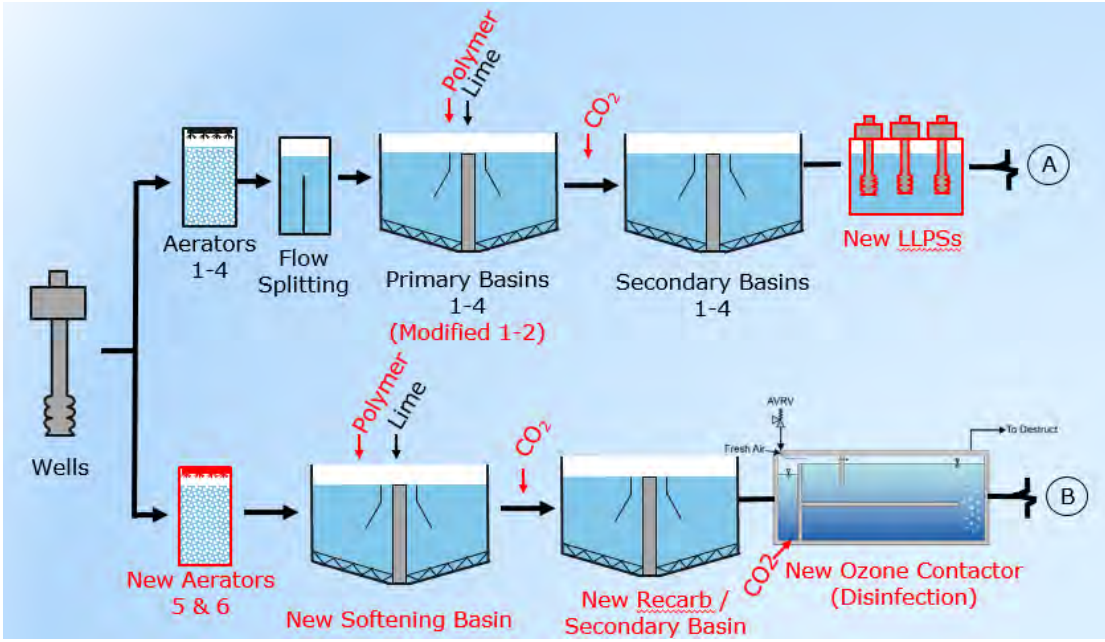



Figure 27 Alternative B2, S1.1, S2.1, S3.2 Process Flow Schematic Part I

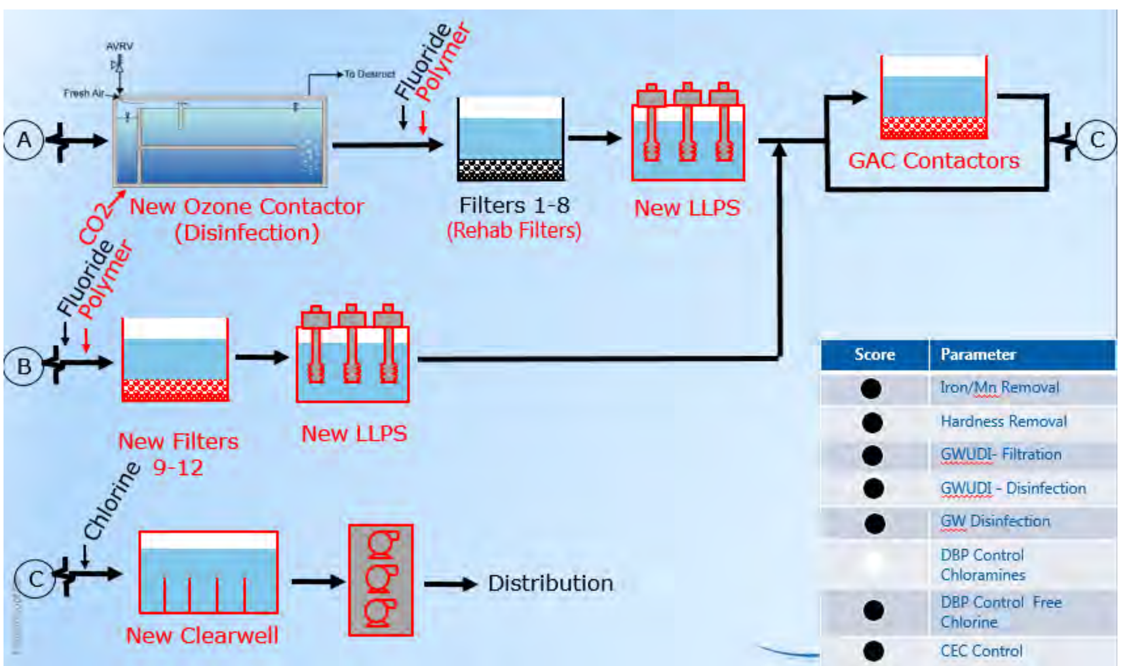



Figure 28 Alternative B2, S1.1, S2.1, S3.2 Process Flow Schematic Part II

## 4.6 Final Rankings

Using the layouts, refined costs, and updated scores, the shortlisted alternatives were evaluated and re-ranked. The updated rankings were presented to the DWPWG during the Final Ranking Workshop held on January 29, 2018. A summary of the final rankings with respect to the updated non-economic and economic criterion are presented in Figure 29.

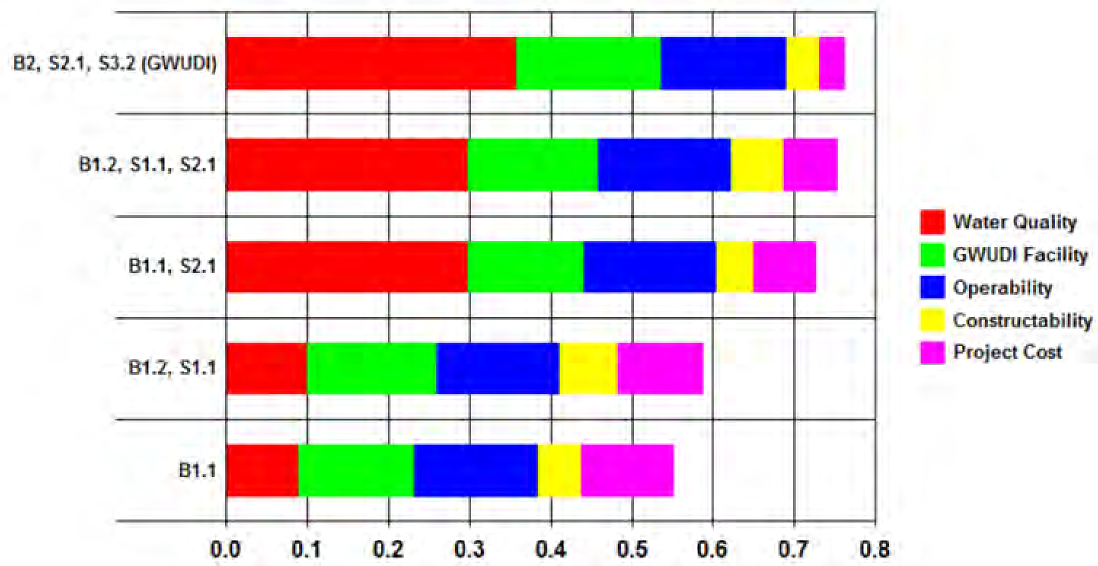



Figure 29 Final Ranking of Shortlisted Alternatives

Similar to the initial evaluation, because of the high weight given to Water Quality and GWUDI, it was the higher cost alternatives that scored highest and provided the most benefit. The benefit/cost ratios were again analyzed for the shortlisted alternatives and a summary is presented in Figure 30.

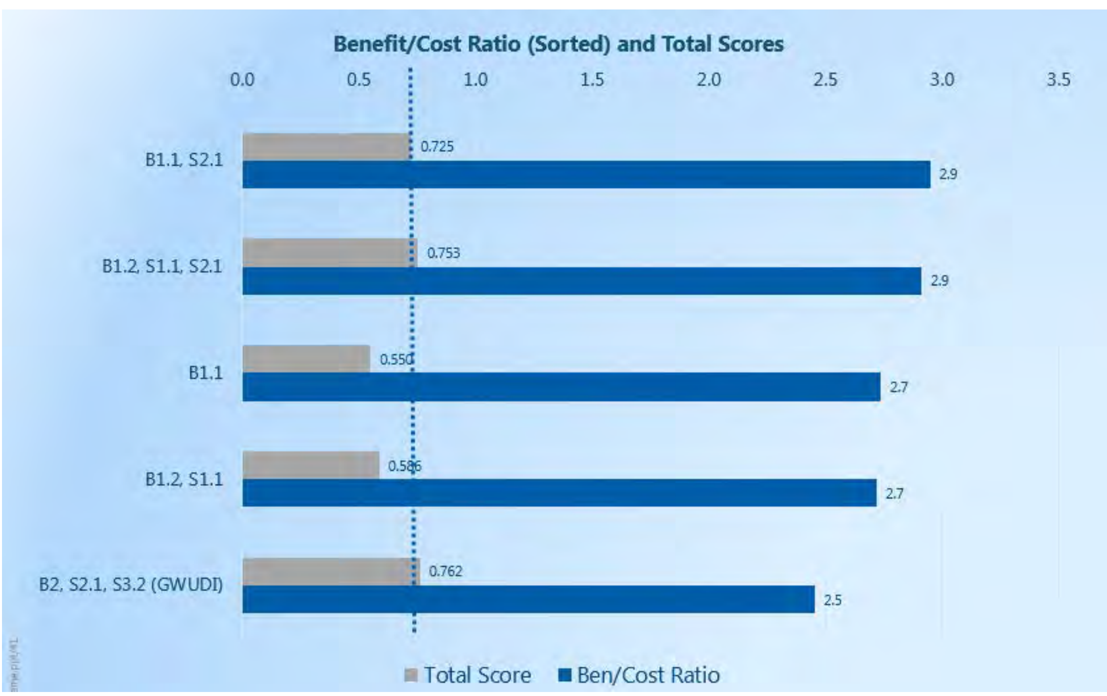



Figure 30 Benefit/Cost Ratios for Shortlisted Alternatives

The benefit/cost ratios showed that although the alternative containing ozone/Biofiltration (B2, S1.1, S2.1, S3.2), scored incrementally higher than the other alternatives, it had the lowest benefit/cost ratio. Because of this, removing this alternative from consideration was recommended. This left the group with two very viable sets of alternatives that can each be implemented in phases. Alternative B1.1 offers the lowest cost at $160 million with a total score of 0.550 and can be upgraded to B1.1, S2.1 with a score of 0.725 for an extra $61 million. Alternative B1.2, S1.1, on the other hand, offers a similar pattern at a slightly higher score (0.586) for $178 million and it can be upgraded to B1.2, S1.1, S2.1 with a score of 0.753 for an extra $58 million. This concept of phasing the recommended alternatives is presented in Figure 31.

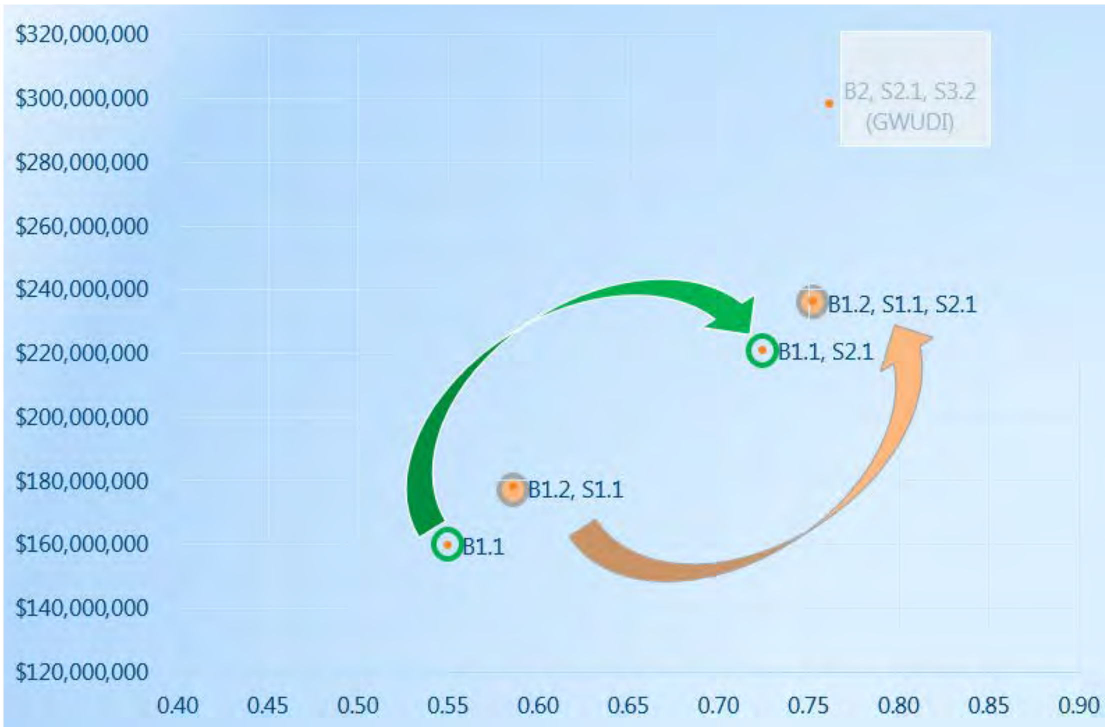



Figure 31 Recommended Alternatives Scores vs. Life Cycle Cost

## 4.7 Recommendations of Drinking Water Planning Work Group

The DWPWG met on February 26, 2018 to review the final ranking results and provide the final recommendations. The findings and recommendations of the DWPWG are as follows:

1. DWPWG Findings:
    a. The McBaine WTP should consider processes that meet the requirements for a GWUDI Facility.
    b. The McBaine WTP should utilize treatment technologies to achieve Disinfection By-Products (DBP) compliance without the need for chloramines and to also assist in removal of Contaminants of Emerging Concern (CEC's).

2. DWPWG Recommendations:
    a. Priority should be given to first restoring the plant to its 32 MGD capacity prior to increasing capacity to 48 MGD.
    b. The base alternatives of B1.1, B1.2, and B2 should be evaluated with the supplemental processes to achieve improved water quality through a phased approach.
    c. The design on the selected alternative should begin no later than 2020, as indicated in Carollo's analysis, to be in operation no later than 2024, unless design and construction are able to be accomplished sooner.
    d. In order to improve water quality while the new process train is in design, and construction, repair and/or enhancement of the current filters and pilot testing done to make every effort to return to free chlorine disinfection.
    e. The rehabilitation and/or enhancement initiatives outlined in the Condition Assessment will address deficiencies in the facility and system and request an updated timeline for these initiatives be produced by Water and Light.

Appendix A

# DWPWG ORDINANCE

Introduced by Treece Council Bill No. R 48-17 A



**A RESOLUTION**

establishing a Drinking Water Planning Work Group to assist in an update of the 2011 Water Treatment Plant Expansion Preliminary Design Report.

BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF COLUMBIA, MISSOURI, AS FOLLOWS:

SECTION 1. There is hereby established a Drinking Water Planning Work Group to assist in an update of the 2011 Water Treatment Plant Expansion Preliminary Design Report and to provide guidance to the Water and Light Advisory Board and City Council on the following:

- Review current drinking water regulations, including what types of disinfection methods comply with regulations.
- Review Columbia's current water supply conditions.
- Assess the current state of utility industry and customer-side water treatment technology and cost.
- Review and provide input on developed recommendations.
- Develop drinking water planning recommendations.

SECTION 2. The Drinking Water Planning Work Group shall consist of seven (7) members comprised as follows:

- One (1) member shall be a City Council member appointed by the City Council. The initial City Council member appointee is Karl Skala.
- Six (6) members shall be appointed by the City Utilities – Water and Light Director from the drinking water customer user groups set forth herein. The initial six (6) appointees are as follows:

  1. Residential customer member – Julie Ryan (CoMo Safe Water)
  2. Commercial customer member – Matt Off (Director, Rockbridge HyVee)
  3. Industrial customer member – Ron Pruett (3M, Plant Engineering)
  4. Water industry professional member – Terry Merritt (Alliance Water Resources)

5. Educational institution member – Randy Jackson (Environmental Engineer, Columbia Public School District)
6. Healthcare industry member – Michael Szewczyk, MD (Chair, Columbia/Boone County Board of Health)

SECTION 3. The Drinking Water Planning Work Group shall also include the following non-voting members:

- Two (2) ad hoc non-voting members shall be members of the Water and Light Advisory Board to be appointed by the Water and Light Advisory Board.

- One (1) ad hoc non-voting member shall be from the Office of Sustainability to be appointed by the Sustainability Manager.

SECTION 4. A quorum to hold a meeting shall consist of four (4) voting members. All meetings shall be open to involvement and participation by as many additional community members who desire to attend.

SECTION 5. The Drinking Water Planning Work Group shall make a final report to the Water and Light Advisory Board of its findings and recommendations by December 31, 2017. The Work Group shall be dissolved upon submitting its final report.

SECTION 6. The Drinking Water Planning Work Group shall be provided reasonable staff support.

ADOPTED this 3rd day of April, 2017.

ATTEST:

City Clerk

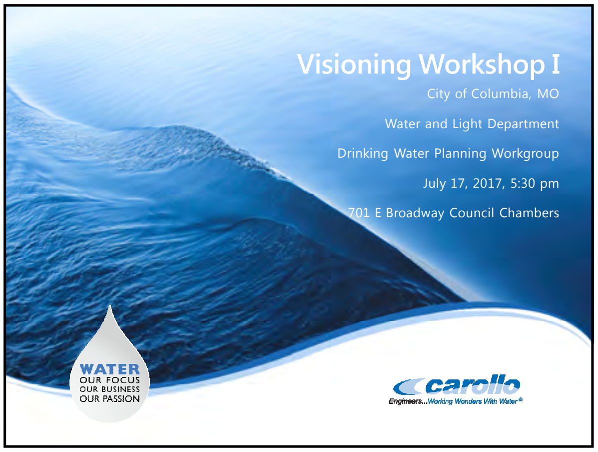
Mayor and Presiding Officer

APPROVED AS TO FORM:

City Counselor

Appendix B

# KICKOFF WORKSHOP





## Draft Mission Statement of Planning Workgroup

- "To enhance the quality of life for Columbia, Missouri Citizens by providing direction to Columbia Water and Light on the best means to continue its mission to provide at an affordable price; high-quality water and dependable service that exceed customer expectations; protects and ensures a long-term water supply for future generations; and serves as responsible stewards of public health, utility resources, and the environment."

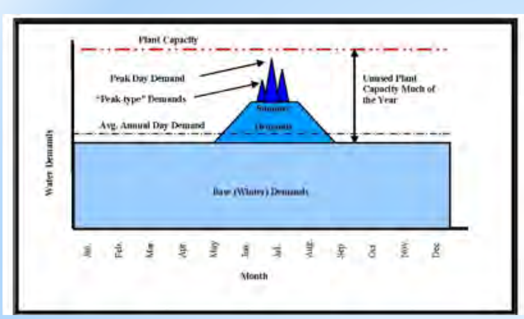
## Challenges to Accomplishing Mission

- Affordability: % of Median Household Income
- Capacity: Satisfy Future Water Demands
- Water Quality:
- Environmental Stewardship:

## Capacity Studies

- **2007 Water System Study (Jacobs)**
- **2007 Ground Water Flow in McBaine Bottoms (USGS)**
- 2010 University of Missouri Columbia Report
- 2011 Preliminary Expansion Study (Carollo)
- 2012 Well Siting Study (Black and Veatch)
- **2015 Long Range Planning Study (Jacobs)**
- 2016 Water Treatment Plant Condition Assessment (Black and Veatch)
- **2016 Integrated Water Supply Plan (Black and Veatch)**
- ***2017 Integrated Management Plan (HDR)***

## Capacity: Water Demand Basics

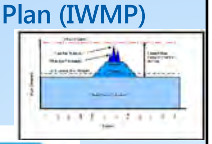


## Columbia Water Supply System

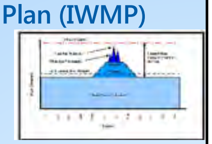

Figure 3-2. McBaine Well Field and Water Treatment Plant

| CONDITION | TOTAL INSTALLED CAPACITY (MAXIMUM) | FIRM INSTALLED CAPACITY (SAFE YIELD) |
|---|---|---|
| [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] |

## 2016 Integrated Water Master Plan (IWMP)




## 2016 Integrated Water Master Plan (IWMP)



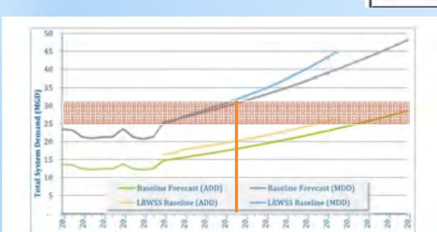
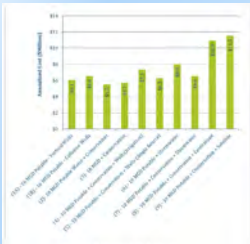
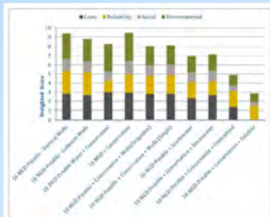



Figure 4-18 Demand Forecasts, including comparison to LRWSS Baseline

## 2016 Integrated Water Master Plan Analysis





## 2016 Integrated Water Master Plan Recommendations

- Expand Existing Wellfield by 16 mgd
- Continued Use of Deep Wells For Non Potable Irrigation
- Continued Use of ASR wells
- Review Conservation Program and Expand Outreach
- No IPR or DPR
- No Non-Potable System (Stormwater reuse)


## Project Driver Water Quality – Existing Treatment

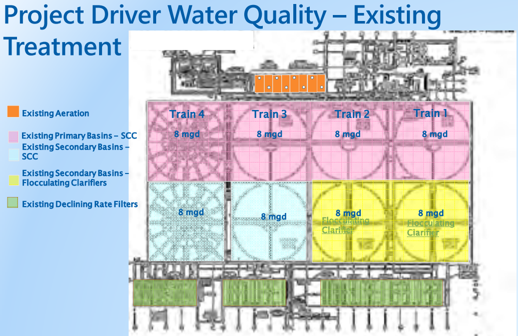
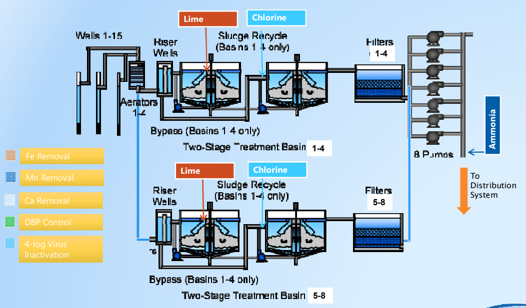



**Figure ES.2 Plan View of Existing Treatment Process**
Executive Summary
McBaine Water Treatment Plant Preliminary Design
Columbia Water and Light

## Project Driver Water Quality – Existing Treatment Achievements

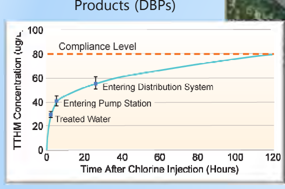



## Water Quality Studies

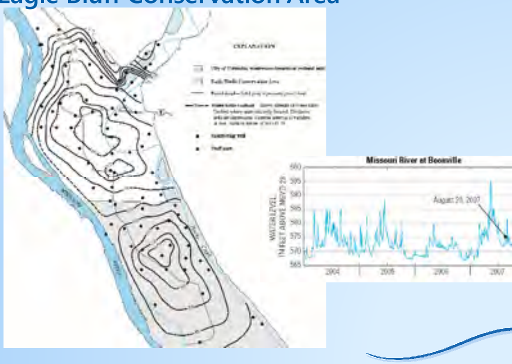
- 2007 Water System Study (Jacobs)
- **2007 Ground Water Flow in McBaine Bottoms (USGS)**
- **2010 University of Missouri Columbia Report**
- **2011 Preliminary Expansion Study (Carollo)**
- **2012 Well Siting Study (Black and Veatch)**
- 2015 Long Range Planning Study (Jacobs)
- **2016 Water Treatment Plant Condition Assessment (Black and Veatch)**
- 2016 Integrated Water Supply Plan (Black and Veatch)
- 2017 Integrated Management Plan (HDR)

## Project Driver: Water Quality

- Water Quantity
- Water Quality
  - Emerging Contaminants of Concern (ECC)
  - Disinfection By-Products (DBPs)

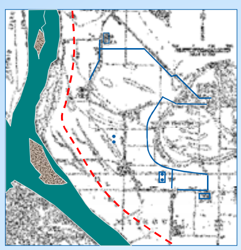



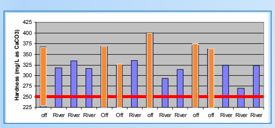
## Water Quality: Source Water Influences from Eagle Bluff Conservation Area



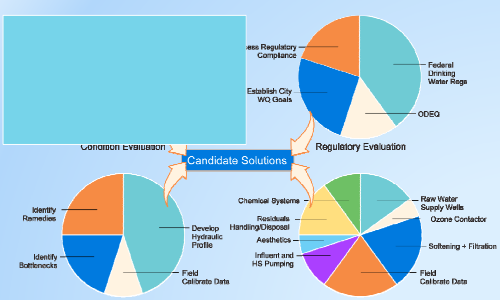

## Water Treatment Potential Issues- State Reclassification of Source

- Water Quantity
- Water Quality
- State Reclassification of Source as GWUDI





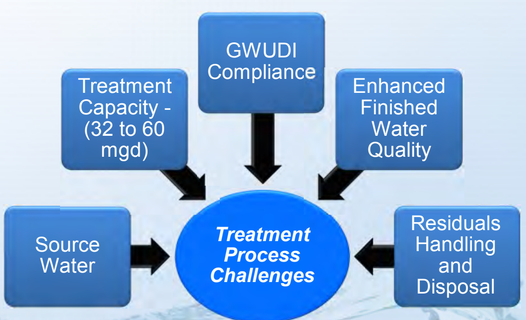
## Scope of Services – 2011 Carollo Report



## Scope of Services- 2011 Carollo Report

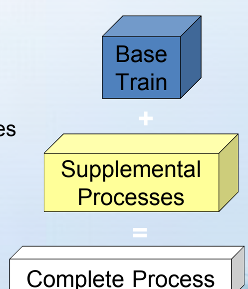
- Task 1 – Project Inception ✓
- Task 2 – Data Collection and Analysis ✓
- Task 3 – Regulatory Evaluation ✓
- Task 4 – Process Evaluation ✓
- Task 5 – Hydraulic Evaluation ✓
- Task 6 – Develop Alternatives ✓
- Task 7 – Analysis and Recommendations ✓

## Scope of Services- 2011 Carollo Report




## Treatment Alternative Identification

- "Base" Treatment Trains
  - Conventional Softening
  - Split Treatment
- "Supplemental" Processes
  - GAC
  - MIEX
  - Deep Bed Filtration
  - Secondary Aeration
  - UV, Ozone

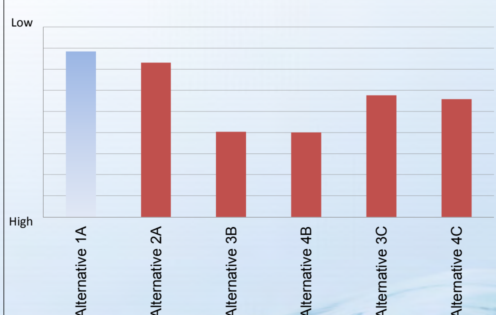


## Final Selection: Cost Benefit Analysis

| Alternative | ECC Reduction | Free Chlorine | Permitting | MOPO | Ability to Communicate To Public | Life-Cycle Cost ($M) | Cost Differential ($M) |
|---|---|---|---|---|---|---|---|
| 1A Existing | - | - | ++ | ++ | - | 95 | - |
| 3C Ozone BAF | ++ | + | – – | – | +++ | 122 | 27 |
| 3B GAC Filters | + | + | + | ++ | ++ | 159 | 64 |

Edmond_presentation.pptx

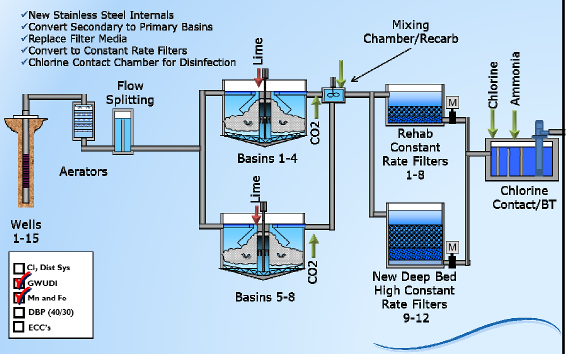
## Cost : Benefit Analysis




## Water Quality Studies

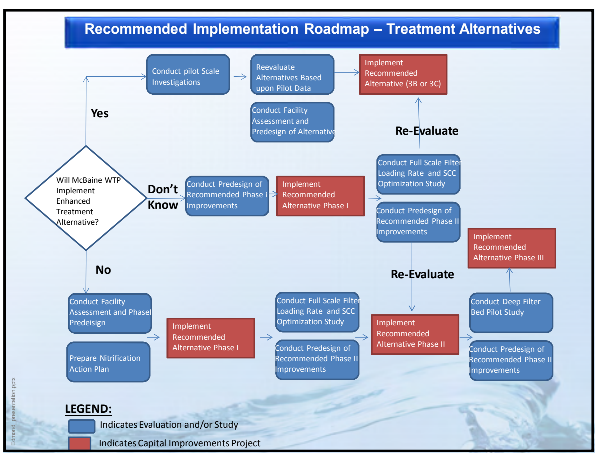
- 2007 Water System Study (Jacobs)
- **2007 Ground Water Flow in McBaine Bottoms (USGS)**
- **2010 University of Missouri Columbia Report**
- **2011 Preliminary Expansion Study (Carollo)**
- **2012 Well Siting Study (Black and Veatch)**
- 2015 Long Range Planning Study (Jacobs)
- **2016 Water Treatment Plant Condition Assessment (Black and Veatch)**
- 2016 Integrated Water Supply Plan (Black and Veatch)
- 2017 Integrated Management Plan (HDR)

## Alternative 1A- Conventional Softening

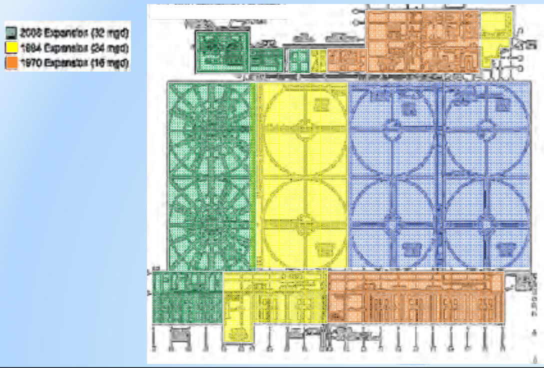



## Treatment Recommendation Summary

- Implement Alternative 1A.
- **Do Not** consider treatment for CEC's.
- Continue use of chloramines & develop formal nitrification action plan.
- Conduct condition assessment of McBaine WTP and include in budgetary cost.
- Master Plan facilities for GWUDI Compliance.
- Plan for phased implementation of Alternative 1A. Accelerate if GWUDI compliance is necessary.



## Project Driver: Condition



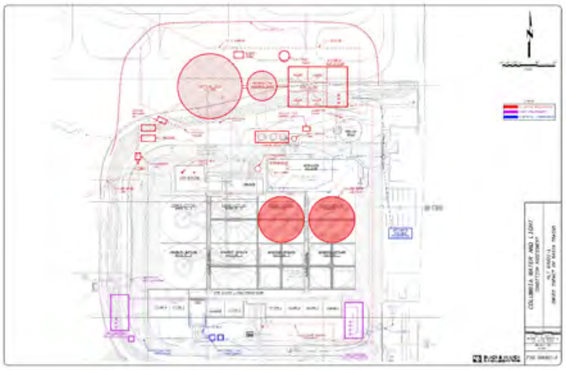

## Water Quality Studies

- 2007 Water System Study (Jacobs)
- 2007 Ground Water Flow in McBaine Bottoms (USGS)
- 2010 University of Missouri Columbia Report
- 2011 Preliminary Expansion Study (Carollo)
- 2012 Well Siting Study (Black and Veatch)
- 2015 Long Range Planning Study (Jacobs)
- **2016 Water Treatment Plant Condition Assessment (Black and Veatch)**
- 2016 Integrated Water Supply Plan (Black and Veatch)
- 2017 Integrated Management Plan (HDR)

## 2016 Condition Assessment

- New Water Demand/Capacity Results – 2015 LRWSS eliminate need for 65 mgd.
- Capacity Downgraded from 32 to 24 mgd.
- Growth of wintertime demands may not permit Expansion within Basins when needed.
- Water Quality Considerations:
  - Continue existing treatment process goals
  - Locate Wells to avoid State Classification of Water as GWUDI

## 2016 Condition Assessment



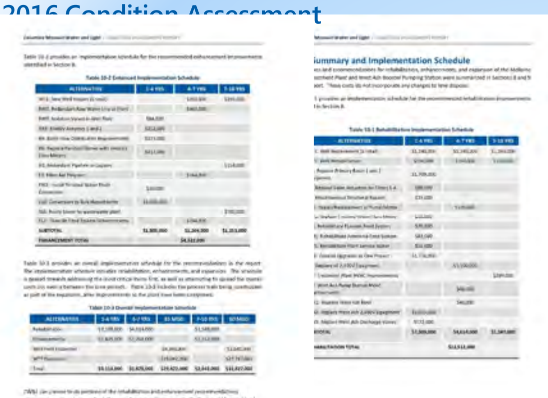

## 2016 Condition Assessment

Columbia Missouri Water and Light

**Table 9-1 Costs for Expansion Alternatives (in $1,000s of Dollars)**

| ALTERNATIVE | EXP 45-1 | EXP 45-2 | EXP 45-3 | EXP 60-1 | EXP 60-2 | EXP 60-3 | GWUDI-1 | GWUDI-2 |
|---|---|---|---|---|---|---|---|---|
| | [illegible] | New Basins | Single Stage | [illegible] | 2 Basins | Single Stage | [illegible] | [illegible] |
| **Water Supply** | | | | | | | | |
| Wells | $3,640 | $3,640 | $3,640 | $7,280 | $7,280 | $7,280 | $7,280 | $7,280 |
| Raw Water Piping | $2,720 | $2,720 | $2,720 | $3,312 | $3,312 | $3,312 | $3,312 | $3,312 |
| **Water Supply Construction Total** | **$6,360** | **$6,360** | **$6,360** | **$10,592** | **$10,592** | **$10,592** | **$10,592** | **$10,592** |
| **Treatment Plant Expansion** | | | | | | | | |
| General Requirements | $3,065 | $3,285 | $3,834 | $6,080 | $6,220 | $7,423 | $6,518 | $6,840 |
| Site Structures/Site Piping | $3,421 | $3,816 | $5,418 | $4,224 | $4,110 | $8,493 | $4,371 | $4,881 |
| [illegible] | $961 | $961 | $988 | $1,685 | $1,756 | $1,958 | $1,806 | $1,958 |
| Basins | $2,925 | $4,486 | $2,283 | $5,852 | $7,530 | $5,164 | $5,852 | $7,530 |
| Filters | $8,191 | $7,138 | $8,191 | $17,318 | $16,495 | $18,951 | $17,318 | $17,318 |
| Clearwells/Transfer Pumping | $1,621 | $1,351 | $2,948 | $2,759 | $2,509 | $5,604 | $3,851 | $4,094 |
| Contact Basins | $0 | $0 | $2,099 | $0 | $0 | $3,865 | $0 | $0 |
| High Service Pumping | $2,273 | $2,273 | $2,273 | $4,545 | $4,418 | $4,418 | $7,376 | $7,376 |
| Chemical Feed Systems | $1,768 | $1,868 | $2,318 | $5,862 | $6,074 | $6,700 | $5,912 | $6,474 |
| Electrical and Instrumentation | $5,136 | $5,403 | $5,379 | $7,967 | $8,110 | $8,723 | $8,186 | $8,329 |
| **Treatment Plant Subtotal** | **$27,353** | **$29,771** | **$35,721** | **$56,287** | **$57,828** | **$71,058** | **$61,109** | **$64,643** |
| **Construction Total** | **$33,713** | **$36,131** | **$42,081** | **$66,879** | **$68,420** | **$81,650** | **$71,701** | **$75,235** |
| Engineering/Administration | $5,057 | $5,420 | $6,312 | $10,032 | $10,263 | $12,248 | $10,755 | $11,285 |
| **PROJECT TOTAL** | **$38,770** | **$41,551** | **$48,393** | **$76,911** | **$78,683** | **$93,898** | **$82,456** | **$86,520** |

## 2016 Condition Assessment

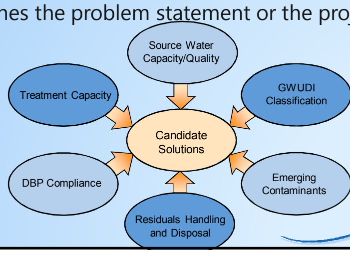


## Environmental Stewardship

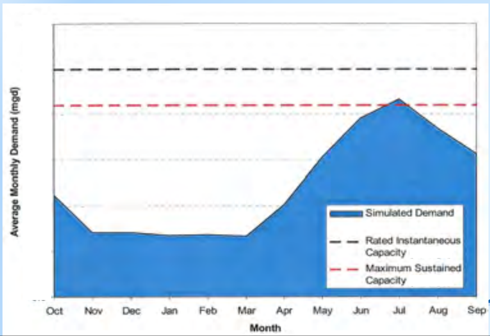

## Project Visioning Topics

## Why is Project Visioning Important?

- Establishes the boundaries of the Project.
- Establishes the stakeholders for the project.
- Establishes the mission statement for the project.
- Establishes the problem statement or the project.



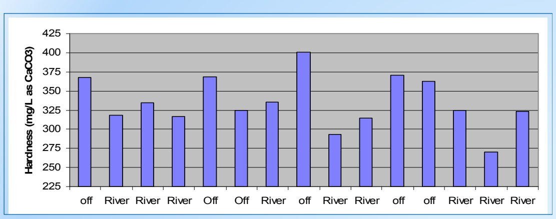
## Project Visioning – Defining Sustained and Tipping Point Capacities



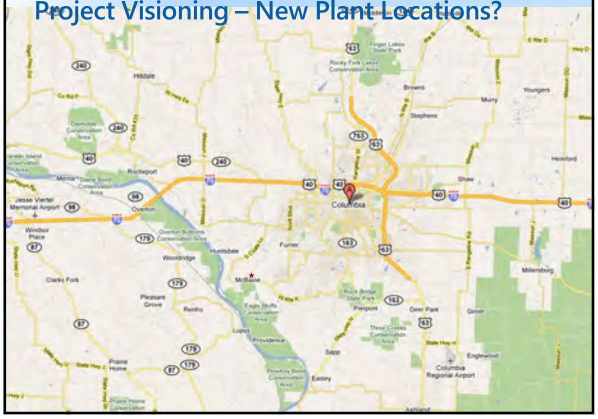

## Project Visioning – Attaining GWUDI Compliance @ McBaine

- Turbidity Removal
- Disinfection By Product Precursor Removal
- Disinfection

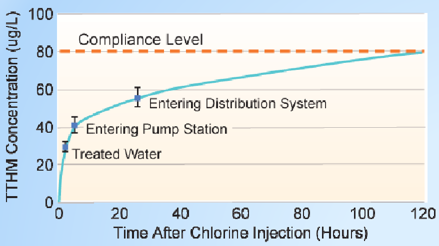

## Project Visioning – Continue Softening Goals



## Project Visioning – New Plant Locations?




## Project Visioning – Future of Chloramination




## Project Visioning – Future of Existing Water Source

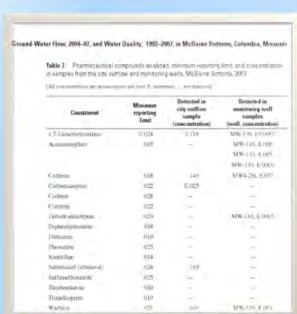

Ground-Water Flow, 2004–07, and Water Quality, 1992–2007, in McBaine Bottoms, Columbia, Missouri

**Table 7.** Pharmaceutical compounds analyzed, minimum reporting limit, and concentration in samples from the city outflow and monitoring wells, McBaine Bottoms, 2007

| Constituent | Minimum reporting limit | Detected in city outflow sample (concentration) | Detected in monitoring well samples (well, concentration) |
|---|---|---|---|

A water or wastewater issue? (EDC’s, Pharm, Nitrate, etc.)

## Structured Decision Analysis (SDA) provides for inclusive and informed decision making by all stakeholders

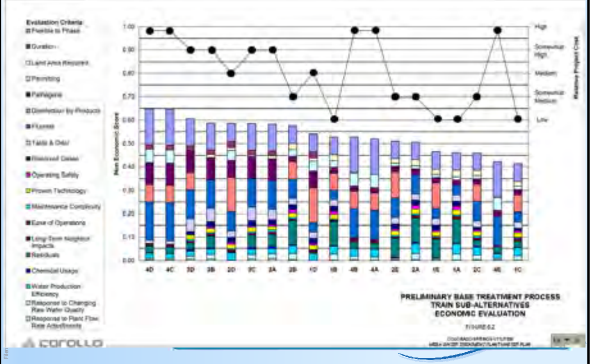

## Decision Analysis Uses a Proven Process to aid the Decision Makers – Phase I

- Define the decision makers and a simple and clear decision statement
- Define a potential set of viable alternatives
- Select the criteria that will be used to differentiate the alternatives
- Assign weights to the criteria and assure there is no redundancy nor 'must haves'

## Decision Analysis Uses a Proven Process to aid the Decision Makers – Phase II

- Rank each alternative against each criteria
- Identify 'data gaps' or 'knowledge gaps' as a part of the ranking
- Fill 'data and knowledge gaps'
- Re-rank alternatives

## Decision Analysis Uses a Proven Process to aid the Decision Makers – Phase III




## Define Project Stakeholders and Discuss Roles

## Discuss/Review Contents of Visioning Questionnaire

- Plant Capacity
- Potential Alternate Plant Site Locations
- Chloramination Future
- Microcontaminant Removal Future
- Facilities That Are Not to be Retained
- Limitation of existing facility
- Budget/Schedule Constraints
- Others?



## Next Steps/Schedule

**WORKSHOP CALENDAR CHART**
**COLUMBIA UPDATE TO PLANT EXPANSION REPORT**

| Description | Start Date | End Date | Prime | Secondary | May 2017 | June 2017 | July 2017 | Aug 2017 | Sep 2017 | Oct 2017 | Nov 2017 | Dec 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DELIVERABLE: Distribute Draft Visioning Questionnaire to attendees | May 29, 2017 | June 12, 2017 | C | | | | | | | | | |
| ACTION: Review questionnaire and be prepared to comment at meeting | NA | NA | M | C | | | | | | | | |
| WORKSHOP: Visioning I | June 12, 2017 | June 12, 2017 | C | M | | | | | | | | |
| DELIVERABLE: Submit Final Visioning Questionnaire | June 12, 2017 | June 29, 2017 | C | M | | | | | | | | |
| WORKSHOP: Visioning Workshop II | July 10, 2017 | July 10, 2017 | C | M | | | | | | | | |
| DELIVERABLE: Develop Criteria Matrix | July 10, 2017 | July 31, 2017 | C | M | | | | | | | | |
| WORKSHOP: Criteria Development and Ranking | Aug 14, 2017 | Aug 14, 2017 | C | M | | | | | | | | |
| DELIVERABLE: Summary TM (Draft) of Treatment Alternatives | Aug 14, 2017 | Sept 1, 2017 | C | M | | | | | | | | |
| WORKSHOP: Review Summary TM | Sept 11, 2017 | Sept 11, 2017 | M | C | | | | | | | | |
| DELIVERABLE: Summary and Revised TM | Sept 11, 2017 | Oct 2, 2017 | | | | | | | | | | |
| WORKSHOP: Treatment Alternative Screening I | Oct 9, 2017 | Oct 9, 2017 | C | M | | | | | | | | |
| DELIVERABLE: Revised TM and Rankings | Oct 9, 2017 | Oct 30, 2017 | C | M | | | | | | | | |
| WORKSHOP: Treatment Alternative Screening II | Nov 13, 2017 | Nov 13, 2017 | M | C | | | | | | | | |
| Develop Final TM including Cost Summary | Nov 13, 2017 | Dec 11, 2017 | C | M | | | | | | | | |
| WORKSHOP: Final Alternatives Review and Selection Workshop | TBD | TBD | C | M | | | | | | | | |

Filename.ppt/51


General Comments By
Public, Members, Staff


Next Meeting Aug 14, 2017

Appendix C

# SUMMARY OF VISIONING QUESTIONNAIRE AND RESULTS

# VISIONING QUESTIONNAIRE

## PART I - PURPOSE AND INSTRUCTIONS

The purpose of this questionnaire is to establish a vision and identify the boundaries for the Drinking Water Planning Group to assist in the update of the 2011 Water Treatment Plant Preliminary Design Report. As someone who has been identified by the Columbia Water and Light Department as a stakeholder in this process, your input is of value and will result in a more thorough and comprehensive update. Please feel free to attach any additional information to this form. **Please only answer questions in areas that you are familiar with or have knowledge about.**

Any questions regarding this form should be addressed to **Thomas Crowley at tcrowley@carollo.com.**

We will collect and Review this information as part of our Visioning and Kickoff Workshop II to be Conducted On **August 14, 2017.**

## PART II – RESPONDENT INFORMATION

1. Please provide the information below regarding the respondent:

Name:

Title:

Occupation:

Phone:

Fax:

Date:

2. Please provide a brief description of your goals for the project.

## PART III - QUESTIONNNAIRE

Water Treatment Plant Configuration:

1. To reduce anticipated operational expenses, should the current treatment goals to soften the water be abandoned in favor of less expensive treatment measures? ( This may cause some consumers to install in-home water softeners)

- ☐ Continue Softening Treatment Goals
- ☐ Discontinue Softening Treatment Goals

Please list the reasons for your selection:

2. The secondary regulations concern the aesthetic aspects of a drinking water supply rather than the health aspects. Should any new treatment processes consider satisfying the current secondary regulations (suggested limits) as well as the primary regulations (required by law)? Satisfying the secondary regulations is currently done at the existing facilities.

- ☐ Continue Satisfying Secondary Suggested Limits for Aesthetic Properties
- ☐ Discontinue Satisfying Secondary Suggested Limits for Aesthetic Properties

Please list the reasons for your selection:

Water Treatment Plant Configuration (cont.):

3. Should the study examine abandoning and demolishing the existing water treatment plant (32 mgd) and constructing an entirely new facility with source water obtained from a different location at a significant cost to current and future customers?

- ☐ Existing Supply and Treatment Plant Should be abandoned
- ☐ Continue Use of Current Source and Treatment Facility

Please list the reasons for your selection:

4. The end of this questionnaire provides a glossary of the advanced treatment technology and the potential benefits this technology would provide. Please select which of these advanced technologies you would like to see the study address. Please list the reasons for your selections.

- ☐ Membrane Filtration
- ☐ Nano/Reverse Osmosis
- ☐ Advanced Oxidation
- ☐ Ion Exchange
- ☐ Advanced Disinfection
- ☐ Ozone/Infiltration
- ☐ Advanced Biofiltration
- ☐ Air Stripping
- ☐ Enhanced Softening
- ☐ All of the Above
- ☐ Others (Please List Below)

  ________________

  ________________

  ________________

Please list the reasons for your selection:

Water Treatment Plant Configuration (cont.):

5. To satisfy regulations associated with disinfection by products, the City of Columbia converted from free chlorine to chloramines in the distribution system and conducts periodic conversions to chlorine to avoid issues that are associated with nitrification. There are more costly technologies that can be employed to satisfy all disinfection by product regulations **and** permit switching back to chlorine. Given this, how important is it to you that the City of Columbia switches back to the exclusive use of free chlorine in the distribution system? Please state the reasons for your selection:

- ☐ Absolutely Critical to Switch Back to Chlorine
- ☐ Very Important to Switch Back to Chlorine
- ☐ Not Very Important
- ☐ Stay with Chloramines
- ☐ Other (Please list) ________________________

In the space allotted below please state your reasons for the selection made above:

Water Treatment Plant Configuration (cont.):

6. Past investigations of surface water and groundwater sources in Missouri and throughout the country have detected the presence of extremely low levels (one drop in 20 Olympic swimming pools) of Endocrine Disrupting (estrogen, etc) and Pharmaceutical (acetaminophen, etc.) compounds in many drinking water supplies. Studies to determine if long-term exposure to the low concentrations of these constituents impact human health are at least 10+ years away and it is not certain when (if at all) some or all of these constituents will be regulated. Technologies that remove or destroy these compounds from the supply are available but are significantly more costly to implement than the current treatment process. Given this, how important is it to you that this study considers processes that remove or destroy these compounds? Please state the reasons for your selection.

- ☐ Absolutely Critical to Remove or Destroy these Compounds No Matter the Expense.
- ☐ Study Should Evaluate the Costs/Benefits of Technologies that Remove or Destroy these Compounds.
- ☐ Not Very Important that Study Considers Removal/Destruction of these Compounds.
- ☐ Study **Should Not** Consider Removal/Destruction of these Compounds.
- ☐ Other (Please list)_________________________

In the space allotted below please state your reasons for the selection made above:

Water Treatment Plant Configuration (cont.):

7. Green elements at a water facility are elements that minimize chemical use and maximize energy efficiency. Should a "green" element be a consideration for ranking and analysis of treatment alternatives?

- ☐ Yes
- ☐ No
- ☐ Other (Please List) _______________

In the space allotted below please list the reasons for your response:

8. Are there any other issues regarding treatment that should be addressed?

- ☐ Yes (please list) ______________
- ☐ No

In the space allotted below please list the reasons for your response:

*******************************END OF QUESTIONNAIRE **************************

## PART IV GLOSSARY OF WATER TREATMENT TECHNOLOGIES

Advanced Biofiltration: Technologies that utilize an exterior carbon source and other nutrients in lieu of Ozone to establish and maintain a biofiltration process (a filter bed laden with microorganisms that break down organic matter into carbon dioxide, water and salts). These processes have proven effective in reducing the extremely low levels (one drop in 20 Olympic swimming pools) of some Endocrine Disrupting (estrogen, etc) and Pharmaceutical (acetaminophen, etc.) compounds found in many of the nations drinking water supplies. This treatment may provide enhanced removal of disinfection by product precursors and may permit the re-establishment of free chlorine as a secondary (distribution) system disinfectant.

Advanced Disinfection: Technologies (Ozone, chlorine dioxide, UV, low pressure membrane filtration) that are approved by the US EPA to provide primary disinfection of drinking water that meet or exceed national standards without the use of free chlorine. This does not eliminate the use of chlorination in the process. Chlorination or Chloramination will be required by the Missouri Department of Natural resources following this process to produce a measurable residual disinfectant in the distribution system. Some of these technologies may provide enhanced removal of disinfection by product precursors and may permit the re-establishment of free chlorine as a secondary (distribution) system disinfectant.

Advanced Oxidation: The process of adding or generating powerful oxidants to oxidize trace levels of organic or microbiological organisms in water. These processes have proven effective in reducing the extremely low levels (one drop in 20 Olympic swimming pools) of some Endocrine Disrupting (estrogen, etc) and Pharmaceutical (acetaminophen, etc.) compounds found in many of the nations drinking water supplies.

Air Stripping: Technologies involving the transferring of volatile components of a liquid into an air stream. Some of the disinfection by-products generated from drinking water chlorination can be safely removed from drinking water through this process. This treatment may provide enhanced removal of disinfection by products and may permit the re-establishment of free chlorine as a secondary (distribution) system disinfectant.

Enhanced Softening: The process of adding an excess of alkaline agent (lime, caustic soda, etc.) to water to remove hardness (calcium and magnesium ions) via precipitation. This treatment may provide enhanced removal of disinfection by product precursors and may permit the re-establishment of free chlorine as both a primary and secondary (distribution) system disinfectant.

## PART IV GLOSSARY OF WATER TREATMENT TECHNOLOGIES (CONT.)

Ion Exchange: A reversible chemical reaction between an insoluble solid and a solution during which ions may be interchanged. This separation process, as it applies to Columbia, would be to examine fixed bed or dispersed magnetic resins to fix some organic ions to the resins. This treatment may provide enhanced removal of disinfection by product precursors and may permit the re-establishment of free chlorine as both a primary and secondary (distribution) system disinfectant.

Ozone/Biofiltration: A combined water treatment process to reduce natural organic matter (NOM) which is a water disinfectant byproduct precursor. Water is first assonated (ozone is mixed into the water flow to oxidize organic matter, iron and manganese) and then passed through a biofilter (a filter bed laden with microorganisms that break down organic matter into carbon dioxide, water and salts). These processes have proven effective in reducing the extremely low levels (one drop in 20 Olympic swimming pools) of some Endocrine Disrupting (estrogen, etc) and Pharmaceutical (acetaminophen, etc.) compounds found in many of the nations drinking water supplies. This treatment may provide enhanced removal of disinfection by product precursors and may permit the re-establishment of free chlorine as a secondary (distribution) system disinfectant.

Micro/Ultra Filtration: Water under moderate pressure (25-50 psig) is forced through a membrane, a thin material with very small pores, stopping small particles (including bacteria). This is proven to provide an effective barrier to most pathogens but is not effective in removing ions (softening) or most organic compounds.

Nano/Reverse Osmosis: Water under high pressure (75-120 psig) is forced through a membrane using a separation process that employs the principles of reverse osmosis to remove dissolved contaminants from water; typically applied for membrane softening or the removal of dissolved organic contaminants. This treatment may provide enhanced removal of disinfection by product precursors and may permit the re-establishment of free chlorine as both a primary and secondary (distribution) system disinfectant. In addition, these processes have proven effective in reducing the extremely low levels (one drop in 20 Olympic swimming pools) of some Endocrine Disrupting (estrogen, etc) and Pharmaceutical (acetaminophen, etc.) compounds found in many of the nations drinking water supplies.

## PART IV GLOSSARY OF WATER TREATMENT TECHNOLOGIES (CONT.)

| | |
|---|---|
| Softening (precipitative): | The process of adding an alkaline agent (lime, caustic soda, etc.) to water to remove hardness (calcium) via precipitation. This is done to reduce scaling in water heaters and otherwise improve other aesthetic aspects of drinking water. |
| Ion Exchange: | A reversible chemical reaction between an insoluble solid and a solution during which ions may be interchanged. This separation process, as it applies to Columbia, would be to examine fixed bed or dispersed magnetic resins to fix some organic ions to the resins. This treatment may provide enhanced removal of disinfection by product precursors and may permit the re-establishment of free chlorine as both a primary and secondary (distribution) system disinfectant. |

Appendix D

# SUMMARY OF VISIONING WORKSHOPS

# Visioning Workshop II

City of Columbia, MO

Water and Light Department

Drinking Water Planning Workgroup

August 14, 2017, 5:30 pm

701 E Broadway Council Chambers

WATER OUR FOCUS OUR BUSINESS OUR PASSION

carollo Engineers...Working Wonders With Water®

## Workshop Agenda

- Review of Questionnaire
- Treatment Technologies Overview
- Primary and Secondary Drinking Water Regulations
- Softening Presentation
- CEC Presentation
- Disinfection By Products Presentation
- Treatment Technologies Overview
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members, and Staff
- Next Meeting Date

## Draft Mission Statement of Planning Workgroup

- "To enhance the quality of life for Columbia, Missouri Citizens by providing direction to Columbia Water and Light on the best means to continue its mission to provide at an affordable price; high-quality water and dependable service ~~that exceeds customer expectations~~; protects and ensures a long-term water supply for future generations; and serves as responsible stewards of public health, utility resources, and the environment."

## Review of Questionnaire

## Review of Questionnaire - Purpose

VISIONING QUESTIONNAIRE

PART I – PURPOSE AND INSTRUCTIONS

The purpose of this questionnaire is to establish a vision and identify the boundaries for the Water Treatment Plant Preliminary Design Report project. As someone who has been identified by the Columbia Water and Light Department as a stakeholder in this process, your input is of value and will result in a more thorough and comprehensive study. Please feel free to attach any additional information to this form. **Please only answer questions in areas that you are familiar with or have knowledge about.**

## Review of Questionnaire-

Source Water Supply

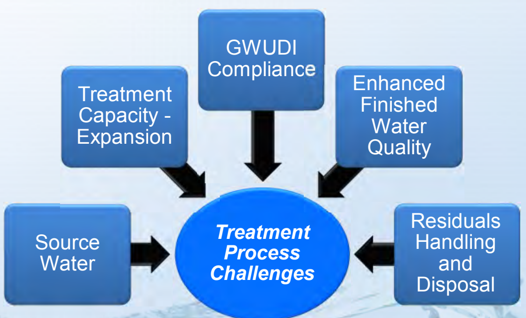
1. Are you satisfied with the quality of the existing water supply source?

   - ☐ Yes
   - ☐ No
   - ☐ Other (Please List) _______________

   In the space allotted below please list the reasons for your response:

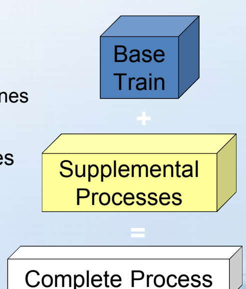
2. Should this study consider other sources of supply? If so, which sources and why?


## Scope of Services- 2011 Carollo Report




## Treatment Alternative Identification

- “Base” Treatment Trains
  - Conventional Softening
  - Disinfection – Chloramines
  - Conventional Filtration
- “Supplemental” Processes
  - GAC
  - MIEX
  - Deep Bed Filtration
  - Secondary Aeration
  - UV, Ozone



# Primary and Secondary Drinking Water Regulations

## Primary Drinking Water Regulations

- What are primary Drinking water regulations and how do they vary based upon source water classification?
- What are Secondary Drinking Water Regulations?

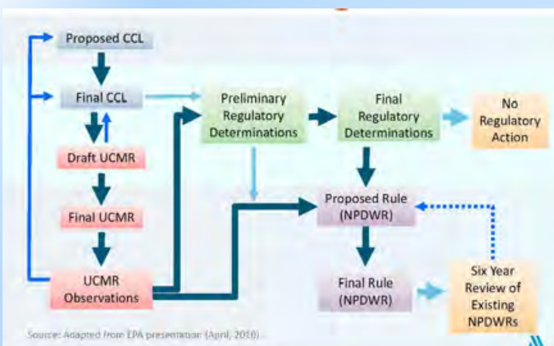
## Primary Drinking Water Standards

- The National **Primary Drinking Water Regulations** (NPDWR) are legally enforceable **primary standards** and treatment techniques that apply to public **water** systems. **Primary standards** and treatment techniques protect public health by limiting the levels of contaminants in **drinking water**.
- These levels are based on consideration of health risks, technical feasibility of treatment, and cost-benefit analysis. (MCLs) which are established to protect the public against consumption of drinking water contaminants that present a risk to human health. An MCL is the maximum allowable amount of a contaminant in drinking water which is delivered to the consumer.

## Primary Drinking Water Standards – EPA Regulatory Framework

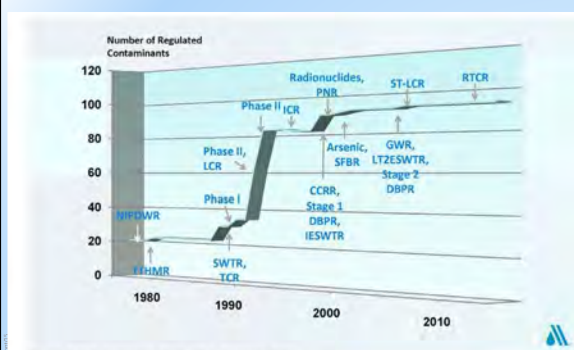
- Under the Safe Drinking Water Act, promulgated in 1974, the USEPA has established drinking water regulations for more than 90 contaminants
- 1986 amendments:
  - Required that EPA review existing regulations every six years, termed the "Six year Review" process
  - Established the Contaminant Candidate List (CCL) process for identifying new contaminants for regulatory determination every five years

## SDWQ Standard Setting Process




Source: AWWA Government Affairs Office (Roberson, 2015)

## SDWA Regulatory Timeline




Source: AWWA Government Affairs Office (Roberson, 2015)

## Contaminant Candidate List Process

| | Year Published | Contaminants Included | Regulatory Determinations |
|---|---|---|---|
| CCL1 | 1998 | • 10 microbial<br>• 50 chemical | • Not to regulate 8 chemicals (incl. manganese) and 1 microorganism (*Acanthamoeba*) |
| CCL2 | 2005 | • 9 microbial<br>• 42 chemical | • Not to regulate 11 chemicals;<br>• More information needed on perchlorate |
| CCL3 | 2009 | • 12 microbial<br>• 104 chemicals | • Preliminary determination to regulate strontium<br>• Not to regulate 4 chemicals |

## Primary Drinking Water Regulations

- What are primary Drinking water regulations and **how do they vary based upon source water classification**?
- What are Secondary Drinking Water Regulations?

## Difference Between GWUDI and GW Boils Down to Three Major Parameters

- Turbidity Removal
- Disinfection By Product Precursor Removal
- Disinfection


- [x] Capacity
- [x] GWUDI
- [ ] Water Quality
- [ ] DBP's

## Primary Drinking Water Regulations

- What are primary Drinking water regulations and how do they vary based upon source water classification?
- **What are Secondary Drinking Water Regulations?**

## Notable Regulations – Safe Drinking Water Act

- EPA has established National Secondary Drinking Water Regulations (NSDWRs) that set non-mandatory water quality standards for 15 contaminants. EPA does not enforce these "secondary maximum contaminant levels" (SMCLs). They are established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to present a risk to human health at the SMCL.
- While SMCLs are not federally enforceable, EPA requires a special notice for exceedance of the fluoride SMCL of 2.0 mg/L. Community water systems that exceed the fluoride SMCL of 2 mg/L, but do not exceed the MCL of 4.0 mg/L for fluoride, must provide public notice to persons served no later than 12 months from the day the water system learns of the exceedance (40 CFR 141.208).

## Secondary Standard Philosophy

- These problems can be grouped into three categories:
  - Aesthetic effects — undesirable tastes or odors;
  - Cosmetic effects — effects which do not damage the body but are still undesirable
  - Technical effects — damage to water equipment or reduced effectiveness of treatment for other contaminants

## Table of Secondary Standards

| Contaminant | Secondary MCL | Noticeable Effects above the Secondary MCL |
|---|---|---|
| Aluminum | 0.05 to 0.2 mg/L* | colored water |
| Chloride | 250 mg/L | salty taste |
| Color | 15 color units | visible tint |
| Copper | 1.0 mg/L | metallic taste; blue-green staining |
| Corrosivity | Non-corrosive | metallic taste; corroded pipes/ fixtures staining |
| Fluoride | 2.0 mg/L | tooth discoloration |
| Foaming agents | 0.5 mg/L | frothy, cloudy; bitter taste; odor |
| Iron | 0.3 mg/L | rusty color; sediment; metallic taste; reddish or orange staining |
| Manganese | 0.05 mg/L | black to brown color; black staining; bitter metallic taste |
| Odor | 3 TON (threshold odor number) | "rotten-egg", musty or chemical smell |
| pH | 6.5 - 8.5 | low pH: bitter metallic taste; corrosion<br>high pH: slippery feel; soda taste; deposits |
| Silver | 0.1 mg/L | skin discoloration; graying of the white part of the eye |
| Sulfate | 250 mg/L | salty taste |
| Total Dissolved Solids (TDS) | 500 mg/L | hardness; deposits; colored water; staining; salty taste |
| Zinc | 5 mg/L | metallic taste |

## Continue Secondary Standards

2. The secondary regulations concern the aesthetic aspects of a drinking water supply rather than the health aspects. Should any new treatment processes consider satisfying the current secondary regulations (suggested limits) as well as the primary regulations (required by law)? Satisfying the secondary regulations is currently done at the existing facilities.

- ☐ Continue Satisfying Secondary Suggested Limits for Aesthetic Properties
- ☐ Discontinue Satisfying Secondary Suggested Limits for Aesthetic Properties

Please list the reasons for your selection:

## Softening Presentation

## Softening in Visioning Workshop

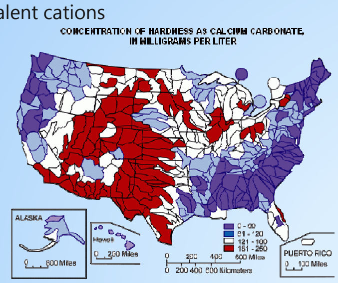
1. To reduce anticipated operational expenses, should the current treatment goals to soften the water be abandoned in favor of less expensive treatment measures? ( This may cause some consumers to install in-home water softeners)

- [ ] Continue Softening Treatment Goals
- [ ] Discontinue Softening Treatment Goals

Please list the reasons for your selection:

## Softening Basics

- Removal of Calcium and Magnesium
  - Divalent cations



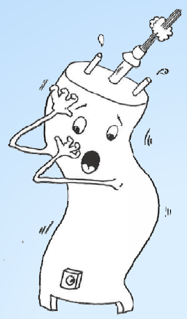

USGS 2005 Streamflow

## Why Remove Hardness ?

- Aesthetics
  - American Institute of Laundering
    - Costs are 2X for hard versus soft
  - Synthetic detergents
    - Better than fatty acids (basic)
    - Builders - consumed by hard water
  - Purdue University
    - Fabrics - wear out 15% quicker
    - Colors fade
    - Whites darken
  - Reduced equipment life
    - 30% reduction - washing machines
    - Hot water heaters

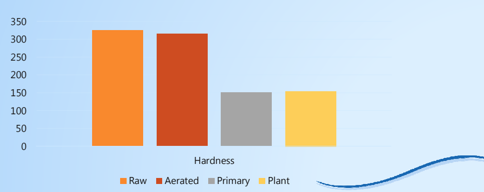
## Water Hardness is a Balance for Hot Water Heaters

- Low hardness – Corrosion
  - Soft water 2x or 3X anode consumption
- Hard water – Calcium carbonate build up
  - Slows heat transfer – overheating of tank bottom
    - Over temperature – dissolved glass
    - Insulates tank from anode

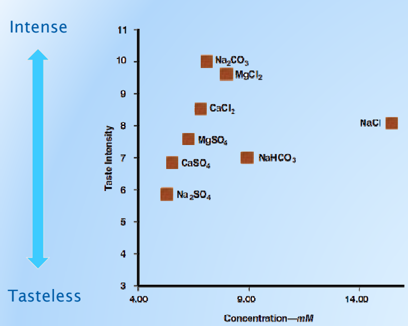


## What is Considered Soft ?

| Hardness Range (mg/L as $CaCO_3$) | Hardness Description |
|---|---|
| 0-75 | Soft |
| 75-150 | Moderately Hard |
| 150-300 | Hard |
| > 300 | Very Hard |
| 1 grains of $CaCO_3$/gallon = 17.1 mg/L | |




## When Do Customers Complain ?



## When Do Customers Complain ?

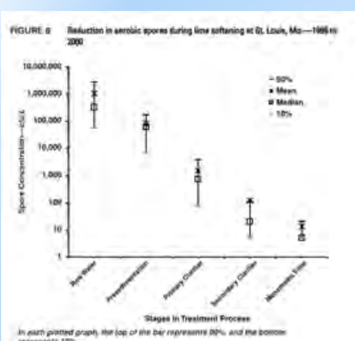
| Potability Grade | TDS mg/L |
|---|---|
| Excellent | < 80 |
| Good | 81–450 |
| Fair | 451–760 |
| Poor | 761–1,020 |
| Unacceptable | > 1,021 |

Variability of water quality and temperature have big effects

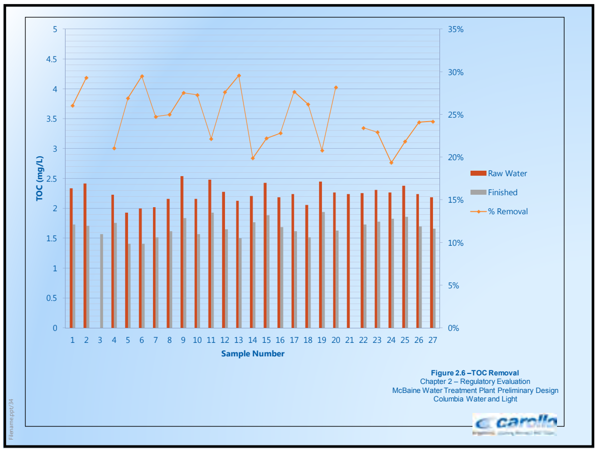
## What can Softening Do ?

- Removes
  - Hardness
  - Heavy metals (lead, cadmium, copper, zinc, chromium mercury, arsenic)
  - Barium
  - Silica
  - Fluoride
  - Iron
  - Manganese
  - Turbidity
  - Organics (color)
  - Oil
  - Algae, bacteria and viruses
  - Radium, uranium, gross alpha, beta
  - Reduces corrosion
  - Will not remove Iocane

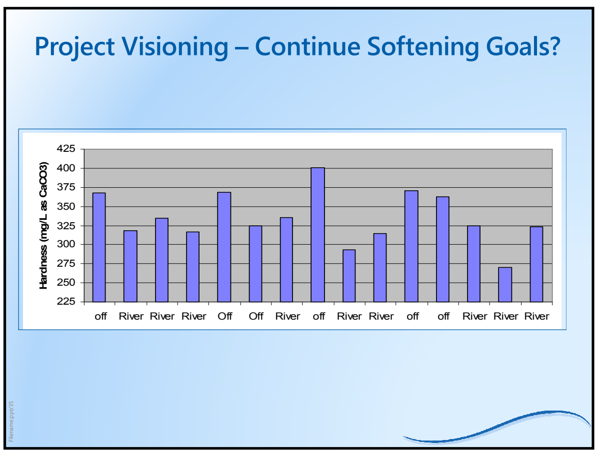

## Pathogen Removal Is Significant in Softening Process




LT2ESWTR grants an additional 0.5 log Cryptosporidium Removal



TOC (mg/L)
Sample Number
Raw Water
Finished
% Removal
Figure 2.6 –TOC Removal
Chapter 2 – Regulatory Evaluation
McBaine Water Treatment Plant Preliminary Design
Columbia Water and Light

Project Visioning – Continue Softening Goals?
Hardness (mg/L as CaCO3)
off River River River Off Off River off River River off off River River River


CEC Presentation

## Contaminant Candidate List Process

### Draft CCL4 – February 14, 2015

- Remainders from CCL3, minus
  - Positives for perchlorate (2011) and strontium (preliminary 2014)
  - Four negative preliminary determinations in 2014
- 110 chemical contaminants, including
  - Cyanotoxins
  - Manganese
- 12 microbial contaminants

## UCMR Monitoring Approach

**Monitoring Frequency:**
- GW systems: 2x in a year
- SW systems: Quarterly in a year
- UCMR4 will follow seasonal sampling approach for cyanotoxins

**Monitoring Locations:**
- Can vary depending on contaminant
  - UCMR1 – all entry points
  - UCMR2 – included distribution system samples for nitrosamines
  - UCMR3 – included distribution system samples for Cr(VI)

**CWS Participants:**
- List 1 monitored in all PWSs serving more than 10,000 people and a subset (800) of PWSs serving less than 10,000
- List 2 monitored in all PWSs serving more than 100,000 people and subset of PWSs serving less people

## UCMR4 – Monitoring between 2018 - 2020

| Contaminant | Sampling Point(s) | Method |
|---|---|---|
| Cyanotoxins: total microcystin & 5 congeners, anatoxin-a, cylindrospermopsin, nodularin | Entry point | EPA 546, EPA 544 and 545 |
| Germanium | Entry point | EPA 200.8, SM 3125 |
| Manganese | Entry point | |
| 8 pesticides | Entry point | EPA 525.3 |
| 3 alcohols | Entry point | EPA 541 |
| 3 other semivolatile compounds | Entry point | EPA 530 |
| 3 brominated DBPs[1] & indicator compounds[2] | Distribution system | EPA 552.3 or 557 |

[1] HAA5, HAA6Br, HAA9
[2] TOC, bromide, temperature and pH

## 3rd Six Year Review Identified 8 NPDWRs for Regulatory Revision

- Stage 1 and 2 D/DBPR (TTHM, HAA5, Chlorite)
- *Cryptosporidium*
- Heterotrophic Bacteria
- *Giardia lamblia*
- *Legionella*
- Viruses

https://www.epa.gov/dwsixyearreview/six-year-review-3-drinking-water-standards

## Executive Order 13771 and 13777 on Reducing Regulatory Burden

- January 30, 2017 EO 13771 Reducing Regulation and Controlling Regulatory Costs
  - Any new regulation must be coupled with two de-regulations
- February 24, 2017 EO 13777
  - Within 60 days of order, agencies must designate Regulatory Reform Officers to oversee regulatory reform initiatives, including compliance with EO 13771

https://www.whitehouse.gov/the-press-office/2017/02/24/presidential-executive-order-enforcing-regulatory-reform-agenda

## Regulatory Horizon

| Contaminant | Regulatory Framework | Probability* |
|---|---|---|
| Perchlorate | 2011 decision to regulate; NRDC settlement | Likely |
| Lead | Proposed Long Term-LCR rule expected 2017 | Likely |
| Cyanotoxins | 2015 health advisories (HA); UCMR4; CCL4 | Likely |
| Strontium | 2014 preliminary decision to regulate | Likely |
| Chlorate | 3rd Six Year Review; Pesticide Office | Possible |
| NDMA | 3rd Six Year Review | Possible |
| Cr(VI) | UCMR3; CCL4 | Possible |
| 1,4-dioxane | UCMR3; CCL4 | Maybe |
| Perfluorocompounds | 2016 revised HA; UCMR3; CCL4 | Maybe |
| Brominated DBPs | UCMR4; 3rd Six Year Review | Maybe |
| Manganese | UCMR4; CCL4 | Maybe |

* Based on AWWA Government Affairs (Roberson, 2015); "Likely" – regulation in 5 years; "Possible" – 50/50 chance of final regulation in 5-10 years; "Maybe" – anything can happen

## Project Visioning – Presence of CEC's in Supply

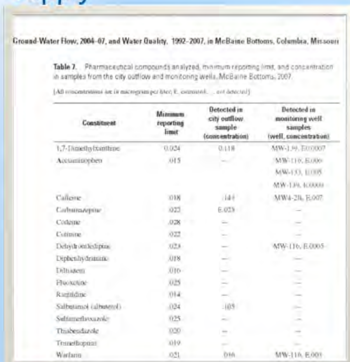

Ground-Water Flow, 2004–07, and Water Quality, 1992–2007, in McBaine Bottoms, Columbia, Missouri

Table 7. Pharmaceutical compounds analyzed, minimum reporting limit, and concentration in samples from the city outflow and monitoring wells, McBaine Bottoms, 2007.

[All concentrations are in micrograms per liter; E, estimated; —, not detected]

| Constituent | Minimum reporting limit | Detected in city outflow sample (concentration) | Detected in monitoring well samples (well, concentration) |
|---|---|---|---|
| 1,7-Dimethylxanthine | 0.024 | 0.118 | MW-13S, E0.0007 |
| Acetaminophen | .015 | — | MW-11S, E.006 |
| | | | MW-13D, E.005 |
| | | | MW-13S, E.0009 |
| Caffeine | .018 | .144 | MW4-28, E.007 |
| Carbamazepine | .022 | E.023 | — |
| Codeine | .028 | — | — |
| Cotinine | .022 | — | — |
| Dehydronifedipine | .023 | — | MW-11S, E.0005 |
| Diphenhydramine | .018 | — | — |
| Diltiazem | .016 | — | — |
| Fluoxetine | .025 | — | — |
| Ranitidine | .014 | — | — |
| Salbutamol (albuterol) | .024 | .105 | — |
| Sulfamethoxazole | .025 | — | — |
| Thiabendazole | .020 | — | — |
| Trimethoprim | .019 | — | — |
| Warfarin | .021 | .016 | MW-11S, E.001 |

Snapshot in time.

Extent and types are unknown.

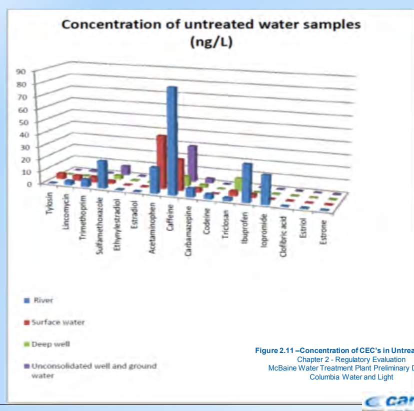
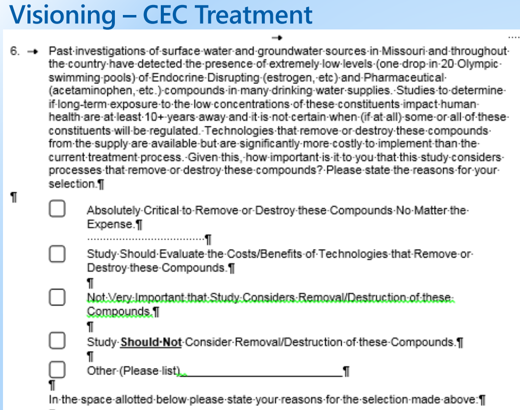



Figure 2.11 – Concentration of CEC's in Untreated Water
Chapter 2 - Regulatory Evaluation
McBaine Water Treatment Plant Preliminary Design
Columbia Water and Light

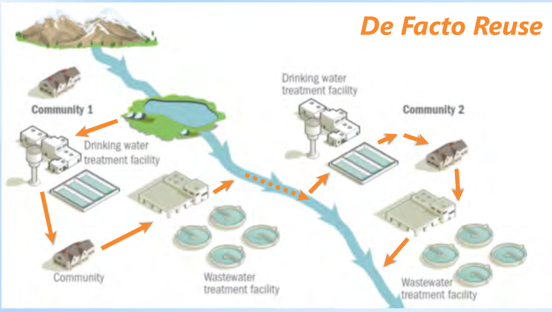
## Visioning – CEC Treatment


6. Past investigations of surface water and groundwater sources in Missouri and throughout the country have detected the presence of extremely low levels (one drop in 20 Olympic swimming pools) of Endocrine Disrupting (estrogen, etc) and Pharmaceutical (acetaminophen, etc.) compounds in many drinking water supplies. Studies to determine if long-term exposure to the low concentrations of these constituents impact human health are at least 10+ years away and it is not certain when (if at all) some or all of these constituents will be regulated. Technologies that remove or destroy these compounds from the supply are available but are significantly more costly to implement than the current treatment process. Given this, how important is it to you that this study considers processes that remove or destroy these compounds? Please state the reasons for your selection.

- ☐ Absolutely Critical to Remove or Destroy these Compounds No Matter the Expense.
- ☐ Study Should Evaluate the Costs/Benefits of Technologies that Remove or Destroy these Compounds.
- ☐ Not Very Important that Study Considers Removal/Destruction of these Compounds.
- ☐ Study **Should Not** Consider Removal/Destruction of these Compounds.
- ☐ Other (Please list) ____________________

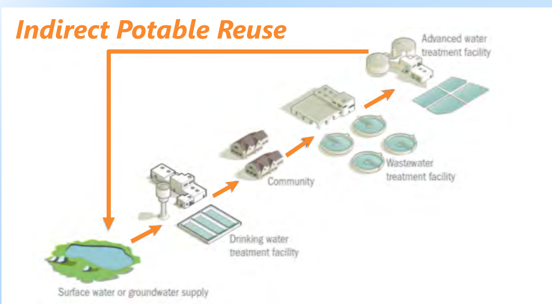
In the space allotted below please state your reasons for the selection made above.

## Reuse and the Urban Water Cycle



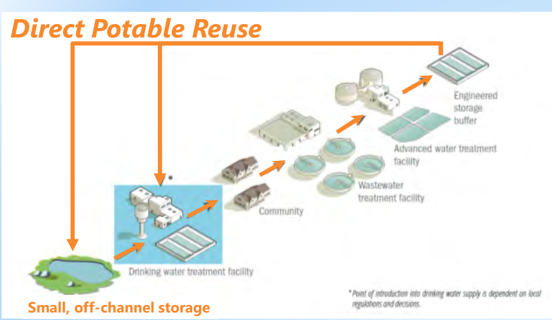

*Source: AWWA Potable Reuse 101*

## Reuse and the Urban Water Cycle

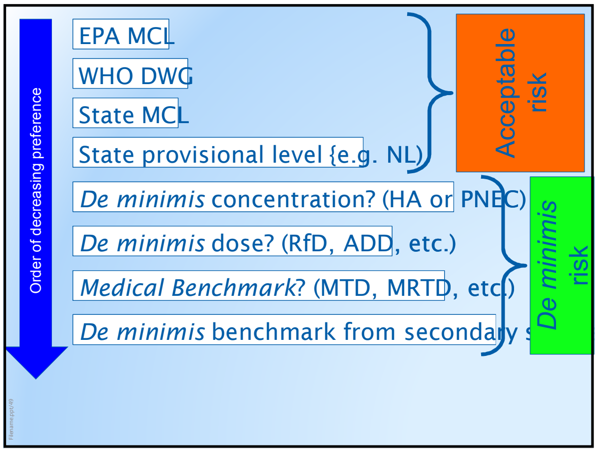



*Source: AWWA Potable Reuse 101*

## Reuse and the Urban Water Cycle




*Source: AWWA Potable Reuse 101*




## NWRI Expert Panel Recommendations (WateReuse-11-02)

| | Contaminant of Emerging Concern | Public Health Criterion | Secondary Effluent Concentration |
|---|---|---|---|
| ng/L | N-nitrosodimethylamine (NDMA) | 10 ng/L | Varies |
| | Perfluorooctanoic acid (PFOS) | 200 ng/L* | Not Measured |
| | Estrone (E1) | 320 ng/L | 14 ng/L |
| | 17β-estradiol (E2) | N/A | < 5 ng/L |
| | 17α-ethinylestradiol (EE2) | N/A | < 5 ng/L |
| | Perfluorooctanoic acid (PFOA) | 400 ng/L* | Not Measured |
| ug/L | 1,4-dioxane | 1 μg/L | Not Measured |
| | Cotinine | 1 μg/L | 0.049 μg/L |
| | Phenytoin (Dilantin) | 2 μg/L | 0.210 μg/L |
| | Atenolol | 4 μg/L | 0.450 μg/L |
| | TCEP | 5 μg/L | 0.110 μg/L |
| | Carbamazepine | 10 μg/L | 0.320 μg/L |
| | Primidone | 10 μg/L | 0.440 μg/L |
| | DEET | 200 μg/L | 0.046 μg/L |
| | Meprobamate | 200 μg/L | 0.190 μg/L |
| mg/L | Triclosan | 2 mg/L | 0.000063 mg/L |
| | Sucralose | 150 mg/L | 0.017 mg/L |

## Indicator TOrCs

- Frequent Occurrence at 'High' Concentrations (relative to detection limits)
- Availability and Reliability of Analytical Methods (LC-MS/MS → expensive!)
- Performance validation
  - **Biotransformation** → Activated Sludge, Biofiltration, Environmental Buffer
    - High = Caffeine, Naproxen, Ibuprofen
    - Low = Carbamazepine, Meprobamate, Sucralose
  - **Adsorption** → Activated Sludge, Granular Activated Carbon, Environmental Buffer
    - High = Triclosan, Triclocarban, Bisphenol A
    - Low = Caffeine, Meprobamate, Sucralose
  - **Oxidation** → Chlorine, Ozone, Hydroxyl Radicals
    - High = Carbamazepine, Triclosan, Bisphenol A
    - Low = TCEP, Meprobamate, Sucralose
  - **Photolysis** → UV, Environmental Buffer
    - High = Diclofenac, Triclosan, NDMA
    - Low = Primidone, Meprobamate, Sucralose
  - **Wastewater influence**
    - Primidone, Meprobamate, Sucralose

UNLV 31

## Pharmaceuticals Make Good Headlines…

Daily Mail .com

Home | U.K. | News | Sports | U.S. Showbiz | Australia | Femail | Health | Science | Money

**Is YOUR water poisoned by other people's pills? Top scientist warns of 'health timebomb' caused by prescription drugs washed down drains**

http://www.dailymail.co.uk/health/article-3339996/Top-scientist-warns-health-timebomb-caused-prescription-drugs-washed-drains.html

Filename.ppt/52

## Pharmaceuticals Make Good Headlines…

In Big Spring, we found…

Table 4.1 Health-Based Criteria and Measured Concentrations

| Chemical | Health Criterion | WWTP Effluent | DPR Product Water |
|---|---|---|---|
| Carbamazepine | 10 µg/L | <0.01 µg/L | <0.0005 µg/L |
| Estrone | 320 ng/L | <0.2 ng/L | <0.2 ng/L |
| Meprobamate | 200 µg/L | 0.23 µg/L | 0.00045 µg/L |
| Atenolol | 4 µg/L | 0.33 µg/L | <0.001 µg/L |
| Primidone | 10 µg/L | 0.19 µg/L | <0.0005 µg/L |
| PFOA | 70 ng/L[4] | 12 ng/L | < 5 ng/L |
| PFOS | 70 ng/L[4] | 5.4 ng/L | < 1 ng/L |
| 1,4-dioxane | 1 µg/L | 0.36 µg/L[5] | <0.07 µg/L[5] |
| DEET | 200 µg/L | 0.19 µg/L | 0.15 µg/L |
| Triclosan | 2.1 mg/L | 0.0018 µg/L | < 0.01 µg/L |
| Sucralose[6] | 150 mg/L | 0.041 mg/L | 0.000150 mg/L |
| TCEP | 5 µg/L | 2.1 µg/L | < 0.01 µg/L |

Anti-anxiety drug (Meprobamate)

Blood pressure med! (Atenolol)

Anti-convulsant! (Primidone)

Insect repellant! (DEET)

Anti-microbial! (Triclosan)

…and more!

Steinle-Darling et al (2016). Direct Potable Reuse Monitoring. Final Report to Texas Water Development Board (also WE&RF 14-10)

Filename.ppt/53

## …but they Do NOT Drive Public Health Risk!

Table 4.1 Health-Based Criteria and Measured Concentrations

| Chemical | Health Criterion | WWTP Effluent | DPR Product Water |
|---|---|---|---|
| Carbamazepine | 10 µg/L | <0.01 µg/L | <0.0005 µg/L |
| Estrone | 320 ng/L | <0.2 ng/L | <0.2 ng/L |
| Meprobamate | 200 µg/L | 0.23 µg/L | 0.00045 µg/L |
| Atenolol | 4 µg/L | 0.33 µg/L | <0.001 µg/L |
| Primidone | 10 µg/L | 0.19 µg/L | <0.0005 µg/L |
| PFOA | 70 ng/L[4] | 12 ng/L | < 5 ng/L |
| PFOS | 70 ng/L[4] | 5.4 ng/L | < 1 ng/L |
| 1,4-dioxane | 1 µg/L | 0.36 µg/L[5] | <0.07 µg/L[5] |
| DEET | 200 µg/L | 0.19 µg/L | 0.15 µg/L |
| Triclosan | 2.1 mg/L | 0.0018 µg/L | < 0.01 µg/L |
| Sucralose[6] | 150 mg/L | 0.041 mg/L | 0.000150 mg/L |
| TCEP | 5 µg/L | 2.1 µg/L | < 0.01 µg/L |

Steinle-Darling et al (2016). Direct Potable Reuse Monitoring. Final Report to Texas Water Development Board (also WE&RF 14-10)

## Other DPR Research Concludes the Same

| Compound (ng/L) | Typical Effluent | Guidance Value |
|---|---|---|
| Atenolol | 710 | 70,000 |
| Atrazine | 28 | 1,000 |
| DEET | 140 | 2,500,000 |
| Gemfibrozil | 31 | 45,000 |
| Naproxen | <25 | 220,000 |

Data from Reuse-05-05, 08-05, 11-02, and Benotti et al 2009, ES&T 43 (3), 597-603

| | Max Secondary WWTP Conc (µg/L) | Max UF-Ozone-BAC Conc. (µg/L) | Max Drinking Water Conc. (µg/L) | DWEL (µg/L) | Liters per day to meet DWEL |
|---|---|---|---|---|---|
| Phenytoin | 0.11 | <0.001 | 0.019 | 6.8 | 700 |
| Carbamazepine | 0.14 | <0.0005 | 0.018 | 12 | 1,300 |
| Fluoxetine | Not Reported | <0.0005 | 0.0082 | 34 | 82,000 |
| Diazepam | Not Reported | <0.0003 | 0.00033 | 35 | 210,000 |
| Gemfibrozil | 0.031 | <0.0003 | 0.0021 | 45 | 43,000 |
| Atenolol | 0.71 | <0.001 | 0.018 | 70 | 7,800 |
| Meprobamate | 0.041 | 0.008 | 0.042 | 260 | 13,000 |
| Bisphenol A | <0.05 | <0.005 | 0.025 | 1,800 | 140,000 |
| Sulfamethoxazole | 0.57 | <0.0003 | 0.003 | 18,000 | 12,000,000 |


*...and Texas doesn't regulate them anyway.*

See Water Environment & Reuse Foundation Project No. 11-02 and 15-01 for details.

## Said another way:

*"Not everything that counts can be counted, and* ***not everything that can be counted counts****."*

Note: This quote is often attributed to Albert Einstein, but credit should more likely go to sociologist William Bruce Cameron, who wrote this in paper published in 1963.
Source: http://quoteinvestigator.com/2010/05/26/everything-counts-einstein/

## Project Visioning – Future of Existing Water Source

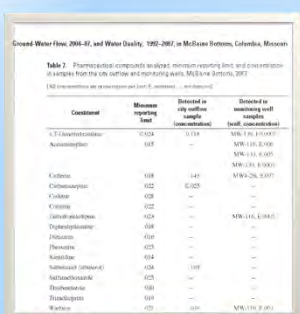
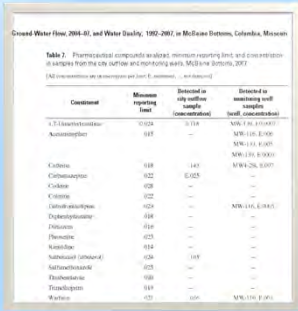

Ground-Water Flow, 2004–07, and Water Quality, 1992–2007, in McBaine Bottoms, Columbia, Missouri

Table 7. Pharmaceutical compounds analyzed, minimum reporting limit, and concentration in samples from the city outflow and monitoring wells, McBaine Bottoms, 2007

| Constituent | Minimum reporting limit | Detected in city outflow sample (concentration) | Detected in monitoring well samples (well, concentration) |
|---|---|---|---|

A water or wastewater issue? (EDC's, Pharm, Nitrate, etc.)

## Project Visioning – Considering Treatment for CEC's



Ground-Water Flow, 2004–07, and Water Quality, 1992–2007, in McBaine Bottoms, Columbia, Missouri

**Table 7.** Pharmaceutical compounds analyzed, minimum reporting limit, and concentration in samples from the city outflow and monitoring wells, McBaine Bottoms, 2007

[illegible]

| Constituent | Minimum reporting limit | Detected in city outflow sample (concentration) | Detected in monitoring well samples (well, concentration) |
|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] |

A water or wastewater issue? (EDC's, Pharm, Nitrate, etc.)

## Disinfection By Products

## Visioning - Disinfection By Products

Water Treatment Plant Configuration (cont.):

5. To satisfy regulations associated with disinfection by products, the City of Columbia converted from free chlorine to chloramines in the distribution system and conducts periodic conversions to chlorine to avoid issues that are associated with nitrification. There are more costly technologies that can be employed to satisfy all disinfection by product regulations **and** permit switching back to chlorine. Given this, how important is it to you that the City of Columbia switches back to the exclusive use of free chlorine in the distribution system? Please state the reasons for your selection.

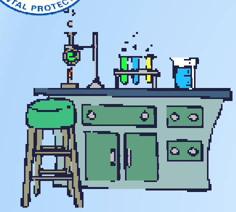
- ☐ Absolutely Critical to Switch Back to Chlorine
- ☐ Very Important to Switch Back to Chlorine
- ☐ Not Very Important
- ☐ Stay with Chloramines
- ☐ Other (Please list) ____________________

In the space allotted below please state your reasons for the selection made above:

Page Break

## Maximum Contaminant Levels for Disinfection Byproducts

TTHM MCL = 0.080 mg/L
HAA5 MCL = 0.060 mg/L

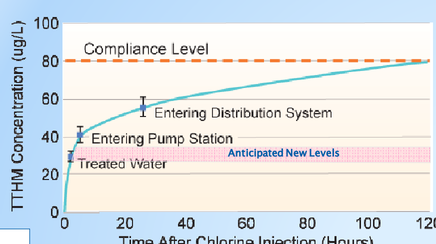


- Apply to CWSs and NTNCWSs that add a disinfectant to their water
- Reduce risks of cancer, liver and kidney damage, reproductive problems associated with elevated levels of byproducts

## MDNR Notice of Violation

- In 2007 Columbia's water supply exceeds Federal MCL for TTHMs
- Average concentration of 82.3 ppb
- April 2008 – MDNR notice of violation

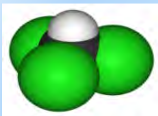
## Historical Disinfection By Products - Columbia



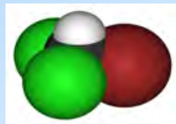

- ☐ Capacity
- ☐ GWUDI
- ☐ Water Quality
- ☑ DBP's

## Total Trihalomethanes

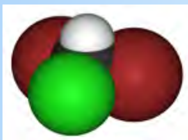
- Chloroform



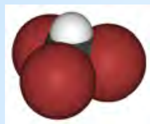
- Bromodichloromethane



- Dibromochloromethane

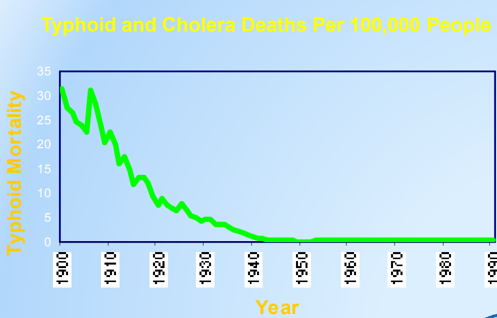


- Bromoform



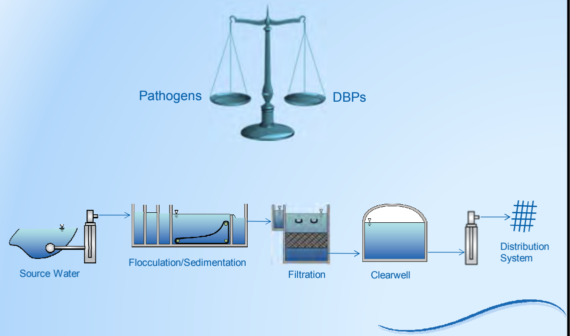
## Why Chlorinate if It Produces Byproducts?

## History of Chlorination in the U.S.



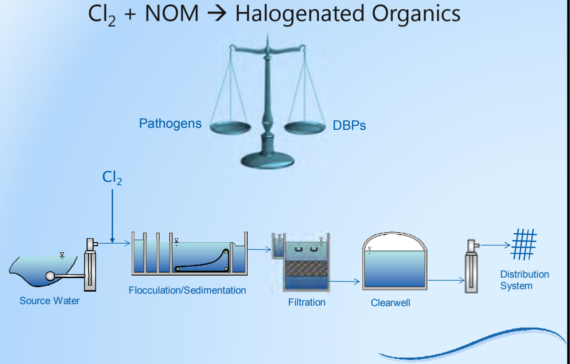
## Problem Description

$Cl_2$ + NOM → Halogenated Organics



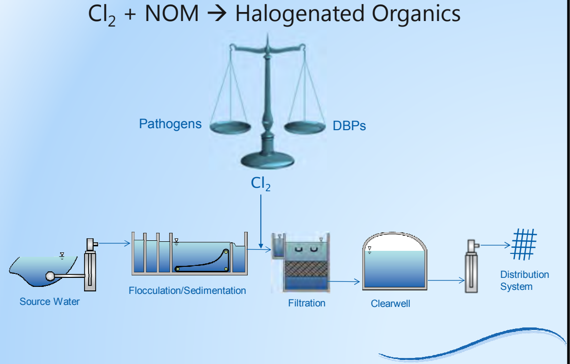

## Problem Description

$Cl_2$ + NOM → Halogenated Organics




## Problem Description

$Cl_2$ + NOM → Halogenated Organics



## Why Chloramines? Chloramination vs. Chlorination

Advantages

- Lower HAA and THM formation
- More stable disinfectant

Disadvantages

- Poorer disinfectant
- May lead to nitrification in the distribution system

## What are Chloramines?

$HOCl + NH_3 \leftrightarrow NH_2Cl + H_2O$ (monochloramine)

$HOCl + NH_2Cl \leftrightarrow NHCl_2 + H_2O$ (dichloramine)

$HOCl + NHCl_2 \leftrightarrow NCl_3 + H_2O$ (trichloramine)

## What are Chloramines?

$HOCl + NH_3 \leftrightarrow NH_2Cl + H_2O$ (monochloramine)

$HOCl + NH_2Cl \leftrightarrow NHCl_2 + H_2O$ (dichloramine)

$HOCl + NHCl_2 \leftrightarrow NCl_3 + H_2O$ (trichloramine)

## Chloramine chemistry is complicated, but we know a lot about it

Table 7-1 – Monochloramine autodecomposition model

| No. | Reaction | Rate or Equilibrium Constant | Reference |
|---|---|---|---|
| 1 | $HOCl + NH_3 \rightarrow NH_2Cl + H_2O$ | $4.2 \times 10^6\ M^{-1}s^{-1}$ | Jafvert and Valentine (1992) |
| 2 | $NH_2Cl + H_2O \rightarrow NH_3 + HOCl$ | $2.1 \times 10^{-5}\ s^{-1}$ | Morris and Isaac (1981) |
| 3 | $NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$ | $2.8 \times 10^2\ M^{-1}s^{-1}$ | Margerum *et al.* (1978) |
| 4 | $NHCl_2 + H_2O \rightarrow HOCl + NH_2Cl$ | $6.4 \times 10^{-7}\ s^{-1}$ | Margerum *et al.* (1978) |
| 5 | $NH_2Cl + NH_2Cl \rightarrow NHCl_2 + NH_3$ | pH dependent[a] | Vikesland *et al.* (2001) |
| 6 | $NHCl_2 + NH_3 \rightarrow NH_2Cl + NH_2Cl$ | $6.1 \times 10^4\ M^{-1}s^{-1}$ | Hand and Margerum (1983) |
| 7 | $NH_2Cl + NHCl_2 \rightarrow N_2 + 3H^+ + 3Cl^-$ | $1.5 \times 10^{-2}\ M^{-1}s^{-1}$ | Leao (1981) |
| 8 | $NHCl_2 + H_2O \rightarrow NOH + 2HCl$ | $1.1 \times 10^2\ M^{-1}s^{-1}$ | Jafvert and Valentine (1987) |
| 9 | $NOH + NHCl_2 \rightarrow N_2 + HOCl + HCl$ | $2.8 \times 10^4\ M^{-1}s^{-1}$ | Leao (1981) |
| 10 | $NOH + NH_2Cl \rightarrow N_2 + H_2O + HCl$ | $8.3 \times 10^3\ M^{-1}s^{-1}$ | Leao (1981) |
| 11 | $HOCl \leftrightarrow H^+ + OCl^-$ | $pK_a = 7.54$ | Bodner and Pardue (1995) |
| 12 | $NH_4^+ \leftrightarrow NH_3 + H^+$ | $pK_a = 9.24$ | Bodner and Pardue (1995) |
| 13 | $H_2CO_3 \leftrightarrow HCO_3^- + H^+$ | $pK_a = 6.35$ | Bodner and Pardue (1995) |
| 14 | $HCO_3^- \leftrightarrow CO_3^{2-} + H^+$ | $pK_a = 10.33$ | Bodner and Pardue (1995) |

[a] $k_5 = k_{H^+}[H^+] + k_{H_2CO_3}[H_2CO_3] + k_{HCO_3^-}[HCO_3^-]$ where $k_{H_2CO_3} = 11\ M^{-2}s^{-1}$, $k_{HCO_3^-} = 0.22\ M^{-2}h^{-1}$, $k_{H^+} = 6944\ M^{-2}s^{-1}$

NOH is the unidentified monochloramine auto-decomposition intermediate

Table 7-2 – Important bromide - monochloramine reactions in drinking water treatment

| No. | Reaction | Rate or Equilibrium Constant | Reference |
|---|---|---|---|
| 15 | $HOCl + Br^- \rightarrow HOBr + Cl^-$ | $1.55 \times 10^3\ M^{-1}s^{-1}$ | Kumar and Margerum (1987) |
| 16 | $HOBr + NH_3 \rightarrow NH_2Br + H_2O$ | $7.5 \times 10^7\ M^{-1}s^{-1}$ | Wajon and Morris (1980) |
| 17 | $OBr^- + NH_3 \rightarrow NH_2Br + OH^-$ | $7.6 \times 10^4\ M^{-1}s^{-1}$ | Wajon and Morris (1980) |
| 18 | $NH_2Br + H_2O \rightarrow HOBr + NH_3$ | $1.5 \times 10^{-3}\ s^{-1}$ | Haag and Lietzke (1980) |
| 19 | $NH_2Br + NH_2Br \rightarrow NHBr_2 + NH_3$ | pH dependent[a] | Lei *et al.* (2004) |
| 20 | $NHBr_2 + NH_3 \rightarrow NH_2Br + NH_2Br$ | pH dependent[b] | Lei *et al.* (2004) |
| 21 | $NH_2Br + NHBr_2 \rightarrow N_2 + 3H^+ + 3Br^-$ | pH dependent[c] | Lei *et al.* (2004) |
| 22 | $NHBr_2 + NHBr_2 + H_2O \rightarrow N_2 + HOBr + 3H^+ + 3Br^-$ | $8.9\ M^{-1}s^{-1}$ | Lei *et al.* (2004) |
| 23 | $HOBr + NH_2Cl \rightarrow NHBrCl + H_2O$ | $2.86 \times 10^5\ M^{-1}s^{-1}$ | Gazda and Margerum (1994) |
| 24 | $OBr^- + NH_2Cl \rightarrow NHBrCl + OH^-$ | $2.2 \times 10^4\ M^{-1}s^{-1}$ | Gazda and Margerum (1994) |
| 25 | $NH_2Cl + NH_2Cl + Br^- \rightarrow NHBrCl + Cl^- + NH_3$ | pH dependent[d] | Trofe *et al.* (1980); This work |
| 26 | $NHBrCl + NHBrCl + H_2O \rightarrow N_2 + HOBr + HBr + 2HCl$ | $17\ M^{-1}s^{-1}$ | Valentine 1983; This work |
| 27 | $HOBr \leftrightarrow OBr^- + H^+$ | $pK_a = 8.8$ | Haag and Hoigne (1983) |

[a] $k_{19} = 0.5\ M^{-1}s^{-1} + 5 \times 10^8\ M^{-2}s^{-1}[H^+] + 290\ M^{-2}s^{-1}[NH_4^+] + 540\ M^{-2}s^{-1}[HCO_3^-]$

[b] $k_{20} = 1\ M^{-1}s^{-1} + 1 \times 10^9\ M^{-2}s^{-1}[H^+] + 190\ M^{-2}s^{-1}[NH_4^+] + 180\ M^{-2}s^{-1}[HCO_3^-]$

[c] $k_{21} = 6.2\ M^{-1}s^{-1} + 8.3 \times 10^8\ M^{-2}s^{-1}[OH^-] + 3.2 \times 10^3\ M^{-2}s^{-1}[CO_3^{2-}]$

[d] $k_{25} = 8.3 \times 10^3\ M^{-2}s^{-1}[NH_2Cl][Br^-][H^+]$

## Chloramines – Other Considerations

- Chloramine has been around for 90 years
- One in five Americans has chloraminated water
- EPA stated in its 1994 review that: "*In humans, health effects do not appear to be associated with levels of residual monochloramines typically found in drinking water*"
- Some individuals and groups may be inalterably opposed to the introduction of chloramines

## Columbia Conversion to Chloramination

- Conversion from free chlorine disinfection to chloramination.
- Free Chlorine "burns" to limit nitrification

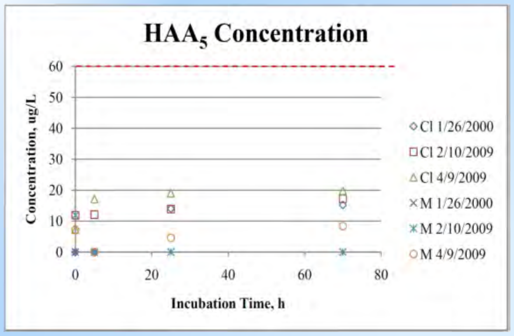



**Figure 2.9 –HAA Concentration using Chloramines (Source: Columbia, MODBP Project)**
Chapter 2 – Regulatory Evaluation
McBaine Water Treatment Plant Preliminary Design
Columbia Water and Light

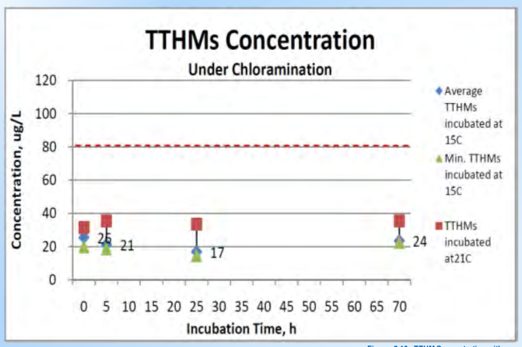
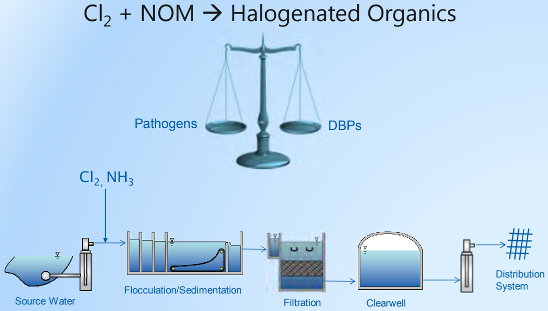



**Figure 2.10 –TTHM Concentration with Chloramines (Source: Columbia, MODBP Project)**
Chapter 2 - Regulatory Evaluation
McBaine Water Treatment Plant Preliminary Design
Columbia Water and Light

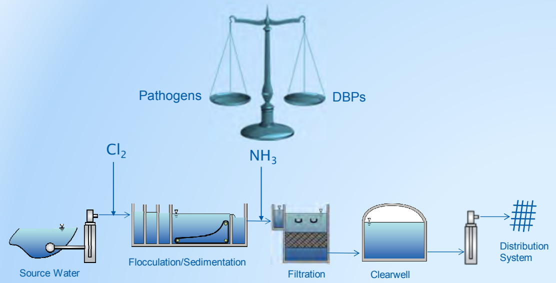
## Problem Description

$Cl_2$ + NOM → Halogenated Organics



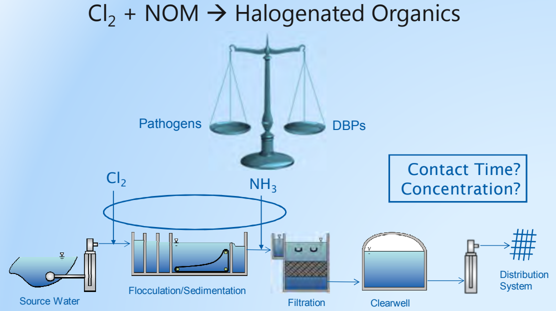
## Problem Description

$Cl_2$ + NOM → Halogenated Organics

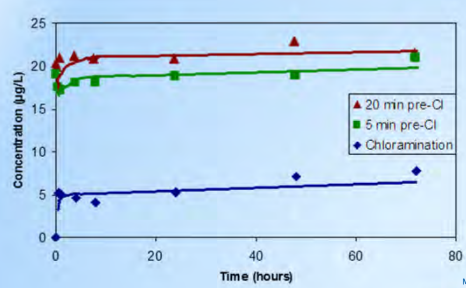



## Problem Description

$Cl_2$ + NOM → Halogenated Organics



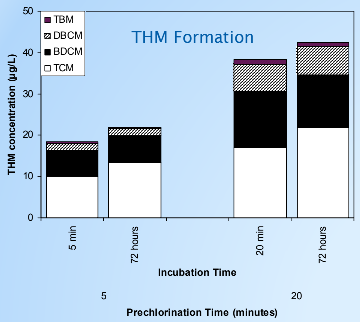

## Most HAA formation occurs during Prechlorination




Metedeconk River

Source: Pope et al., 2006

## Most THM formation occurs during prechlorination




Source: Pope et al., 2006

## HAA formation during chloramination:

| Factors that Impact HAA Formation | |
|---|---|
| pH | HAA ⇧ as pH ⇩ |
| Bromide | HAA ⇧ as Bromide ⇧ |
| Total Organic Carbon (TOC) | HAA ⇩ as TOC ⇩ |
| Chlorine/Nitrogen Ratio | HAA ⇧ as $Cl_2$/N ⇧ |
| Temperature | HAA ⇧ as Temperature ⇧ |
| Residual | HAA ⇧ as Residual ⇧ |

## The EPA Currently Regulates 11 DBPs

- 4 THMs (80 µg/L)
- 5 HAAs (60 µg/L)
- Chlorite (1 mg/L)
- Bromate (10 µg/L)

**But, > 600 DBPs Have Been Identified**

## And > 50% are still unknown

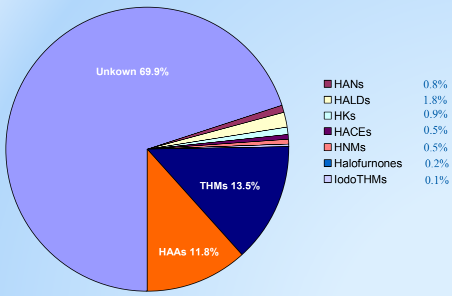


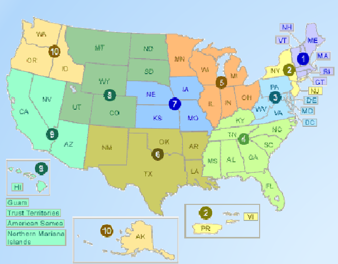

Figure adapted from Richardson et al., 2003

## Several of emerging DBPs are on the EPA Contaminant Candidate List (CCL3)

- 6 Nitrosamines (e.g., NDMA)
- Formaldehyde
- Bromochloromethane
- Chlorate

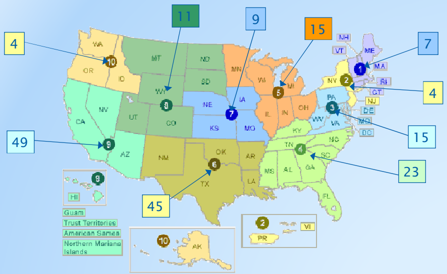
The 6 Nitrosamines were screened as part of the Unregulated Contaminant Monitoring Rule (UCMR2)

## UCMR2 NDMA Occurrence Data




1. Number of PWS in each region with NDMA Concentration greater than MRL
2. Approximately 750 utilities nationwide were surveyed

## UCMR2 NDMA Occurrence Data

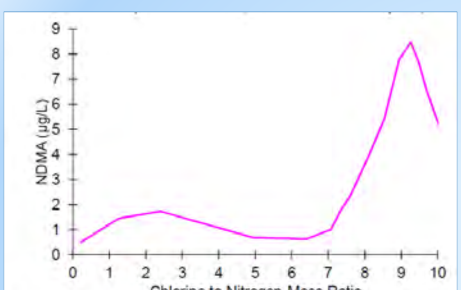



Number of PWS in each region with NDMA Concentration greater than MRL

## NDMA

- Chlorination
  - Cationic Coagulation Polymers and Coagulant Aids (i.e., poly-DADMAC and epi-DMA)
- Chloramination
  - Formation is increased near breakpoint
  - Preoxidation with chlorine or ozone may decrease
- California Action Level = 10 ng/L

## Nitrosamine (NDMA) formation is linked to chloramine formation conditions




Source: Schreiber and Mitch (2007)

## NDMA formation may be reduced by:

1. Reducing dichloramine formation during chloramination
   a) Add chlorine upstream of ammonia at WTP
   b) Elevate pH
   c) Minimize Chlorine to Nitrogen Ratio
      i. Trade-offs with nitrification control
2. Add oxidants (e.g. free chlorine, ozone) prior to ammonia addition
3. Manage polymer addition
4. Source water protection (wastewater impacted source waters may form more NDMA)

Treatment Technologies Evaluation

## Visioning – Treatment Technologies

4. The end of this questionnaire provides a glossary of the advanced treatment technology and the potential benefits this technology would provide. Please select which of these advanced technologies you would like to see the study address. Please list the reasons for your selections.

- ☐ Membrane Filtration
- ☐ Nano/Reverse Osmosis
- ☐ Advanced Oxidation
- ☐ Ion Exchange
- ☐ Advanced Disinfection
- ☐ Ozone/Infiltration
- ☐ Advanced Biofiltration
- ☐ Air Stripping
- ☐ Enhanced Softening
- ☐ All of the Above
- ☐ Others (Please List Below)

Please list the reasons for your selection:

# Alternative Development

## "Fatal Flaw" and "Must Include" List

- "Must Include" or the Alternative will be eliminated from consideration
  - Capacity without Purchasing Water
  - Satisfy Regulatory Requirements
  - Meets Secondary Standards (Fe and Mn)
  - Meets Hardness Goal of 150 mg/L
  - Uses existing well field
  - Optimize existing infrastructure
  - Satisfy GWUDI compliance

## "Fatal Flaw" and "Must Include" List

- "Fatal Flaw" will eliminate Potential Alternative from consideration
  - Technology has never been built at this scale
  - Inappropriate technology
  - Extremely inflated costs
  - Not acceptable to the Community

## Technologies for Evlaution

**Oxidation Technologies**

Ferrate, Chlorine, Chlorine dioxide, Ozone, Ozone / H2O2, UV / H2O2, UV / TiO2, P. Acid / UV, Permanganate

**Hardness Removal Technologies**

Conventional Softening, Enhanced Softening, Softening with caustic, Split Treatment, Pelletized Lime Reactor, Nanofiltration, Reverse Osmosis, High Rate Softening, Anion Exchange

**Filtration Technologies**

Nanofiltration, RO, Membranes (low pressure), Biological filtration, Alternative filtration (bag, earth, slow sand), Conventional Filtration, Deep bed with constant rate filtration, Manganese coated filter media, Greensand Filtration

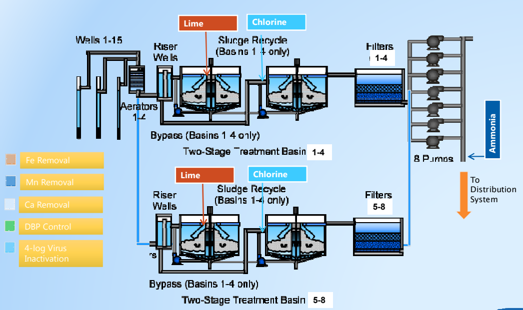
**Disinfection By Product Control**

GAC Filter Contactors, PAC Contactors – Acticarb, Post Filtration GAC Columns, Nanofiltration/RO, Enhanced Coagulation, PAC, Ozone/Biofiltration, EC Bromide Removal, Chlorine Dose Control, MIEX, Air Stripping, TOC Specific Resin

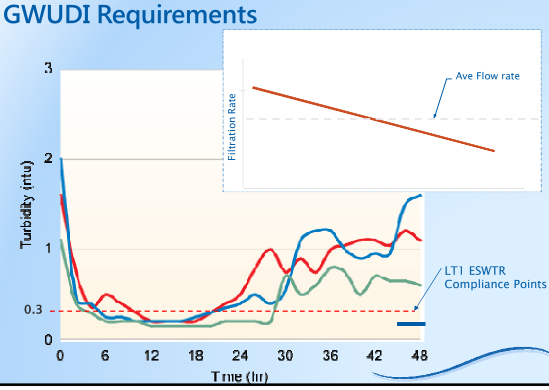
**Disinfection Technologies**

Chlorine, Chloramines, Ozone, Permanganate, UV, Chlorine Dioxide, Ferrate, Periacetic Acid

## Project Driver Water Quality – Existing Treatment Achievements




## Existing Filter Design Inadequate to Meet GWUDI Requirements



**Slide 99**

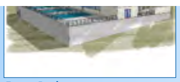
**u30** Comment on the declining rate mode. Not appropriate for what they have. Find alot in Iowa because Cleasby. Slow Start concept. Maximum filtration rate.

user, 4/27/2009

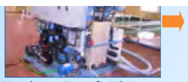
## Filtration Improvements

- Option I – Deep Bed Filtration
- Option II – Membranes

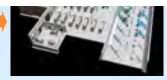
Micro/Ultra Filtration: Water under moderate pressure (25-50 psig) is forced through a membrane, a thin material with very small pores, stopping small particles (including bacteria). This is proven to provide an effective barrier to most pathogens but is not effective in removing ions (softening) or most organic compounds.



Deep Bed
Austin, TX (50 mgd)

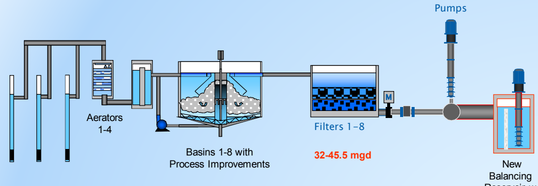


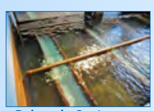
Membrane Retrofit Pilot
Kansas City, MO (230 mgd)



Membrane Expansion
Olathe, KS (30 mgd)

## Option 1 – Convert To Constant Rate Filtration & Increase Production



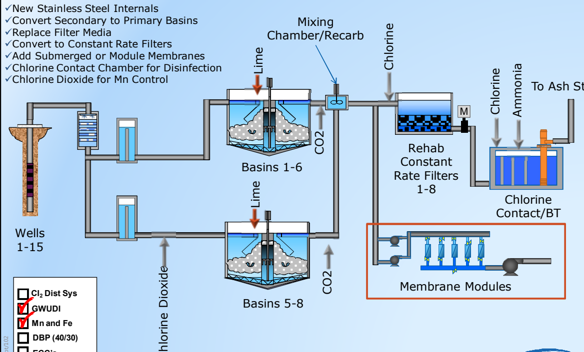



Colorado Springs

Key Project Members:
Robert Morroni
Bryant Bench

## Alternative No. 1B Membranes

- ✓New Stainless Steel Internals
- ✓Convert Secondary to Primary Basins
- ✓Replace Filter Media
- ✓Convert to Constant Rate Filters
- ✓Add Submerged or Module Membranes
- ✓Chlorine Contact Chamber for Disinfection
- ✓Chlorine Dioxide for Mn Control



## Technologies for Evlaution

| Oxidation Technologies | | | | |
|---|---|---|---|---|
| Ferrate | Chlorine | Chlorine dioxide | Ozone | Ozone / H2O2 |
| | UV / H2O2 | UV / TiO2 | P. Acid / UV | Permanganate |

Hardness Removal Technologies

Nano/Reverse Osmosis: Water under high pressure (75-120 psig) is forced through a membrane using a separation process that employs the principles of reverse osmosis to remove dissolved contaminants from water; typically applied for membrane softening or the removal of dissolved organic contaminants. This treatment may provide enhanced removal of disinfection by product precursors and may permit the re-establishment of free chlorine as both a primary and secondary (distribution) system disinfectant. In addition, these processes have proven effective in reducing the extremely low levels (one drop in 20 Olympic swimming pools) of some Endocrine Disrupting (estrogen, etc) and Pharmaceutical (acetaminophen, etc.) compounds found in many of the nations drinking water supplies.

| | | | |
|---|---|---|---|
| Chlorine Dose Control | MIEX | Air Stripping | TOC Specific Resin |

| Disinfection Technologies | | | |
|---|---|---|---|
| Chlorine | Chloramines | Ozone | Permanganate |
| UV | Chlorine Dioxide | Ferrate | Periacetic Acid |

## Technologies for Evlaution

| Oxidation Technologies | | | | |
|---|---|---|---|---|
| Ferrate | Chlorine | Chlorine dioxide | Ozone | Ozone / H2O2 |
| | UV / H2O2 | UV / TiO2 | P. Acid / UV | Permanganate |

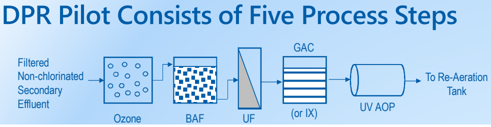
Softening (precipitative): The process of adding an alkaline agent (lime, caustic soda, etc.) to water to remove hardness (calcium) via precipitation. This is done to reduce scaling in water heaters and otherwise improve other aesthetic aspects of drinking water.

Ion Exchange: A reversible chemical reaction between an insoluble solid and a solution during which ions may be interchanged. This separation process, as it applies to Columbia, would be to examine fixed bed or dispersed magnetic resins to fix some organic ions to the resins This treatment may provide enhanced removal of disinfection by product precursors and may permit the re-establishment of free chlorine as both a primary and secondary (distribution) system disinfectant.

| | | | |
|---|---|---|---|
| GAC Filter Contactors | PAC Contactors – Acticarb | Columns | Nanofiltration/RO |
| Enhanced Coagulation | PAC | Ozone/Biofiltration | EC Bromide Removal |
| Chlorine Dose Control | MIEX | Air Stripping | TOC Specific Resin |

| Disinfection Technologies | | | |
|---|---|---|---|
| Chlorine | Chloramines | Ozone | Permanganate |
| UV | Chlorine Dioxide | Ferrate | Periacetic Acid |

## DPR Pilot Consists of Five Process Steps




Ozone/Biofiltration: A combined water treatment process to reduce natural organic matter (NOM) which is a water disinfectant byproduct precursor. Water is first assonated (ozone is mixed into the water flow to oxidize organic matter, iron and manganese) and then passed through a biofilter (a filter bed laden with microorganisms that break down organic matter into carbon dioxide, water and salts). These processes have proven effective in reducing the extremely low levels (one drop in 20 Olympic swimming pools) of some Endocrine Disrupting (estrogen, etc) and Pharmaceutical (acetaminophen, etc.) compounds found in many of the nations drinking water supplies. This treatment may provide enhanced removal of disinfection by product precursors and may permit the re-establishment of free chlorine as a secondary (distribution) system disinfectant.

## DPR Pilot Consists of Five Process Steps

GAC

Filtered

Advanced Disinfection: Technologies (Ozone, chlorine dioxide, UV, low pressure membrane filtration) that are approved by the US EPA to provide primary disinfection of drinking water that meet or exceed national standards without the use of free chlorine. This does not eliminate the use of chlorination in the process. Chlorination or Chloramination will be required by the Missouri Department of Natural resources following this process to produce a measurable residual disinfectant in the distribution system. Some of these technologies may provide enhanced removal of disinfection by product precursors and may permit the re-establishment of free chlorine as a secondary (distribution) system disinfectant.¶

¶

¶

Advanced Oxidation: The process of adding or generating powerful oxidants to oxidize trace levels of organic or microbiological organisms in water. These processes have proven effective in reducing the extremely low levels (one drop in 20 Olympic swimming pools) of some Endocrine Disrupting (estrogen, etc) and Pharmaceutical (acetaminophen, etc.) compounds found in many of the nations drinking water supplies.¶

## Ozone ($O_3$): Looks Like This

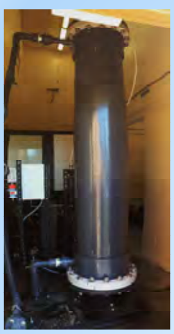
$O_3$

BAF

UF

GAC

UV/AOP



$O_3$ Contactor


$O_3$ Generator / Panel

## Ozone ($O_3$): Disinfects Virus and Destroys Many Organics

$O_3$

BAF

UF

GAC

UV/AOP

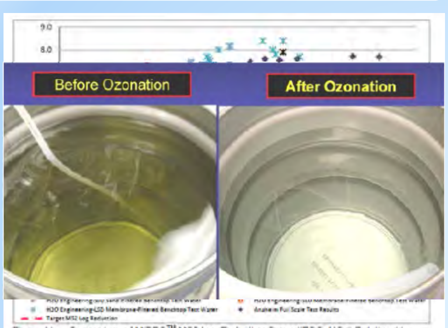



Figure 11 Comparison of MIPRO™ MS2 Log Reduction-Ozone/(TOC+NO$_2^-$) Relationship with Results of Different Studies

## Biologically Active Filtration (BAF): Looks Like This

- $O_3$
- BAF
- UF
- GAC
- UV/AOP

***"Oxelia" is Xylem's Combination of Wedeco Ozone and Leopold BAF***

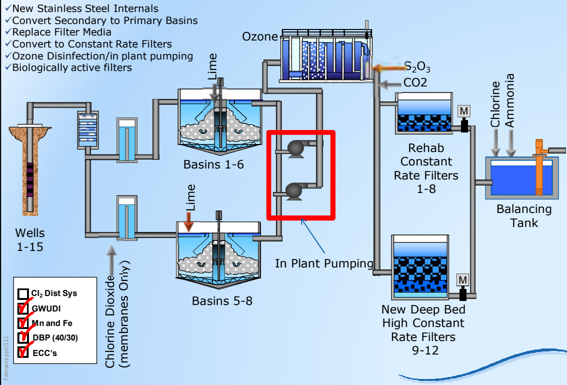
## BAF: Breaks Down Organics and Mitigates NDMA Formed

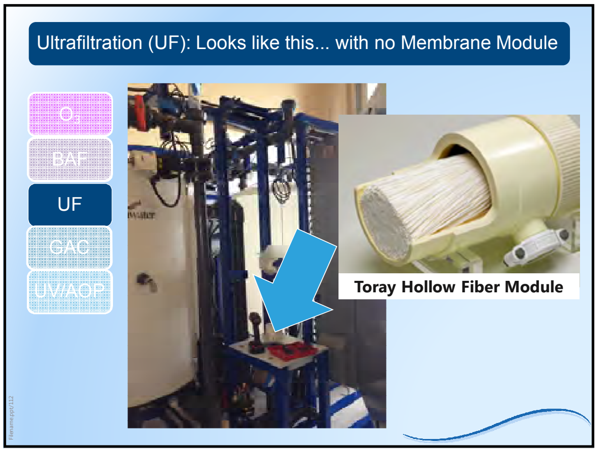
- $O_3$
- BAF
- UF
- GAC
- UV/AOP

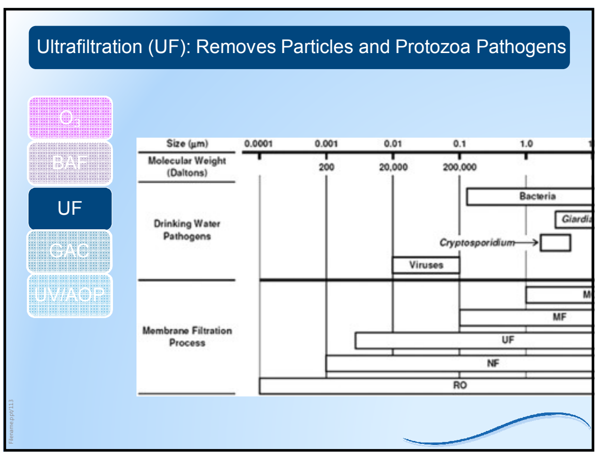
| Compound | Max. Recommended Value, ng/L | Secondary Effluent, ng/L | , Tertiary Effluent with UV ng/L | $O_3$, BAF Filtrate, ng/L |
|---|---|---|---|---|
| Atenolol | 70,000 | 710 | 120 | <25 |
| Atrazine | 1,000 | 28 | <10 | <10 |
| Bisphenol A | 200,000 | <50 | <50 | <50 |
| Carbamazepine | 1,000 | 140 | 192 | <10 |
| DEET | 2,500,000 | 54 | 232 | <25 |
| Diclofenac | 1,800 | 62 | 57 | <25 |
| Gemfibrozil | 45,000 | 31 | 12 | <10 |
| Ibuprofen | 400,000 | <25 | <25 | <25 |
| Meprobamate | 260,000 | 41 | 362 | 190 |
| Musk Ketone | 350,000 | <100 | <100 | <100 |
| Naproxen | 220,000 | <25 | <25 | <25 |
| Phenytoin | 6,800 | 110 | 113 | 33 |
| Primidone | 10,000 | 67 | 168 | 31 |
| Sulfamethoxazole | 35,000 | 570 | 1,150 | <25 |
| Triclosan | 350 | 26 | 38 | <25 |
| Trimethoprim | 70,000 | 280 | 43 | <10 |
| TCEP | 1,000 | 540 | 349 | <200 |

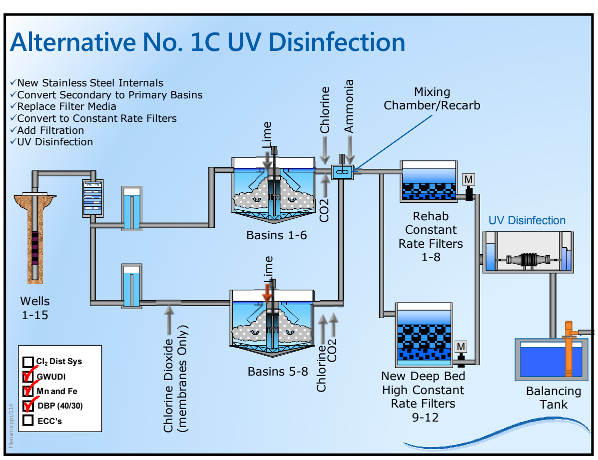
## Alternative No. 1D Advanced Oxidation

- ✓New Stainless Steel Internals
- ✓Convert Secondary to Primary Basins
- ✓Replace Filter Media
- ✓Convert to Constant Rate Filters
- ✓Ozone Disinfection/in plant pumping
- ✓Biologically active filters




Ultrafiltration (UF): Looks like this... with no Membrane Module
$O_3$
BAF
UF
GAC
UV/AOP
Toray Hollow Fiber Module


Ultrafiltration (UF): Removes Particles and Protozoa Pathogens
$O_3$
BAF
UF
GAC
UV/AOP
Size (µm)
0.0001
0.001
0.01
0.1
1.0
Molecular Weight (Daltons)
200
20,000
200,000
Drinking Water Pathogens
Bacteria
Cryptosporidium
Viruses
Membrane Filtration Process
MF
UF
NF
RO


Alternative No. 1C UV Disinfection
✓New Stainless Steel Internals
✓Convert Secondary to Primary Basins
✓Replace Filter Media
✓Convert to Constant Rate Filters
✓Add Filtration
✓UV Disinfection
Lime
Chlorine
Ammonia
Mixing Chamber/Recarb
CO2
M
Basins 1-6
Rehab Constant Rate Filters 1-8
UV Disinfection
Lime
Wells 1-15
Basins 5-8
Chlorine
CO2
New Deep Bed High Constant Rate Filters 9-12
Balancing Tank
Chlorine Dioxide (membranes Only)
$Cl_2$ Dist Sys
GWUDI
Mn and Fe
DBP (40/30)
ECC's

## Granular Activated Carbon (GAC): Looks Like This

- $O_3$
- BAF
- UF
- GAC
- UV/AOP

## GAC: Provides Polishing and "Backup" Treatment

- $O_3$
- BAF
- UF
- GAC
- UV/AOP

**Removal of PFOS and PFOA Through Full-Scale Treatment**

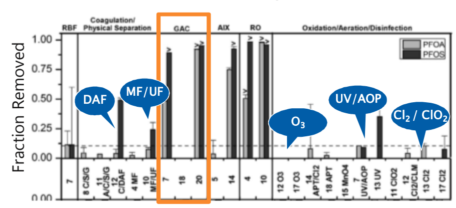
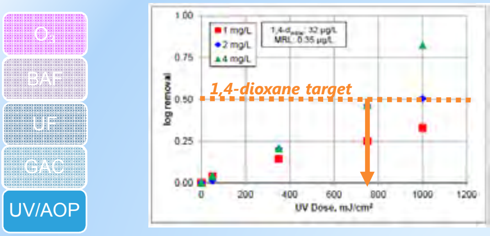



Figure 1. in Appleman *et al*, 2014. *Water Research, 51, 246-255.*

## Ultraviolet Light / Advanced Oxidation Process (UV/AOP)

- $O_3$
- BAF
- UF
- GAC
- UV/AOP

## UV/AOP: ***Additional*** Polishing and ***Significant*** Disinfection




| Target | 1.0 log | 2.0 log | 3.0 log | 4.0 log |
|---|---|---|---|---|
| Crypto | 2.5 | 5.8 | 12 | 22 |
| Giardia | 2.1 | 5.2 | 11 | 22 |
| Adenovirus | 58 | 100 | 143 | 186 |

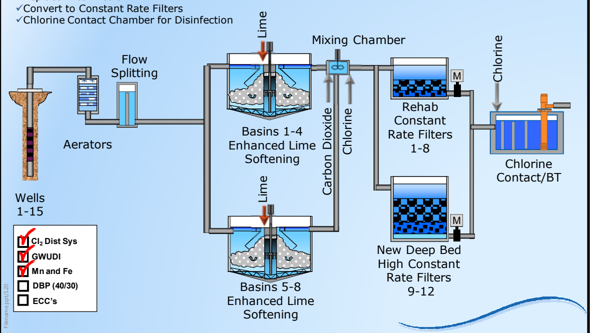
USEPA, 2006

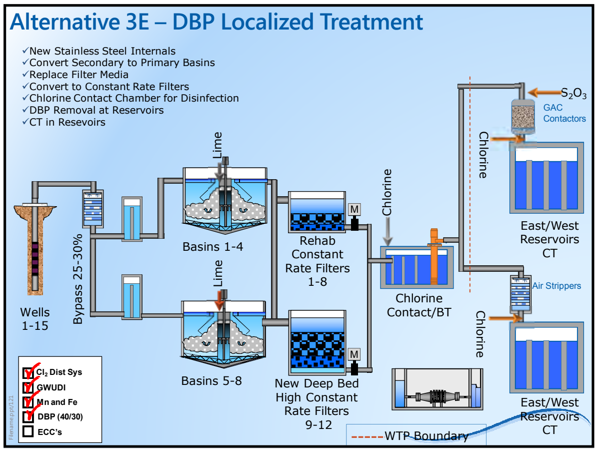
## Other Technologies – DBP Control

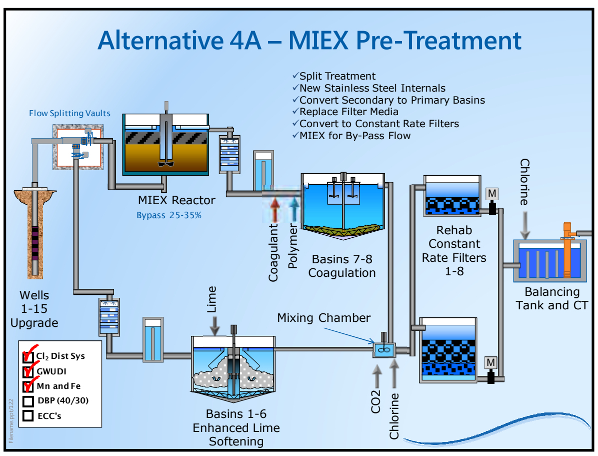
- Enhanced Softening
- Post Treatment Aeration/Stripping
- Post Treatment Adsorption – GAC
- Pretreatment – MIEX
- Treatment – GAC Filter Absorbers

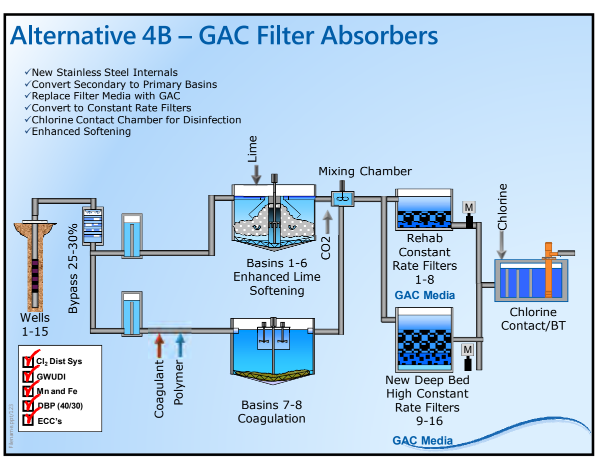
## Alternative No.3D – Enhanced Softening

✓New Stainless Steel Internals
✓Convert Secondary to Primary Basins
✓Enhanced Softening
✓Replace Filter Media
✓Convert to Constant Rate Filters
✓Chlorine Contact Chamber for Disinfection




Alternative 3E – DBP Localized Treatment
✓New Stainless Steel Internals
✓Convert Secondary to Primary Basins
✓Replace Filter Media
✓Convert to Constant Rate Filters
✓Chlorine Contact Chamber for Disinfection
✓DBP Removal at Reservoirs
✓CT in Resevoirs
Wells 1-15
Bypass 25-30%
Lime
Basins 1-4
Lime
Basins 5-8
Rehab Constant Rate Filters 1-8
New Deep Bed High Constant Rate Filters 9-12
M
Chlorine
Chlorine Contact/BT
Chlorine
$S_2O_3$
GAC Contactors
East/West Reservoirs CT
Air Strippers
Chlorine
East/West Reservoirs CT
WTP Boundary
Cl2 Dist Sys
GWUDI
Mn and Fe
DBP (40/30)
ECC's


Alternative 4A – MIEX Pre-Treatment
✓Split Treatment
✓New Stainless Steel Internals
✓Convert Secondary to Primary Basins
✓Replace Filter Media
✓Convert to Constant Rate Filters
✓MIEX for By-Pass Flow
Flow Splitting Vaults
MIEX Reactor
Bypass 25-35%
Coagulant
Polymer
Basins 7-8 Coagulation
Rehab Constant Rate Filters 1-8
M
Chlorine
Balancing Tank and CT
Wells 1-15 Upgrade
Lime
Mixing Chamber
Basins 1-6 Enhanced Lime Softening
CO2
Chlorine
Cl2 Dist Sys
GWUDI
Mn and Fe
DBP (40/30)
ECC's


Alternative 4B – GAC Filter Absorbers
✓New Stainless Steel Internals
✓Convert Secondary to Primary Basins
✓Replace Filter Media with GAC
✓Convert to Constant Rate Filters
✓Chlorine Contact Chamber for Disinfection
✓Enhanced Softening
Lime
Mixing Chamber
Wells 1-15
Bypass 25-30%
Basins 1-6 Enhanced Lime Softening
CO2
Rehab Constant Rate Filters 1-8
GAC Media
M
Chlorine
Chlorine Contact/BT
Coagulant
Polymer
Basins 7-8 Coagulation
New Deep Bed High Constant Rate Filters 9-16
GAC Media
Cl2 Dist Sys
GWUDI
Mn and Fe
DBP (40/30)
ECC's

Updated Action/Decision Log

## DECISION LOG

**DECISION LOG**

Project: 0
Client: City of Columbia, MO
Job #: 0
Contract #: 0

UPDATED 8/14/2017
BY : CL

| ITEM No. | DECISION BY | DECISION FORUM | DECISION DESCRIPTION | DECISION DATE | COMMENTS |
|---|---|---|---|---|---|
| 1 | City | Townhall Meeting | Terry is appointed the chairman for the group, no one was opposed. | 10-Jul-17 | Vice chair is still open and will be filled in the future. |
| 2 | City | Townhall Meeting | Decision/Action log to include decisions made, date of the decision, who made the decision, etc. If there was a vote, the voting results are to be included. | 10-Jul-17 | |
| 3 | City | Townhall Meeting | All cost impacts to be displayed in anticipated rate increase to a typical user. | 10-Jul-17 | Usage rate increases associated with planne[d] improvements. |
| 4 | City/Carollo | Townhall Meeting | Develop a systematic approach for evaluation of all alternatives. Score each of the alternatives as they relate to water quality, not monetary value, to distinguish the goals of the municipality. | 10-Jul-17 | Try and remove all emotional biases. |
| 5 | | | | | |
| 6 | | | | | |

Filename.ppt/125

## ACTION LOG

**ACTION ITEM LOG**

Project:
Client: City of Columbia, MO
Job #:
Contract #:

DATE : 8/14/2017
BY : CL

| ITEM No. | RESPONSIBLE PARTY | ACTION ITEM | ITEM DATE | TARGET RESOLUTION DATE | ITEM COMPLETION DATE | COMMENTS |
|---|---|---|---|---|---|---|
| 1 | Carollo | Compartmentalize the emerging contaminants of concern (ECC's) and their scope | 10-Jul-17 | | | |
| 2 | Carollo | Provide insight to the public regarding model development and the model's capabilities | 10-Jul-17 | | | |
| 3 | City/Public | Ask about what is most concerning so Carollo can narrow in and explain the things that are difficult to understand. | 10-Jul-17 | | | |

Filename.ppt/126

Next Steps

## Next Steps

- Summarize Visioning Questionnaire
- Set Boundaries for Project
- Conduct Fatal Flaw Analysis and Present Recommendations
- Introduce Structured Decision Analysis
- Next Meeting: September 11, 2017

General Comments


Confirm Next Meeting
Date 9/11/17

# FINAL VISIONING WORKSHOP

City of Columbia, MO

Water and Light Department

Drinking Water Planning Workgroup

September 11, 2017, 5:30 pm

701 E Broadway Council Chambers

WATER OUR FOCUS OUR BUSINESS OUR PASSION

carollo Engineers...Working Wonders With Water®

## Workshop Purpose

- Finalize Visioning Exercise
  - Boundaries for Investigations
  - Establish Finished Water Quality Goals
- Introduce Structured Decision Analysis
  - Background
  - Homework – Criteria Development

## Workshop Agenda

- Review Visioning Questionnaire Responses
- Review Missioning Statement
- Set Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Introduction to Structured Decision Analysis
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members, and Staff
- Next Meeting Date

## Summary of Visioning Questionnaires

## Water Treatment Plant Configuration

1. To reduce anticipated operational expenses, should the current treatment goals to soften the water be abandoned in favor of less expensive treatment measures? ( This may cause some consumers to install in-home water softeners)

   4 Continue Softening Treatment Goals

   0 Discontinue Softening Treatment Goals

- Citizens are accustomed to softened water
- Softening delivers a higher quality product that customers expect

## Water Treatment Plant Configuration

2. The secondary regulations concern the aesthetic aspects of a drinking water supply rather than the health aspects. Should any new treatment processes consider satisfying the current secondary regulations (suggested limits) as well as the primary regulations (required by law)? Satisfying the secondary regulations is currently done at the existing facilities.

   4 Continue Satisfying Secondary Suggested Limits for Aesthetic Properties

   0 Discontinue Satisfying Secondary Suggested Limits for Aesthetic Properties

- Good to be ahead of the game. Secondary limits could be future regulations.
- Customers expect this quality of product

## Water Treatment Plant Configuration

3. Should the study examine abandoning and demolishing the existing water treatment plant (32 mgd) and constructing an entirely new facility with source water obtained from a different location at a significant cost to current and future customers?

- 1 Existing Supply and Treatment Plant Should be abandoned
- 2 Continue Use of Current Source and Treatment Facility

- Abandon:
  - The investment in the existing facilities would be beyond our reasonable ability to pay.
- Continue Use:
  - Potential source issues (GW v GWUDI) can be met with treatment options as they arise.

## Water Treatment Plant Configuration

4. The end of this questionnaire provides a glossary of the advanced treatment technology and the potential benefits this technology would provide. Please select which of these advanced technologies you would like to see the study address. Please list the reasons for your selections.

- 2 Membrane Filtration
- 1 Nano/Reverse Osmosis
- Advanced Oxidation
- 1 Ion Exchange
- 1 Advanced Disinfection
- 1 Ozone/Infiltration
- 1 Advanced Biofiltration
- Air Stripping
- Enhanced Softening
- 1 All of the Above
- Others (Please List Below)
  - GAC

## Water Treatment Plant Configuration

5. To satisfy regulations associated with disinfection by products, the City of Columbia converted from free chlorine to chloramines in the distribution system and conducts periodic conversions to chlorine to avoid issues that are associated with nitrification. There are more costly technologies that can be employed to satisfy all disinfection by product regulations **and** permit switching back to chlorine. Given this, how important is it to you that the City of Columbia switches back to the exclusive use of free chlorine in the distribution system? Please state the reasons for your selection:

- 1 Absolutely Critical to Switch Back to Chlorine
- ☐ Very Important to Switch Back to Chlorine
- ☐ Not Very Important
- 1 Stay with Chloramines
- 2 Other (Please list)__________

- Other:
  - Would like to use free chlorine if we could still meet the DBP rule.
  - Prefer the solution that provides the most flexibility and benefits.

## Water Treatment Plant Configuration

6. Past investigations of surface water and groundwater sources in Missouri and throughout the country have detected the presence of extremely low levels (one drop in 20 Olympic swimming pools) of Endocrine Disrupting (estrogen, etc) and Pharmaceutical (acetaminophen, etc.) compounds in many drinking water supplies. Studies to determine if long-term exposure to the low concentrations of these constituents impact human health are at least 10+ years away and it is not certain when (if at all) some or all of these constituents will be regulated. Technologies that remove or destroy these compounds from the supply are available but are significantly more costly to implement than the current treatment process. Given this, how important is it to you that this study considers processes that remove or destroy these compounds? Please state the reasons for your selection.

- 1 Absolutely Critical to Remove or Destroy these Compounds No Matter the Expense.
- 4 Study Should Evaluate the Costs/Benefits of Technologies that Remove or Destroy these Compounds.
- ☐ Not Very Important that Study Considers Removal/Destruction of these Compounds.
- ☐ Study **Should Not** Consider Removal/Destruction of these Compounds.
- ☐ Other (Please list)______________________

## Water Treatment Plant Configuration

7. Green elements at a water facility are elements that minimize chemical use and maximize energy efficiency. Should a "green" element be a consideration for ranking and analysis of treatment alternatives?

- 4 Yes
- ☐ No
- ☐ Other (Please List) ______________

- Columbia is a "green" town.
- Energy efficiency is important to the plant's bottom line.

## Water Treatment Plant Configuration

8. Are there any other issues regarding treatment that should be addressed?

- 3 Yes (please list) ______________
- 1 No

- YES:
  - Cost/benefit assessment of treatment options if classification changes to GWUDI.
  - Staffing.
  - Continued use or discontinuation of fluoride.


## Draft Mission Statement of Planning Workgroup

- "To enhance the quality of life for Columbia, Missouri Citizens by providing direction to Columbia Water and Light on the best means to continue its mission to provide at an affordable price; high-quality water and dependable service ~~that exceeds customer expectations~~; protects and ensures a long-term water supply for future generations; and serves as responsible stewards of public health, utility resources, and the environment."

Do we want to make this more specific? I.e. best treatment process at the existing WTP?

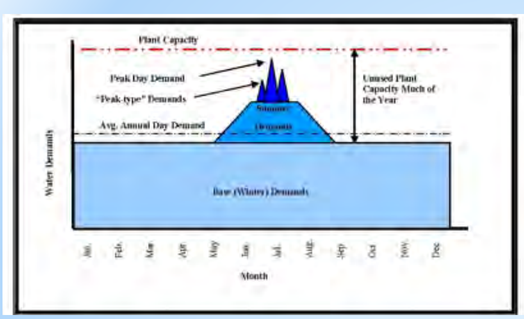
## Project Boundary Exercise

- Water Supply
- Finished Water Quality Goals
- Project Framework

## Project Boundary Exercise

- Water Supply
- Finished Water Quality Goals
- Project Framework

## Water Supply Exercise – Basic Definitions



## Water Supply Exercise – 2016 IWRP Recommendations

- Establish Future Demand Scenarios
- Basic Assumptions – Well Field:
  - Wells will continue to be a source of supply (29.6 mgd).
  - Wells will be expanded based upon maximizing supply.
    - 1300 feet between well "pairs"
    - 200 feet from "surface water" source
  - Well Field has "space" for 52 mgd (30 wells, 2 standby)

## Water Supply Exercise – 2016 IWRP Recommendations

- Basic Assumptions – Water Quality:
  - Utilize Chloride to Monitor
  - Bias against high chloride wells (blend)
  - Consider repurposing Close wells as "cutoff" wells
  - Consider possibility of reclassification as GWUDI to allow flexibility to move wells closer to river

## Water Supply Exercise- 2016 IWRP Recommendations

- Maximize Local Supply for Non Potable Use
  - Deep Wells for large irrigating/industrial supply
- Continue but do not expand ASR program

## Water Supply Exercise-2016 IWRP Recommendations

- Continue to expand and refine Conservation Program but harsh measures are not required due to abundance of Supply sources.
- Continue resolution with Integrated Stormwater Plan recommendations.

## Water Supply Exercise Boundaries

| Statement | YES | NO | MAYBE |
|---|---|---|---|
| The DWPWG Accepts the Recommendation of the IWRP | ☑ | | |
| GWUDI Compliant Facility is Required | | | |
| | | | |

## GWUDI vs GW Only

- Survey Results
- Decision Impacts

## Water Supply Exercise Boundaries

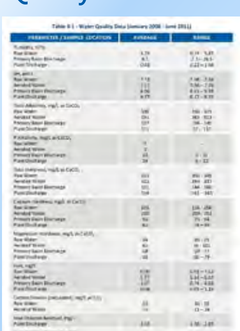
| Statement | YES | NO | MAYBE |
|---|---|---|---|
| The DWPWG Accepts the Recommendation of the IWRP | ☑ | | |
| GWUDI Compliant Facility is Required | | | |
| Others? | | | |

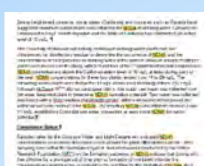
☑

## Project Boundary Exercise

- Water Supply
- Finished Water Quality Goals
- Project Framework

## Finished Water Quality Goals – Raw Water Quality.





Occurrence of Pharmaceuticals in McBaine Bottoms

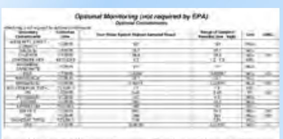
| [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|
| 1,7 Dimethyxanthine (Metabolite of Caffeine) | 0.118 | Diltiazem | – |
| Acetaminophen | – | Floroxetine | – |
| Caffeine (Starbucks) | 0.143 | Ranitidine | – |
| Carbamazepine (Anti-seizure) | 0.022 | Salbutamol (Asthma) | 0.105 |
| Codeine | – | Sulfamethoxazole | – |
| Cotinine | – | Thiabendazole | – |
| Dehydramine | – | Trimethoprim | – |
| Diphenhydramine | – | Warfarin (Blood thinner) | 0.036 |

## Regulatory Horizon

| Contaminant | Regulatory Framework | Probability* |
|---|---|---|
| Perchlorate | 2011 decision to regulate; NRDC settlement | Likely |
| Lead | Proposed Long Term-LCR rule expected 2017 | Likely |
| Cyanotoxins | 2015 health advisories (HA); UCMR4; CCL4 | Likely |
| Strontium | 2014 preliminary decision to regulate | Likely |
| Chlorate | 3rd Six Year Review; Pesticide Office | Possible |
| NDMA | 3rd Six Year Review | Possible |
| Cr(VI) | UCMR3; CCL4 | Possible |
| 1,4-dioxane | UCMR3; CCL4 | Maybe |
| Perfluorocompounds | 2016 revised HA; UCMR3; CCL4 | Maybe |
| Brominated DBPs | UCMR4; 3rd Six Year Review | Maybe |
| Manganese | UCMR4; CCL4 | Maybe |

* Based on AWWA Government Affairs (Roberson, 2015); "Likely" – regulation in 5 years; "Possible" – 50/50 chance of final regulation in 5-10 years; "Maybe" – anything can happen

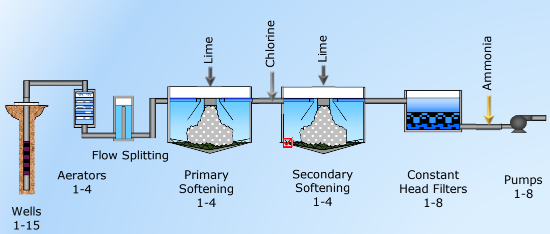
## 2016 Finished Water Quality Report


Optional Monitoring (not required by EPA)


Regulated Contaminants

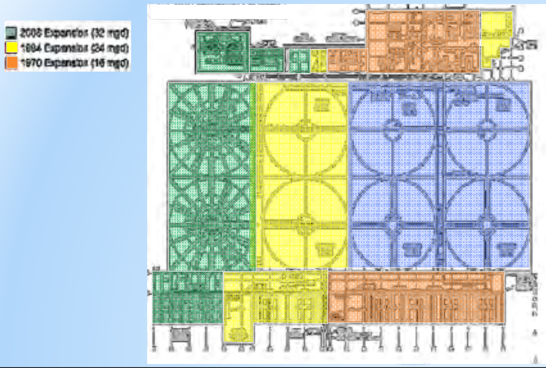
Violations and Health Effects Information

## Existing Plant

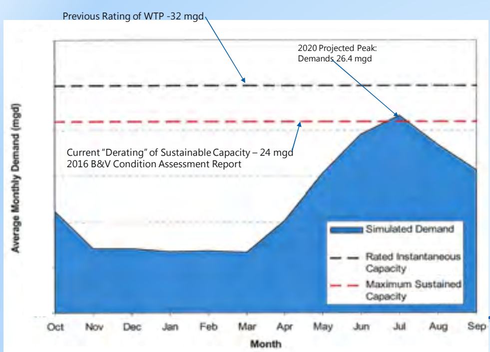



- ☐ GWUDI Compliance
- ☑ 4-log Virus
- ☐ $Cl_2$ Dist Sys
- ☑ Hardness/Stability
- ☑ Mn and Fe
- ☑ DBP (40/30)
- ☐ CEC's

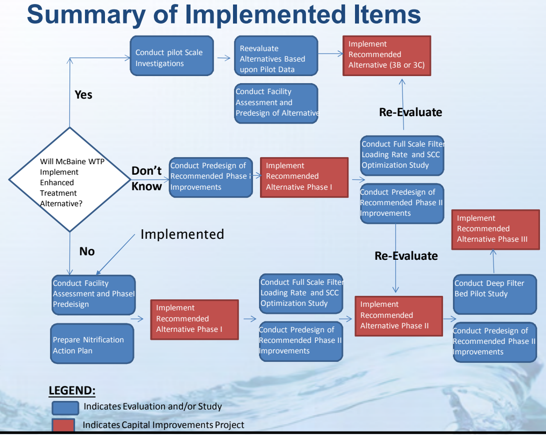
## Existing Plant - Condition




## Existing Plant - Capacity




## Summary of Implemented Items



## Water Treatment Plant Configuration

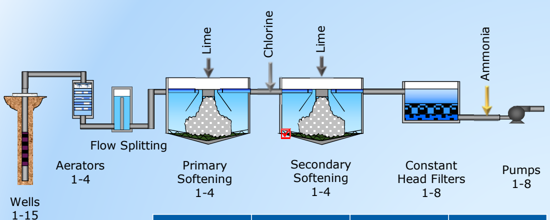
3. Should the study examine abandoning and demolishing the existing water treatment plant (32 mgd) and constructing an entirely new facility with source water obtained from a different location at a significant cost to current and future customers?

1 Existing Supply and Treatment Plant Should be abandoned

2 Continue Use of Current Source and Treatment Facility

- Abandon:
  - The investment in the existing facilities would be beyond our reasonable ability to pay.
- Continue Use:
  - Potential source issues (GW v GWUDI) can be met with treatment options as they arise.

## Existing Plant - Schematic




| Parameter | YES | NO | |
|---|---|---|---|
| Do We Keep the Existing Plant? | ☑ | | |
| | | | |

- ☐ GWUDI Compliance
- ☑ 4-log Virus
- ☐ $Cl_2$ Dist Sys
- ☑ Hardness/Stability
- ☑ Mn and Fe
- ☑ DBP (40/30)
- ☐ CEC's

## Finished Water Quality Goals:

| Parameter | Regulatory Value | Enhanced WQ Value | YES | NO | MAYBE |
|---|---|---|---|---|---|
| Turbidity | ≤ 0.3 NTU for 95% of individual Filter Readings<br>≤ 1.0 NTU in 100% of individual Filter Readings | Eventual Goal of Partnership Standards for New Designs:<br>≤ 0.1 NTU for 95% of individual Filter Readings<br>≤ 0.3 NTU in 100% for individual filter Readings. | | ☑ | |
| Disinfection | Giardia – 2 log<br>Virus – 4 log<br>Cryptosporidium – 2 log (bin 1) | NONE | | ☑ | |
| TTHM<br>HAA | ≤ 80ug/L RAA<br>≤ 60 ug/L RAA | ≤ 64 ug/L RAA<br>≤ 48 ug/L RAA | | ☑ | |
| Total Chlorine entering System | < 4.0 mg/L | 1.2-1.5 mg/L | | ☑ | |
| NDMA | NR | < 10 ng/L | | ☑ | |
| Chlorate | NR | NR | | ☑ | |
| Brominated DBP's | NR | (See TTHM/HAA) | | ☑ | |

## Water Treatment Plant Configuration

5. To satisfy regulations associated with disinfection by products, the City of Columbia converted from free chlorine to chloramines in the distribution system and conducts periodic conversions to chlorine to avoid issues that are associated with nitrification. There are more costly technologies that can be employed to satisfy all disinfection by product regulations **and** permit switching back to chlorine. Given this, how important is it to you that the City of Columbia switches back to the exclusive use of free chlorine in the distribution system? Please state the reasons for your selection:

- 1 Absolutely Critical to Switch Back to Chlorine
- ☐ Very Important to Switch Back to Chlorine
- ☐ Not Very Important
- 1 Stay with Chloramines
- 2 Other (Please list)________________

- Other:
  - Would like to use free chlorine if we could still meet the DBP rule.
  - Prefer the solution that provides the most flexibility and benefits.

## Water Treatment Plant Configuration

6. Past investigations of surface water and groundwater sources in Missouri and throughout the country have detected the presence of extremely low levels (one drop in 20 Olympic swimming pools) of Endocrine Disrupting (estrogen, etc) and Pharmaceutical (acetaminophen, etc.) compounds in many drinking water supplies. Studies to determine if long-term exposure to the low concentrations of these constituents impact human health are at least 10+ years away and it is not certain when (if at all) some or all of these constituents will be regulated. Technologies that remove or destroy these compounds from the supply are available but are significantly more costly to implement than the current treatment process. Given this, how important is it to you that this study considers processes that remove or destroy these compounds? Please state the reasons for your selection.

- 1 Absolutely Critical to Remove or Destroy these Compounds No Matter the Expense.
- 4 Study Should Evaluate the Costs/Benefits of Technologies that Remove or Destroy these Compounds.
- ☐ Not Very Important that Study Considers Removal/Destruction of these Compounds.
- ☐ Study **Should Not** Consider Removal/Destruction of these Compounds.
- ☐ Other (Please list)________________

## Finished Water Quality Goals:

| Parameter | Regulatory Value | Enhanced WQ Value | YES | NO | MAYBE |
|---|---|---|---|---|---|
| CEC's | Not Regulated | Treatment Process to Maximize Removal of Type of Compounds detected. | | | ☑ |
| Chloramines | Not Regulated | Eliminate Need for Chloramines in System | | | ☑ |
| Fluoride | 4.0 mg/L MCL<br>0.7 mg/L MCLg | 0.0 mg/L MCLg | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

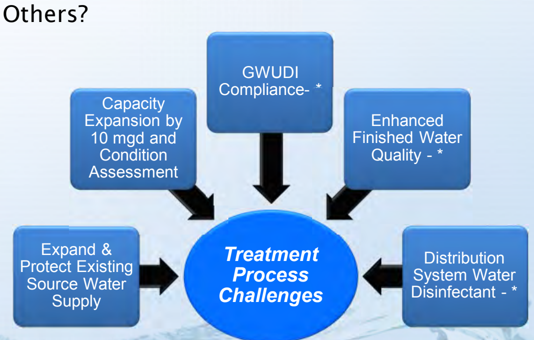
☑

## Project Boundary Exercise

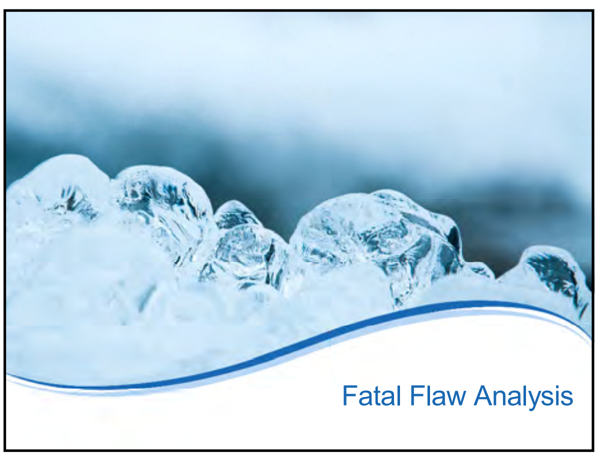
- Water Supply
- Finished Water Quality Goals
- Project Framework

## Framework for Decision Process

Others?




* Established by Today's Workshop



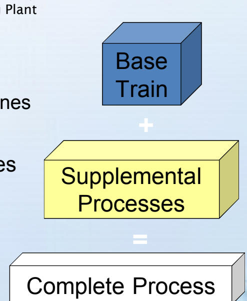
## "Fatal Flaw" and "Must Include" List

- "Must Include" or the Alternative will be eliminated from consideration
  - Capacity without Purchasing Water
  - Satisfy Regulatory Requirements
  - Meets Secondary Standards (Fe and Mn)
  - Meets Hardness Goal of 150 mg/L
  - Uses existing well field
  - Optimize existing infrastructure
  - Satisfy GWUDI compliance

## Treatment Alternative Identification

Modification/Demolition of Existing Plant

- "Base" Treatment Trains
  - Conventional Softening
  - Disinfection – Chloramines
  - Conventional Filtration
- "Supplemental" Processes
  - GAC
  - MIEX
  - Deep Bed Filtration
  - Secondary Aeration
  - UV, Ozone




## "Fatal Flaw" and "Must Include" List

- "Fatal Flaw" will eliminate Potential Alternative from consideration
  - Technology has never been built at this scale
  - Inappropriate technology
  - Extremely inflated costs
  - Not acceptable to the Community

## Technologies for Fatal Flaw Evaluation

### CEC Oxidation/Removal Technologies

| | | | | |
|---|---|---|---|---|
| Ferrate | Chlorine | Chlorine dioxide | Ozone | Ozone / H2O2 |
| Wet Air Oxidation | UV / H2O2 | UV / TiO2 | P. Acid / UV | Permanganate |

### Hardness Removal Technologies

| | | | | | | |
|---|---|---|---|---|---|---|
| Conventional Softening | Enhanced Softening | Softening with caustic | Split Treatment | Pelletized Lime Reactor | Nanofiltration | Reverse Osmosis |
| High Rate Softening | Anion Exchange | | | | | |

### Filtration Technologies

| | | | | |
|---|---|---|---|---|
| Nanofiltration | RO | Membranes (low pressure) | Biological filtration | Alternative filtration (bag, earth, slow sand) |
| Conventional Filtration | | Deep bed with constant rate filtration | Manganese coated filter media | Greensand Filtration |

### Disinfection By Product Control

| | | | |
|---|---|---|---|
| GAC Filter Contactors | PAC Contactors – Acticarb | Post Filtration GAC Columns | Nanofiltration/RO |
| Enhanced Coagulation | PAC | Ozone/Biofiltration | EC Bromide Removal |
| Chlorine Dose Control | MIEX | Air Stripping | TOC Specific Resin |

### Disinfection Technologies

| | | | |
|---|---|---|---|
| Chlorine | Chloramines | Ozone | Permanganate |
| UV | Chlorine Dioxide | Ferrate | Periacetic Acid |

## Structured Decision Analysis Introduction

## Structured Decision Analysis

***When it hurts to think about it….***

### Workshop No. 1 - Decision Analysis Uses a Proven Process to aid the Decision Makers

1. ✓ Define the decision makers and a simple and clear decision statement
2. ✓ Define a potential set of viable alternatives
3. ✓ Select the criteria that will be used to differentiate the alternatives
4. ✓ Assign weights to the criteria and assure there is no redundancy nor 'must haves'

### Workshop No. 2 - Decision Analysis Uses a Proven Process to aid the Decision

1. Rank each alternative against each criteria
2. Identify 'data gaps' or 'knowledge gaps' as a part of the ranking
3. Fill relevant 'data and knowledge gaps' or use 'Engineering Judgment'
4. Re-rank alternatives

### Workshop No. 3 - Decision Analysis Uses a Proven Process to aid the Decision

1. Complete final ranking of each alternative
2. Select 'best' alternative
3. Test sensitivity of 'best' (the gut check analysis)
4. Assign the 'devil's advocate' to assure a robust decision

Updated Action/Decision Log

## DECISION LOG

**DECISION LOG**

Project: 0

Client: City of Columbia, MO
Job #: 0
Contract #: 0

UPDATED 9/11/2017
BY: CL

| ITEM No. | DECISION BY | DECISION FORUM | DECISION DESCRIPTION | DECISION DATE | COMMENTS |
|---|---|---|---|---|---|
| 1 | City | Townhall Meeting | Terry is appointed the chairmain for the group, no one was opposed. | 14-Aug-17 | Vice Chair has been filled. |
| 2 | City | Townhall Meeting | Decision/Action log to include decisions made, date of the decision, who made the decision, etc. If there was a vote, the voting results are to be included. | 10-Jul-17 | |
| 3 | City | Townhall Meeting | All cost impacts to be displayed in anticipated rate increase to a typical user. | 10-Jul-17 | Usage rate increases associated with planned improvements. |
| 4 | City/Carollo | Townhall Meeting | Develop a systematic approach for evaluation of all alternatives. Score each of the alternatives as they relate to water quality, not monetary value, to distinguish the goals of the municipality. | 10-Jul-17 | Try and remove all emotional biases. |
| 5 | City | Townhall Meeting | Julie is appointed vice chair for the group with no objections. | 14-Aug-17 | |
| 6 | City | Townhall Meeting | Questionnaire is to be filled out by members of the committee and city staff. | 14-Aug-17 | Public should be involved in the future when decisions are narrowed down. |
| 7 | | | | | |
| 8 | | | | | |

## ACTION LOG

**ACTION ITEM LOG**

Project:

Client: City of Columbia, MO
Job #:
Contract #:

DATE: 8/14/2017
BY: CL

| ITEM No. | RESPONSIBLE PARTY | ACTION ITEM | ITEM DATE | TARGET RESOLUTION DATE | ITEM COMPLETION DATE | COMMENTS |
|---|---|---|---|---|---|---|
| 1 | Carollo | Compartmentalize the emerging contaminants of concern (ECC's) and their score | 10-Jul-17 | 14-Aug-17 | 14-Aug-17 | |
| 2 | Carollo | Provide insight to the public regarding model development and the models capabilities. | 10-Jul-17 | 11-Sep-17 | 11-Sep-17 | Carollo Working on Model Fact Sheet |
| 3 | City/Public | Ask about what is most concerning so Carollo can narrow in and explain the things that are difficult to understand. | 10-Jul-17 | 11-Sep-17 | | |
| 4 | Carollo | Create handout with mission statement for review and approval at next meeting | 14-Aug-17 | 11-Sep-17 | 11-Sep-17 | Confirmed Mission statement at 9/11/17 meeting |
| 5 | City/Public | All questionnaires filled out and to Shawn by the 25th | 14-Aug-17 | 25-Aug-17 | 25-Aug-17 | Carollo received 6 surveys and summarized in 09/11/17 meeting |
| 6 | Shawn | Make available monitoring well data (upload to website) | 14-Aug-17 | 11-Sep-17 | | |
| 7 | Shawn | Develop historical timeline of where Columbia has been and where they are now with treatment | 14-Aug-17 | 11-Sep-17 | | |
| 8 | Carollo | Send out copies of the presentation to everybody that attended the meeting | 14-Aug-17 | 15-Aug-17 | 15-Aug-17 | Carollo working on Binder for all and provide at subsequent meeting |
| 9 | Carollo | Summarize recommendations of previous study that has already been performed compared to what is being performed now. | 14-Aug-17 | 11-Sep-17 | 11-Sep-17 | |
| 10 | Carollo | Include annual water quality report in next presentation | 14-Aug-17 | 11-Sep-17 | 11-Sep-17 | |
| 11 | Carollo | Prepare Project Binder with all previously presented information including criteria worksheets | 11-Sep-17 | 9-Oct-17 | | Carollo to distribute at next meeting |

Edmond_presentation.pptx

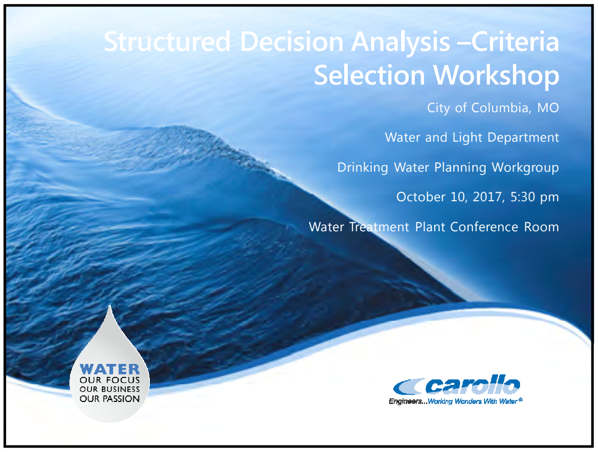

## Next Steps

- Carollo:
  - Complete Fatal Flaw Analysis Based Upon Visioning framework.
  - Develop Base Treatment Alternatives
  - Develop Additional Treatment Alternatives
  - Present Potential Treatment Alternatives for Shortlisting
- Workgroup:
  - Review Criteria and add/subtract
- Carollo/Workshop
  - Paired Comparison of Criteria to establish importance.
  - Shortlist of Treatment Alternatives
- Next Meeting: October 10th, 18th, 23rd


Confirm Next Meeting
Date 10/10/17, 10/18/17,
10/23/17

Appendix E

# SUMMARY OF STRUCTURED DECISION ANALYSIS WORKSHOPS





## Agenda

- Review Mission Statement
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Agenda

- **Review Mission Statement**
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

Filename.ppt/4

## Agenda

- Review Mission Statement
- **Review Water Quality Goals**
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

Filename.ppt/5

## Finished Water Quality Goals:

| Parameter | Regulatory Value | Enhanced WQ Value | YES | NO | MAYBE |
|---|---|---|---|---|---|
| Turbidity | ≤ 0.3 NTU for 95% of individual Filter Readings<br>≤ 1.0 NTU in 100% of individual Filter Readings | Eventual Goal of Partnership Standards for New Designs:<br>≤ 0.1 NTU for 95% of individual Filter Readings<br>≤ 0.3 NTU in 100% for individual filter Readings. | | | ☑ |
| Disinfection | Giardia – 2 log<br>Virus – 4 log<br>Cryptosporidium – 2 log (bin 1) | NONE | | | ☑ |
| TTHM<br>HAA | ≤ 80ug/L RAA<br>≤ 60 ug/L RAA | ≤ 64 ug/L RAA<br>≤ 48 ug/L RAA | ☑ | | |
| Total Chlorine entering System | < 4.0 mg/L | 1.2-1.5 mg/L | | | ☑ |
| NDMA | NR | < 10 ng/L | ☑ | | |
| Chlorate | NR | NR | ☑ | | |
| Brominated DBP's | NR | (See TTHM/HAA) | ☑ | | |

Filename.ppt/6

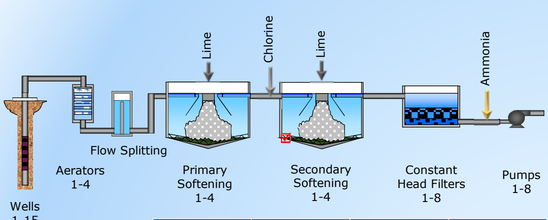
## Finished Water Quality Goals:

| Parameter | Regulatory Value | Enhanced WQ Value | YES | NO | MAYBE |
|---|---|---|---|---|---|
| CEC's | Not Regulated | Treatment Process to Maximize Removal of Type of Compounds detected. | | | ☑ |
| Chloramines | Not Regulated | Eliminate Need for Chloramines in System | | | ☑ |
| Fluoride | 4.0 mg/L MCL<br>0.7 mg/L MCLg | 0.0 mg/L MCLg | | ☑ | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

## Agenda

- Review Mission Statement
- Review Water Quality Goals
- **Summarize Visioning/Project Boundaries**
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Existing Plant - Schematic




| Parameter | YES | NO | |
|---|---|---|---|
| Do We Keep the Existing Plant? | ☑ | | |
| | | | |

- ☐ GWUDI Compliance
- ☑ 4-log Virus
- ☐ $Cl_2$ Dist Sys
- ☑ Hardness/Stability
- ☑ Mn and Fe
- ☑ DBP (40/30)
- ☐ CEC's

## Water Supply Exercise Boundaries

| Statement | YES | NO | MAYBE |
|---|---|---|---|
| The DWPWG Accepts the Recommendation of the IWRP | ☑ | | |
| GWUDI Compliant Facility is Required | | | ☑ |
| Others? | | | |

Filename.ppt/10

## Project Driver Water Quality – Existing Treatment

Existing Aeration
Existing Primary Basins – SCC
Existing Secondary Basins – SCC
Existing Secondary Basins – Flocculating Clarifiers
Existing Declining Rate Filters

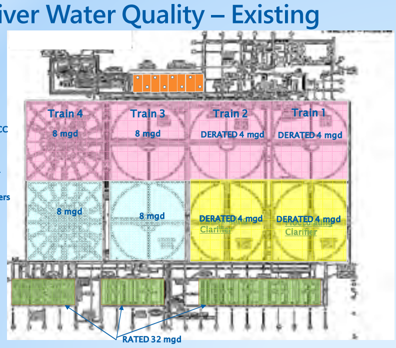
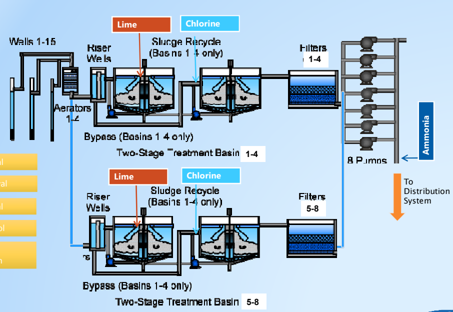



Figure ES.2 Plan View of Existing Treatment Process
Executive Summary
McBaine Water Treatment Plant Preliminary Design
Columbia Water and Light

Filename.ppt/11

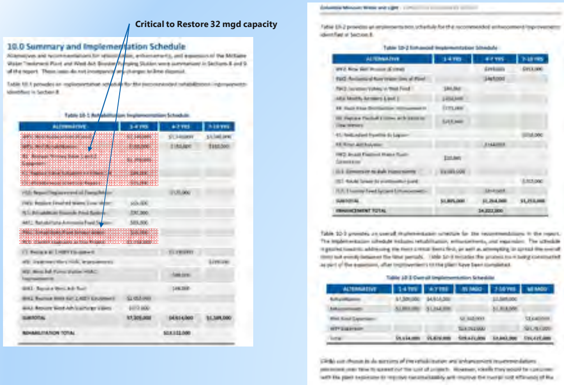
## Project Driver Water Quality – Existing Treatment Achievements

Fe Removal
Mn Removal
Ca Removal
DBP Control
4-log Virus Inactivation

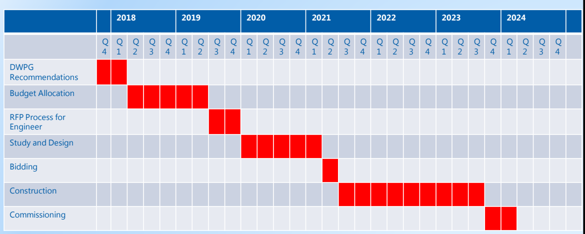



Filename.ppt/12

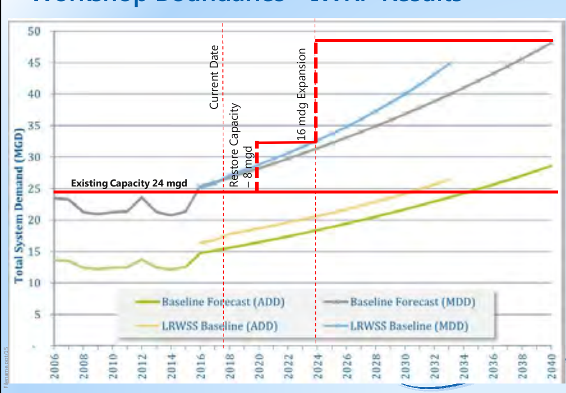
## 2016 Condition Assessment




## Example Timeline for Type of WTP Improvements We are Considering




## Workshop Boundaries – IWRP Results



## Project Visioning- "Must Include List"

- "Must Include" or the Alternative will be eliminated from consideration
  - Reuse Existing Plant Infrastructure
  - Continued Expansion of Wellfield per IWRP
  - Meets all water quality goals for Groundwater Facility (current treatment level- softening).
  - Addresses Ageing Infrastructure as Identified in 2016 Condition Assessment to restore capacity of 32 mgd in short term (next 3 years).
  - Expansion of Plant to 48 mgd per IWRP by 2024

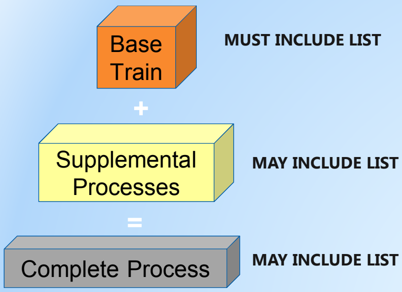
## Project Visioning- "May Include List"

- "May Include" will be distinguished as a second or third tier alternative
  - Meets all water quality goals for a GWUDI Facility
  - Will enable plant to eliminate chloramines as a disinfectant in the distribution system.
  - Will maximize reduction of CEC's

## Agenda

- Review Mission Statement
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- **Fatal Flaw Analysis Review/Discussion**
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

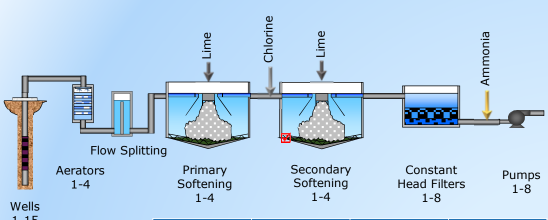
## Treatment Alternative Identification




## "Fatal Flaw" and "Must Include" List

- "Fatal Flaw" will eliminate Potential Alternative from consideration
  - Technology has never been built at this scale
  - Inappropriate technology
  - Extremely inflated costs
  - Not acceptable to the Community

## Existing Plant - Schematic




- [ ] GWUDI Compliance
- [x] 4-log Virus
- [ ] $Cl_2$ Dist Sys
- [x] Hardness/Stability
- [x] Mn and Fe
- [x] DBP (64/34)
- [ ] CEC's

| Parameter | YES | NO | |
|---|---|---|---|
| Do We Keep the Existing Plant? | ☑ | | |
| | | | |

## Technologies for Fatal Flaw Evaluation - BASE

- Never Attempted at this Scale
- Extremely Inflated Costs
- Public Acceptance Limited
- Not Necessary/Inappropriate Technology to Achieve Goals

**Hardness Removal Technologies**

| | | | | | |
|---|---|---|---|---|---|
| Conventional Softening | Enhanced Softening | ~~Softening with caustic~~ | Split Treatment | Pelletized Lime Reactor | ~~Nanofiltration~~ ~~Reverse Osmosis~~ |
| High Rate Softening | ~~Anion Exchange~~ | ~~Electromagnetic~~ | | | |

**Filtration Technologies**

| | | | | |
|---|---|---|---|---|
| ~~Nanofiltration~~ | ~~RO~~ | Membranes (low pressure) | ~~Biological filtration~~ | ~~Alternative filtration (bag, earth, slow sand)~~ |
| Conventional Filtration | ~~Cartridge Filtration~~ | Deep bed with constant rate filtration | ~~Manganese coated filter media~~ | ~~Greensand Filtration~~ |

Filename.ppt/22

## Treatment Alternative Identification

Base Train — **MUST INCLUDE LIST**

\+

Supplemental Processes — **MAY INCLUDE LIST**

=

Complete Process — **MAY INCLUDE LIST**

Filename.ppt/23

## Technologies Screened for Fatal Flaw Analysis- Supplemental Process

- Never Attempted at this Scale
- Extremely Inflated Costs
- Public Acceptance Limited
- Not Necessary/Inappropriate Technology to Achieve Goals

**CEC Oxidation/Removal Technologies**

| | | | | |
|---|---|---|---|---|
| ~~Ferrate~~ | ~~Chlorine~~ | ~~Chlorine dioxide~~ | Ozone | Ozone / H2O2 |
| ~~Wet Air Oxidation~~ | UV / H2O2 | ~~UV / TiO2~~ | ~~P. Acid / UV~~ | ~~Permanganate~~ |

**Filtration Technologies**

| | | | | |
|---|---|---|---|---|
| ~~Nanofiltration~~ | ~~RO~~ | ~~Membranes (low pressure)~~ | Biological filtration | ~~Alternative filtration (bag, earth, slow sand)~~ |
| ~~Conventional Filtration~~ | | ~~Deep bed with constant rate filtration~~ | ~~Manganese coated filter media~~ | ~~Greensand Filtration~~ |

**Disinfection By Product Control**

| | | | |
|---|---|---|---|
| GAC Filter Contactors | PAC Contactors – Acticarb | Post Filtration GAC Contactors | ~~Nanofiltration/RO~~ |
| ~~Enhanced Coagulation~~ | ~~PAC~~ | ~~Ozone/Biofiltration~~ | ~~EC Bromide Removal~~ |
| ~~Chlorine Dose Control~~ | MIEX | ~~Air Stripping~~ | ~~TOC Specific Resin~~ |
| Chloramination w/ NA Plan | | | |

Filename.ppt/24

## Agenda

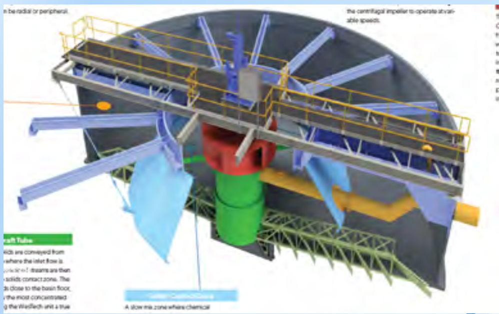
- Review Mission Statement
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- **Treatment Process Review and Shortlist Discussion**
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Base Treatment Alternatives

- Softening:
  - Conventional Softening (B1)
  - High Rate Softening (B2)
  - Pellet Softening (B3)
  - Nanofiltration/RO (B4)
- Filtration:
  - None
  - Conventional
  - High Rate Conventional
  - Membrane
- DBP Control:
  - Chloramines
- Disinfection:
  - Chlorine

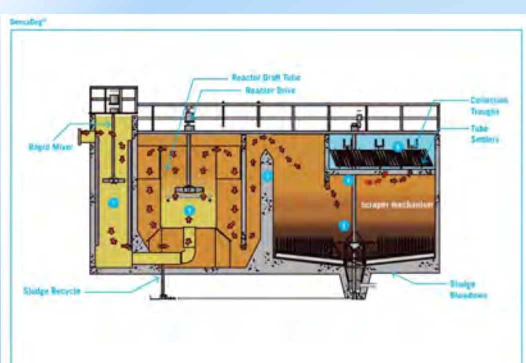
## Conventional Softening

## Conventional Softening Units



High Rate Softening

## High Rate Softening



## Pellet Softening

## Conventional Softening and Pellet Softening Utilizes Same Chemistry but Physically and Hydraulically Different

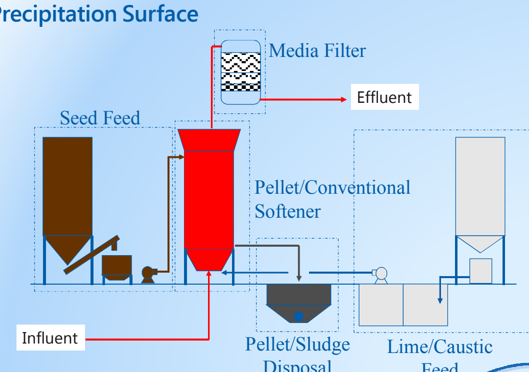
**CONVENTIONAL SOFTENING**

- Proven US Technology
- Low rate (1.75 gpm/sf) = large foot print
- Requires open tank = energy loss
- Residuals require drying ponds or mechanical dewatering

**PELLET SOFTENING**

- Fluidized bed using sand/calcium carbonate seed
- Can utilize lime or caustic
- High rate (35 gpm/sf) = small footprint
- Can be operated in a pressure vessel = save energy
- Residuals easily dewatered by gravity

## Pellet Softening Process Utilizes Seed Pellets for Precipitation Surface

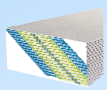


## Chino CRF Utilizes Pellet Softening

## Pure Calcium Carbonate Has Missouri Market Value

Specialty MINERALS

Identified 12 potential users in Denver



Drywall

Concrete

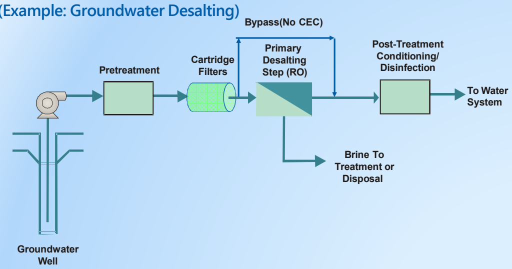
Porcelain

Chino - At a pellet production rate of 26 tons/day - revenue stream of over $5.4 million over the 20 year life cycle.

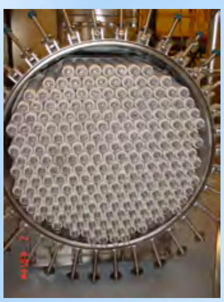
## Nanofiltration/RO

## A Primary Desalting RO System has Several Components

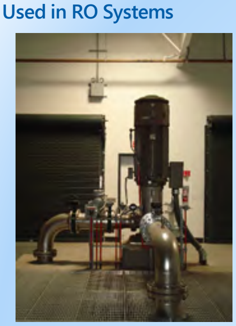
(Example: Groundwater Desalting)




## Horizontal Cartridge Filter Orientation Provides Easier Access for Operators



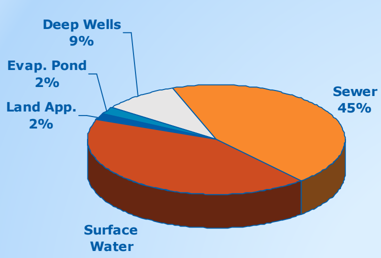
## Vertical Turbine High Pressure Feed Pumps are Commonly Used in RO Systems



## This RO plant in Hilton Head, SC Treats 3-mgd in Four RO Trains

## Depending on Feed Water Chemistry, Post-Treatment may include Decarbonation

## Current Practice Of Brine Management In The USA



## Brine Management Options Fall Into Distinct Categories

- Never Attempted at this Scale
- Extremely Inflated Costs
- Public Acceptance Limited
- Not Necessary/Inappropriate Technology to Achieve Goals

| Brine Disposal | Beneficial Reuse | Brine Treatment |
| --- | --- | --- |
| ~~Surface Water Discharge[1]~~ | ~~Cooling Water~~ | Volume Reduction |
| ~~Sewer Disposal[1]~~ | ~~Land Application~~ | Chemical Precipitation |
| ~~Deep Well Injection~~ | ~~Irrigation~~ | Brine Concentrators |
| ~~Zero Liquid Discharge~~ | ~~Dust Control~~ | ~~Zero Liquid Discharge~~ |
| Evaporation Ponds | ~~Wetlands~~ | ~~Crystallizers~~ |

1 – Includes export pipelines/brine lines

## Depending Upon Brine Volume Or Ultimate Method Of Disposal, Brine Management May Take More Than One Step

| Initial Brine Volume Reduction | Intermediate Brine Concentration | Final Solidification |
| --- | --- | --- |
| Chemical Precipitation | Thermal Brine Concentrator | Crystallizers |
| Softening followed by "Secondary RO" | Vapor Compression Brine Concentrator | Evaporation Ponds |
| | | Enhanced Evaporation using Solar Bee |

## Potential Base Treatment Alternatives

| Base | Softening | | | | Filtration | | | | DBP Control | | Disinfection | | Relative Cost |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Conv | HR | Pellet | RO | Conv | HR | Mem | None | Chloramines | No additional | Chlorine | | |
| **B1-1** | X | | | | X | | | | X | | X | | Low |
| **B1-2** | X | | | | | X | | | X | | X | | Low |
| **B1-3** | X | | | | | | X | | X | | X | | M/H |
| **B2-1** | | X | | | X | | | | X | | X | | Low |
| **B2-2** | | X | | | | X | | | X | | X | | Med |
| **B2-3** | | X | | | | | X | | X | | X | | M/H |
| **B3-1** | | | X | | | | | X | X | | X | | Med |
| **B4-1** | | | | X | | | | X | X | | X | | Highest |
| **OTHER** | | | | | | | | | | | | | |

Groundwater Treatment Plant ONLY (B3-1, B4-1)

## Technologies Screened for Fatal Flaw Analysis- Supplemental Process

- Never Attempted at this Scale
- Extremely Inflated Costs
- Public Acceptance Limited
- Not Necessary/Inappropriate Technology to Achieve Goals

**CEC Oxidation/Removal Technologies**

| | | | | |
|---|---|---|---|---|
| ~~Ferrate~~ | ~~Chlorine~~ | ~~Chlorine dioxide~~ | Ozone | Ozone / H2O2 |
| ~~Wet Air Oxidation~~ | UV / H2O2 | ~~UV / TiO2~~ | ~~P-Acid / UV~~ | ~~Permanganate~~ |

**Filtration Technologies**

| | | | | |
|---|---|---|---|---|
| ~~Nanofiltration~~ | ~~RO~~ | ~~Membranes (low pressure)~~ | Biological filtration | ~~Alternative filtration (bag, earth, slow sand)~~ |
| ~~Conventional Filtration~~ | | ~~Deep bed with constant rate filtration~~ | ~~Manganese coated filter media~~ | ~~Greensand Filtration~~ |

**Disinfection By Product Control**

| | | | |
|---|---|---|---|
| GAC Filter Contactors | PAC Contactors – Acticarb | Post Filtration GAC Contactors | ~~Nanofiltration/RO~~ |
| ~~Enhanced Coagulation~~ | ~~PAC~~ | ~~Ozone/Biofiltration~~ | ~~EC Bromide Removal~~ |
| ~~Chlorine Dose Control~~ | MIEX | ~~Air Stripping~~ | ~~TOC Specific Resin~~ |
| Chloramination w/ NA Plan | | | |

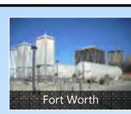
Filename.ppt/46

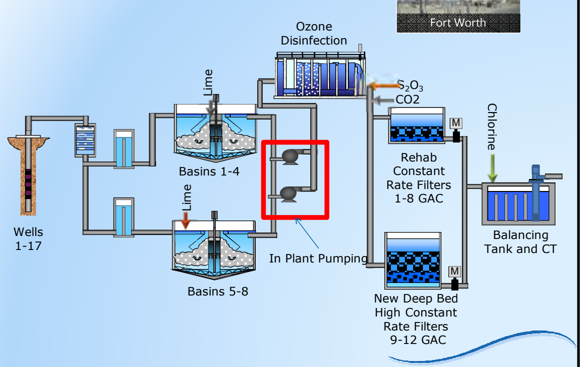
## Supplemental Process

| Suppli | CEC Removal | | | | DBP Control | | | | | | | | Relative Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ozone/Peroxide (S1) | UV/Peroxide (S2) | None | | MIEX (S3) | GAC Contactors (S4) | GAC Filters (S5) | Acticarb (PAC) (S6) | | | | | |
| B1-1-S1S5 | X | | | | | | X | | | | | | Lower |
| ~~B1-1-S2S5~~ | | ~~X~~ | | | | | ~~X~~ | | | | | | ~~M-H~~ |
| ~~B1-1-S3S5~~ | ~~X~~ | | | | ~~X~~ | | | | | | | | ~~Highest~~ |
| B1-1-S3 | | | X | | X | | | | | | | | M-H |
| B1-1-S4 | | | X | | | X | | | | | | | Lower |
| B1-1-S6 | | | X | | | | | X | | | | | M-H |
| B1-1-S1S4 | X | | | | | X | | | | | | | High |
| B1-3-S4 | | | | | | | X | | | | | | M-H |
| B1-3-S6 | | | | | | | | X | | | | | High |
| B3-1-S1S5 | X | | | | | | X | | | | | | High |
| B3-1-S5 | | | | | | | X | | | | | | M-H |
| B4-1 | | | | | | | | | | | | | Highest |

Filename.ppt/47

## Alternative B-1-S1S5

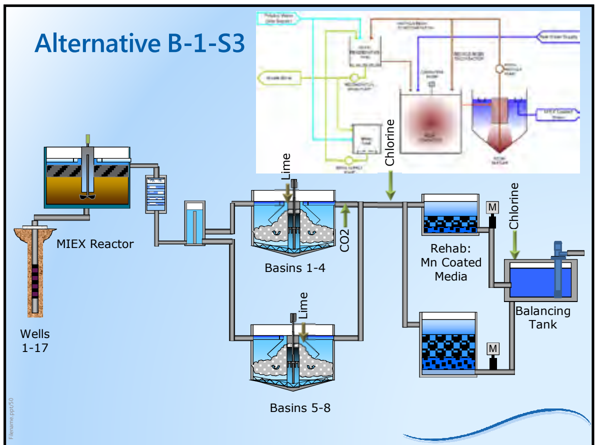


## Supplemental Process

| Alt. | CEC Removal | | | | DBP Control | | | | | Relative Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ozone/Peroxide (S1) | UV/Peroxide (S2) | None | | MIEX (S3) | GAC Contactors (S4) | GAC Filters (S5) | Acticarb (PAC) (S6) | | |
| B1-1-S1S5 | X | | | | | | X | | | Lower |
| ~~B1-1-S2S5~~ | | ~~X~~ | | | | | ~~X~~ | | | ~~M-H~~ |
| ~~B1-1-S3S5~~ | ~~X~~ | | | | ~~X~~ | | | | | ~~Highest~~ |
| B1-1-S3 | | | X | | X | | | | | M-H |
| B1-1-S4 | | | X | | | X | | | | Lower |
| B1-1-S6 | | | X | | | | | X | | M-H |
| B1-1-S1S4 | X | | | | | X | | | | High |
| B1-3-S4 | | | | | | | X | | | M-H |
| B1-3-S6 | | | | | | | | X | | High |
| B3-1-S1S5 | X | | | | | | X | | | High |
| B3-1-S5 | | | | | | | X | | | M-H |
| B4-1 | | | | | | | | | | Highest |
| OTHER | | | | | | | | | | |

## Alternative B-1-S3

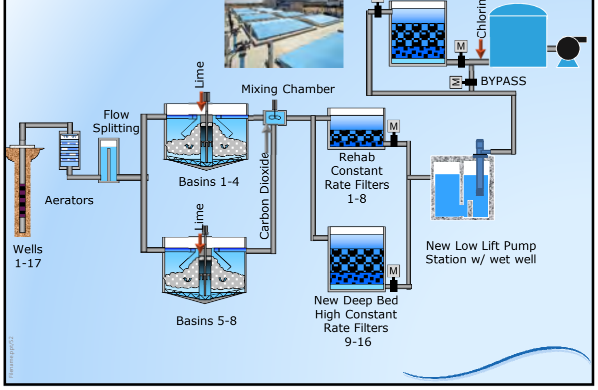




## Supplemental Process

| Alt. | CEC Removal | | | | DBP Control | | | | | Relative Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ozone/Peroxide (S1) | UV/Peroxide (S2) | None | | MIEX (S3) | GAC Contactors (S4) | GAC Filters (S5) | Acticarb (PAC) (S6) | | |
| B1-1-S1S5 | X | | | | | | X | | | Lower |
| ~~B1-1-S2S5~~ | | ~~X~~ | | | | | ~~X~~ | | | ~~M-H~~ |
| ~~B1-1-S3S5~~ | ~~X~~ | | | | ~~X~~ | | | | | ~~Highest~~ |
| B1-1-S3 | | | X | | X | | | | | M-H |
| B1-1-S4 | | | X | | | X | | | | Lower |
| B1-1-S6 | | | X | | | | | X | | M-H |
| B1-1-S1S4 | X | | | | | X | | | | High |
| B1-3-S4 | | | | | | | X | | | M-H |
| B1-3-S6 | | | | | | | | X | | High |
| B3-1-S1S5 | X | | | | | | X | | | High |
| B3-1-S5 | | | | | | | X | | | M-H |
| B4-1 | | | | | | | | | | Highest |
| OTHER | | | | | | | | | | |

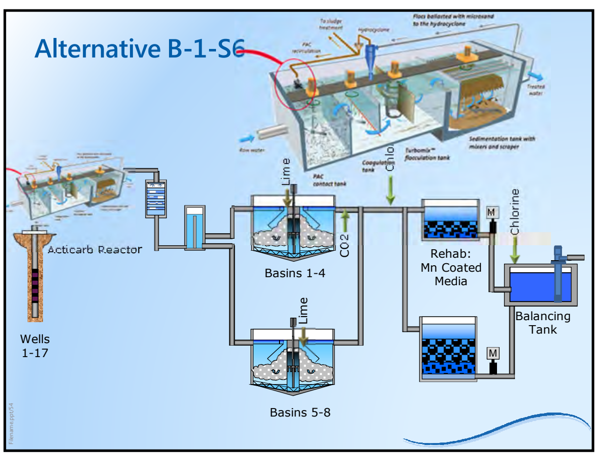
## Alternative B1-S4




## Supplemental Process

| Alt. | CEC Removal | | | | DBP Control | | | | | | Relative Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ozone/Peroxide (S1) | UV/Peroxide (S2) | None | | MIEX (S3) | GAC Contactors (S4) | GAC Filters (S5) | Acticarb (PAC) (S6) | | | |
| B1-1-S1S5 | X | | | | | | X | | | | Lower |
| ~~B1-1-S2S5~~ | | ~~X~~ | | | | | ~~X~~ | | | | ~~M-H~~ |
| ~~B1-1-S3S5~~ | ~~X~~ | | | | ~~X~~ | | | | | | ~~Highest~~ |
| B1-1-S3 | | | X | | X | | | | | | M-H |
| B1-1-S4 | | | X | | | X | | | | | Lower |
| B1-1-S6 | | | X | | | | | X | | | M-H |
| B1-1-S1S4 | X | | | | | X | | | | | High |
| B1-3-S4 | | | | | | | X | | | | M-H |
| B1-3-S6 | | | | | | | | X | | | High |
| B3-1-S1S5 | X | | | | | | X | | | | High |
| B3-1-S5 | | | | | | | X | | | | M-H |
| B4-1 | | | | | | | | | | | Highest |
| OTHER | | | | | | | | | | | |

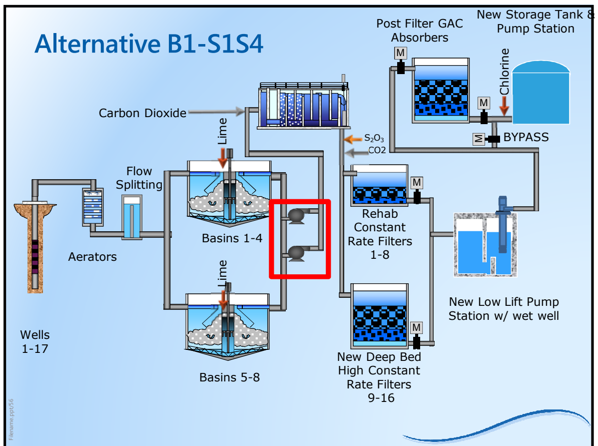
## Alternative B-1-S6



## Supplemental Process

| Alt. | CEC Removal | | | | DBP Control | | | | | Relative Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ozone/Peroxide (S1) | UV/Peroxide (S2) | None | | MIEX (S3) | GAC Contactors (S4) | GAC Filters (S5) | Acticarb (PAC) (S6) | | |
| B1-1-S1S5 | X | | | | | | X | | | Lower |
| ~~B1-1-S2S5~~ | | ~~X~~ | | | | | ~~X~~ | | | ~~M-H~~ |
| ~~B1-1-S3S5~~ | ~~X~~ | | | | ~~X~~ | | | | | ~~Highest~~ |
| B1-1-S3 | | | X | | X | | | | | M-H |
| B1-1-S4 | | | X | | | X | | | | Lower |
| B1-1-S6 | | | X | | | | | X | | M-H |
| B1-1-S1S4 | X | | | | | X | | | | High |
| B1-3-S4 | | | | | | | X | | | M-H |
| B1-3-S6 | | | | | | | | X | | High |
| B3-1-S1S5 | X | | | | | | X | | | High |
| B3-1-S5 | | | | | | | X | | | M-H |
| B4-1 | | | | | | | | | | Highest |
| OTHER | | | | | | | | | | |

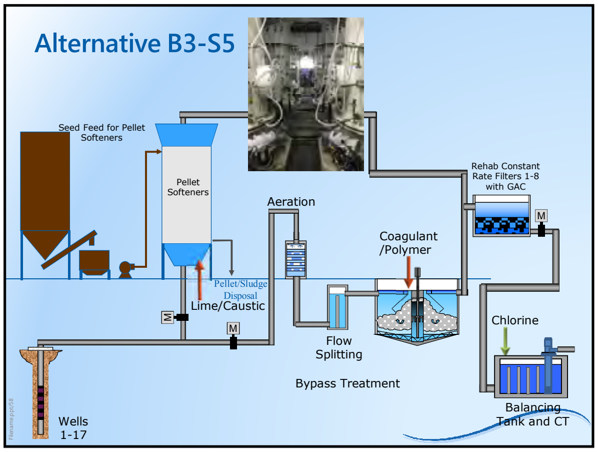
## Alternative B1-S1S4




## Supplemental Process

| Alt. | CEC Removal | | | | DBP Control | | | | | Relative Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ozone/Peroxide (S1) | UV/Peroxide (S2) | None | | MIEX (S3) | GAC Contactors (S4) | GAC Filters (S5) | Acticarb (PAC) (S6) | | |
| B1-1-S1S5 | X | | | | | | X | | | Lower |
| ~~B1-1-S2S5~~ | | ~~X~~ | | | | | ~~X~~ | | | ~~M-H~~ |
| ~~B1-1-S3S5~~ | ~~X~~ | | | | ~~X~~ | | | | | ~~Highest~~ |
| B1-1-S3 | | | X | | X | | | | | M-H |
| B1-1-S4 | | | X | | | X | | | | Lower |
| B1-1-S6 | | | X | | | | | X | | M-H |
| B1-1-S1S4 | X | | | | | X | | | | High |
| B1-3-S4 | | | | | | | X | | | M-H |
| B1-3-S6 | | | | | | | | X | | High |
| B3-1-S1S5 | X | | | | | | X | | | High |
| B3-1-S5 | | | | | | | X | | | M-H |
| B4-1 | | | | | | | | | | Highest |
| OTHER | | | | | | | | | | |

## Alternative B3-S5




## Agenda

- Review Mission Statement
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- **Introduction to Structured Decision Analysis (SDA)**
- Criteria Selection
- Criteria Ranking
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Structured Decision Analysis (SDA) provides for inclusive and informed decision making by all stakeholders

## Decision Analysis Uses a Proven Process to aid the Decision Makers – Phase I

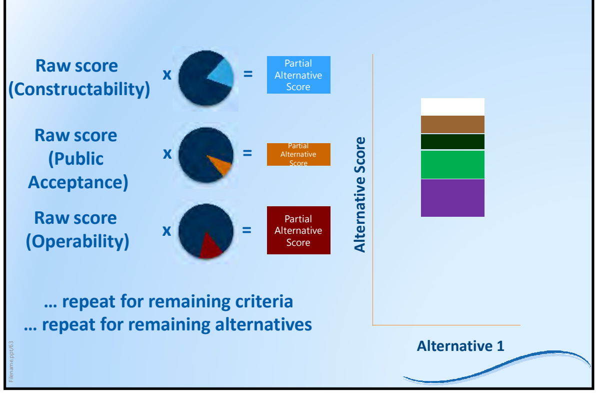
- Define the decision makers and a simple and clear decision statement
- Define a potential set of viable alternatives
- Select the criteria that will be used to differentiate the alternatives
- Assign weights to the criteria and assure there is no redundancy nor 'must haves' (pass/fail crtieria)

## Decision Analysis Uses a Proven Process to aid the Decision Makers – Phase II

- Score each alternative against each criterion (without "weight")
- Identify 'data gaps' or 'knowledge gaps' as a part of the scoring
- Fill 'data and knowledge gaps'
- Combine the scores and weights to rank the alternatives

*Alternatives __scoring best__ against the __most important__ criteria will rank highest*

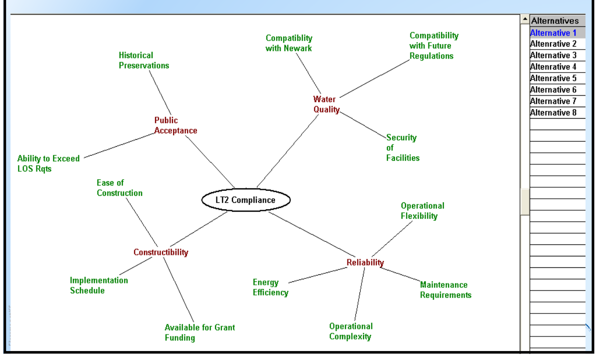
## Alternative Weighted Scoring Process



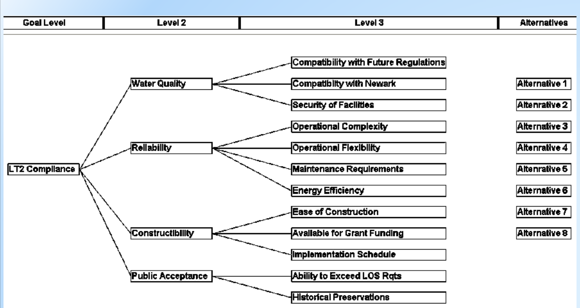
## Decision Analysis Uses a Proven Process to aid the Decision Makers – Phase III

- Complete final ranking of each alternative
- Select 'best' alternative
- Test sensitivity of 'best' (the gut check analysis)
- Assign the 'devil's advocate' to assure a robust decision

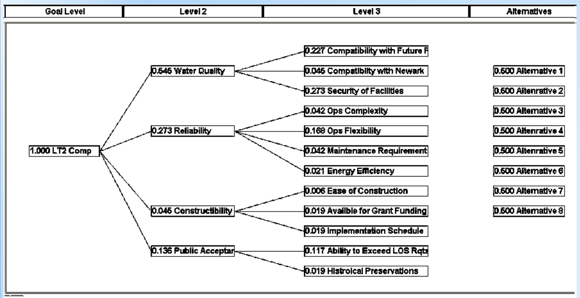
## The brainstorming session identifies the selection criteria for the alternative evaluation



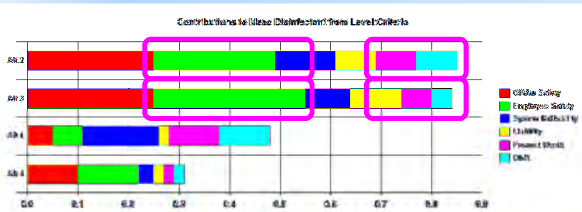

## The brainstorming is converted into a mathematical model for rankings and evaluation



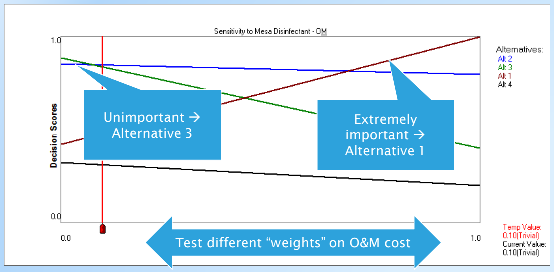
## The brainstorming is converted into a mathematical model for rankings and evaluation




## Model Results Help Screen Alternatives and Understand Tradeoffs



## Sensitivity Analyses Help Make Robust Decisions



## Agenda

- Review Mission Statement
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- **Criteria Selection**
- **Criteria Ranking**
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Current Evaluation Criteria & Scores

| **A. Constructability** | | |
|---|---|---|
| Maintenance of plant operation | Plant must be able to produce finished water during construction activities. | 0 - Unable to phase process with multiple plant shutdowns.<br>10 - Many options for phasing process alternative with minimal disruption to existing plant operations. |
| Schedule | Construction duration in months, shorter duration is desired. | 0 - Very long construction period.<br>10 - Short construction period. |
| Space Requirements | Square feet, Smaller footprint is better. | 0 - Largest footprint required to accommodate WTP structures (not including residuals handling).<br>10 - Smallest footprint required to accommodate WTP structures (not including residuals handling). |
| Permitting | Number of permits required and difficulty to obtain. | 0 - Numerous permits needed requiring significant involvement from multiple stakeholders.<br>10 - Minimal permitting requirements with limited stakeholder involvement. |

## Current Evaluation Criteria & Scores

| **Public Acceptance** | | |
|---|---|---|
| Water Quality | Minimize formation of DBPs | 0 - DBP concentrations in the distribution system comply with regulatory requirements but are not reduced from existing DBP concentrations.<br>10 – DBP concentrations in distribution system is reduced and meets the goal of 80% TTHMs and 80% of HAA MCLs. |
| Sustainability | Minimize carbon footprint<br>Minimize chemical usage<br>Maximize energy efficiency<br>Opportunities for reuse | 0 - Process is not energy efficient and uses large quantities of chemicals for treatment. No opportunities for reusing waste materials.<br>10 - Process is efficient and uses small quantities of chemicals, uses less energy and offers opportunities for reusing waste materials. |
| Future Regulations | A process that can remove ECCs is good | 0 - No removal of ECCs<br>10 - Highest removal of ECC compounds based upon Best Available Control Technology. |
| Communication | A process that is easily communicated to and accepted by the public and the decision makers is good | 0 - Process alternative is difficult to demonstrate to stakeholders and is difficult to obtain stakeholder buy-in.<br>10 – Process alternative is easy to explain and widely acceptable to stakeholders. |

## Current Evaluation Criteria and Scores

| C. Operability | | |
|---|---|---|
| Residuals Production | Tons per year<br>Smaller quantities of residuals are desired. | 0 - High residuals production.<br>10 - Low residuals production. |
| Staffing Requirements | Alternatives that do not require intensive training and large numbers of operators are desirable. | 0 - Extensive training is required and the process requires several operators at any given time.<br>10 - Training requirements are less complicated and fewer operators are required to operate the process. |
| Proven Technology | Alternatives including processes with a proven track record score higher than newer, less proven technologies. | 0 - No full-scale installations.<br>10 - Extensive full-scale experience both in number of installations and number of years in service. |
| Maintenance Complexity | Mechanical Intensity. Alternatives with more processes and/or a higher degree of sophistication are less desirable. | 0 - Numerous processes with extensive short- and long-term maintenance needs.<br>10 - Fewer processes with low level of sophistication. |
| Source water Treatability | Alternatives includes processes that can handle large variability in source water quality without impact to finished water quality is good. | 0 - Many processes sensitive to water quality changes requiring frequent operator intervention.<br>10- Fewer processes sensitive to water quality changes requiring less operator intervention. |

## Current Evaluation Criteria and Scores

- Others:
  - Operational Costs
  - Maintenance Costs
  - Life Cycle Costs
  - Capital Costs
  - Impact on Rates as compared to ???? (MHI???, Fixed income customer???)
  - GWUDI Compliance

## Pairwise Comparison Exercise

## Sub-criteria Pairwise - Constructability

| CONSTRUCTABILITY COMPARISON | | | | | |
|---|---|---|---|---|---|
| | Maintain Plant Operations | Schedule | Space Requirements | Permitting | |
| Maintain Plant Operations | NA | | | | |
| Schedule | NA | NA | | | |
| Space Requirements | NA | NA | NA | | |
| Permitting | NA | NA | NA | NA | |
| | | | | | NA |

| COST COMPARISON | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Life Cycle | Operational | Maintenance | Capital | | | |
| Life Cycle | NA | | | | | | |
| Operational | NA | NA | | | | | |
| Maintenance | NA | NA | NA | | | | |
| Capital | NA | NA | NA | NA | | | |



## Sub-criteria Pairwise – Water Quality

| WATER QUALITY COMPARISON | | | | | |
|---|---|---|---|---|---|
| | Water Quality Goals -TTHMS | Sustainability | Water Quality – CEC's | Communication | |
| Water Quality Goals - TTHMS | NA | | | | |
| Sustainability | NA | NA | | | |
| Water Quality- CEC's | NA | NA | NA | | |
| Communication | NA | NA | NA | NA | |
| | | | | | NA |



## Sub-criteria Pairwise – Operability

| OPERABILITY COMPARISON | | | | | |
|---|---|---|---|---|---|
| | Residuals Production | Staffing Requirements | Proven Technology | Complexity | Source Water Quality |
| Residuals Production | NA | | | | |
| Staffing Requirements | NA | NA | | | |
| Proven Technology | NA | NA | NA | | |
| Complexity | NA | NA | NA | NA | |
| Source Water Quality | NA | NA | NA | NA | NA |

## Pairwise Comparison

| Criteria | Constructability | Water Quality | Operability | GWUDI | COST | |
|---|---|---|---|---|---|---|
| Constructability | NA | | | | | |
| Water Quality | NA | NA | | | | |
| Operability | NA | NA | NA | | | |
| GWUDI | NA | NA | NA | NA | | |
| COST | NA | NA | NA | NA | NA | |
| | | | | | | |
| | | | | | | |

## Agenda

- Review Mission Statement
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- **Review Action/Decision Logs**
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Agenda

- Review Mission Statement
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- **Review Action/Decision Logs**
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Agenda

- Review Mission Statement
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- Review Action/Decision Logs
- **Review Next Steps**
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Next Steps

- Development of Shortlisted Alternatives
  - Process Schematic
  - Description with respect to criteria
  - Estimated Costs: Capital and Life Cycle
- Issue TM prior to Meeting
- Meeting to review and rank alternatives with respect to criteria: (Shorten Shortlist)

## Agenda

- Review Mission Statement
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- Review Action/Decision Logs
- Review Next Steps
- **General Comments by Public, Members and Staff**
- Next Meeting Date
- Adjournment

## Agenda

- Review Mission Statement
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- **Next Meeting Date – Monday November 13, 2017 5:30 pm Broadway**
- Adjournment

## Agenda

- Review Mission Statement
- Review Water Quality Goals
- Summarize Visioning/Project Boundaries
- Fatal Flaw Analysis Review/Discussion
- Treatment Process Review and Shortlist Discussion
- Introduction to Structured Decision Analysis (SDA)
- Criteria Selection
- Criteria Ranking
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date – Monday November 13, 2017 5:30 pm Broadway
- **Adjournment**

# Pairwise Comparison and Preliminary Ranking Workshop

City of Columbia, MO

Water and Light Department

Drinking Water Planning Workgroup

November 13, 2017, 5:30 pm

Water Treatment Plant Conference Room

WATER
OUR FOCUS
OUR BUSINESS
OUR PASSION

carollo
Engineers...Working Wonders With Water®

## Agenda

- Finalize Mission Statement
- Review Pairwise Comparison Result
- Review Project Boundaries
- Discuss/Review Alternatives and Carollo Shortlist
- SDA Model
- Discuss and Rank Shortlisted Alternatives
- Review Data Gaps
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Agenda

- **Finalize Mission Statement**
- Review Pairwise Comparison Result
- Review Project Boundaries
- Discuss/Review Alternatives and Carollo Shortlist
- SDA Model
- Discuss and Rank Shortlisted Alternatives
- Review Data Gaps
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Finalize Mission Statement and Goals


FINAL Draft Mission Statements for Drinking Water Planning Workgroup:

Mission Statement: Provide planning recommendations to the Water and Light Advisory Board and the City Council regarding the expansion of the water treatment system by establishing water quality goals, determining assessment criteria, and, conducting a thorough, objective, assessment of industry accepted treatment technologies to determine the process or processes that best meet these criteria.

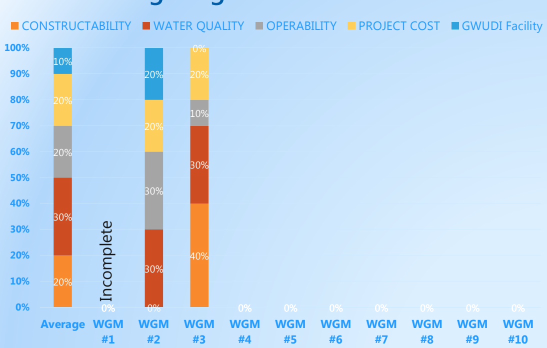
The Goals of the Drinking Water Planning Workgroup are as follows:

- Review current planning strategies for water supply and verify current goals and planning horizon for water treatment capacity expansion.
- Considering current regulations, potential future regulations, and potential enhancements, review and recommend potential long term water quality goals.
- Assess the state of the industry and shortlist potential treatment strategies that meet or exceed some or all of the potential long term water quality goals based upon industry acceptance and long term (present worth) costs.
- Formulate a set of criteria upon which potential treatment strategies to meet or exceed potential goals will be evaluated.
- Objectively evaluate and rank potential treatment strategies that meet planning horizon goals using a structured decision analysis model.
- Conduct a sensitivity analysis of decisions to review robustness and defensibility of decisions to potential changes in criterion assessments.
- Through this objective process, develop planning recommendations to guide the Water and Light Advisory Board and City Council regarding the water treatment system.

## Agenda

- Finalize Mission Statement
- **Review Pairwise Comparison Result**
- Review Project Boundaries
- Discuss/Review Alternatives and Carollo Shortlist
- SDA Model
- Discuss and Rank Shortlisted Alternatives
- Review Data Gaps
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Criteria Weighting Results



## Voting to Accept Pairwise Comparisons

- Accept pairwise comparisons as is?
- Potentially delay schedule to incorporate pairwise comparisons from this workshop?

## Final Schedule


## Constructability Pairwise Comparison

| 1. CONSTRUCTABILITY PAIRWISE COMPARISON WORKSHEET | | | | | |
|---|---|---|---|---|---|
| | Maintain Plant Operations | Schedule | Space Requirements | Permitting | |
| Maintain Plant Operations | NA | Maintain Plant Operations | 67% Space<br>33% Maint. O. | Maintain Plant Operations | |
| Schedule | NA | NA | Space Requirements | Permitting | |
| Space Requirements | NA | NA | NA | 67% Permit<br>33% Space | |
| Permitting | NA | NA | NA | NA | |
| | | | | | |
| Notes:<br>1. Do not use Shaded Spaces | | | | | |

## Water Quality Pairwise Comparison

| B. WATER QUALITY PAIRWISE COMPARISON | | | | | |
|---|---|---|---|---|---|
| | Water Quality Goals -TTHMS | Sustainability | Water Quality – CEC's | Communication | |
| Water Quality Goals - TTHMS | NA | TTHMs | TTHMs | TTHMs | |
| Sustainability | NA | NA | Sustainability | Sustainability | |
| Water Quality-CEC's | NA | NA | NA | CECs | |
| Communication | NA | NA | NA | NA | |

Notes:
1. Do not use Shaded Spaces

## Operability Pairwise Comparison

| C. OPERABILITY PAIRWISE COMPARISON WORKSHEET | | | | | |
|---|---|---|---|---|---|
| | Residuals Production | Staffing Requirements | Proven Technology | Complexity | Source Water Quality |
| Residuals Production | NA | 67% Staffing 33% Res. | Proven Tech | Complexity | 67% Source WQ 33% Residuals |
| Staffing Requirements | NA | NA | 67% Tech. 33% Staffing | 67% Staffing 33% Complexity | 67% Staffing 33% Source WQ |
| Proven Technology | NA | NA | NA | 67% Complexity 33% Tech. | Proven Tech |
| Complexity | NA | NA | NA | NA | Complexity |
| Source Water Quality | NA | NA | NA | NA | NA |

Notes:
1. Do not use shaded spaces.

## Cost Comparison Pairwise Comparison

| D. COST PAIRWISE COMPARISON WORKSHEET | | | | |
|---|---|---|---|---|
| | Life Cycle | Operational | Maintenance | Capital |
| Life Cycle | NA | 67% Operational 33% Life Cycle | 67% Maintenance 33% Life Cycle | 67% Capital 33% Life Cycle |
| Operational | NA | NA | Operational | 67% Operational 33% Capital |
| Maintenance | NA | NA | NA | 67% Capital 33% Maintenance |
| Capital | NA | NA | NA | NA |

Notes:
1. Do not use shaded spaces.

## GWUDI/Major Pairwise Comparison

**E. GWUDI/MAJOR PAIRWISE COMPARISON WORKSHEET**

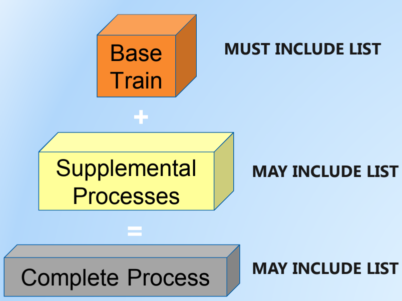
| | A. Constructability | B. Water Quality | C. Operability | D. Cost | E. GWUDI |
|---|---|---|---|---|---|
| A. Constructability | NA | 67% Water Quality 33% Const. | 67% Op. 33% Const. | 50% Cost 50% Const. | 50% GWUDI 50% Const. |
| B. Water Quality | NA | NA | Water Quality | 67% WQ 33% Cost | WQ |
| C. Operability | NA | NA | NA | 50% Op. 50% Cost | Op. |
| D. Cost | NA | NA | NA | NA | 50% GWUDI 50% Cost |
| E. GWUDI | NA | NA | NA | NA | NA |

Notes:
1. Do not use shaded spaces.

## Agenda

- Finalize Mission Statement
- Review Pairwise Comparison Result
- **Review Project Boundaries**
- Discuss/Review Alternatives and Carollo Shortlist
- SDA Model
- Discuss and Rank Shortlisted Alternatives
- Review Data Gaps
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Treatment Alternative Identification



## "Fatal Flaw" and "Must Include" List

- "Fatal Flaw" will eliminate Potential Alternative from consideration
  - Technology has never been built at this scale
  - Inappropriate technology
  - Extremely inflated costs
  - Not acceptable to the Community

## Fatal Flaw Analysis Base Treatment Trains

- [Yellow] Never Attempted at this Scale
- [Brown] Extremely Inflated Costs
- [Blue] Public Acceptance Limited
- [Red] Not Necessary/Inappropriate Technology to Achieve Goals

**Hardness Removal Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| | Conventional Softening |
| | High Rate Softening |
| [Brown] | Enhanced Softening |
| [Brown] | Softening with Caustic |
| [Yellow] | Anion Exchange |
| [Red] | Split Treatment |
| | Nanofiltration/RO |
| | Pelletized Lime Reactor |
| [Yellow] | Electromagnetic |
| [Yellow] [Brown] | Home POU devices |

→

**Hardness Removal Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| | **Conventional Softening** |
| | **High Rate Softening** |
| | |
| | |
| | |
| | |
| | **Nanofiltration/RO** |
| | **Pelletized Lime Reactor** |
| | |
| | |

## Fatal Flaw Analysis Base Treatment Trains

- [Yellow] Never Attempted at this Scale
- [Brown] Extremely Inflated Costs
- [Blue] Public Acceptance Limited
- [Red] Not Necessary/Inappropriate Technology to Achieve Goals

**Filtration Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| | Conventional Filtration – Constant Rate |
| | Ultrafiltration Membranes |
| | Deep bed filtration – Constant Rate |
| [Red] | Alternative (Slow Sand Diatomaceous Earth) |
| | MnO2 Coated Media Filtration |
| [Brown] [Yellow] | Manganese Greensand |
| | Nanofiltration/RO |
| [Red] | Cartridge Filtration |
| | Declining Rate Filtration |

→

**Filtration Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| | **Conventional Filtration – Constant Rate** |
| | **Ultrafiltration Membranes** |
| | **Deep Bed Filters – Constant Rate** |
| | |
| | |
| | |
| | **Nanofiltration/RO** |
| | |
| | **Declining Rate Filtration** |

## Fatal Flaw Analysis Advanced Treatment

- Yellow: Never Attempted at this Scale
- Dark yellow/brown: Extremely Inflated Costs
- Blue: Public Acceptance Limited
- Red: Not Necessary/Inappropriate Technology to Achieve Goals

**CEC Removal/Oxidation Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| Red | Ferrate |
| Red | Free Chlorine |
| | Chlorine Dioxide |
| | Ozone or Ozone/Peroxide |
| Brown, Yellow | Wet Air Oxidation |
| | UV/Peroxide |
| Brown, Yellow | UV/Titanium Dioxide |
| Brown, Yellow | UV/Peracetic Acid |
| Red | Permanganate |

→

**CEC/Oxidation Removal Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| | |
| | |
| | **Chlorine Dioxide (Mn Only)** |
| | **Ozone or Ozone Peroxide** |
| | |
| | **UV/Peroxide** |
| | **Nanofiltration/RO** |
| | |
| | |

## Fatal Flaw Analysis Advanced Treatment

- Yellow: Never Attempted at this Scale
- Dark yellow/brown: Extremely Inflated Costs
- Blue: Public Acceptance Limited
- Red: Not Necessary/Inappropriate Technology to Achieve Goals

**DBP Precursor Removal Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| Red | GAC Filter Contactors |
| | PAC Contactors (Actiflow CARBtm) |
| | Post Filter GAC Contactors |
| | NanoFiltration/RO |
| | Enhanced Coagulation |
| Red | Ozone Biofiltration |
| Red | Chlorine Dose Control |
| Yellow | Anion Exchange Beds |
| | Chloramination (w/ Nitrification Action Plan) |
| | MIEX (magnetic Ion Exchange) |
| Brown | Air Stripping |
| Brown | Electrodialysis |

→

**DBP Precursor Removal Technology**

| Fatal Flaw | Treatment Technology |
|---|---|
| | |
| | **PAC Contactors (Actiflow CARBtm)** |
| | **Post Filter GAC Contactors** |
| | **NanoFiltration/RO** |
| | Enhanced Coagulation (only in Bypass) |
| | |
| | |
| | |
| | Chloramination (w/ Nitrification Action Plan) |
| | **MIEX (magnetic Ion Exchange)** |
| | |
| | |

## Project Visioning- "Must Include List"

- "Must Include" or the Alternative will be eliminated from consideration
  - Reuse Existing Plant Site
  - Continued Expansion of Wellfield per IWRP
  - Meets all water quality goals for Groundwater Facility (current treatment level- softening).
  - Addresses Aging Infrastructure as Identified in 2016 Condition Assessment to restore capacity of 32 mgd in short term (next 3 years).
  - Expansion of Plant to 48 mgd per IWRP by 2024

## 2020 Project To Restore Capacity

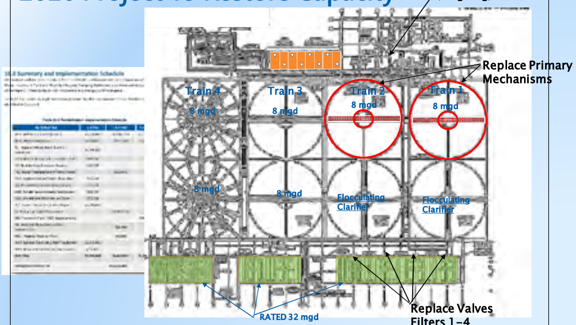
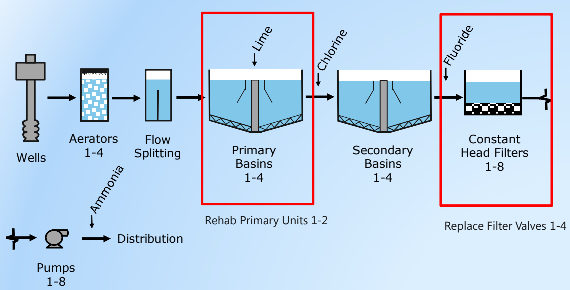



Figure ES.2 Plan View of Existing Treatment Process
Executive Summary
McBaine Water Treatment Plant Preliminary Design
Columbia Water and Light

## Existing Plant



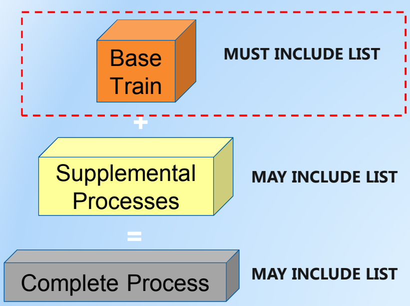

## Project Visioning- “May Include List”

- “May Include” will be distinguished as a second or third tier alternative
  - Meets all water quality goals for a GWUDI Facility
  - Will enable plant to eliminate chloramines as a disinfectant in the distribution system.
  - Will maximize reduction of CEC’s

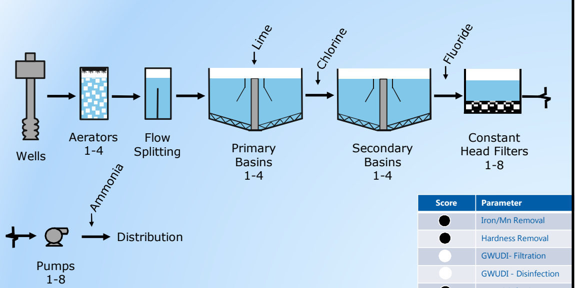
## Agenda

- Finalize Mission Statement
- Review Pairwise Comparison Result
- Review Project Boundaries
- **Discuss/Review Alternatives and Carollo Shortlist**
- SDA Model
- Discuss and Rank Shortlisted Alternatives
- Review Data Gaps
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Treatment Alternative Identification




## Existing Plant




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ○ | GWUDI- Filtration |
| ○ | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |

## Columbia WTP Expansion Alternatives

| Alternatives | | | |
|---|---|---|---|
| **Base Alternative** | **GWUDI Compliance** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B4 – Replace Plant w/RO Facility | ● | ● | ◐ |
| | | | Add S3.1 or S3.2 |
| B5 – Replace Conventional Softening w/Pellet Softening | ● | ○ | ○ |
| | | Add S2.1, S2.2, S2.3 | Add S3.1 or S3.2 |

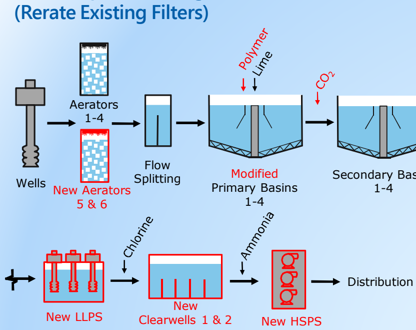
● Yes, ◐ Partial, ○ No

Adder for GWUDI
- S1.1 – Expansion to GWUDI

Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB

Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

## B1.1 – Expand Existing Plant w/ Conventional Softening (Rerate Existing Filters)




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |

## Columbia WTP Expansion Alternatives

| Alternatives | | | |
|---|---|---|---|
| **Base Alternative** | **GWUDI Compliance** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B4 – Replace Plant w/RO Facility | ● | ● | ◐ |
| | | | Add S3.1 or S3.2 |
| B5 – Replace Conventional Softening w/Pellet Softening | ● | ○ | ○ |
| | | Add S2.1, S2.2, S2.3 | Add S3.1 or S3.2 |

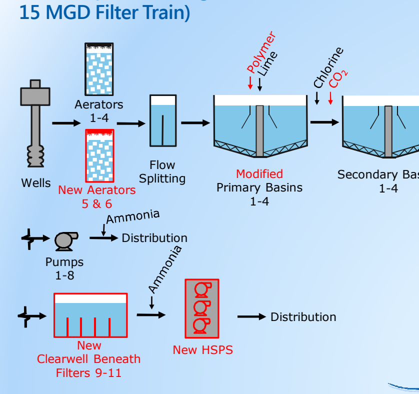
● Yes, ◐ Partial, ○ No

Adder for GWUDI
- S1.1 – Expansion to GWUDI

Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB

Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

## B1.2 – Expand Existing Plant w/ Conventional Softening (New 15 MGD Filter Train)




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ◐ | GWUDI- Filtration |
| ◔ | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |

## Columbia WTP Expansion Alternatives

| Alternatives | | | |
|---|---|---|---|
| **Base Alternative** | **GWUDI Compliance** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B4 – Replace Plant w/RO Facility | ● | ● | ◐ |
| | | | Add S3.1 or S3.2 |
| B5 – Replace Conventional Softening w/Pellet Softening | ● | ○ | ○ |
| | | Add S2.1, S2.2, S2.3 | Add S3.1 or S3.2 |

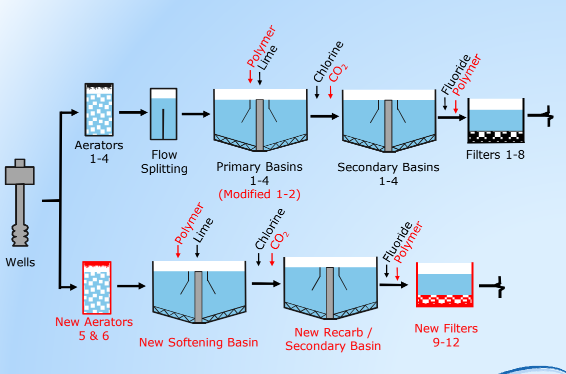
● Yes, ◐ Partial, ○ No

Adder for GWUDI
- S1.1 – Expansion to GWUDI

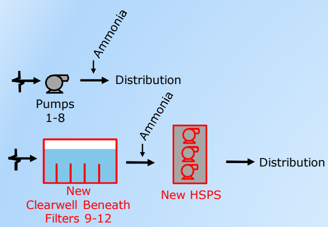
Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB

Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

## B2 – New 15 MGD Treatment Train



## B2 – New 15 MGD Treatment Train




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ◐ | GWUDI- Filtration |
| ◔ | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |

## Columbia WTP Expansion Alternatives

| Alternatives | | | |
|---|---|---|---|
| **Base Alternative** | **GWUDI Compliance** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B4 – Replace Plant w/RO Facility | ● | ● | ◐ |
| | | | Add S3.1 or S3.2 |
| B5 – Replace Conventional Softening w/Pellet Softening | ● | ○ | ○ |
| | | Add S2.1, S2.2, S2.3 | Add S3.1 or S3.2 |

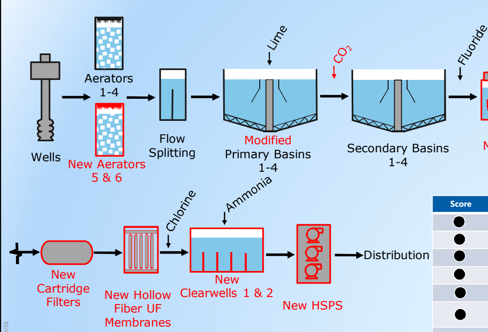
● Yes, ◐ Partial, ○ No

Adder for GWUDI
- S1.1 – Expansion to GWUDI

Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB

Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

## B3 – Replace Filters w/ Ultrafiltration Membranes




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |

## Columbia WTP Expansion Alternatives

| Alternatives | | | |
|---|---|---|---|
| **Base Alternative** | **GWUDI Compliance** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B4 – Replace Plant w/RO Facility | ● | ● | ◐ |
| | | | Add S3.1 or S3.2 |
| B5 – Replace Conventional Softening w/Pellet Softening | ● | ○ | ○ |
| | | Add S2.1, S2.2, S2.3 | Add S3.1 or S3.2 |

● Yes, ◐ Partial, ○ No

Adder for GWUDI
- S1.1 – Expansion to GWUDI

Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB

Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

Filename.ppt/37

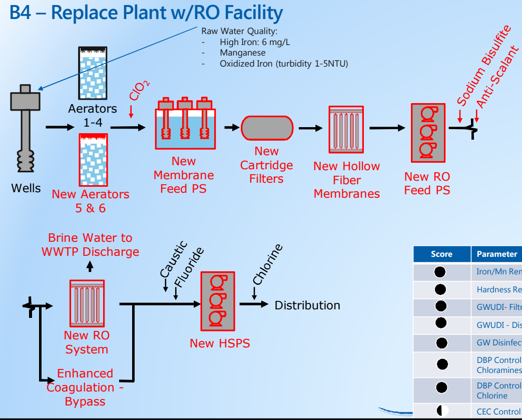
## Source Water Quality

| Parameter | Units | Range (Wells) |
|---|---|---|
| Hardness, Total | mg/L as $CaCO_3$ | 218 – 534 |
| Calcium | mg/L as $CaCO_3$ | 189 – 265 |
| Magnesium | mg/L as $CaCO_3$ | 61 – 79 |
| Iron (Total) | mg/L | 2.8 – 14.2 |
| Manganese (Total | mg/L | 0.197 – 1.33 |
| Turbidity | NTU | 0.14-2.5 |

*Historical raw water quality from McBaine WTP Expansion Preliminary Design Report (Carollo, 2012)

Filename.ppt/38

## B4 – Replace Plant w/RO Facility




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ● | DBP Control Free Chlorine |
| ◐ | CEC Control |

Filename.ppt/39

## Columbia WTP Expansion Alternatives

| Alternatives | | | |
|---|---|---|---|
| **Base Alternative** | **GWUDI Compliance** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B4 – Replace Plant w/RO Facility | ● | ● | ◐ |
| | | | Add S3.1 or S3.2 |
| B5 – Replace Conventional Softening w/Pellet Softening | ● | ○ | ○ |
| | | Add S2.1, S2.2, S2.3 | Add S3.1 or S3.2 |

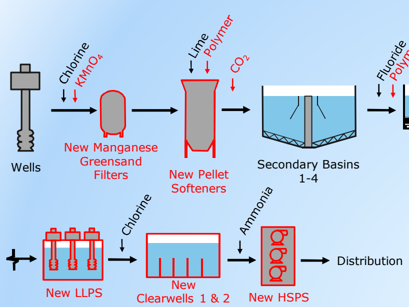
● Yes, ◐ Partial, ○ No

Adder for GWUDI
- S1.1 – Expansion to GWUDI

Adder for DBP Control
- S2.1 – GAC
- S2.2 – MIEX
- S2.3 – Actiflo™ CARB

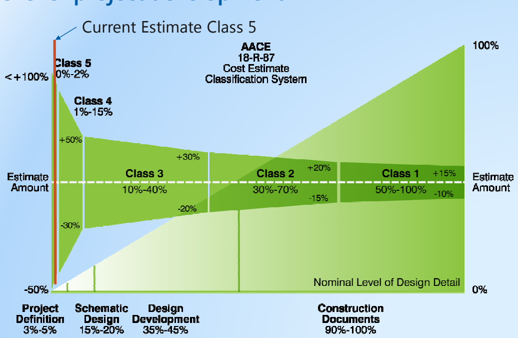
Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 – Ozone

## B5 – Replace Conventional Softening w/Pellet Softening



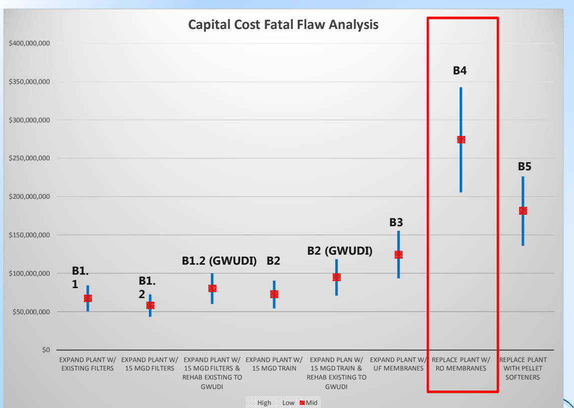

| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |

## The level of accuracy of cost estimating follows the level of project development

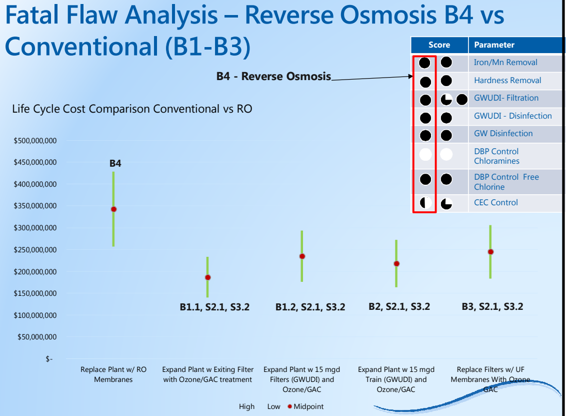


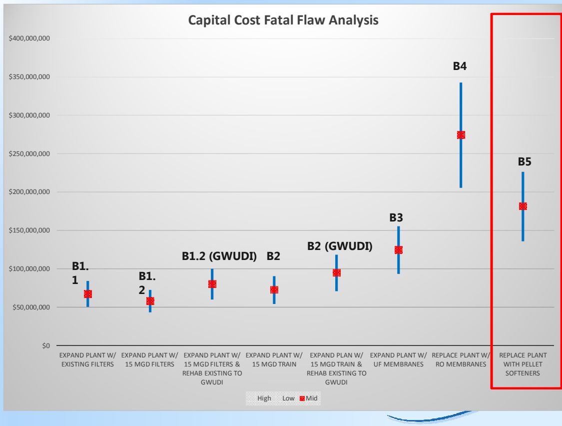
## Cost Estimate

- Class 5 AACE – Order of Magnitude
- Markups –
  - General Conditions – 8%
  - Contractor Overhead and Profit – 10%
  - General Conditions – 8%
  - Engineering and Admin – 12%
  - Contingency – 50%
- All alternatives provide a plant capacity of 48 mgd
- Cost Development
  - 2016 Condition Assessment
  - Historical data
  - Market Trends
  - Vendor Quotes
  - Cost Estimating Manuals
- O&M
  - 13 MGD Average Annual Flow
  - Current Dosages
  - $0.08 per kWh
  - 0.25% of Capital for O&M

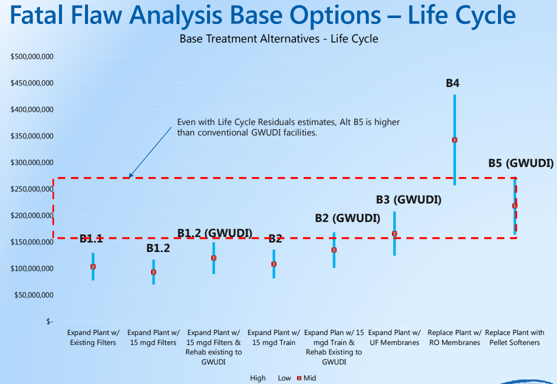



## Fatal Flaw Analysis – Reverse Osmosis B4 vs Conventional (B1-B3)





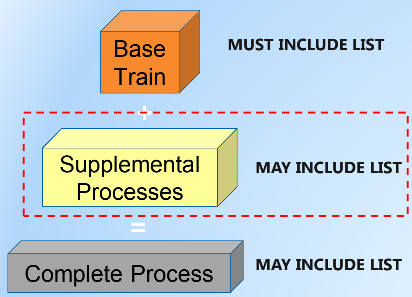

## Fatal Flaw Analysis Base Options – Life Cycle




## Fatal Flaw Analysis

- Eliminate B4 from Consideration:
  - RO membranes too expensive
  - Permitting of Brine disposal problematic
  - Well water quality (oxidized iron, turbidity, silica) not conducive to RO treatment, requires pre-treatment prior to membranes.
  - Conventional technologies with advanced treatment still less expensive to achieve same goals.
- Eliminate B5 from Consideration:
  - Pellet softeners too expensive (capital)
  - Insufficient sales revenue to tip operational costs in favor of pellet softening
  - Well water quality (iron, manganese) not conducive to Pellet softeners. Require pretreatment to remove iron/manganese to prevent fouling.
  - Other base alternatives achieve same goals with lower costs (hardness removal)

## Treatment Alternative Identification




## Columbia WTP Expansion Alternatives

| Alternatives | | | |
|---|---|---|---|
| **Base Alternative** | **GWUDI Compliance** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| ~~B4 – Replace Plant w/RO Facility~~ | ● | ● | ◐ |
| | | | ~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~●~~ | ~~○~~ | ~~○~~ |
| | | ~~Add S2.1, S2.2, S2.3~~ | ~~Add S3.1 or S3.2~~ |

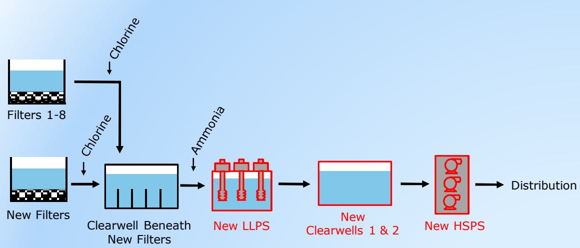
● Yes, ◐ Partial, ○ No

Adder for GWUDI
- S1.1 – Expansion to GWUDI

Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB

Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

## S1.1 – Expansion to GWUDI



## Columbia WTP Expansion Alternatives

**Alternatives**

| Base Alternative | GWUDI Compliance | DBP Control | CEC Removal |
|---|---|---|---|
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| ~~B4 – Replace Plant w/RO Facility~~ | ~~●~~ | ~~●~~ | ~~◐~~ |
| | | | ~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~●~~ | ~~○~~ | ~~○~~ |
| | | ~~Add S2.1, S2.2, S2.3~~ | ~~Add S3.1 or S3.2~~ |

● Yes, ◐ Partial, ○ No

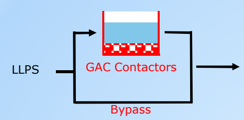
Adder for GWUDI
- S1.1 – Expansion to GWUDI

Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB

Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

Filename.ppt/52

## S2.1 – GAC





Filename.ppt/53

## Columbia WTP Expansion Alternatives

**Alternatives**

| Base Alternative | GWUDI Compliance | DBP Control | CEC Removal |
|---|---|---|---|
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| ~~B4 – Replace Plant w/RO Facility~~ | ~~●~~ | ~~●~~ | ~~◐~~ |
| | | | ~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~●~~ | ~~○~~ | ~~○~~ |
| | | ~~Add S2.1, S2.2, S2.3~~ | ~~Add S3.1 or S3.2~~ |

● Yes, ◐ Partial, ○ No

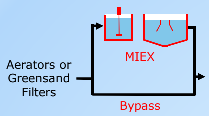
Adder for GWUDI
- S1.1 – Expansion to GWUDI

Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB

Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

Filename.ppt/54

## S2.2 –MIEX ™




Filename.ppt/55

## Columbia WTP Expansion Alternatives

| Alternatives | | | |
|---|---|---|---|
| Base Alternative | GWUDI Compliance | DBP Control | CEC Removal |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, S2.2, or S2.3 | Add S3.1 or S3.2 |
| ~~B4 – Replace Plant w/RO Facility~~ | ● | ● | ◐ |
| | | | ~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~●~~ | ~~○~~ | ~~○~~ |
| | | ~~Add S2.1, S2.2, S2.3~~ | ~~Add S3.1 or S3.2~~ |

● Yes, ◐ Partial, ○ No

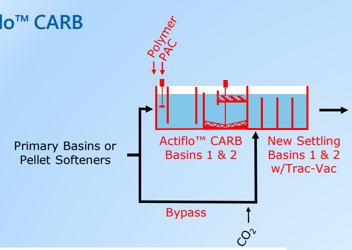
Adder for GWUDI
- S1.1 – Expansion to GWUDI

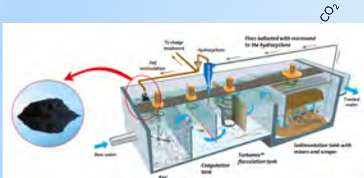
Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB

Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

Filename.ppt/56

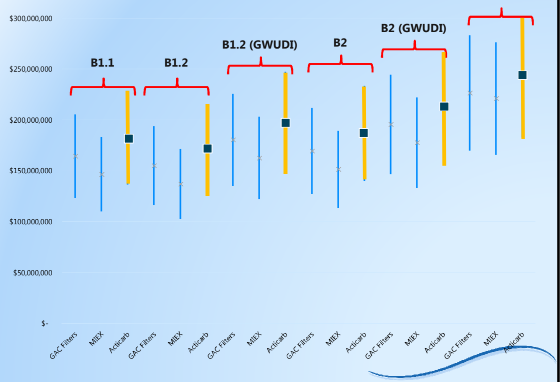
## S2.3 – Actiflo™ CARB



Filename.ppt/57

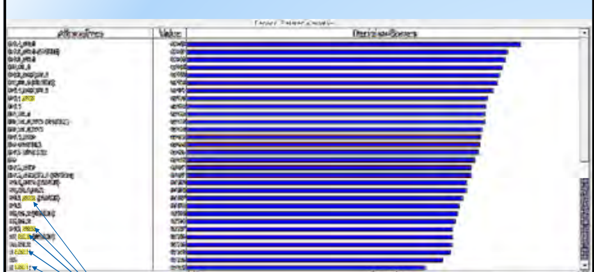
## Fatal Flaw Analysis DBP Control Technologies




## Fatal Flaw Analysis

- Eliminate S2.3 (Actiflo Carb) from Consideration:
  - Incorporation into existing treatment train more difficult
  - Higher operating costs due to solids disposal and Chemical (PAC) costs
  - GAC and/or MIEX are better alternative to controlling DBP's.

## Results: Average Criteria Weighting



S2.2 Alternative Generally low scores.

## Fatal Flaw Analysis

- Eliminate MIEX S2.2:
  - Permitting- Brine Stream Disposal
  - Operability- More complicated control than other DBP control technology.
  - Constructability – Difficult integration within existing processes.

## Columbia WTP Expansion Alternatives

| Alternatives | | | |
|---|---|---|---|
| **Base Alternative** | **GWUDI Compliance** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| ~~B4 – Replace Plant w/RO Facility~~ | ● | ● | ◐ |
| | | | ~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~●~~ | ~~○~~ | ~~○~~ |
| | | ~~Add S2.1, S2.2, S2.3~~ | ~~Add S3.1 or S3.2~~ |

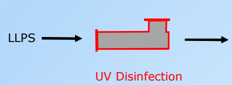
● Yes, ◐ Partial, ○ No

Adder for GWUDI
- S1.1 – Expansion to GWUDI

Adder for DBP Control
- S2.1 – GAC
- ~~S2.2 – MIEX~~
- ~~S2.3 – Actiflo™ CARB~~

Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

## S3.1 – UV Disinfection




## Columbia WTP Expansion Alternatives

| Alternatives | | | |
|---|---|---|---|
| **Base Alternative** | **GWUDI Compliance** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| ~~B4 – Replace Plant w/RO Facility~~ | ● | ● | ◐ |
| | | | ~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~●~~ | ~~◒~~ | ~~◒~~ |
| | | ~~Add S2.1, S2.2, S2.3~~ | ~~Add S3.1 or S3.2~~ |

● Yes, ◐ Partial, ○ No

Adder for GWUDI
- S1.1 – Expansion to GWUDI

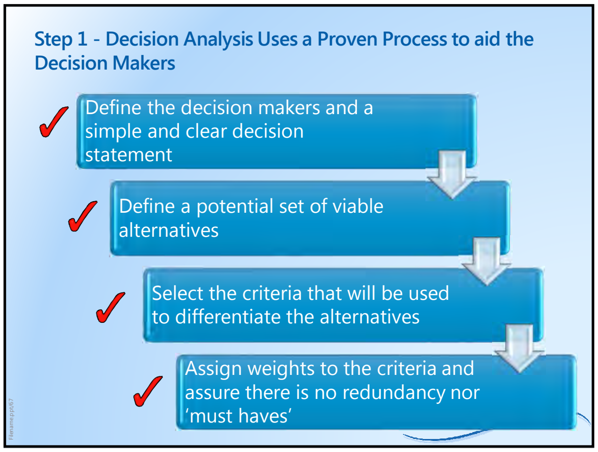
Adder for DBP Control
- S2.1 – GAC
- ~~S2.2 – MIEX~~
- ~~S2.3 – Actiflo™ CARB~~

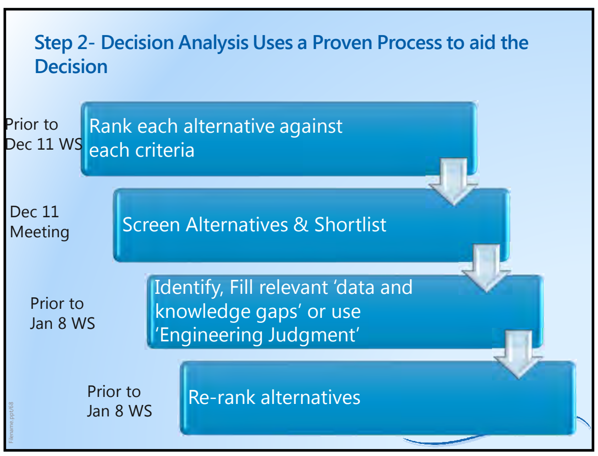
Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

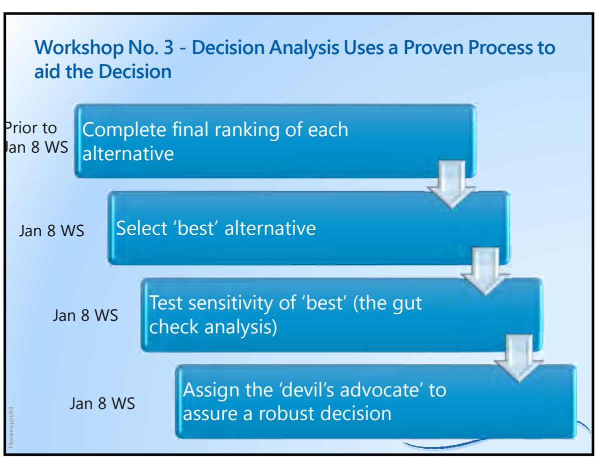
## S3.2 – Ozone


## Agenda

- Finalize Mission Statement
- Review Pairwise Comparison Result
- Review Project Boundaries
- Discuss/Review Alternatives and Carollo Shortlist
- **SDA Model**
- Discuss and Rank Shortlisted Alternatives
- Review Data Gaps
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment


Step 1 - Decision Analysis Uses a Proven Process to aid the Decision Makers
Define the decision makers and a simple and clear decision statement
Define a potential set of viable alternatives
Select the criteria that will be used to differentiate the alternatives
Assign weights to the criteria and assure there is no redundancy nor 'must haves'


Step 2- Decision Analysis Uses a Proven Process to aid the Decision
Prior to Dec 11 WS
Rank each alternative against each criteria
Dec 11 Meeting
Screen Alternatives & Shortlist
Prior to Jan 8 WS
Identify, Fill relevant 'data and knowledge gaps' or use 'Engineering Judgment'
Prior to Jan 8 WS
Re-rank alternatives


Workshop No. 3 - Decision Analysis Uses a Proven Process to aid the Decision
Prior to Jan 8 WS
Complete final ranking of each alternative
Jan 8 WS
Select 'best' alternative
Jan 8 WS
Test sensitivity of 'best' (the gut check analysis)
Jan 8 WS
Assign the 'devil's advocate' to assure a robust decision

## Agenda

- Finalize Mission Statement
- Review Pairwise Comparison Result
- Review Project Boundaries
- Discuss/Review Alternatives and Carollo Shortlist
- SDA Model
- **Discuss and Rank Shortlisted Alternatives – Tabled Until December 11, 2017?**
- Review Data Gaps
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Columbia WTP Expansion Alternatives

| Alternatives | | | |
|---|---|---|---|
| **Base Alternative** | **GWUDI Compliance** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF Membranes | ● | ○ | ○ |
| | | Add S2.1, ~~S2.2, or S2.3~~ | Add S3.1 or S3.2 |
| ~~B4 – Replace Plant w/RO Facility~~ | ● | ● | ◐ |
| | | | ~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~●~~ | ~~◒~~ | ~~◒~~ |
| | | ~~Add S2.1, S2.2, S2.3~~ | ~~Add S3.1 or S3.2~~ |

● Yes, ◐ Partial, ○ No

Adder for GWUDI
- S1.1 – Expansion to GWUDI

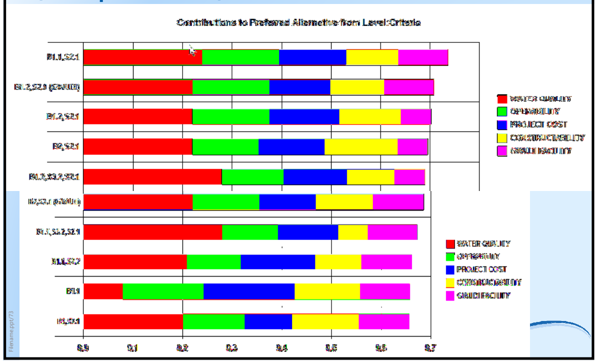
Adder for DBP Control
- S2.1 – GAC
- ~~S2.2 – MIEX~~
- ~~S2.3 – Actiflo™ CARB~~

Adder for CEC Removal
- S3.1 – UV Disinfection
- S3.2 - Ozone

## Shortlisted Alternatives

| # | Base Alt. | Title | Sup. Alt. | Title |
|---|---|---|---|---|
| 1 | B1.1 | Expand Plant w/ Existing Filters | NA | |
| 2 | B1.1 | Expand Plant w/ Existing Filters | S2.1 | GAC Filters |
| 3 | B1.1 | Expand Plant w/ Existing Filters | S3.2 | Ozone/Biof. |
| 4 | B1.1 | Expand Plant w/ Existing Filters | S2.1, S3.1 | GAC Filters, UV Disinfection |
| 5 | B1.1 | Expand Plant w/ Existing Filters | S2.1, S3.2 | GAC Filters, Ozone/Biof. |
| 6 | B1.2 | Expand Plant w/ New 15 mgd Filters | NA | |
| 7 | B1.2 | Expand Plant w/ New 15 mgd Filters | S1.1 | GWUDI |
| 8 | B1.2 | Expand Plant w/ New 15 mgd Filters | S1.1, S2.1 | GWUDI, GAC Filters |
| 9 | B1.2 | Expand Plant w/ New 15 mgd Filters | S1.1, S3.2 | GWUDI, Ozone/Biof. |
| 10 | B1.2 | Expand Plant w/ New 15 mgd Filters | S1.1, S2.1, S3.2 | GWUDI, GAC Filters, Ozone/Biof. |
| 11 | B2 | Expand Plant w/ New 15 mgd Train | NA | |
| 12 | B2 | Expand Plant w/ New 15 mgd Train | S1.1 | GWUDI |
| 13 | B2 | Expand Plant w/ New 15 mgd Train | S1.1, S2.1 | GWUDI, GAC Filters |
| 14 | B2 | Expand Plant w/ New 15 mgd Train | S1.1, S3.2 | GWUDI, Ozone/Biof. |
| 15 | B2 | Expand Plant w/ New 15 mgd Train | S1.1, S2.1, S3.2 | GWUDI, GAC Filters, Ozone/Biof. |
| 16 | B3 | Replace Filters w/ UF Membranes | NA | |
| 17 | B3 | Replace Filters w/ UF Membranes | S2.1 | GAC Filters |
| 18 | B3 | Replace Filters w/ UF Membranes | S3.2 | Ozone/Biof. |
| 29 | B3 | Replace Filters w/ UF Membranes | S2.1, S3.2 | GAC Filters, Ozone/Biof. |

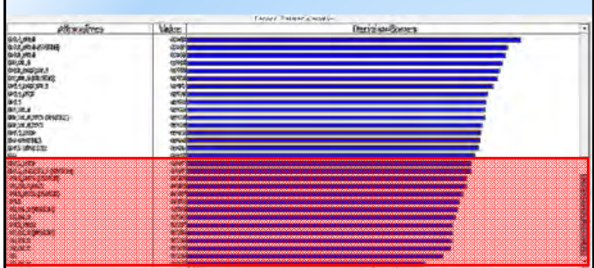
## Results (Top 10) : Average Criteria Weighting (Hempel, Pruett)




**Preliminary Ranking**

| ALTERNATIVE | AVERAGE WEIGHT | MERRITT - NA missing weights | HEMPEL | PRUETT | SKALA - NA missing weights | RYAN - NA missing weights | SZEWCZYK - NA missing weights | FALLIS - NA missing weights | CONWAY - NA missing weights | OFF - NA missing weights | JACKSON - NA missing weights |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B1.1,S2.1 | 1 | | 1 | 6 | | | | | | | |
| B1.2,S2.1 (GWUDI) | 2 | | 2 | 9 | | | | | | | |
| B1.2,S2.1 | 3 | | 8 | 2 | | | | | | | |
| B2,S2.1 | 4 | | 15 | 1 | | | | | | | |
| B1.2,S3.2,S2.1 | 5 | | 6 | 5 | | | | | | | |
| B2,S2.1 (GWUDI) | 6 | | 5 | 4 | | | | | | | |
| B1.1,S3.2,S2.1 | 7 | | 3 | 19 | | | | | | | |
| B1.1,S2.2 | 8 | | 10 | 24 | | | | | | | |
| B1.1 | 9 | | 11 | 20 | | | | | | | |
| B3,S2.1 | 10 | | 13 | 7 | | | | | | | |
| B2,S2.1,S3.2 (GWUDI) | 11 | | 4 | 14 | | | | | | | |
| B2,S2.1,S3.2 | 12 | | 12 | 10 | | | | | | | |
| B1.1,S3.2 | 13 | | 9 | 21 | | | | | | | |
| B2 (GWUDI) | 14 | | 17 | 8 | | | | | | | |
| B1.2 (GWUDI) | 15 | | 19 | 12 | | | | | | | |
| B2 | 16 | | 24 | 3 | | | | | | | |
| B1.2,S3.2 | 17 | | 23 | 11 | | | | | | | |
| B1.2,S3.2,S2.1 (GWUD | 18 | | 7 | 28 | | | | | | | |
| B1.2,S3.2 (GWUDI) | 19 | | 16 | 25 | | | | | | | |
| B3,S2.1,S3.2 | 20 | | 14 | 15 | | | | | | | |
| B1.2,S2.2 (GWUDI) | 21 | | 20 | 29 | | | | | | | |
| B1.2 | 22 | | 27 | 17 | | | | | | | |
| B2,S3.2 (GWUDI) | 23 | | 18 | 22 | | | | | | | |
| B2,S3.2 | 24 | | 26 | 13 | | | | | | | |
| B1.2,S2.2 | 25 | | 28 | 27 | | | | | | | |
| B2,S2.2 (GWUDI) | 26 | | 21 | 26 | | | | | | | |
| B3,S3.2 | 27 | | 22 | 18 | | | | | | | |
| B2,S2.2 | 28 | | 29 | 16 | | | | | | | |
| B3 | 29 | | 25 | 23 | | | | | | | |
| B3,S2.2 | 30 | | 30 | 30 | | | | | | | |

## Results: Average Criteria Weighting (Hempel, Pruett)



## Shortlisted Alternatives

| # | Base Alt. | Title | Sup. Alt. | Title |
|---|---|---|---|---|
| 1 | B1.1 | Expand Plant w/ Existing Filters | NA | |
| 2 | B1.1 | Expand Plant w/ Existing Filters | S2.1 | GAC Filters |
| 3 | B1.1 | Expand Plant w/ Existing Filters | S3.2 | Ozone/Biof. |
| 4 | B1.1 | Expand Plant w/ Existing Filters | S2.1, S3.1 | GAC Filters, UV Disinfection |
| 5 | B1.1 | Expand Plant w/ Existing Filters | S2.1, S3.2 | GAC Filters, Ozone/Biof. |
| 6 | B1.2 | Expand Plant w/ New 15 mgd Filters | NA | |
| 7 | B1.2 | Expand Plant w/ New 15 mgd Filters | S1.1 | GWUDI |
| 8 | B1.2 | Expand Plant w/ New 15 mgd Filters | S1.1, S2.1 | GWUDI, GAC Filters |
| 9 | B1.2 | Expand Plant w/ New 15 mgd Filters | S1.1, S3.2 | GWUDI, Ozone/Biof. |
| 10 | B1.2 | Expand Plant w/ New 15 mgd Filters | S1.1, S2.1, S3.2 | GWUDI, GAC Filters, Ozone/Biof. |
| 11 | B2 | Expand Plant w/ New 15 mgd Train | NA | |
| 12 | B2 | Expand Plant w/ New 15 mgd Train | S1.1 | GWUDI |
| 13 | B2 | Expand Plant w/ New 15 mgd Train | S1.1, S2.1 | GWUDI, GAC Filters |
| 14 | B2 | Expand Plant w/ New 15 mgd Train | S1.1, S3.2 | GWUDI, Ozone/Biof. |
| 15 | B2 | Expand Plant w/ New 15 mgd Train | S1.1, S2.1, S3.2 | GWUDI, GAC Filters, Ozone/Biof. |
| 16 | B3 | Replace Filters w/ UF Membranes | NA | |
| 17 | B3 | Replace Filters w/ UF Membranes | S2.1 | GAC Filters |
| 18 | B3 | Replace Filters w/ UF Membranes | S3.2 | Ozone/Biof. |
| 29 | B3 | Replace Filters w/ UF Membranes | S2.1, S3.2 | GAC Filters, Ozone/Biof. |



## Agenda

- Finalize Mission Statement
- Review Pairwise Comparison Result
- Review Project Boundaries
- Discuss/Review Alternatives and Carollo Shortlist
- SDA Model
- Discuss and Rank Shortlisted Alternatives
- **Review Data Gaps**
- Review Action/Decision Logs
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment



## Identify and Review Data Gaps

- General:
  - Develop Layouts to clarify constructability ratings.
  - Modify alternatives to address potential permitting issues (if possible).
  - Modify alternative to address potential operability issues. (if possible).
- B1.1, B1.2 (GWUDI), and B2 (GWUDI) Alternatives
  - (B1.1) Rerating of Filters to > 6 gpm/sqft for 45 mgd
  - Improvement of exisitng filters (32 mgd) for GWUDI
- GAC S1.2 Alternatives
  - GAC cost and replacement frequency
  - Revisit MIEX (if necessary) as potential for some options
- Ozone Alternatives:
  - Develop Bromate control strategies and costs
- UV alternatives:
  - Update costs for Transmittance values.

## Agenda

- Finalize Mission Statement
- Review Pairwise Comparison Result
- Review Project Boundaries
- Discuss/Review Alternatives and Carollo Shortlist
- SDA Model
- Discuss and Rank Shortlisted Alternatives
- Review Data Gaps
- **Review Action/Decision Logs**
- Review Next Steps
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## DECISION LOG

DECISION LOG

Project: Preliminary Design Report Update - [illegible]
Client: City of Columbia, MO
Job #:
Contract #:
UPDATED: [illegible]
BY: [illegible]

| ITEM No. | DECISION BY | DECISION FORUM | DECISION DESCRIPTION | DECISION DATE | COMMENTS |
|---|---|---|---|---|---|
| 7 | City | Townhall Meeting | The group accepted the recommendation outlined in the [illegible] that the source water be supplied by vertical wells in the existing wellfield | [illegible]-Sep-17 | |
| 8 | City | Townhall Meeting | The group should consider a facility that is [illegible] compliant | [illegible]-Sep-17 | |
| 9 | City | Townhall Meeting | The group decided to expand the existing plant as opposed to abandoning and building a new plant | [illegible]-Sep-17 | |
| 10 | City | Townhall Meeting | Finished water quality goals for TTHM and HAA shall meet the enhanced VQ values of ≤ [illegible] µg/L TTHM and ≤ [illegible] µg/L HAA, respectively | [illegible]-Sep-17 | |
| 11 | City | Townhall Meeting | Finished water quality goals for total chlorine entering the system may meet current regulatory values or the enhanced VQ values of ≤ 4.0 mg/L and [illegible] mg/L, respectively | [illegible]-Sep-17 | This depends on use of free chlorine or chloramines |
| 12 | City | Townhall Meeting | Finished water quality goals for NDMA shall meet the enhanced VQ values of ≤ 10 ng/L | [illegible]-Sep-17 | |
| 13 | City | Townhall Meeting | Finished water quality goals for Chlorate shall meet the enhanced VQ values | [illegible]-Sep-17 | |
| 14 | City | Townhall Meeting | Finished water quality goals for Brominated DBP's shall meet the enhanced VQ values | [illegible]-Sep-17 | |
| 15 | City | Townhall Meeting | Finished water quality goals for CEC's may meet current regulatory values or the enhanced VQ values | [illegible]-Sep-17 | |
| 16 | City | Townhall Meeting | Finished water quality goals for [illegible] may meet current regulatory values or the enhanced VQ values | [illegible]-Sep-17 | |
| 17 | City | Townhall Meeting | Finished water quality goals for Fluoride shall meet current regulatory values to maintain around 0.7 mg/L | [illegible]-Sep-17 | |
| 18 | City/Carollo | Townhall Meeting | Next meeting will be held at the McBaine WTP at 5:30 pm with a plant tour before | [illegible]-Sep-17 | |
| 19 | | | | | |

## ACTION LOG

ACTION ITEM

Project: Preliminary Design Report Update - Project Workshops
Client: City of Columbia, MO
Job #:
Contract #:
DATE: 10/10/2017
BY: BH

| ITEM No. | RESPONSIBLE PARTY | ACTION ITEM | ITEM DATE | TARGET RESOLUTION DATE | ITEM COMPLETION DATE | COMMENTS |
|---|---|---|---|---|---|---|
| 11 | Carollo | Provide binder containing past and future material to committee members | 11-Sep-17 | Oct-17 | 10-Oct-17 | |
| 12 | Carollo | Modify and present mission statement at the next meeting for approval | 11-Sep-17 | Oct-17 | 10-Oct-17 | |
| 13 | Shawn | Send out poll to group for next months meeting date with October 10 being the preferred date | 11-Sep-17 | Sep-17 | 12-Sep-17 | |
| 14 | Carollo | Send out updated mission statement | 10-Oct-17 | 13-Oct-17 | 12-Oct-17 | |
| 15 | Carollo/Shawn | Send out scoring sheets for sub-criteria cross-examination exercise | 10-Oct-17 | 13-Oct-17 | 12-Oct-17 | |
| 16 | City | Fill out and return scoring sheets for sub-criteria cross-examination exercise | 10-Oct-17 | 1 week before next meeting | | Committee Members will select which sub-criteria are more important than others |
| 17 | Carollo/Shawn | Send out poll to group for next months meeting date | 10-Oct-17 | 13-Oct-17 | 13-Oct-17 | |
| | | | | | | |

## Agenda

- Finalize Mission Statement
- Review Pairwise Comparison Result
- Review Project Boundaries
- Discuss/Review Alternatives and Carollo Shortlist
- SDA Model
- Discuss and Rank Shortlisted Alternatives
- Review Data Gaps
- Review Action/Decision Logs
- **Review Next Steps**
- General Comments by Public, Members and Staff
- Next Meeting Date
- Adjournment

## Next Steps

- Carollo:
  - Preliminary Ranking of Remaining Alternatives
  - Identify Data Gaps and Resolve
  - Update Costs and Rankings Based upon Data gaps
- Workgroup:
  - Review Preliminary Ranking of Remaining Alternatives
  - Develop list of questions/concerns 1 week prior to meeting.
- Carollo/Workshops – December 11/January 8
  - Review final shortlist and criteria ranking
  - Conduct sensitivity analysis
  - Determine final recommendation/draft summary

## Agenda

- Finalize Mission Statement
- Review Pairwise Comparison Result
- Review Project Boundaries
- Discuss/Review Alternatives and Carollo Shortlist
- SDA Model
- Discuss and Rank Shortlisted Alternatives
- Review Data Gaps
- Review Action/Decision Logs
- Review Next Steps
- **General Comments by Public, Members, and Staff**
- Next Meeting Date
- Adjournment


Agenda
Finalize Mission Statement
Review Pairwise Comparison Result
Review Project Boundaries
Discuss/Review Alternatives and Carollo Shortlist
SDA Model
Discuss and Rank Shortlisted Alternatives
Review Data Gaps
Review Action/Decision Logs
Review Next Steps
General Comments by Public, Members and Staff
Next Meeting Date: December 11, 2017 5:30 pm
Adjournment


Agenda
Finalize Mission Statement
Review Pairwise Comparison Result
Review Project Boundaries
Discuss/Review Alternatives and Carollo Shortlist
SDA Model
Discuss and Rank Shortlisted Alternatives
Review Data Gaps
Review Action/Decision Logs
Review Next Steps
General Comments by Public, Members and Staff
Next Meeting Date
Adjournment

# Pairwise Comparison and Preliminary Ranking Workshop

City of Columbia, MO

Water and Light Department

Drinking Water Planning Workgroup

January 8, 2018, 5:30 pm

Water Treatment Plant Conference Room

WATER OUR FOCUS OUR BUSINESS OUR PASSION

carollo Engineers...Working Wonders With Water®

## Agenda

- Pairwise Comparison
- Base Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Supplemental Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Review Data Gaps & Action/Decision Logs
- Review Final Steps
- General Comment by Public, Members, and Staff
- Next Meeting Date – FINAL DECISION MAKING AND PUBLIC SUMMARY WORKSHOPS

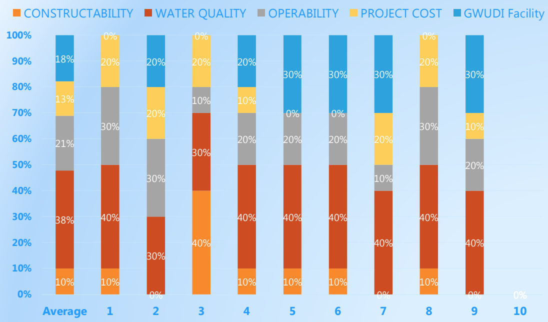
## Agenda

- **Pairwise Comparison**
- Base Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Supplemental Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Review Data Gaps & Action/Decision Logs
- Review final Steps
- General Comment by Public, Members, and Staff
- Next Meeting Date – FINAL DECISION MAKING AND PUBLIC SUMMARY WORKSHOPS

## Pairwise Comparison Surveys

- Distributed ranking worksheets to members of Drinking Water Planning Workgroup.
- Received 10 out of 10 fully completed responses – Thank you!!!

## Criteria Weighting Results




## Summary of Pairwise Comparisons

- Most participants scored water quality highest
- Most participants scored cost and GWUDI higher.
- Operability was more important that constructability to most participants.

WATER QUALITY > PROJECT COST / GWUDI Facility > OPERABILITY > CONSTRUCTABILITY

## Proposed Final Schedule


VH7

## Step 1 - Decision Analysis Steps that Have Already Been Implemented

- ✓ Define the decision makers and a simple and clear decision statement
- ✓ Define a potential set of viable alternatives
- ✓ Select the criteria that will be used to differentiate the alternatives
- ✓ Assign weights to the criteria and assure there is no redundancy nor 'must haves'

VH6 VH8

## Step 2- Decision Analysis – Where We Are Today

- ✓ Rank each alternative against each criteria
- This Meeting ✓ Screen Alternatives & Shortlist
- Gaps identified today – fill in prior to Re-rank: Identify, Fill relevant 'data and knowledge gaps' or use 'Engineering Judgment'
- Prior to Feb 12 Meeting: Re-rank alternatives

## Workshop No. 3 - Decision Analysis Finalized and Tested

- Feb 12 WS — Select 'best' alternative
- Feb 12 WS — Test sensitivity of 'best' (the gut check analysis)
- Feb 12 WS — Assign the 'devil's advocate' to assure a robust decision

## Agenda

- Pairwise Comparison
- **Base Alternatives:**
  - **Discuss/Review Alternatives and Carollo Shortlist**
  - **SDA Model Development**
  - **Discuss and Rank Shortlisted Alternatives**
- Supplemental Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Review Data Gaps & Action/Decision Logs
- Review Final Steps
- General Comment by Public, Members, and Staff
- Next Meeting Date – FINAL DECISION MAKING AND PUBLIC SUMMARY WORKSHOPS

## Base Trains Includes All of the Must Have Items

Base Train — **MUST INCLUDE LIST**

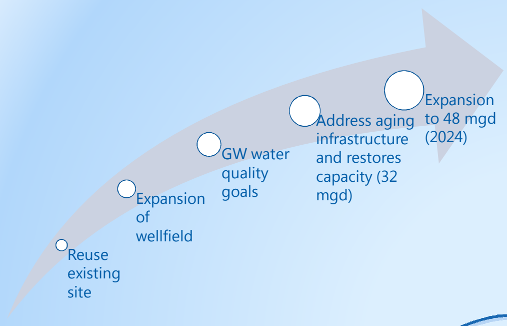
\+

Supplemental Processes — **MAY INCLUDE LIST**

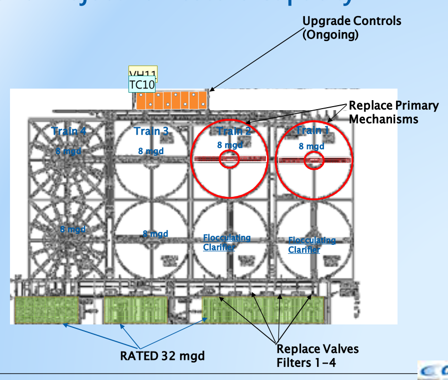
=

Complete Process

## Project Visioning- "Must Include List"

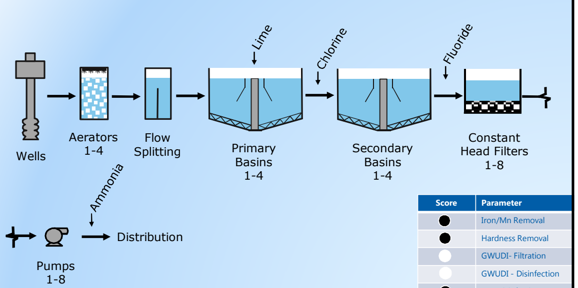



## 2020 Project To Restore Capacity




VH12

## Existing Plant Meets Some of Your Project Goals




| Score | Parameter |
| --- | --- |
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ○ | GWUDI- Filtration |
| ○ | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |

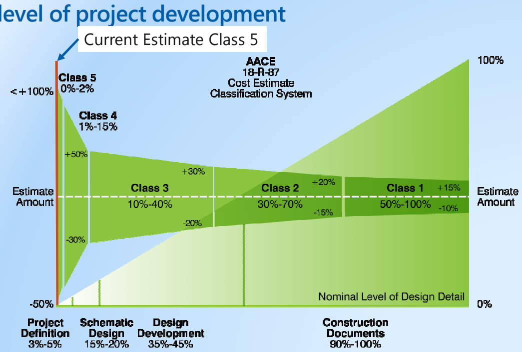
## Some of the Base Train Expansion Alternatives Meet GWUDI Requirements

**Alternatives**

| Base Alternative | GWUDI Compliance |
|---|---|
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ Add S1.1 |
| B2 – New 15 mgd Treatment Train | ○ Add S1.1 |
| B3 – Replace Filters w/ UF Membranes | ● |
| B4 – Replace Plant w/RO Facility | ● |
| B5 – Replace Conventional Softening w/Pellet Softening | ● |

● Yes, ◐ Partial, ○ No

## The level of accuracy of cost estimating follows the level of project development

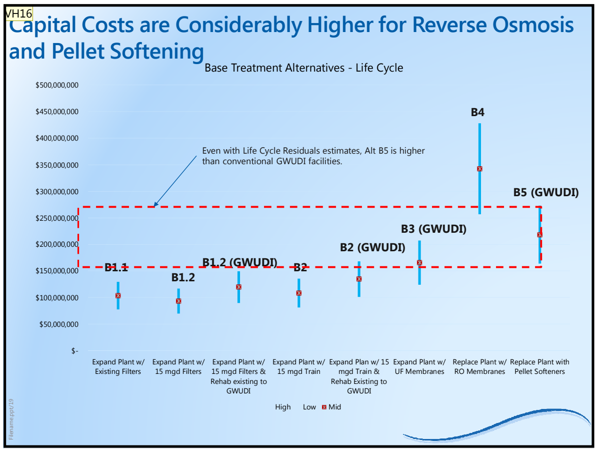


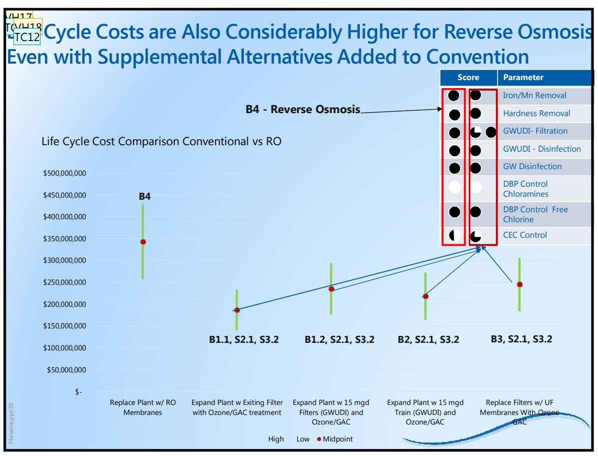

VH13

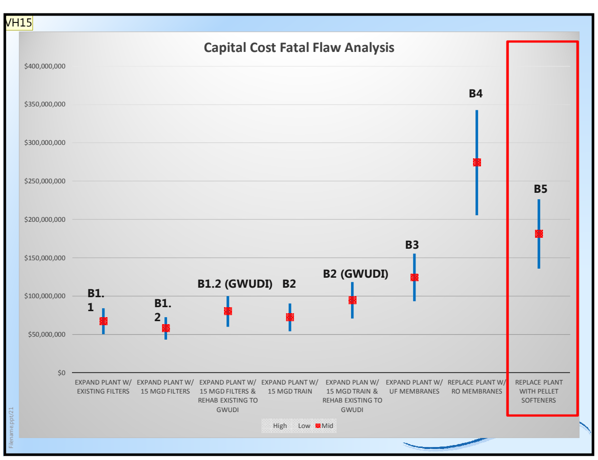
## Class 5 AACE Cost Estimate - Order of Magnitude

- Markups
  - GCs – 8%
  - Contractor O&P – 10%
  - Eng. and Admin – 12%
  - Contingency – 50%
- O&M
  - 13 MGD Average Annual Flow
  - Current Dosages
  - $0.08 per kWh
  - 0.25% of Capital for O&M
- Cost Development
  - 2016 Condition Assessment
  - Historical data
  - Market Trends
  - Vendor Quotes
  - Cost Estimating Manuals

All base alternatives provide a plant capacity of 48 mgd


VH16
Capital Costs are Considerably Higher for Reverse Osmosis and Pellet Softening
Base Treatment Alternatives - Life Cycle
Even with Life Cycle Residuals estimates, Alt B5 is higher than conventional GWUDI facilities.
B1.1
B1.2
B1.2 (GWUDI)
B2
B2 (GWUDI)
B3 (GWUDI)
B4
B5 (GWUDI)
$500,000,000
$450,000,000
$400,000,000
$350,000,000
$300,000,000
$250,000,000
$200,000,000
$150,000,000
$100,000,000
$50,000,000
$-
Expand Plant w/ Existing Filters
Expand Plant w/ 15 mgd Filters
Expand Plant w/ 15 mgd Filters & Rehab existing to GWUDI
Expand Plant w/ 15 mgd Train
Expand Plan w/ 15 mgd Train & Rehab Existing to GWUDI
Expand Plant w/ UF Membranes
Replace Plant w/ RO Membranes
Replace Plant with Pellet Softeners
High Low Mid


VH17
TC12
Cycle Costs are Also Considerably Higher for Reverse Osmosis Even with Supplemental Alternatives Added to Convention
B4 - Reverse Osmosis
Score
Parameter
Iron/Mn Removal
Hardness Removal
GWUDI- Filtration
GWUDI - Disinfection
GW Disinfection
DBP Control Chloramines
DBP Control Free Chlorine
CEC Control
Life Cycle Cost Comparison Conventional vs RO
$500,000,000
$450,000,000
$400,000,000
$350,000,000
$300,000,000
$250,000,000
$200,000,000
$150,000,000
$100,000,000
$50,000,000
$-
B4
B1.1, S2.1, S3.2
B1.2, S2.1, S3.2
B2, S2.1, S3.2
B3, S2.1, S3.2
Replace Plant w/ RO Membranes
Expand Plant w Exiting Filter with Ozone/GAC treatment
Expand Plant w 15 mgd Filters (GWUDI) and Ozone/GAC
Expand Plant w 15 mgd Train (GWUDI) and Ozone/GAC
Replace Filters w/ UF Membranes With Ozone GAC
High Low Midpoint


VH15
Capital Cost Fatal Flaw Analysis
$400,000,000
$350,000,000
$300,000,000
$250,000,000
$200,000,000
$150,000,000
$100,000,000
$50,000,000
$0
B1.1
B1.2
B1.2 (GWUDI)
B2
B2 (GWUDI)
B3
B4
B5
EXPAND PLANT W/ EXISTING FILTERS
EXPAND PLANT W/ 15 MGD FILTERS
EXPAND PLANT W/ 15 MGD FILTERS & REHAB EXISTING TO GWUDI
EXPAND PLANT W/ 15 MGD TRAIN
EXPAND PLAN W/ 15 MGD TRAIN & REHAB EXISTING TO GWUDI
EXPAND PLANT W/ UF MEMBRANES
REPLACE PLANT W/ RO MEMBRANES
REPLACE PLANT WITH PELLET SOFTENERS
High Low Mid

## We Propose Eliminating Reverse Osmosis and Pellet Softening Due to High Capital and Life Cycle Cost Without Corresponding Benefits

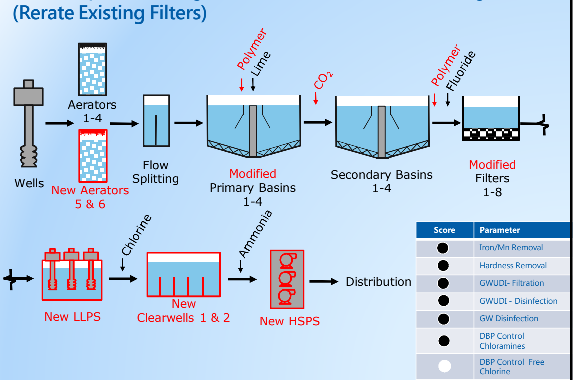
**Alternatives**

| Base Alternative | GWUDI Compliance |
|---|---|
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○<br>Add S1.1 |
| B2 – New 15 mgd Treatment Train | ○<br>Add S1.1 |
| B3 – Replace Filters w/ UF Membranes | ● |
| ~~B4 – Replace Plant w/RO Facility~~ | ● |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ● |

Fatal Flaws

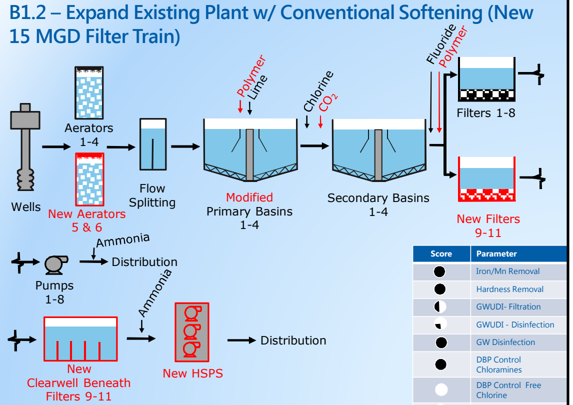
● Yes, ◐ Partial, ○ No

## B1.1 – Expand Existing Plant w/ Conventional Softening (Rerate Existing Filters)

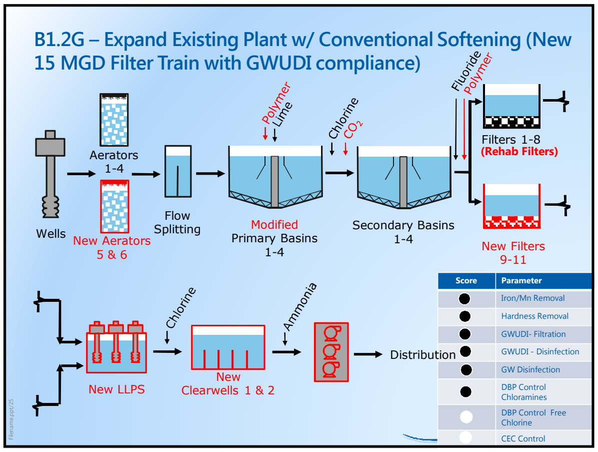


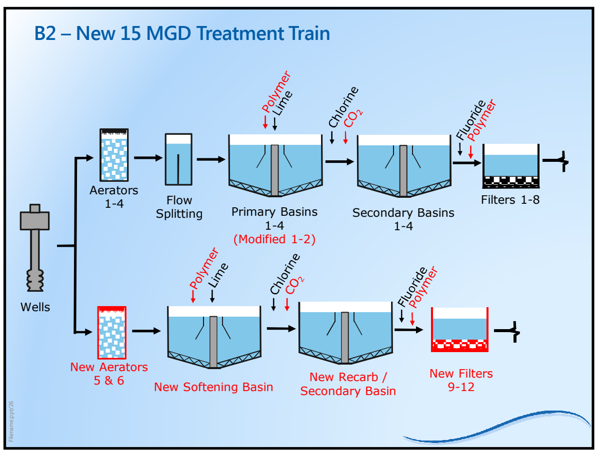

| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |

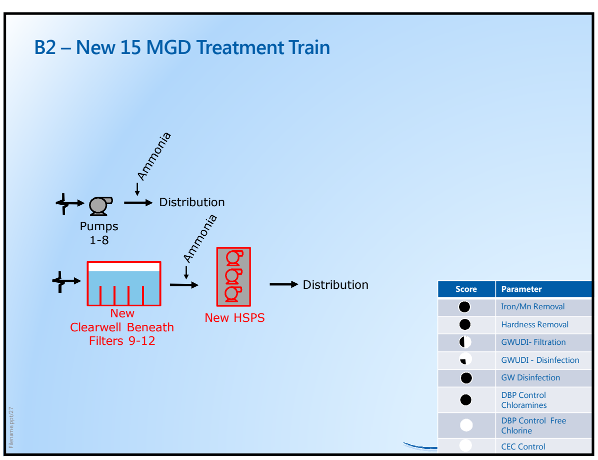
## B1.2 – Expand Existing Plant w/ Conventional Softening (New 15 MGD Filter Train)



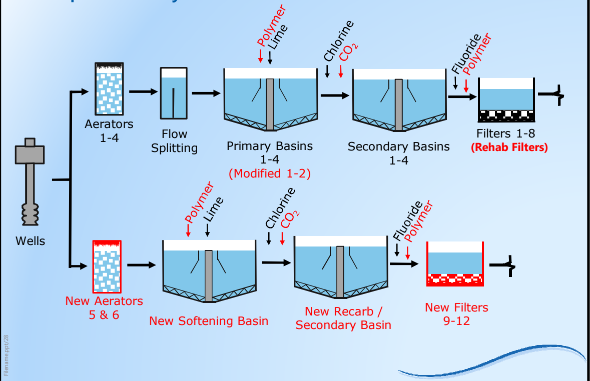

| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ◐ | GWUDI- Filtration |
| ◔ | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |


B1.2G – Expand Existing Plant w/ Conventional Softening (New 15 MGD Filter Train with GWUDI compliance)
Wells
Aerators 1-4
New Aerators 5 & 6
Flow Splitting
Polymer
Lime
Modified Primary Basins 1-4
Chlorine
$CO_2$
Secondary Basins 1-4
Fluoride
Polymer
Filters 1-8
(Rehab Filters)
New Filters 9-11
New LLPS
Chlorine
New Clearwells 1 & 2
Ammonia
Distribution
Score
Parameter
Iron/Mn Removal
Hardness Removal
GWUDI- Filtration
GWUDI - Disinfection
GW Disinfection
DBP Control Chloramines
DBP Control Free Chlorine
CEC Control

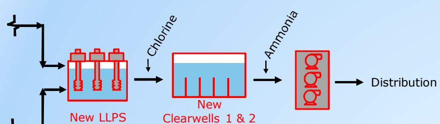

B2 – New 15 MGD Treatment Train
Wells
Aerators 1-4
Flow Splitting
Polymer
Lime
Primary Basins 1-4 (Modified 1-2)
Chlorine
$CO_2$
Secondary Basins 1-4
Fluoride
Polymer
Filters 1-8
New Aerators 5 & 6
Polymer
Lime
New Softening Basin
Chlorine
$CO_2$
New Recarb / Secondary Basin
Fluoride
Polymer
New Filters 9-12


B2 – New 15 MGD Treatment Train
Ammonia
Distribution
Pumps 1-8
Ammonia
New Clearwell Beneath Filters 9-12
New HSPS
Distribution
Score
Parameter
Iron/Mn Removal
Hardness Removal
GWUDI- Filtration
GWUDI - Disinfection
GW Disinfection
DBP Control Chloramines
DBP Control Free Chlorine
CEC Control

## B2 (GWUDI) – New 15 MGD Treatment Train with GWUDI Compliant Facility

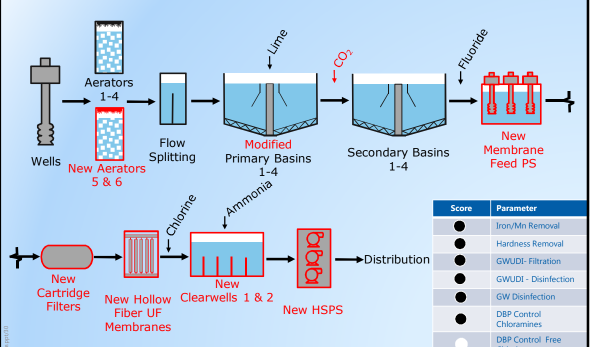



## B2 – New 15 MGD Treatment Train (GWUDI Facility)_




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |

## B3 – Replace Filters w/ Ultrafiltration Membranes




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |

VH21

## Basis for Carollo Ranking of Base Alternatives

**Industry Benchmarking Standards**
- AWWA Benchmarking Studies
- MO DNR design guidance
- 10 State Standards
- EPA Standards/Guidance

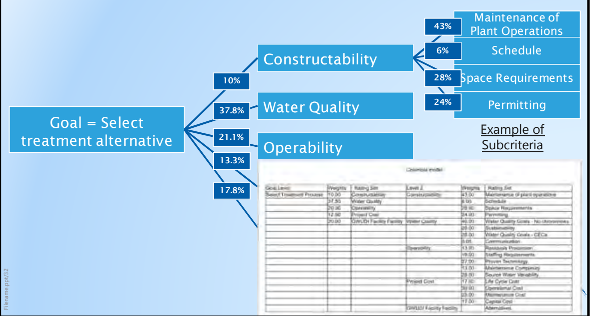
**Carollo Experts**
- Softening
- Filtration
- Disinfection
- WQ

**Cost Ranking**
- Based on mid-level range of Class 5 estimate

## Typical Structured Decision Analysis (SDA) Model Setup

Step 1: Identified Main Criteria, and subcriteria

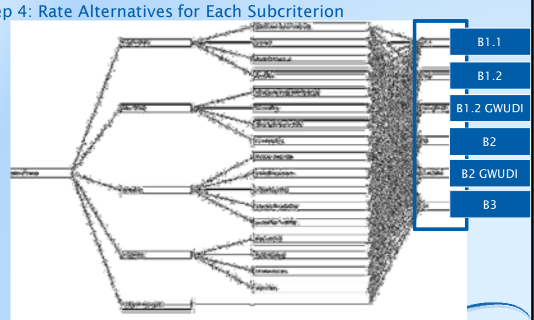
Step 2: Assigned Weights to each criterion and subcriterion

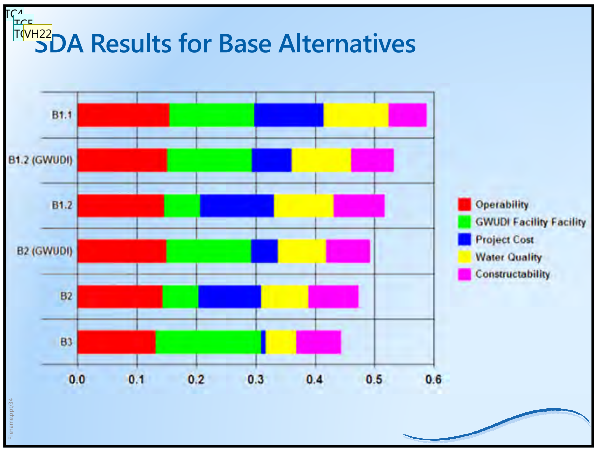


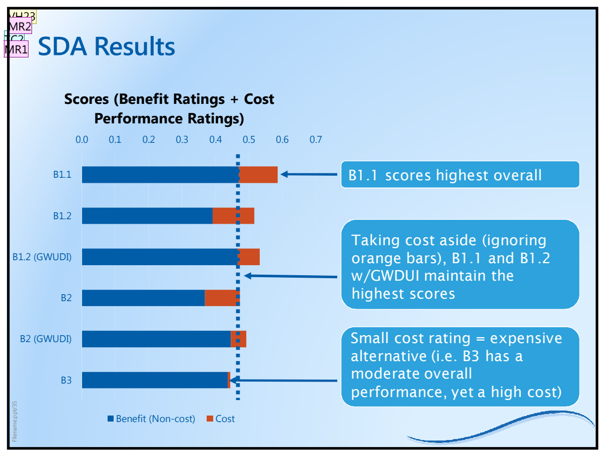

## Typical Structured Decision Analysis (SDA) Model Setup

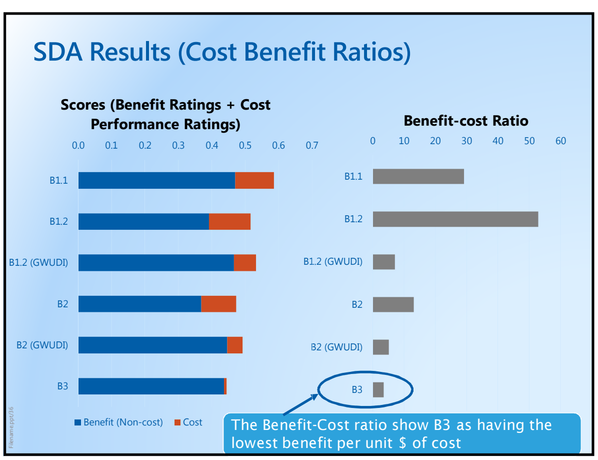
Step 3: Identify Alternatives

Step 4: Rate Alternatives for Each Subcriterion

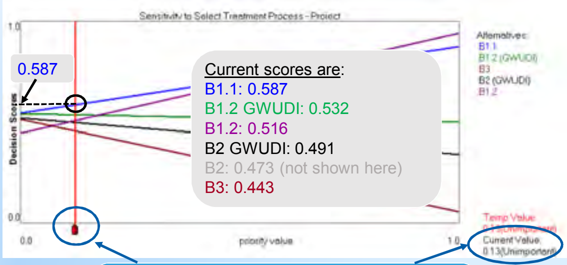



SDA Results for Base Alternatives
B1.1
B1.2 (GWUDI)
B1.2
B2 (GWUDI)
B2
B3
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Operability
GWUDI Facility Facility
Project Cost
Water Quality
Constructability


SDA Results
Scores (Benefit Ratings + Cost Performance Ratings)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
B1.1
B1.2
B1.2 (GWUDI)
B2
B2 (GWUDI)
B3
B1.1 scores highest overall
Taking cost aside (ignoring orange bars), B1.1 and B1.2 w/GWDUI maintain the highest scores
Small cost rating = expensive alternative (i.e. B3 has a moderate overall performance, yet a high cost)
Benefit (Non-cost)
Cost

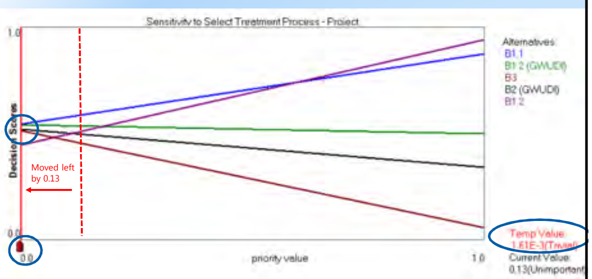

SDA Results (Cost Benefit Ratios)
Scores (Benefit Ratings + Cost Performance Ratings)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
B1.1
B1.2
B1.2 (GWUDI)
B2
B2 (GWUDI)
B3
Benefit (Non-cost)
Cost
Benefit-cost Ratio
0 10 20 30 40 50 60
B1.1
B1.2
B1.2 (GWUDI)
B2
B2 (GWUDI)
B3
The Benefit-Cost ratio show B3 as having the lowest benefit per unit $ of cost

## Sensitivity Analysis – Example on Sensitivity to Project Cost



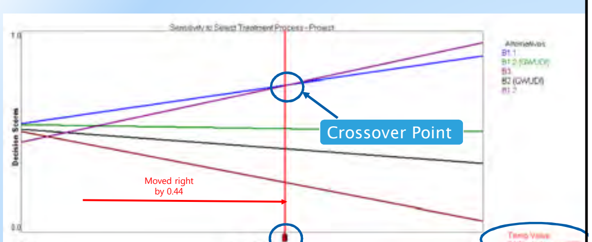

Currently, the "Project Costs" criterion is 13.3% and therefore accounts for 0.13 (rounded) of the total decision score.

## Sensitivity Analysis – Example on Sensitivity to Project Cost




If we shift the red line (= weight of the Project Costs Criterion) to the left, all the way to a weight of 0, B1.1 maintains the highest score (0.470), but almost equal to B1.2 (GWUDI) (0.466), and the 3rd best score becomes B2 (GWUDI)

## Sensitivity Analysis – Example on Sensitivity to Project Cost




If we shift to the right, B1.1 maintains the best score until the lines cross at a weight of 0.57 (i.e. project cost needs to account for a minimum of 57% of the overall scoring for B1.2 to score higher). This is out of range, and confirms that the ranking is not sensitive to project cost.

## Definition of Criticality

- The smallest shift necessary to affect the ranking of the 2 highest alternatives gauges the sensitivity
- That amount is called the criticality
- Project cost example:
  - Mathematically, a shift of 0.147 (to the left) would be necessary
  - The criticality is 14.7% for Project Costs. The model is therefore not sensitive to the weight on Project Costs.
- The criticality is assessed for all criteria weights. The higher the criticality number, the less sensitive the model is to the subject criteria.

## Criticality of Most Sensitive Criteria

| Criticality | Criterion Name | Explanation |
|---|---|---|
| 14.7% | Project Costs | Not sensitive. The Project Cost weight would need to be negative to make B1.2 GWUDI rank higher than B1.1 |
| 14.9% | GWUDI Facility | Not sensitive. The GWUDI Facility weight would need to be reduced from 18% to 3.1% to make B1.2 rank higher than B1.1 |
| 21.7% | Constructability | Not sensitive. The Constructability weight would need to increase from 10% to 31.7% for B1.2 to rank higher than B1.1 |
| 43.5% | Sustainability | Not sensitive at all. There are no different weight that changes the ranking |

## Ranking Questions/Discussions

- SDA Model manipulation

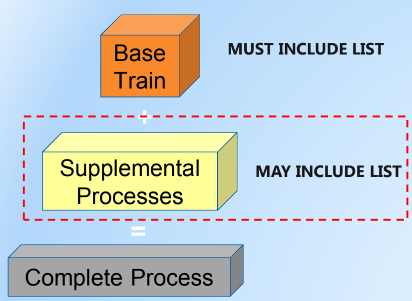
## Conclusions of SDA Analysis

- Eliminate B3 (UF membranes) from further consideration.
- Move forward with other base alternatives to pair with supplemental alternatives.

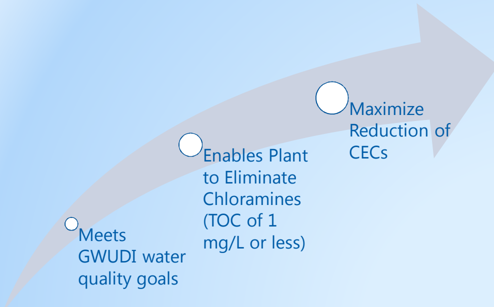
## Agenda

- Pairwise Comparison
- Base Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- **Supplemental Alternatives:**
  - **Discuss/Review Alternatives and Carollo Shortlist**
  - **SDA Model Development**
  - **Discuss and Rank Shortlisted Alternatives**
- Review Data Gaps & Action/Decision Logs
- Review Final Steps
- General Comment by Public, Members, and Staff
- Next Meeting Date – FINAL DECISION MAKING AND PUBLIC SUMMARY WORKSHOPS

## Treatment Alternative Identification



## Project Visioning- "May Include List" (Second and Third Tier Alternatives)




VH26

## GAC Can Be Added to Any of the Three Base Alternatives

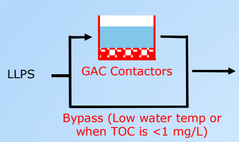
| Alternatives | | |
|---|---|---|
| **Base Alternative** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ○<br>Add S2.1, S2.2, S2.3, or S2.4 | ○<br>Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○<br>Add S2.1, S2.2, S2.3, or S2.4 | ○<br>Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○<br>Add S2.1, S2.2, S2.3, or S2.4 | ○<br>Add S3.1 or S3.2 |
| ~~B3 – Replace Filters w/ UF Membranes~~ | ~~◐~~<br>~~Add S2.1, S2.2, or S2.3~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |
| ~~B4 – Replace Plant w/RO Facility~~ | ~~●~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~◐~~<br>~~Add S2.1, S2.2, S2.3~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |

Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB
- S2.4 – Ozone/Biofiltration

Adder for CEC Removal
- S3.1 – UV Disinfection/Peroxide
- S3.2 – Ozone/Biofiltration

● Yes, ◐ Partial, ○ No

## S2.1 – GAC




## MIEX Can Be Added to Any of the Three Base Alternatives

| Alternatives | | |
|---|---|---|
| **Base Alternative** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ○<br>Add S2.1, S2.2, S2.3, or S2.4 | ○<br>Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○<br>Add S2.1, S2.2, S2.3, or S2.4 | ○<br>Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○<br>Add S2.1, S2.2, S2.3, or S2.4 | ○<br>Add S3.1 or S3.2 |
| B3 – Replace Filters w/ UF ~~Membranes~~ | ~~○~~<br>~~Add S2.1, S2.2, or S2.3~~ | ~~○~~<br>~~Add S3.1 or S3.2~~ |
| ~~B4 – Replace Plant w/RO Facility~~ | ~~●~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~○~~<br>~~Add S2.1, S2.2, S2.3~~ | ~~○~~<br>~~Add S3.1 or S3.2~~ |

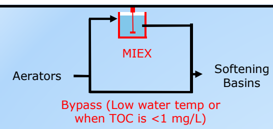
Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB
- S2.4 – Ozone/Biofiltration

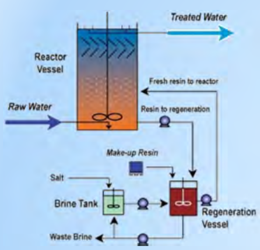
Adder for CEC Removal
- S3.1 – UV Disinfection/Peroxide
- S3.2 – Ozone/Biofiltration

● Yes, ◐ Partial, ○ No

Filename.ppt/49

## S2.2 –MIEX ™




Filename.ppt/50

## Actiflo™ Carb Can Be Added to Any of the Three Base Alternatives

| Alternatives | | |
|---|---|---|
| **Base Alternative** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ○<br>Add S2.1, S2.2, S2.3, or S2.4 | ○<br>Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○<br>Add S2.1, S2.2, S2.3, or S2.4 | ○<br>Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○<br>Add S2.1, S2.2, S2.3, or S2.4 | ○<br>Add S3.1 or S3.2 |
| ~~B3 – Replace Filters w/ UF Membranes~~ | ~~○~~<br>~~Add S2.1, S2.2, or S2.3~~ | ~~○~~<br>~~Add S3.1 or S3.2~~ |
| ~~B4 – Replace Plant w/RO Facility~~ | ~~●~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~○~~<br>~~Add S2.1, S2.2, S2.3~~ | ~~○~~<br>~~Add S3.1 or S3.2~~ |

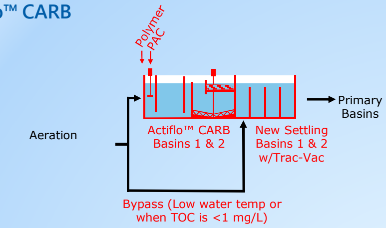
Adder for DBP Control
- S2.1 – GAC
- S2.2 – MIEX
- S2.3 - Actiflo™ CARB
- S2.4 – Ozone/Biofiltration

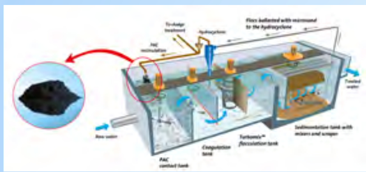
Adder for CEC Removal
- S3.1 – UV Disinfection/Peroxide
- S3.2 – Ozone/Biofiltration

● Yes, ◐ Partial, ○ No

Filename.ppt/51

## S2.3 – Actiflo™ CARB



## Ozone/BAF Can Be Added to Any of the Three Base Alternatives

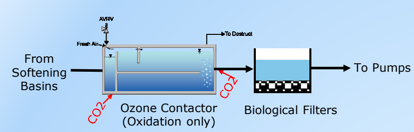
| Alternatives | | |
|---|---|---|
| **Base Alternative** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ○ | ○ |
| | Add S2.1, S2.2, S2.3, or S2.4 | Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ |
| | Add S2.1, S2.2, S2.3, or S2.4 | Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ |
| | Add S2.1, S2.2, S2.3, or S2.4 | Add S3.1 or S3.2 |
| ~~B3 – Replace Filters w/ UF Membranes~~ | ~~◒~~ | ~~◒~~ |
| | ~~Add S2.1, S2.2, or S2.3~~ | ~~Add S3.1 or S3.2~~ |
| ~~B4 – Replace Plant w/RO Facility~~ | ~~●~~ | ~~◐~~ |
| | | ~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~◒~~ | ~~◒~~ |
| | Add S2.1, S2.2, S2.3 | Add S3.1 or S3.2 |

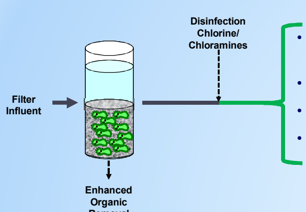
● Yes, ◐ Partial, ○ No

Adder for DBP Control
- S2.1 – GAC
- S2.2 - MIEX
- S2.3 - Actiflo™ CARB
- S2.4 – Ozone/Biofiltration

Adder for CEC Removal
- S3.1 – UV Disinfection/Peroxide
- S3.2 – Ozone/Biofiltration

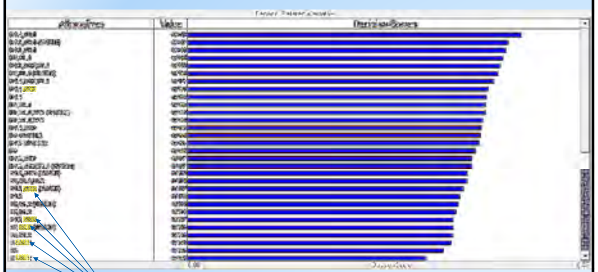
## S2.4 – Ozone/Biofiltration




- Reduced re-growth potential
- Reduced taste and odor
- Reduced DBP potential
- Reduced disinfectant decay

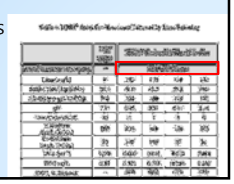
## Fatal Flaw Analysis (S2.2 MIEX)



S2.2 Alternative Generally low scores.

## MIEX Creates a Brine Waste and the Amount of Regeneration Required is Extreme

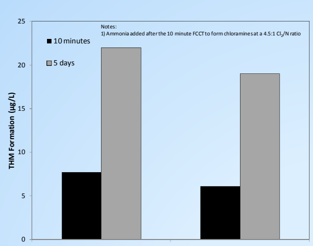
- Eliminate MIEX S2.2:
  - Permitting- Brine Stream Disposal
  - Operability- More complicated control than other DBP control technology.
    - Potential for resin loss resulting in $$$$$ (overflow)
  - Constructability – Difficult integration within existing processes.
  - Life Cycle Cost: Low Bed Volumes
    - Higher resin replacement rate
    - Higher brine generation



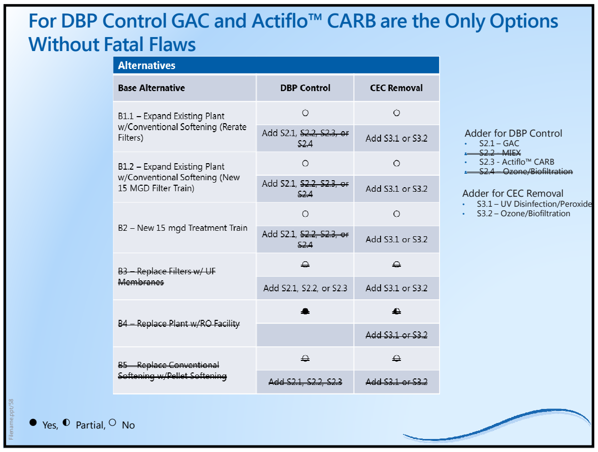
VH28 VH29

## Fatal Flaw Analysis: S2.4

- High degree of uncertainty regarding the potential for Ozone/Biofiltration Meet TTHM precursor removal goals.
- Requires piloting to determine success.




Typical TOC Removal – 10-15%



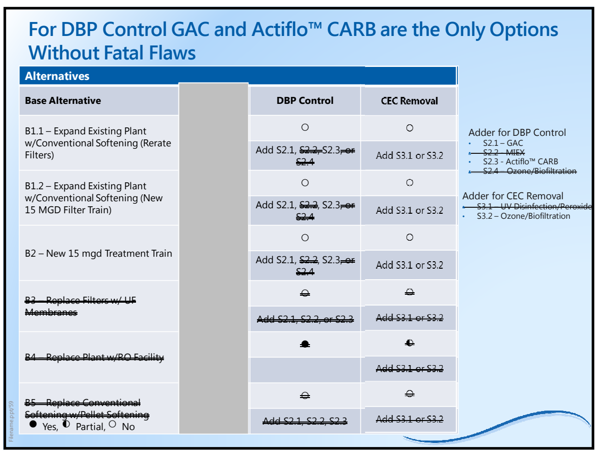
## For DBP Control GAC and Actiflo™ CARB are the Only Options Without Fatal Flaws

| Alternatives | | |
|---|---|---|
| **Base Alternative** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ○<br>Add S2.1, ~~S2.2, S2.3, or S2.4~~ | ○<br>Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○<br>Add S2.1, ~~S2.2, S2.3, or S2.4~~ | ○<br>Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○<br>Add S2.1, ~~S2.2, S2.3, or S2.4~~ | ○<br>Add S3.1 or S3.2 |
| ~~B3 – Replace Filters w/ UF Membranes~~ | ~~◐~~<br>Add S2.1, S2.2, or S2.3 | ~~◐~~<br>Add S3.1 or S3.2 |
| ~~B4 – Replace Plant w/RO Facility~~ | ~~●~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~◐~~<br>~~Add S2.1, S2.2, S2.3~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |

Adder for DBP Control
- S2.1 – GAC
- ~~S2.2 – MIEX~~
- S2.3 - Actiflo™ CARB
- ~~S2.4 – Ozone/Biofiltration~~

Adder for CEC Removal
- S3.1 – UV Disinfection/Peroxide
- S3.2 – Ozone/Biofiltration

● Yes, ◐ Partial, ○ No



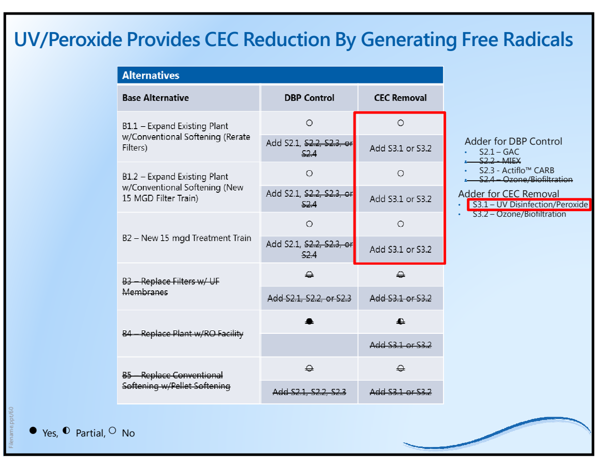
## For DBP Control GAC and Actiflo™ CARB are the Only Options Without Fatal Flaws

| Alternatives | | |
|---|---|---|
| **Base Alternative** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ○<br>Add S2.1, ~~S2.2,~~ S2.3, ~~or S2.4~~ | ○<br>Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○<br>Add S2.1, ~~S2.2~~, S2.3, ~~or S2.4~~ | ○<br>Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○<br>Add S2.1, ~~S2.2~~, S2.3, ~~or S2.4~~ | ○<br>Add S3.1 or S3.2 |
| ~~B3 – Replace Filters w/ UF Membranes~~ | ~~◐~~<br>~~Add S2.1, S2.2, or S2.3~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |
| ~~B4 – Replace Plant w/RO Facility~~ | ~~●~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~◐~~<br>~~Add S2.1, S2.2, S2.3~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |

Adder for DBP Control
- S2.1 – GAC
- ~~S2.2 – MIEX~~
- S2.3 - Actiflo™ CARB
- ~~S2.4 – Ozone/Biofiltration~~

Adder for CEC Removal
- ~~S3.1 – UV Disinfection/Peroxide~~
- S3.2 – Ozone/Biofiltration

● Yes, ◐ Partial, ○ No



## UV/Peroxide Provides CEC Reduction By Generating Free Radicals

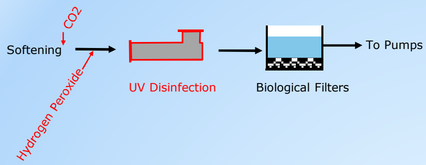
| Alternatives | | |
|---|---|---|
| **Base Alternative** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ○<br>Add S2.1, ~~S2.2, S2.3, or S2.4~~ | ○<br>Add S3.1 or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○<br>Add S2.1, ~~S2.2, S2.3, or S2.4~~ | ○<br>Add S3.1 or S3.2 |
| B2 – New 15 mgd Treatment Train | ○<br>Add S2.1, ~~S2.2, S2.3, or S2.4~~ | ○<br>Add S3.1 or S3.2 |
| ~~B3 – Replace Filters w/ UF Membranes~~ | ~~◐~~<br>Add S2.1, S2.2, or S2.3 | ~~◐~~<br>Add S3.1 or S3.2 |
| ~~B4 – Replace Plant w/RO Facility~~ | ~~●~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ~~◐~~<br>~~Add S2.1, S2.2, S2.3~~ | ~~◐~~<br>~~Add S3.1 or S3.2~~ |

Adder for DBP Control
- S2.1 – GAC
- ~~S2.2 – MIEX~~
- S2.3 - Actiflo™ CARB
- ~~S2.4 – Ozone/Biofiltration~~

Adder for CEC Removal
- S3.1 – UV Disinfection/Peroxide
- S3.2 – Ozone/Biofiltration

● Yes, ◐ Partial, ○ No

## UV/Peroxide Includes UV Lamps Downstream of the Softening Process




## We Recommend Eliminating UV/Peroxide From Consideration

- UV before filtration for removal of assimilable organic carbon (AOC).
- UV Downstream of Softening Has Caused Precipitation Problems (Binney)
- If UV/peroxide is after traditional filtration - GAC Contactors are required (for stabilization).
  - More Costly

Excessive Sleeve Fouling Downstream of Softening

## Similar to UV/Peroxide, Ozone Oxidizes CEC

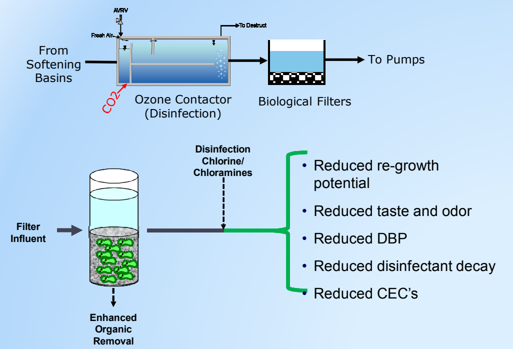
| Alternatives | | | |
|---|---|---|---|
| **Base Alternative** | **GWUDI Compliance** | **DBP Control** | **CEC Removal** |
| B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters) | ● | ○ | ○ |
| | | Add S2.1, ~~S2.2~~, S2.3~~, or S2.4~~ | Add ~~S3.1~~ or S3.2 |
| B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train) | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2~~, S2.3~~, or S2.4~~ | Add ~~S3.1~~ or S3.2 |
| B2 – New 15 mgd Treatment Train | ○ | ○ | ○ |
| | Add S1.1 | Add S2.1, ~~S2.2~~, S2.3~~, or S2.4~~ | Add ~~S3.1~~ or S3.2 |
| ~~B3 – Replace Filters w/ UF Membranes~~ | ● | ~~◓~~ | ~~◓~~ |
| | | ~~Add S2.1, S2.2, or S2.3~~ | ~~Add S3.1 or S3.2~~ |
| ~~B4 – Replace Plant w/RO Facility~~ | ● | ~~●~~ | ~~◐~~ |
| | | | ~~Add S3.1 or S3.2~~ |
| ~~B5 – Replace Conventional Softening w/Pellet Softening~~ | ● | ~~◓~~ | ~~◓~~ |
| | | ~~Add S2.1, S2.2, S2.3~~ | ~~Add S3.1 or S3.2~~ |

● Yes, ◐ Partial, ○ No

Adder for DBP Control
- S2.1 – GAC
- ~~S2.2 - MIEX~~
- S2.3 - Actiflo™ CARB
- ~~S2.4 – Ozone/Biofiltration~~

Adder for CEC Removal
- ~~S3.1 – UV Disinfection/Peroxide~~
- S3.2 – Ozone/Biofiltration

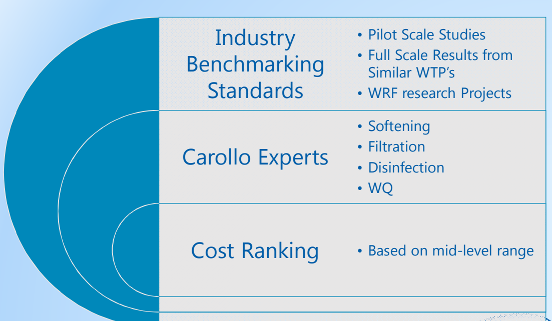
## Ozone/Biofiltration is the Only Technology That Potentially Addresses Both DBP Control and CEC Reduction

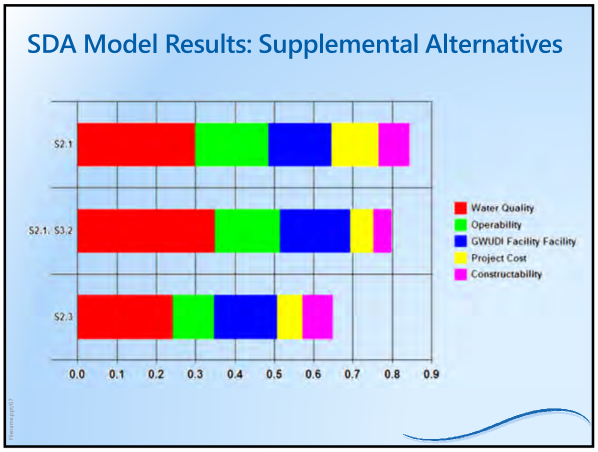


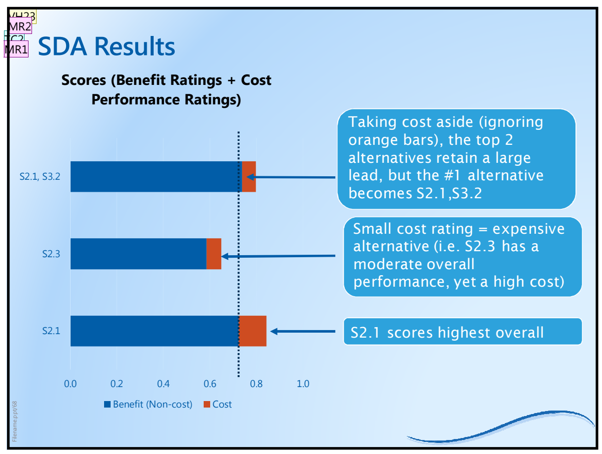

## Supplemental Processes Considered

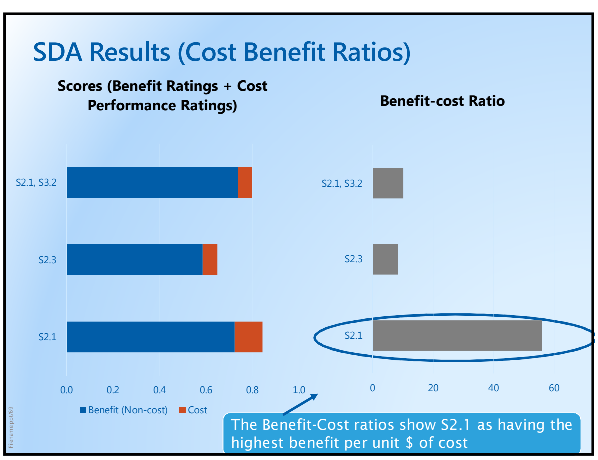
- S2.1 – GAC Filters
- S2.3 – Actiflo™ CARB Technology
- S2.1 and S3.2- Ozone/Biofiltration followed by GAC

## Carollo Ranking of Supplemental Alternatives



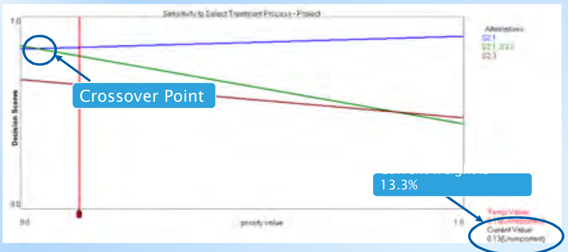

SDA Model Results: Supplemental Alternatives
S2.1
S2.1, S3.2
S2.3
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
Water Quality
Operability
GWUDI Facility Facility
Project Cost
Constructability


SDA Results
Scores (Benefit Ratings + Cost Performance Ratings)
S2.1, S3.2
S2.3
S2.1
0.0 0.2 0.4 0.6 0.8 1.0
Benefit (Non-cost) Cost
Taking cost aside (ignoring orange bars), the top 2 alternatives retain a large lead, but the #1 alternative becomes S2.1,S3.2
Small cost rating = expensive alternative (i.e. S2.3 has a moderate overall performance, yet a high cost)
S2.1 scores highest overall


SDA Results (Cost Benefit Ratios)
Scores (Benefit Ratings + Cost Performance Ratings)
S2.1, S3.2
S2.3
S2.1
0.0 0.2 0.4 0.6 0.8 1.0
Benefit (Non-cost) Cost
Benefit-cost Ratio
S2.1, S3.2
S2.3
S2.1
0 20 40 60
The Benefit-Cost ratios show S2.1 as having the highest benefit per unit $ of cost

VH30 VH31

## SDA Results: Sensitivity Analysis

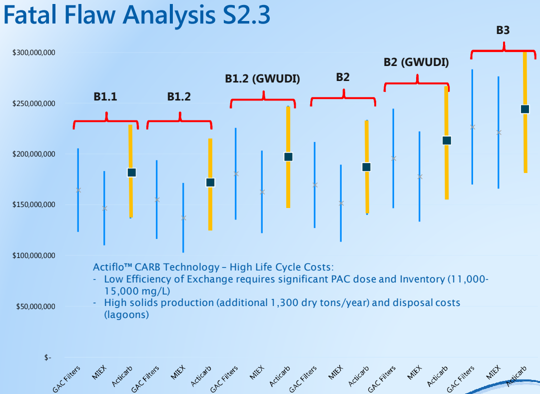



- The model is most sensitive to the Project Costs weight.
- The Crossover Point is at a weight of 0.04, i.e. Unless the Project Costs criterion is weighted at <4% (instead of 13.3%), the ranking would not be affected. This sensitivity is adequate.

## Criticality of Most Sensitive Criteria

| Criticality | Criterion Name | Explanation |
|---|---|---|
| 9.6% | Project Costs | Not very sensitive. The Project Cost weight would need to be reduced from 13% to 3.4% to make S2.1, S3.2 rank higher than S2.1 |
| 14.6% | Constructability | Not sensitive. The Constructability weight (10%) would need to go negative to make S2.1, S3.2 rank higher than S2.1 |
| 16.4% | Water Quality | Not sensitive. The Water Quality weight would need to increase from 38% to 54% to make S2.1, S3.2 rank higher than S2.1 |
| 25.8% | GWUDI Facility | Not sensitive. The GWUDI Facility weight would need to increase from 18% to 42% to make S2.1, S3.2 rank higher than S2.1 |

## Fatal Flaw Analysis S2.3



## Our Recommendation is to Eliminate Actiflo™ Carb from Consideration

- 10 mgd largest installation — Never Built on this Scale
- PAC Use Results in High Costs — Expensive
- Extremely High PAC Doses are Not Green — Not Sustainable

## Ranking Questions/Discussions

- SDA Model manipulation

## Preliminary Ranking and Alternatives Summary:

**Base Concepts:**

B1.1 – Expand Existing Plant w/Conventional Softening (Rerate Filters)

B1.2 – Expand Existing Plant w/Conventional Softening (New 15 MGD Filter Train)

B2 – New 15 mgd Treatment Train

**Supplimental Concepts:**

S1.1– Include improvements for GWUDI Compliance

S2.1 – GAC Filters

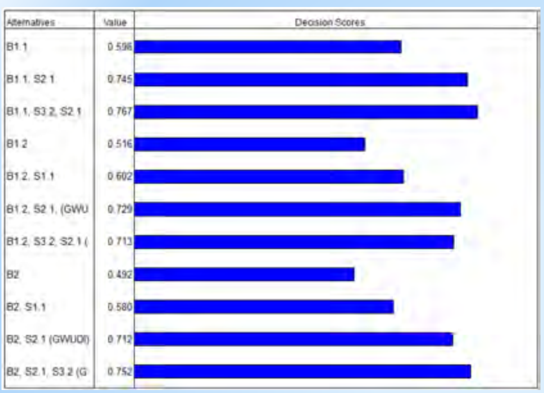
S2.1 and S3.2 – Biofiltration with GAC filters

VH33

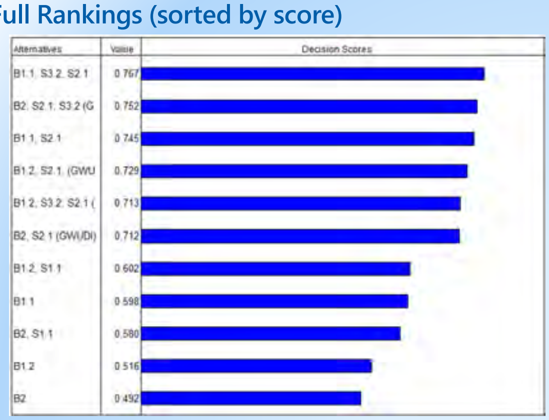
## Treatment Alternatives

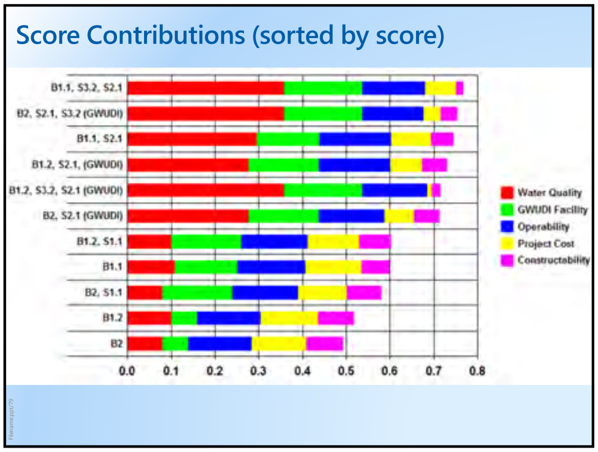
| Base | Supplement | Description | Comments |
|---|---|---|---|
| B1.1 | No Supplement | Only Upgrade Existing | GWUDI Compliant, Requires Chloramines |
| B1.1 | S2.1 | Upgrade Existing With GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine |
| B1.1 | S2.1, S3.2 | Upgrade Existing with Ozone/BAF and GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine |
| B1.2 | No Supplement | New Filters (15mgd) | Not fully GWUDI Compliant<br>Requires Chloramines |
| B1.2 | S1.1 | New Filters (15 mgd) with plant upgraded | GWUDI Compliant<br>Requires Chloramines |
| B1.2 | S1.1, S2.1 | New Filters (15 mgd) with GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine |
| B1.2 | S1.1, S2.1, S3.2 | New Filter (15 mgdd) with Ozone/BAF and GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine<br>Adds CEC's |
| B2 | No Supplement | New Treatment Train (15 mgd) | Not fully GWUDI Compliant<br>Requires Chloramines |
| B2 | S1.1 | New Treatment Train (15 mgd) with plant upgraded. | GWUDI Compliant<br>Requires Chloramines |
| B2 | S1.1, S.2.1 | New Treatment Train (15 mgd) and GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine |
| B2 | S1.1, S2.1, S3.2 | New Treatment Train (15 mgd) with Ozone/BAF and GAC Contactors | GWUDI Compliant<br>Permits use of Free Chlorine<br>Adds CEC's |

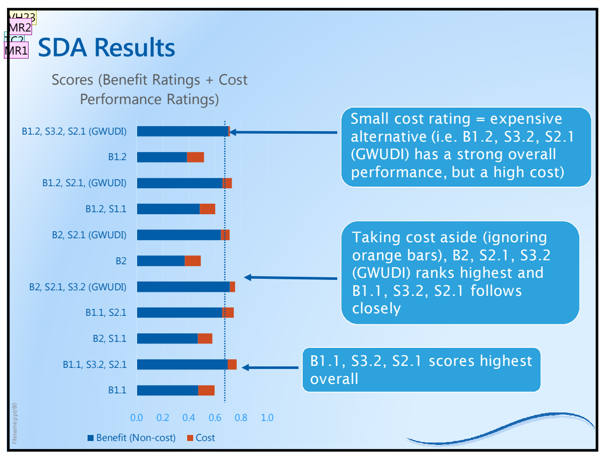
## Full Rankings (by alphabetical order)

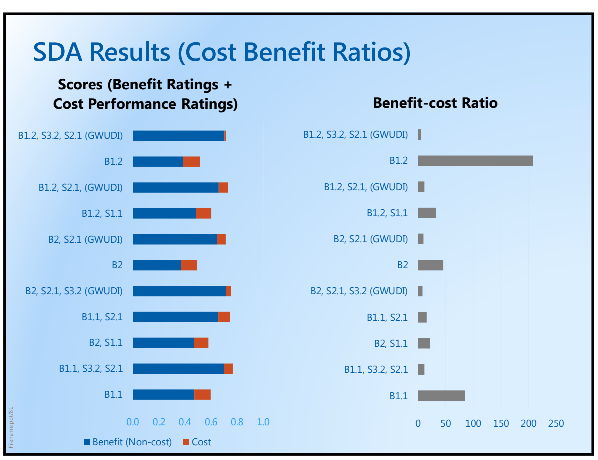



## Full Rankings (sorted by score)

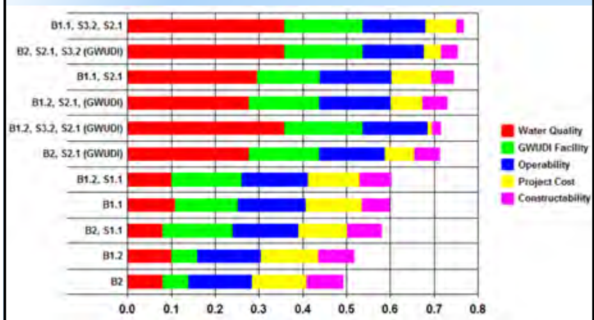



Score Contributions (sorted by score)
B1.1, S3.2, S2.1
B2, S2.1, S3.2 (GWUDI)
B1.1, S2.1
B1.2, S2.1, (GWUDI)
B1.2, S3.2, S2.1 (GWUDI)
B2, S2.1 (GWUDI)
B1.2, S1.1
B1.1
B2, S1.1
B1.2
B2
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
Water Quality
GWUDI Facility
Operability
Project Cost
Constructability


SDA Results
Scores (Benefit Ratings + Cost Performance Ratings)
B1.2, S3.2, S2.1 (GWUDI)
B1.2
B1.2, S2.1, (GWUDI)
B1.2, S1.1
B2, S2.1 (GWUDI)
B2
B2, S2.1, S3.2 (GWUDI)
B1.1, S2.1
B2, S1.1
B1.1, S3.2, S2.1
B1.1
0.0 0.2 0.4 0.6 0.8 1.0
Benefit (Non-cost) Cost
Small cost rating = expensive alternative (i.e. B1.2, S3.2, S2.1 (GWUDI) has a strong overall performance, but a high cost)
Taking cost aside (ignoring orange bars), B2, S2.1, S3.2 (GWUDI) ranks highest and B1.1, S3.2, S2.1 follows closely
B1.1, S3.2, S2.1 scores highest overall


SDA Results (Cost Benefit Ratios)
Scores (Benefit Ratings + Cost Performance Ratings)
Benefit-cost Ratio
B1.2, S3.2, S2.1 (GWUDI)
B1.2
B1.2, S2.1, (GWUDI)
B1.2, S1.1
B2, S2.1 (GWUDI)
B2
B2, S2.1, S3.2 (GWUDI)
B1.1, S2.1
B2, S1.1
B1.1, S3.2, S2.1
B1.1
0.0 0.2 0.4 0.6 0.8 1.0
Benefit (Non-cost) Cost
0 50 100 150 200 250

## Score Contributions (sorted by score)

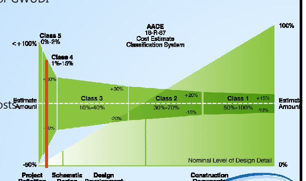



## Agenda

- Pairwise Comparison
- Base Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Supplemental Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- **Review Data Gaps & Action/Decision Logs**
- Review Final Steps
- General Comment by Public, Members, and Staff
- Next Meeting Date – FINAL DECISION MAKING AND PUBLIC SUMMARY WORKSHOPS

## Identify and Review Data Gaps

- General:
  - Develop Layouts to clarify constructability ratings.
  - Modify alternatives to address potential permitting issues (if possible).
  - Modify alternative to address potential operability issues. (if possible).
- B1.1, B1.2 (GWUDI), and B2 (GWUDI) Alternatives
  - (B1.1) Rerating of Filters to > 6 gpm/sqft for 45 mgd
  - Improvement of existing filters (32 mgd) for GWUDI
- GAC S2.1 Alternatives
  - GAC cost and replacement frequency
- Ozone/BAF Alternatives:
  - Develop Bromate control strategies and cost



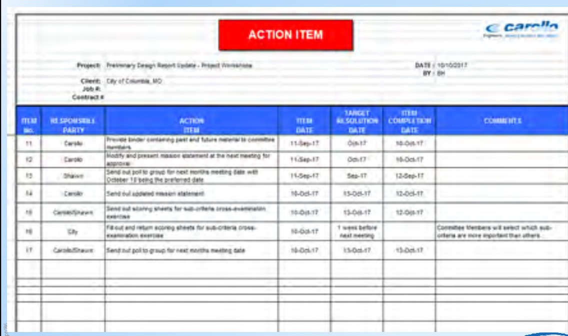
## DECISION LOG


DECISION LOG

Project: [illegible]
Client: City of Columbia, MO
Job #:
Contract #:

| ITEM No. | DECISION BY | DECISION FORUM | DECISION DESCRIPTION | DECISION DATE | COMMENTS |
|---|---|---|---|---|---|
| [illegible] | City | [illegible] | [illegible] | [illegible] | |
| [illegible] | City | [illegible] | [illegible] | [illegible] | |
| [illegible] | City | [illegible] | [illegible] | [illegible] | |
| [illegible] | City | [illegible] | [illegible] | [illegible] | |
| [illegible] | City | [illegible] | [illegible] | [illegible] | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| [illegible] | City | [illegible] | [illegible] | [illegible] | |
| [illegible] | City | [illegible] | [illegible] | [illegible] | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |

## ACTION LOG


ACTION ITEM

Project: Preliminary Design Report Update - Project Workshops
Client: City of Columbia, MO
Job #:
Contract #

DATE : 10/10/2017
BY : BH

| ITEM No. | RESPONSIBLE PARTY | ACTION ITEM | ITEM DATE | TARGET RESOLUTION DATE | ITEM COMPLETION DATE | COMMENTS |
|---|---|---|---|---|---|---|
| 11 | Carollo | Provide binder containing past and future material to committee members | 11-Sep-17 | Oct-17 | 10-Oct-17 | |
| 12 | Carollo | Modify and present mission statement at the next meeting for approval | 11-Sep-17 | Oct-17 | 10-Oct-17 | |
| 13 | Shawn | Send out poll to group for next months meeting date with October 10 being the preferred date | 11-Sep-17 | Sep-17 | 12-Sep-17 | |
| 14 | Carollo | Send out updated mission statement | 10-Oct-17 | 13-Oct-17 | 12-Oct-17 | |
| 15 | Carollo/Shawn | Send out scoring sheets for sub-criteria cross-examination exercise | 10-Oct-17 | 13-Oct-17 | 12-Oct-17 | |
| 16 | City | Fill out and return scoring sheets for sub-criteria cross-examination exercise | 10-Oct-17 | 1 week before next meeting | | Committee Members will select which sub-criteria are more important than others |
| 17 | Carollo/Shawn | Send out poll to group for next months meeting date | 10-Oct-17 | 13-Oct-17 | 13-Oct-17 | |

## Agenda

- Pairwise Comparison
- Base Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Supplemental Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Review Data Gaps & Action/Decision Logs
- **Review Final Steps**
- General Comment by Public, Members, and Staff
- Next Meeting Date – FINAL DECISION MAKING AND PUBLIC SUMMARY WORKSHOPS

## Final Steps

- Carollo:
  - Update Costs and Rankings Based upon Data gap Resolution
  - Final Ranking
  - Prepare Draft and Final Technical Memorandum Update
- Workgroup:
  - Review Final Ranking and make Recommendation to Water and Light Dept
  - Participate in Public Meeting

## Agenda

- Pairwise Comparison
- Base Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Supplemental Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Review Data Gaps & Action/Decision Logs
- Review Final Steps
- **General Comment by Public, Members, and Staff**
- Next Meeting Date – FINAL DECISION MAKING AND PUBLIC SUMMARY WORKSHOPS
  - **February 12, 2017 5:30 pm ?**

## Agenda

- Pairwise Comparison
- Base Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Supplemental Alternatives:
  - Discuss/Review Alternatives and Carollo Shortlist
  - SDA Model Development
  - Discuss and Rank Shortlisted Alternatives
- Review Data Gaps & Action/Decision Logs
- Review Final Steps
- General Comment by Public, Members, and Staff
- **Next Meeting Date – FINAL DECISION MAKING AND PUBLIC SUMMARY WORKSHOPS**
  - **February 12, 2017 5:30 pm ?**


Adjournment

# Final Ranking Workshop

City of Columbia, MO

Water and Light Department

Drinking Water Planning Workgroup

January 29, 2018, 5:30 pm

City Hall Room 1A/1B

WATER OUR FOCUS OUR BUSINESS OUR PASSION

carollo Engineers...Working Wonders With Water®

## Agenda

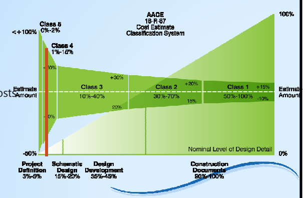
- Data Gap Analysis
- Discuss/Review Shortlisted Alternatives
  - Review Results from Last Meeting
  - Discuss Shortlist Methodology and Shortlisted Alternatives
  - Re-Ranking of Shortlisted Alternatives
  - Select Best Alternatives
  - Sensitivity/Sensibility Check
- Discuss/Review Finalized Recommendation Statement
- General Comment by Public, Members, and Staff
- Next Meeting Date:
  - Public Meeting/Presentation

## Agenda

- Data Gap Analysis
- Discuss/Review Shortlisted Alternatives
  - Review Results from Last Meeting
  - Discuss Shortlist Methodology and Shortlisted Alternatives
  - Re-Ranking of Shortlisted Alternatives
  - Select Best Alternatives
  - Sensitivity/Sensibility Check
- Discuss/Review Finalized Recommendation Statement
- General Comment by Public, Members, and Staff
- Next Meeting Date:
  - Public Meeting/Presentation

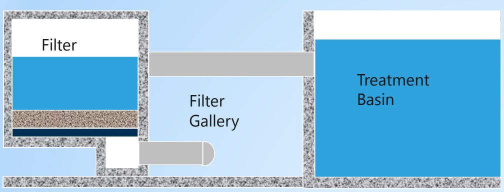
## Identify and Review Data Gaps

- General:
  - Develop Layouts to clarify constructability ratings.
  - Modify alternatives to address potential permitting issues (if possible).
  - Modify alternative to address potential operability issues. (if possible).
- B1.1, B1.2 (GWUDI), and B2 (GWUDI) Alternatives
  - (B1.1) Rerating of Filters to > 6 gpm/sqft for 45 mgd
  - Improvement of existing filters (32 mgd) for GWUDI
- GAC S2.1 Alternatives
  - GAC cost and replacement frequency
- Ozone/BAF Alternatives:
  - Develop Bromate control strategies and costs




## Data Gap Analysis

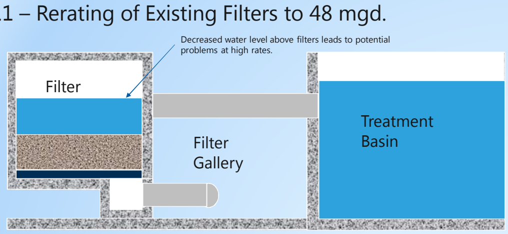
- B1.1 – Rerating of Existing Filters to 48 mgd.




Concern Regarding Hydraulic Efficiencies:
- Increase Media
- Eliminate Gravel and install IMS Cap

## Data Gap Analysis (cont.)

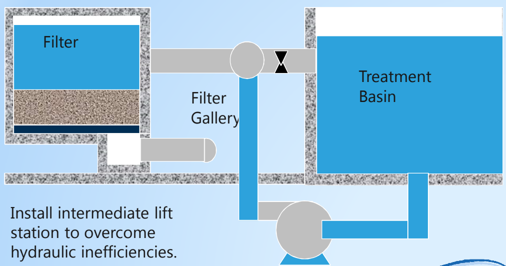
- B1.1 – Rerating of Existing Filters to 48 mgd.




Concern Regarding Hydraulic Efficiencies:
- Increase Media
- Eliminate Gravel and install IMS Cap

## Data Gap Analysis (cont.)

- B1.1 – Rerating of Existing Filters to 48 mgd



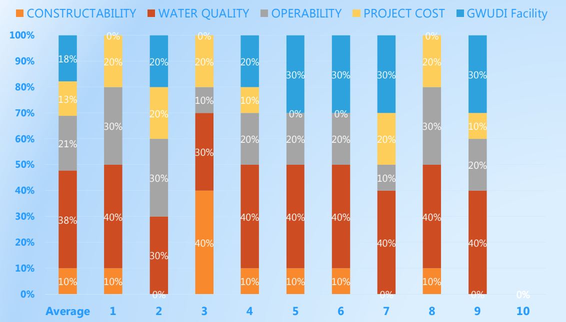

## Data Gap Analysis: S2.1 GAC Contactors

- RSSC (rapid small-scale column) testing required to identify potential Carbon's to test.
- Pilot testing required to determine useful life for DBP management.
- Assumed Carbon Life based upon similar Communities: Every 3 years.

## Agenda

- Data Gap Analysis
- Discuss/Review Shortlisted Alternatives
  - Review Results from Last Meeting
  - Discuss Shortlist Methodology and Shortlisted Alternatives
  - Re-Ranking of Shortlisted Alternatives
  - Select Best Alternatives
  - Sensitivity/Sensibility Check
- Discuss/Review Finalized Recommendation Statement
- General Comment by Public, Members, and Staff
- Next Meeting Date:
  - Public Meeting/Presentation

## Criteria Weighting Results



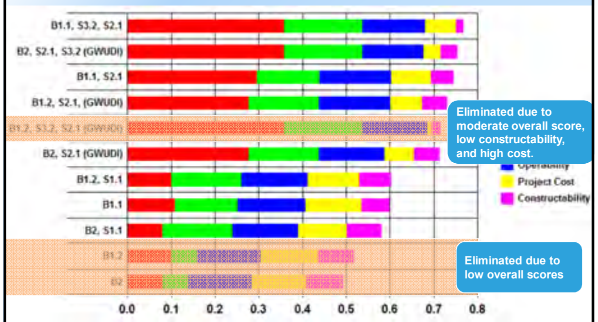

## Summary of Pairwise Comparisons

- Most participants scored water quality highest
- Most participants scored cost and GWUDI higher.
- Operability was more important that constructability to most participants.

WATER QUALITY > PROJECT COST / GWUDI Facility > OPERABILITY > CONSTRUCTABILITY

## Score Contributions (sorted by score)

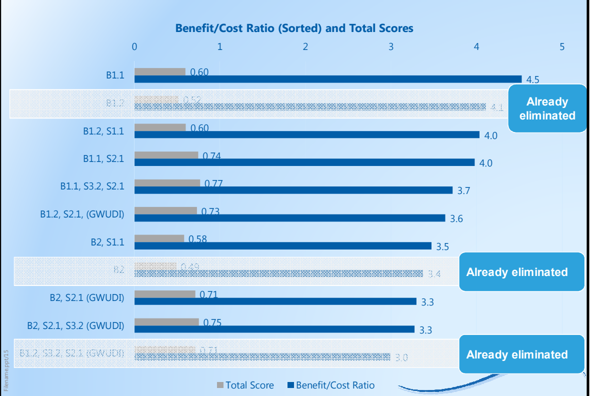
## Score Contributions (sorted by score)



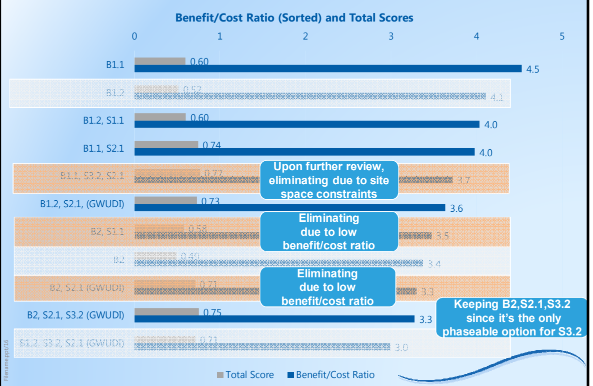

## Summary from Last Meeting

- 3 alternatives not short-listed: B2, B1.2, and B1.2,S3.2,S2.1 (GWUDI)
- Because of Water Quality and GWUDI high rating, results ranked highest cost items because those naturally provided highest benefit.
- However… when examining benefit/cost ratios some of these items were clearly offered little additional benefit with high incremental costs.
- Decision was made to re-rank based upon best benefit: cost ratio plus those alternatives most easily phased to the higher cost alternatives.

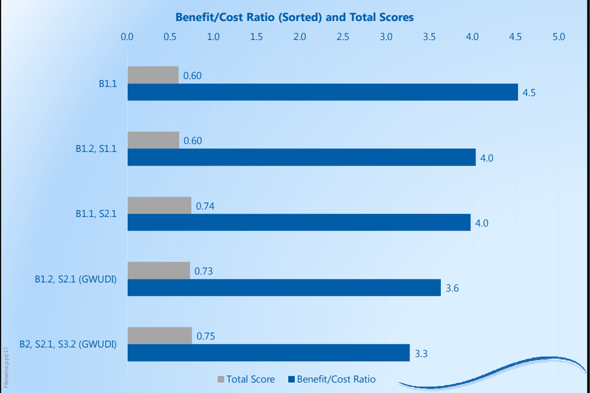
## Ratings and Benefit/Cost Ratios



## Ratings and Benefit/Cost Ratios




## Shortlisted Alternatives:




## Shortlist Rationale

- All alternatives that did not meet GWUDI Eliminated due to low benefit score.
- Alternatives involving Ozone/biofiltration eliminated:
  - Low Cost/Benefit Ratios
  - Ability to phase is extremely poor (exception B2)

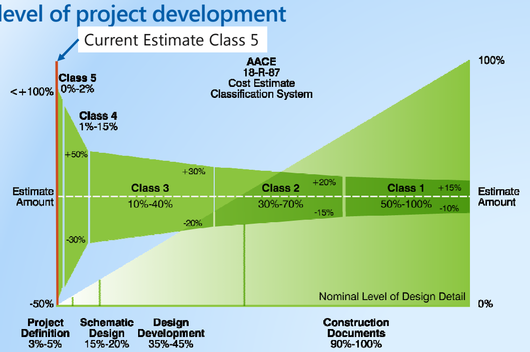
## Step 1 - Decision Analysis Steps that Have Already Been Implemented

- ✓ Define the decision makers and a simple and clear decision statement
- ✓ Define a potential set of viable alternatives
- ✓ Select the criteria that will be used to differentiate the alternatives
- ✓ Assign weights to the criteria and assure there is no redundancy nor 'must haves'

## Step 2- Decision Analysis – Where We Are Today

- ✓ Rank each alternative against each criteria
- ✓ Screen Alternatives & Shortlist
- Identify, Fill relevant 'data and knowledge gaps' or use 'Engineering Judgment'
- Re-rank alternatives

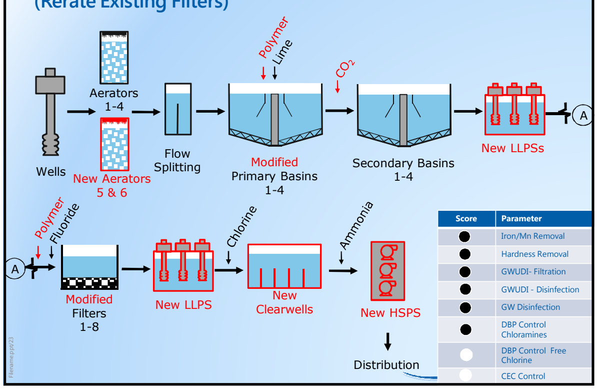
## The level of accuracy of cost estimating follows the level of project development



## Life Cycle Cost Development:

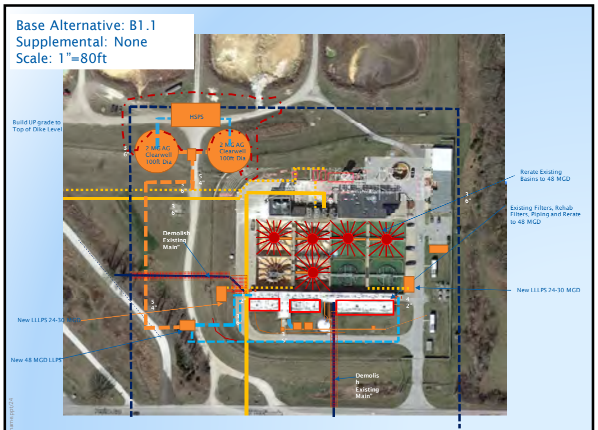
- Phase 0: 2020
- Phase I: 2024
- Phase II: 2029 (assumes 5 year period to pilot/design/construct)
- End of Life Cycle Period: 2044 (20 years from Phase I)

## B1.1 – Expand Existing Plant w/ Conventional Softening (Rerate Existing Filters)




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |

Base Alternative: B1.1
Supplemental: None
Scale: 1"=80ft



## B1.1 Highlights

**Description:** Expand Existing Plant (Rerate Existing Filters)

### Water Quality (37.8%)

- Likely requires chloramines to satisfy current Disinfection By-Product regulations.
- Potential future regulatory concerns (CEC's) will need additional processes.
- No significant improvement in overall water quality (Except for GWUDI Compliance)

### Operability (21.1%)

- Increased Maintenance (New Pumps)
- Low Lift Pumps Required to Control Filtration Process and pump to clearwells , increasing complexity.
- Most efficient use of space (easier phasing)

### GWUDI Facility (17.8%)

- Improved Filtration
- Disinfection to meet SWTR Requirements

### Constructability (10%)

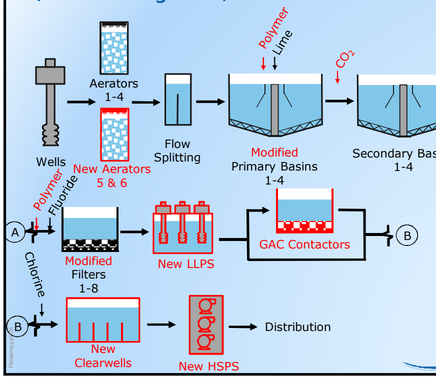
- Large Disruption to Plant Ops (Work on Existing Filters)
- Minimal footprint of new facilities.
- Rerating Filters Requires Permitting Variance

### Project Cost (13.3%)

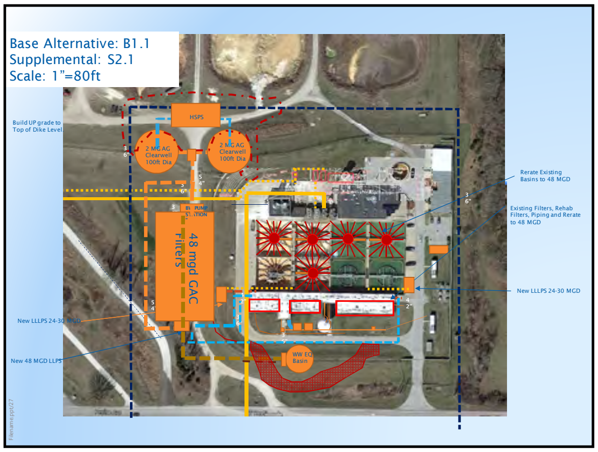
- Capital = $106 million
- O&M = $3.6 million
- Life Cycle = $160 million

*Level of Accuracy (+50% to -30%)
*Wellfield & Raw Water pipeline improvements not included.

## B1.1, S2.1 – Expand Existing Plant w/ Conventional Softening (Rerate Existing Filters) + GAC




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ○ | DBP Control Chloramines |
| ● | DBP Control Free Chlorine |
| ◐ | CEC Control |



## B1.1, S2.1 Highlights

**Description:** Expand Existing Plant (Rerate Existing Filters) and Add Post Filter GAC Contactors

**Water Quality** (37.8%)
- Ability to design finished water quality to meet DBP regulations without relying on Chloramines.
- Robust process that will remove some CEC's. Operating Cost may be impacted by future regulations due to process inefficiencies.

**Operability** (21.1%)
- Additional Staffing
- Staffing Education for New Processes (DBP Control)
- Increased Maintenance (New Pumps and Process)
- Moderate Complexity

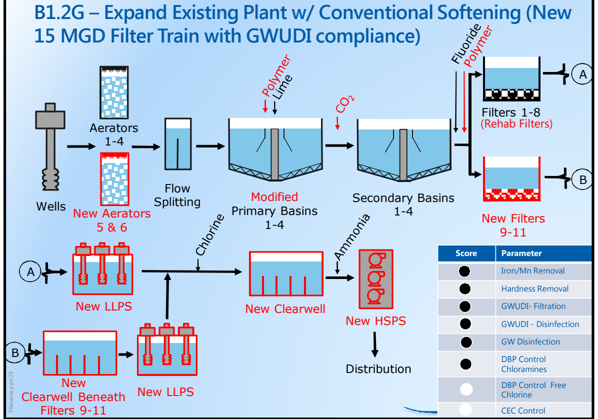
**GWUDI Facility** (17.8%)
- Fully Compliant

**Constructability** (10%)
- Large Disruption to Plant Ops (Work on Existing Filters)
- Large Space Requirements will require some use of lagoon space.
- Rerating Filters Requires Permitting Variance

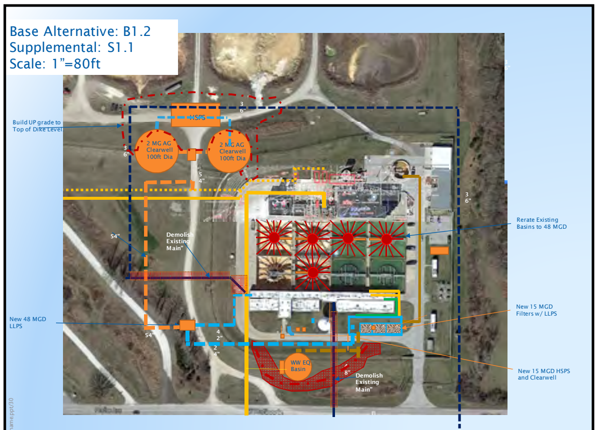
**Project Cost** (13.3%)
- Capital = $152 million
- O&M = $4.7 million
- Life Cycle = $221 million

*Level of Accuracy (+50% to -30%)
*Wellfield & Raw Water pipeline improvements not included.

## B1.2G – Expand Existing Plant w/ Conventional Softening (New 15 MGD Filter Train with GWUDI compliance)




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ● | DBP Control Chloramines |
| ○ | DBP Control Free Chlorine |
| ○ | CEC Control |



## B1.2, S1.1 (GWUDI) Highlights

**Description:** Expand Existing Plant (New Filter Train)

**Water Quality** (37.8%)
- Likely requires chloramines to satisfy current Disinfection By-Product regulations.
- Potential future regulatory concerns (CEC's) will need additional processes.
- No significant improvement in overall water quality (Except for GWUDI Compliance)

**Operability** (21.1%)
- Increased Maintenance (New Pumps and Filters)
- Minimal Complexity
- Low Lift Pumping Required for phasing and to minimize future construction costs.
- A little more difficult to phase.

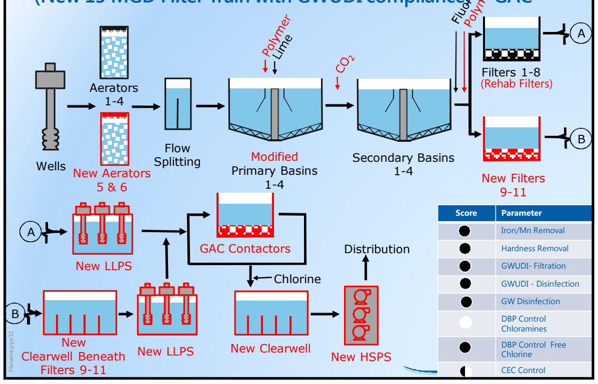
**GWUDI Facility** (17.8%)
- Fully Compliant

**Constructability** (10%)
- Moderate Disruption to Plant Ops
- Moderate Space Requirements

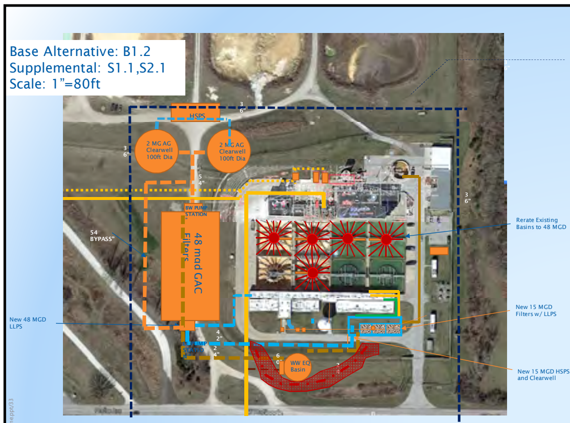
**Project Cost** (13.3%)
- Capital = $124 million
- O&M = $3.6 million
- Life Cycle = $178 million

*Level of Accuracy (+50% to -30%)
*Wellfield & Raw Water pipeline improvements not included.

## B1.2G, S2.1 – Expand Existing Plant w/ Conventional Softening (New 15 MGD Filter Train with GWUDI compliance) & GAC




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ○ | DBP Control Chloramines |
| ● | DBP Control Free Chlorine |
| ◐ | CEC Control |



## B1.2, S1.1(GWUDI), S2.1 Highlights

**Description:** Expand Existing Plant (New Filter Train) and Add GAC Post Filter Contactors.

**Water Quality** (37.8%)
- Ability to design finished water quality to meet DBP regulations without relying on Chloramines.
- Robust process that will remove some CEC's. Operating Cost may be impacted by future regulations due to process inefficiencies.

**Operability** (21.1%)
- Additional Staffing
- Staffing Education for New Processes
- Increased Maintenance (New Pumps, Filters, and Process)
- Moderate Complexity

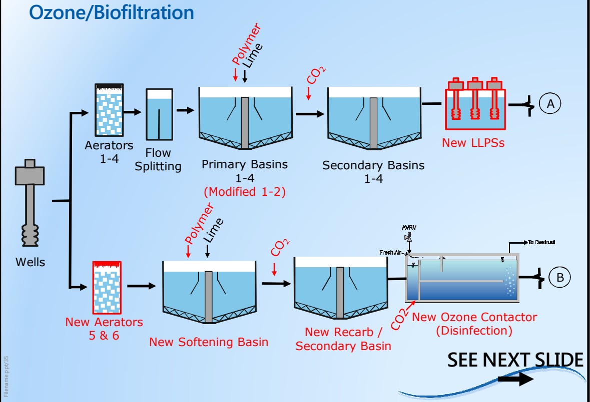
**GWUDI Facility** (17.8%)
- Fully Compliant

**Constructability** (10%)
- Moderate Disruption to Plant Ops
- Large Space Requirements

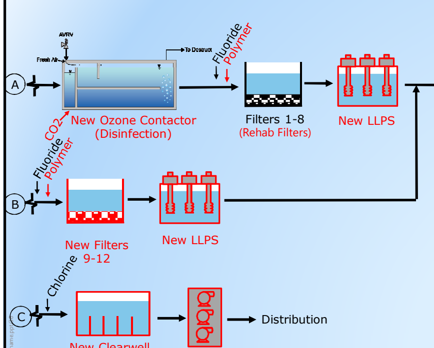
**Project Cost** (13.3%)
- Capital = $166 million
- O&M = $4.7 million
- Life Cycle = $236 million

*Level of Accuracy (+50% to -30%)
*Wellfield & Raw Water pipeline improvements not included.

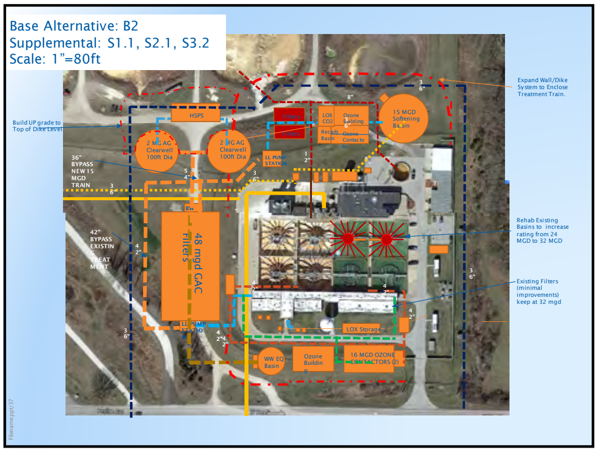
## B2G, S2.1, S3.2 – New 15 MGD Treatment Train + GAC + Ozone/Biofiltration




## B2G, S2.1, S3.2 – New 15 MGD Treatment Train + GAC + Ozone/Biofiltration (Continued)




| Score | Parameter |
|---|---|
| ● | Iron/Mn Removal |
| ● | Hardness Removal |
| ● | GWUDI- Filtration |
| ● | GWUDI - Disinfection |
| ● | GW Disinfection |
| ○ | DBP Control Chloramines |
| ● | DBP Control Free Chlorine |
| ● | CEC Control |




## B2 (GWUDI), S2.1, S3.2 Highlights

**Description:** Expand Existing Plant (New Treatment Train), post treatment Ozone/Biofiltration and post filter GAC contactors.

**Water Quality** (37.8%)
- Ability to design finished water quality to meet DBP regulations without relying on Chloramines.
- Best Available Technology for CEC removal. Synergistic impacts with Post Filter GAC.

**Operability** (21.1%)
- Additional Staffing
- Staffing Education for New Processes
- Increased Maintenance (New Pumps, Filters, and Processes)
- Most Complex Alternative to Operate (two trains with multiple processes)

**GWUDI Facility** (17.8%)
- Fully Compliant

**Constructability** (10%)
- Minimal Disruption to Plant Ops
- High Space Requirements

**Project Cost** (13.3%)
- Capital = $223 million
- O&M = $5.1 million
- Life Cycle = $298 million

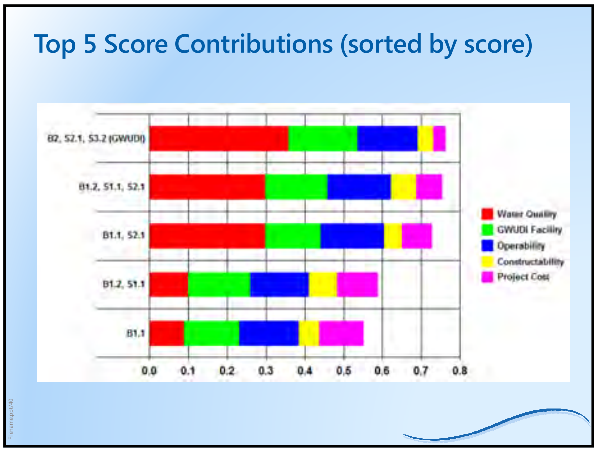
*Level of Accuracy (+50% to -30%)
*Wellfield & Raw Water pipeline improvements not included.

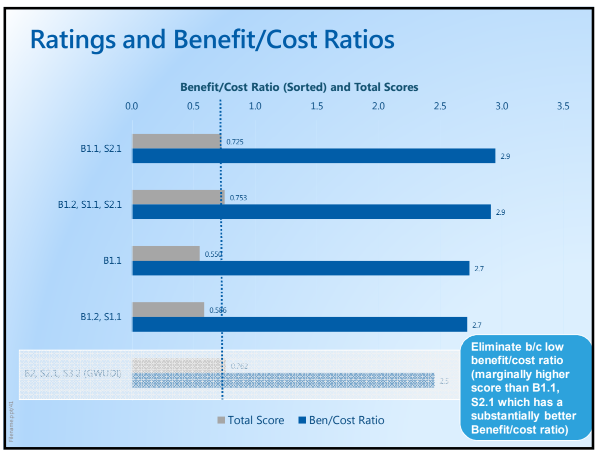
Filename.ppt/38

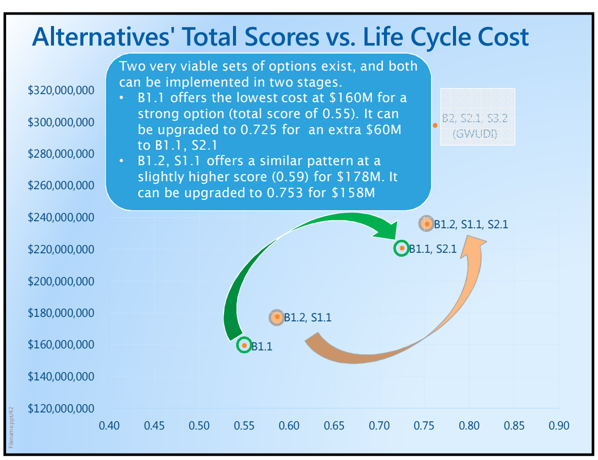
## Workshop No. 7 - Decision Analysis Finalized and Tested

- Select 'best' alternative
- Feb 12 WS — Test sensitivity of 'best' (the gut check analysis)
- Feb 12 WS — Assign the 'devil's advocate' to assure a robust decision

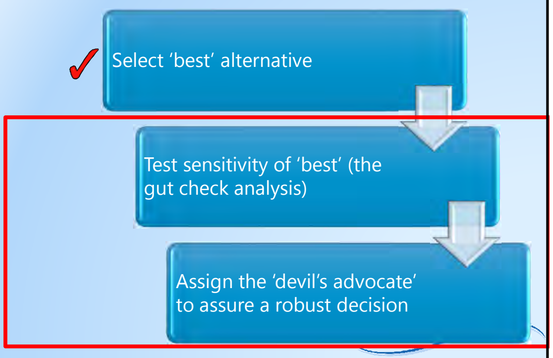
Filename.ppt/39


Top 5 Score Contributions (sorted by score)
B2, S2.1, S3.2 (GWUDI)
B1.2, S1.1, S2.1
B1.1, S2.1
B1.2, S1.1
B1.1
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
Water Quality
GWUDI Facility
Operability
Constructability
Project Cost

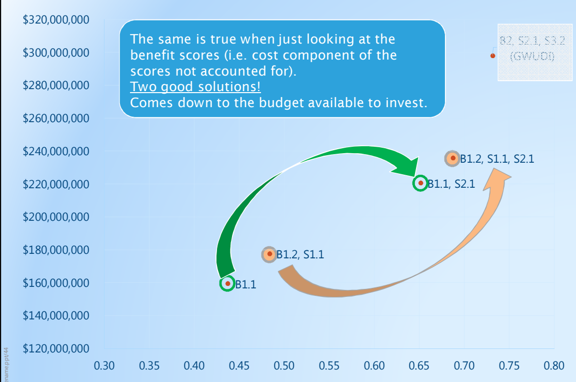

Ratings and Benefit/Cost Ratios
Benefit/Cost Ratio (Sorted) and Total Scores
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
B1.1, S2.1
0.725
2.9
B1.2, S1.1, S2.1
0.753
2.9
B1.1
2.7
B1.2, S1.1
2.7
B2, S2.1, S3.2 (GWUDI)
2.5
Total Score
Ben/Cost Ratio
Eliminate b/c low benefit/cost ratio (marginally higher score than B1.1, S2.1 which has a substantially better Benefit/cost ratio)


Alternatives' Total Scores vs. Life Cycle Cost
Two very viable sets of options exist, and both can be implemented in two stages.
• B1.1 offers the lowest cost at $160M for a strong option (total score of 0.55). It can be upgraded to 0.725 for an extra $60M to B1.1, S2.1
• B1.2, S1.1 offers a similar pattern at a slightly higher score (0.59) for $178M. It can be upgraded to 0.753 for $158M
$320,000,000
$300,000,000
$280,000,000
$260,000,000
$240,000,000
$220,000,000
$200,000,000
$180,000,000
$160,000,000
$140,000,000
$120,000,000
0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90
B2, S2.1, S3.2 (GWUDI)
B1.2, S1.1, S2.1
B1.1, S2.1
B1.2, S1.1
B1.1

## Workshop No. 7 - Decision Analysis Finalized and Tested




## Alternatives' Benefit Scores vs. Life Cycle Cost




## Agenda

- Data Gap Analysis
- Discuss/Review Shortlisted Alternatives
  - Review Results from Last Meeting
  - Discuss Shortlist Methodology and Shortlisted Alternatives
  - Re-Ranking of Shortlisted Alternatives
  - Select Best Alternatives
  - Sensitivity/Sensibility Check
- Discuss/Review Finalized Recommendation Statement
- General Comment by Public, Members, and Staff
- Next Meeting Date:
  - Public Meeting/Presentation

## Adopted Mission Statement and Goals

FINAL Draft Mission Statements for Drinking Water Planning Workgroup:

Mission Statement: Provide planning recommendations to the Water and Light Advisory Board and the City Council regarding the expansion of the water treatment system by establishing water quality goals, determining assessment criteria and, conducting a thorough, objective, assessment of industry accepted treatment technologies to determine the process or processes that best meet those criteria.

The Goals of the Drinking Water Planning Workgroup are as follows:

- Review current planning strategies for water supply and verify current goals and planning horizon for water treatment capacity expansion.
- Considering current regulations, potential future regulations, and potential enhancements, review and recommend potential long term water quality goals.
- Assess the state of the industry and shortlist potential treatment strategies that meet or exceed some or all of the potential long term water quality goals based upon industry acceptance and long term (present worth) costs.
- Formulate a set of criteria upon which potential treatment strategies to meet or exceed potential goals will be evaluated.
- Objectively evaluate and rank potential treatment strategies that meet planning horizon goals using a structured decision analysis model.
- Conduct a sensitivity analysis of decisions to review robustness and defensibility of decisions to potential changes in criterion assessments.
- Through this objective process, develop planning recommendations to guide the Water and Light Advisory Board and City Council regarding the water treatment system.

Filename.ppt/46

## Final Recommendation Statement:

Filename.ppt/47

## Agenda

- Data Gap Analysis
- Discuss/Review Shortlisted Alternatives
  - Review Results from Last Meeting
  - Discuss Shortlist Methodology and Shortlisted Alternatives
  - Re-Ranking of Shortlisted Alternatives
  - Select Best Alternatives
  - Sensitivity/Sensibility Check
- Discuss/Review Finalized Recommendation Statement
- General Comment by Public, Members, and Staff
- Next Meeting Date:
  - Public Meeting/Presentation

Filename.ppt/48

## Agenda

- Data Gap Analysis
- Discuss/Review Shortlisted Alternatives
  - Review Results from Last Meeting
  - Discuss Shortlist Methodology and Shortlisted Alternatives
  - Re-Ranking of Shortlisted Alternatives
  - Select Best Alternatives
  - Sensitivity/Sensibility Check
- Discuss/Review Finalized Recommendation Statement
- General Comment by Public, Members, and Staff
- Next Meeting Date:
  - Public Meeting/Presentation

Appendix F

# DWPWG RECOMMENDATIONS

CITY OF COLUMBIA, MISSOURI

COLUMBIA UTILITIES
COLUMBIA TERMINAL RAILROAD

DATE: March 9, 2018

TO: Mayor and City Council
Water and Light Advisory Board

FROM: Terry Merritt, Chair
Drinking Water Planning Work Group

RE: ***Final Recommendations of the Drinking Water Planning Work Group***

In April 2017, the Drinking Water Planning Work Group was established to assist in the update of the 2011 Water Treatment Plant Expansion Preliminary Design Report and was tasked with the following:

- Reviewing current drinking water regulations, including what types of disinfection methods comply with regulations.
- Reviewing Columbia's current water supply conditions.
- Assessing the current state of utility industry and customer-side water treatment technology and costs.
- Reviewing and providing input on developed recommendations.
- Developing drinking water planning recommendations.

The Work Group met a total of eight times with the final meeting on February 26th, 2018.

The Work Group's findings were as follows:

- The McBaine Water Treatment Plant (McBaine WTP) should consider processes that meet requirements for a Groundwater Under Direct Influence (GWUDI) facility.
- The McBaine WTP should utilize treatment technologies to achieve disinfection byproduct (DBP) compliance without the use of chloramines and to also assist in removal of Contaminants of Emerging Concern (CECs).

The following recommendations were finalized at the meeting on February 26th with all members in favor, excluding Mr. Karl Skala, who abstained his vote:

- Priority should be given to first restoring the plant to its 32 MGD capacity prior to increasing capacity to 48 MGD.

- The base alternatives of B1.1, B1.2, and B2 should be evaluated with the supplemental processes given to achieve improved water quality through a phased approach.
- The design on the selected alternative should begin no later than 2020, as indicated in Carollo's report, to be in operation no later than 2024, unless design and construction are able to be accomplished sooner.
- In order to improve water quality while the new process train is in design and construction, repair and/or enhancement of the current filters and pilot testing done to make every effort to return to free chlorine disinfection.
- The rehabilitation and/or enhancement initiatives outlined in the Condition Assessment will address deficiencies in the facility and system and request an updated timeline for these initiatives be produced by Water and Light.

The Drinking Water Planning Work Group respectfully submits the above recommendations for serious consideration by the Water and Light Advisory Board and Mayor and City Council.