Petitioner's Exhibit No. 4

CITY OF EVANSVILLE

EVANSVILLE WATER AND SEWER UTILITY

INDIANA UTILITY REGULATORY COMMISSION

CAUSE NO. 45545

DIRECT TESTIMONY

OF

SIMON M. BREESE, P.ENG.

SPONSORING ATTACHMENT SMB-1

City of Evansville

Cause No. 45545

Direct Testimony of Simon M. Breese, P.Eng.

Q. Please state your name, occupation, and business address.

A. My name is Simon M. Breese. I am a Vice President at AECOM and National Technical Director, Water Treatment, Americas. My business address is 50 Sportsworld Crossing Road, Suite 290, Kitchener, Ontario, Canada N2P 0A4.

Q. Please describe AECOM and its areas of expertise.

A. AECOM is a large, international multi-disciplinary engineering firm, with over 55,000 employees in 150 countries, and a corporate history dating back to the early 1900's. AECOM specializes in municipal and Federal work covering the Water Sector (including drinking water, wastewater, water resources and linear infrastructure), Transportation, Environmental, and Buildings & Places sectors.

Q. Please summarize your educational background and professional experience.

A. I am a 1986 graduate of the University of Waterloo, Ontario, Canada with a Bachelor's Degree of Applied Science in Chemical Engineering and a 1990 graduate of the University of Waterloo, Ontario, Canada with a Master's Degree of Applied Science in Chemical Engineering. I have been working in the engineering industry the past 34 years, and throughout this time my specialization has been the planning and design of drinking water treatment plants.

Q. Are you a registered professional engineer?

A. Yes. I am based in Canada, and am a registered professional engineer in the Canadian provinces of Ontario, British Columbia, Alberta, and Saskatchewan as well as the Northwest Territories and Nunavut.

Q. Was your firm retained by the City of Evansville acting through its Water and Sewer Utility Board ("Evansville" or "City" or "Petitioner") in connection with these proceedings?

A. Yes.

Q. Would you briefly describe the purposes for which you were retained and the nature and scope of the services which you were to provide?

A. AECOM has been retained by the Evansville Water and Sewer Utility ("EWSU") for the planning and design of the modernization of the water treatment plant. The project has included an initial master planning study to evaluate the existing water treatment plant and identify the recommended approach for modernization of the plant, ranging from rehabilitation of the existing plant through construction of an entirely new plant. Once the recommended alternative is selected, AECOM will complete design and construction services for the new facility.

Q. Are you sponsoring any attachments in this Cause?

A. Yes. I am sponsoring Attachment SMB-1, which is the Water Treatment Plant Advanced Facility Plan ("WTPAFP") prepared by AECOM for its evaluation of the Evansville water treatment plant.

Q. Was Attachment SMB-1 prepared by you or under your supervision?

A. Yes.

Q. What is the purpose of your direct testimony in this proceeding?

A. My testimony will walk through the relevant portions of the WTPAFP and describe the proposed project Evansville intends to finance with the $151,000,000 debt issuance ($181,000,000 if a residuals management facility is required to be constructed) in this Cause.

Q. Please provide an overview of the Water Treatment Plant Advanced Facility Plan.

A. The WTPAFP is divided into the following eleven (11) sections:

- *Section One – Executive Summary* summarizes the key findings of the report, including a summary of the proposed concept;
- *Section Two – Introduction* provides an overview of the Evansville water treatment and supply system, including a description of its existing facilities and the issues currently facing the Water Treatment Plant, and summarizes the objectives for the Project;
- *Section Three – Population Projections and Water Demand* summarizes Evansville's anticipated population growth and draws upon historical usage patterns to formulate future projected demands;
- *Section Four – Water Quality* provides a summary of historical raw water quality drawn from the Ohio River, as well as that of groundwater samples drawn from the local aquifer, to evaluate its potential for use to supplement the surface water supply. This Section also summarizes historical treated water quality from the plant, and establishes treated water quality goals for the project;

- *Section Five – Treatment Plant Condition and Performance Assessment* presents the findings of a detailed review of the condition of the existing plant, as well as historical treatment performance, identifying critical improvements required for continued operation, and also establishing a baseline for evaluation of rehabilitation of the existing plant against other alternatives for meeting water demands;
- *Section Six – Groundwater Supply Investigations* documents the findings of investigations into the availability, sustainable yield, and water quality of groundwater in the area around the existing plant site, to form the basis for evaluation of using groundwater as an alternative approach to meet all or part of the water supply;
- *Section Seven – Surface Water Treatment Alternatives* evaluates a variety of surface water alternatives for the individual primary components of the plant (i.e. river intake, pretreatment, filtration, disinfection, etc.) and considers both upgrading the existing plant and construction of new facilities. The individual components are ranked in this section for inclusion in final plant-wide alternatives presented in Section Nine;
- *Section Eight – Groundwater Treatment Alternatives* evaluates a variety of alternatives for upgrading the plant using a blend of groundwater and surface water from the Ohio River for the total raw water supply;
- *Section Nine – Plant-Wide Alternatives* presents and evaluates a range of integrated alternatives to meet treated water needs and quality objectives using surface water alone, or a combination of surface water and groundwater (it was discovered that groundwater yields from the local aquifer was insufficient to support the entire demand, so alternatives which relied solely on groundwater as the source were not considered);
- *Section Ten – Residuals Management* presents residuals management alternatives for

the recommended treatment plant if the existing NPDES permits are unable to be renewed. This section investigates options for limiting suspended solids in the water supply and construction of dewatering facilities and gives recommendations if residuals management is required with the new facility;

- *Section Eleven – Recommendations* presents on overview of the final evaluated alternatives and provides recommendations.

Q. Please provide a brief overview of the System.

A. The City of Evansville owns and operates an existing, aging 60 mgd conventional surface water treatment plant, which draws from the Ohio River. The original plant was constructed in the 1890s, and has been expanded in several stages over the years as the City has grown, with the oldest major unit processes still in service being Filters 13-20, constructed in the late 1930s and the newest, Filters 35 and 36, completed in 2008.

While generally, the City has been able to consistently meet water demands and treated water standards, many components of the plant infrastructure are beyond their useful life, prone to failure, and in need of major refurbishment or outright replacement. The overall level of reliability and redundancy in the plant poses a risk to the reliable supply of water to the City.

A key area of the concern is the existing 6.5 million gallons treated water reservoir, as this has shown evidence of elevated turbidity when the clearwell level is drawn down, inferring that intrusion of ground water into the reservoir (with an inherent risk of cross-contamination) can occur under some conditions. The clearwell structure is in very poor condition, but EWSU have limited means to remove this structure from service for inspection or repairs to be undertaken without shutting the plant down.

Although the plant is rated for a capacity of 60 mgd, the effective capacity of the plant is thought to be approximately 45 mgd, as performance issues can occur at higher flow rates. Demand has been well below this capacity in recent years, with average day demands in mid to low 20 mgd range, and peak summer demands rarely exceeding 30 mgd. Demand projections anticipate average day demand and peak day demand rising to 36.4 mgd and 49.4 mgd respectively by the year 2050. For this reason, the City adopted a reduced rated design capacity for the upgraded plant of 50 mgd (net).

Q. Please summarize the City's current needs relative to its Treatment System and discuss the issues currently facing this part of the System.

A. The existing plant has been able to consistently meet treated water demands and water quality objectives, but several areas of the plant are in very poor condition, are prone to failure, lack redundancy, and are effectively beyond their design life. Several instances have occurred in recent years where failures of a key piece of equipment have jeopardized the ability to deliver water, and the City of Evansville wishes to undertake either a major refurbishment of the existing plant, or a complete replacement of the plant with new facilities on the same site or at an alternative site, to secure their ability to consistently meet the demand for safe drinking water. Of particular concern are the following areas of the plant:

- The existing 6.5 MG clearwell, which is very difficult to remove from service for inspection or maintenance without a complete plant shutdown. The clearwell is known to be in poor structural condition, and appears to be prone to infiltration from groundwater when operated at lower levels through wall cracks. This represents a pathway for direct contamination of the treated water supply with untreated water and is considered a high risk;

- Plant electrical systems are considered a critical point of potential failure due to their age and condition;

See Appendices B and C of the Water Treatment Plant Advanced Facility Plan for a more detailed description of the critical needs and many challenges the utility is facing with the existing Water Filter Plant.

Q. Did EWSU previously propose to construct a new clearwell to address the issues you identified with the existing 6.5 MG clearwell?

A. Yes. While I was not a witness in Petitioner's last rate case, Cause No. 45073, my understanding is EWSU proposed to build a new 6 MGD clearwell in order to allow EWSU to perform necessary maintenance, inspections and repairs on the existing clearwell and to create redundancy in the system. EWSU's position in Cause No. 45073, as it is in this case, is that the clearwell cannot be taken offline to perform the necessary maintenance for an extended period of time without seriously jeopardizing Evansville's water system. My understanding is the Office of Utility Consumer Counselor ("OUCC") opposed this project in the last case because OUCC witnesses believed Evansville could take the clearwell offline for an extended period of time and perform the repairs during non-peak periods where Evansville's other two clearwells could be kept in service. On rebuttal, Evansville disagreed with the OUCC's contention that the repairs could be performed during non-peak periods with the other two tanks in service. Evansville's witnesses explained why the OUCC's proposal was not feasible and that it would involve risks the utility believes are not reasonable. My understanding is the Indiana Utility Regulatory Commission (the "Commission") agreed with the OUCC in Cause No. 45073 and found Petitioner had failed to demonstrate the reasonableness or need for the project[1].

Q. Does EWSU continue to believe that it is necessary to address the issues with the existing 6.5 MGD clearwell?

A. Yes. As identified on Table 5-1 of the WTPAFP, inspecting and repairing the 6.5 MGD clearwell is identified as a critical priority for continued operation of the system. The clearwell is over 60 years old[2], is in poor condition and in crucial need of inspections and repairs. As discussed in Sections 7.8 and 9.5 of my report, the clearwell is heavily relied upon for storage and operational flow "buffering" prior to pumping to the distribution system and generally cannot be taken out of service without a major disruption in capacity. As further explained, the clearwell has integrity issues relating to infiltration and the Water Treatment Plant is unable to operate without this tank in service. Failure of this clearwell would result in a long-term inability for the plant to reliably produce water. In such a scenario, the system could only rely on the .5 and 1.5 MG clearwells and high service pump station #2, which would reduce plant capacity significantly. Without necessary repairs, the 6.5 MGD clearwell poses a major obstacle for long-term operation of the plant.

Q. What is EWSU proposing in this Cause to address the clearwell issues? Did EWSU consider any alternatives?

A. EWSU is proposing to construct a new 5 MG (two parallel 2.5 MG clearwells) at the new WTP and to take the existing 6.5 MG clearwell out of service. Constructing the clearwell in this fashion (dual cell) will allow EWSU to isolate one 2.5 MG cell and take it offline for rehabilitation and repairs, while keeping the other 2.5 MG clearwell in service.

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[1] *City of Evansville, Indiana*, Cause No. 45073 (IURC 12/5/18) at 16.

[2] The 6.5 MGD clearwell was constructed in 1960.

As described in-depth in the WTPAFP, EWSU considered a number of different alternatives to address the clearwell issues. For example, in the alternative where the WTP would be built at the existing site, the proposal was to build a new 6.0 MGD clearwell and to rehabilitate the existing 6.5 MGD and keep it in service. Although the 6.5 MGD clearwell would technically no longer be needed after the new 6.0 MGD was constructed, the cost to rehabilitate the existing 6.5 MG was estimated at $734,000 and therefore was a relatively minor component of the complete project cost. In this scenario, it was therefore recommended to include rehabilitation given the storage gained at a very low cost per gallon. Nevertheless, as described later in my testimony, this alternative was not chosen as the preferable alternative for a number of reasons, and whether the existing 6.5 MG clearwell was rehabilitated in this scenario or taken completely out of service, it still does not make this alternative more favorable than Alternative 2B (as discussed below).

Q. Please identify the project alternatives considered to address the existing issues you identified with the Treatment System and provide a brief description of each project.

A. The study has undertaken an analysis of four main alternatives for replacement and modernization of the existing water treatment plant, as well as considering a "Do Nothing" alternative involving continued, reactive refurbishment of existing facilities to keep the existing plant in service. It is to be noted that all options considered were based upon a reduction in rated plant capacity compared to the existing plant (50 mgd vs 60 mgd), as a result of updated demand projections.

In the development of these alternatives, evaluations were made of a number of viable treatment unit processes to meet present and anticipated future drinking water standards, as well as consideration of siting alternatives for the plant. Triple bottom line decision modeling was used in making key treatment and siting decisions, to ensure that decisions made reflected not only cost, but also technical, environmental, and social factors.

The final integrated alternatives evaluated were as follows:

- **Alternative 1:** Rehabilitation of the existing water treatment plant, also adding ozone to the treatment train for taste and odor control, disinfection, and to improve the overall robustness of the treatment process against emerging contaminants;
- **Alternative 2:** Construction of a completely new water treatment plant, including conventional pre-treatment (coagulation, flocculation, sedimentation), ozonation, and biologically active filtration for the physical removal of particulate matter, and pathogens, as well as biological removal of dissolved organic carbon for control of disinfection by-products. This Alternative was further sub-divided into two sub-alternatives:
    - ❖ **Alternative 2A:** Construction of the new water treatment plant on the western end of the existing plant. This would involve demolition of part of the existing plant during construction, to make space for new facilities to be constructed, requiring careful construction sequencing;
    - ❖ **Alternative 2B:** Construction of the new water treatment plant on a new site, immediately to the east of the existing plant site, across Waterworks Road. This would allow construction of the new plant with minimal interference to ongoing operation of the existing plant during construction;
- **Alternative 3:** Construction of a new water treatment plant using both surface water from the Ohio River as well as groundwater, in an approximate 50/50 blend. The ground water would be collected in wells near the river and downstream of the existing

plant and would have to be pumped to the plant for treatment. Given the significant differences in water quality between the two water supplies, the proposed plant would utilize the same treatment train as Alternatives 1 and 2 for the surface water supply, but would use pre-oxidation and filtration with membrane softening for treatment of the groundwater supply due to the elevated metals and hardness of the groundwater;

Q. Are any of these listed alternatives not feasible?

A. The "Do Nothing" alternative, whereby the City continues to reactively refurbish and repair aging plant infrastructure on as as-needed basis, is considered infeasible, as the age and condition of the existing facilities are such that the probability of critical failures posing a threat to the reliable supply of safe drinking water will only be expected to increase with time. The work has concluded that construction of a new water treatment plant is the only plausible alternative for EWSU.

Of the integrated alternatives listed above (Alternatives 1 through 3), none are considered infeasible. These alternatives were however refined through consideration of other sub-alternatives, including alternative treatment technologies and other sites, which were considered infeasible for reasons including cost, and not carried into the list of integrated alternatives.

Q. What alternative does the WTPAFP ultimately recommend to address the City's Supply and Treatment System issues?

A. It is recommended that the City construct a new 50 mgd water treatment plant on the new site east of the existing site (Alternative 2B). If residuals management is required, it is recommended to rehabilitate a portion of the existing WTP for residuals management.

The new plant would continue to utilize the existing raw water intake and pump station on the Ohio River. Raw water would be pumped to the new site on the eastern side of Waterworks Drive for treatment. Treatment would include the following treatment processes:

- Coagulation, to neutralize surface charge on raw water particles and pathogens and entrap them within a floc particle;
- Mechanical Flocculation, to gently stir the coagulated water to build a larger floc particle more amenable to gravity settling;
- High Rate Sedimentation: This is similar to the technology used in the existing plant, but utilizes plate settler modules to support the use of substantially higher loading rates in design of the sedimentation basin, allowing them to occupy a markedly smaller footprint. The floc particles formed in flocculation are allowed to settle under gravity in these basins, resulting in clarification of the water. A sludge layer will form on the floor of the basins during normal operation, and this sludge would be intermittently withdrawn from the basins to be handled elsewhere;
- Ozonation: This is a new unit process to the treatment train. Ozone is a very powerful oxidant that is able to oxidize and destroy a number of contaminants of concern, including taste & odor causing compounds, and other emerging contaminants of concern that may be present in the River. Ozone is also able to oxidize naturally occurring organic compounds present in the River water, breaking them into smaller molecules which can then be used as food source by beneficial bacteria in the filtration process downstream;
- Biologically Active Filtration (BAF): BAF uses granular activated carbon filter media

as a support medium for the growth of beneficial bacteria. These bacteria consume the organics oxidized by the ozone process upstream, and effectively remove organics from the water. This will reduce the organic concentration in the water, and consequently will also reduce the potential for the formation of chlorinated disinfection by-products which can be formed when chlorine is used for disinfection. The BAF filters will also be designed as particulate filters, ensuring that the finished water is consistently of low turbidity.

- Chlorine/Chloramine Disinfection: The filtered water will discharge to a new 5 MG clear well, where chlorine will be applied to achieve final disinfection of the water. As the treated water leaves the clear well to be pumped to the distribution system, ammonia will be added to form chloramines, to produce a persistent chloramine residual for distribution.

The plant would be designed to modern design standards, ensuring that ample allowance is made for redundancy and reliability, using multiple trains wherever practical, and providing standby equipment to ensure that demands for safe drinking water can be maintained while allowing units to be removed from service for maintenance.

Q. Why was this alternative chosen?

A. Triple bottom line decision making was used in the decision-making process, balancing cost considerations against a variety of technical, environmental, and social factors. While the estimated cost for constructing a new facility on the new site (Alternative 2B) proved slightly higher than the estimated cost for Alternatives 1 and 2a, these alternatives resulted in higher life cycle cost and would have imposed significant ongoing challenges to keep the plant reliably in service through construction, and intrinsically were considered too risky to adopt.

Alternative 2B was therefore selected as it had the lowest life cycle cost and would effectively eliminate almost all impacts to ongoing operations during construction. This Alternative would include some short-term improvements to the existing plant to improve the reliability of the existing facilities through construction of the new plant.

Q. Were any other alternative sites considered for the plant?

A. Yes. When considering alternative sites for the plant, two other plausible locations were evaluated in addition to the site immediately opposite the existing plant across Waterworks Drive (Site 1). These sites were as follows:

- Site 2: A site approximately 2.4 miles to the southeast of the existing plant, which is presently occupied by a surface parking lot, but is otherwise undeveloped. The site also is located outside the floodplain or any wetlands.
- Site 3: A site approximately 2,900 feet due south of the existing site, along Waterworks Drive, near LST Drive. The site is presently vacant and undeveloped, however the entire site envelope is within the regulatory floodplain of the Ohio River, and unprotected by the existing levee. Development of this site was assumed to require the placement of sufficient fill on the site to raise the plant above the flood elevation.

Q. Why was Site 1 chosen as the preferable alternative?

A. All three of the site alternatives would incur additional costs over and above the cost of the treatment plant: Use of Site 1 would require the relocation of the existing City garage and other miscellaneous site development costs. Estimated incremental costs to the Project for development of Site 1, including this relocation were estimated to be approximately $13.7 million.

Use of Site 2 would require extensive additional buried infrastructure, including a 42-inch raw water main to convey raw water to the site, a new 36-inch treated water main to tie into the existing distribution system, and a 16-inch residuals pipeline to convey waste to the existing outfall, and other miscellaneous site development costs. Estimated incremental costs to the Project for development of Site 2 were estimated to be approximately $29.5 million.

Use of Site 3 would also require new additional buried infrastructure (albeit shorter length than required for Site 2), including a 42-inch raw water main to convey raw water to the site, a new 36-inch treated water main to tie into the existing distribution system, and a 16-inch residuals pipeline to convey waste to the existing outfall, as well as extensive civil works to raise the site above the flood elevation. Estimated incremental costs to the Project for development of Site 1 were estimated to be approximately $31.7 million.

Site 1, directly opposite the existing plant on the eastern side of Waterworks Drive was selected as the preferred site, because although it requires relocation of the existing City garage, the estimated cost of doing so is substantially lower than the estimated incremental costs of developing either Site 2 or 3 for the new plant.

Q. What are the estimated construction costs for this project and how were those cost estimates derived?

A. The estimated costs for the development of Alternative 2B are $151,000,000, including construction contingency but excluding engineering. If a new residuals management facility is required, this will add an estimated $30 Million to the estimated construction cost.

The costs have been derived by AECOM's team of professional cost estimators, and also relying on cost estimates from constructed projects of similar scope and complexity.

Q. Is this project reasonably necessary for the City of Evansville to continue the provision of reasonable and adequate water utility service?

A. Yes, I believe that it is essential. The existing plant is beyond the end of its effective life and continued operation of the plant without undertaking this project would dramatically increase the risk of a major failure occurring which would lead to plant outage and loss of water supply to the City.

Q. Does this conclude your direct testimony in this cause?

A. Yes.

DMS 19845703v1

I, Simon M. Breese affirm under penalties of perjury that the foregoing representations are true and correct to the best of my knowledge, information and belief.

____
Simon M. Breese

Date: May 10th, 2021.

Water Treatment Plant
Advanced Facility Plan

Alternatives Report

March 2021

AECOM

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List of Acronyms

BAF	Biologically Active Filtration
$CaCO_3$	Calcium Carbonate
CFU	Coliform Forming Units
CSMR	Chloride to Sulfate Mass Ratio
CT	Concentration x Time (chlorine disinfection)
DBP	Disinfection Byproducts
EPA	Environmental Protection Agency (or USEPA)
EWSU	Evansville Water and Sewer Utility
GAC	Granular Activated Carbon
GFD	Gallons per Square Foot per Day
GPM	Gallons per Minute
HAA	Haloacetic Acids
HP	Horsepower
HVAC	Heating, Ventilation, and Air Conditioning
IDEM	Indiana Department of Environmental Management
LOX	Liquid Oxygen
LSI	Langelier Saturation Index
MCC	Motor Control Center
MCL	Maximum Contaminant Level
MF	Microfiltration
MG	Million Gallons
MGD	Million Gallons per Day
MGF	Membrane Gravity Filtration
NF	Nanofiltration
NTU	Nephelometric Turbidity Unit
OSG	Onsite Generation (of Hypochlorite)
PAC	Power Activated Carbon
PLC	Programmable Logic Controller
PPD	Pounds per Day
PVC	Polyvinyl Chloride
RBF	Riverbank Filtration
RO	Reverse Osmosis
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TTHM	Total Trihalomethanes
UF	Ultrafiltration
USEPA	United States Environmental Protection Agency
VFD	Variable Frequency Drive
WTP	Water Treatment Plant

1.0 Executive Summary

The Evansville Water and Sewer Utility (EWSU) operates an aging conventional surface water treatment plant (WTP) which experiences typical demands of 20 to 25 million gallons per day (MGD). Various expansions and capital improvements have occurred at the WTP throughout the last 100+ years, resulting in a sprawling facility with varying levels of condition. Collectively, the WTP is in poor condition and failures of major equipment have occurred in recent years with imminent failure of additional infrastructure expected in the near-term. Treatment capabilities are also somewhat limited and the City experiences water quality issues such as taste and odor complaints. This report provides a rigorous evaluation of treatment alternatives to either completely replace the WTP or perform major improvements to ultimately provide EWSU with an upgraded facility yielding long-term reliability and improved water quality. A 'do nothing' alternative is not considered viable given the condition of the plant and risks associated with equipment failures, health and safety hazards, and insufficient levels of treatment. Following an initial evaluation of numerous treatment options, three primary WTP alternatives were identified for final project selection as noted below:

1. **Alternative 1**: Rehabilitation of the existing WTP with addition of a new ozone process;
2. **Alternative 2**: New WTP utilizing conventional pretreatment, ozone, and biologically active filtration as the core treatment processes. Two subcategories are considered for this alternative:
    a. Alternative 2A: Construct the new facility at the current WTP property with partial re-use and re-purposing of existing infrastructure.
    b. Alternative 2B: Construct the new facility on the property east of the existing WTP with virtually no re-use of existing infrastructure. This includes relocation of the City's street maintenance department currently located on this property.
3. **Alternative 3**: 50/50 blend of groundwater and surface water. The WTP features new construction and re-use of portions of the existing WTP. Groundwater treatment processes include metals removal and membrane softening and surface water treatment is conventional.

Selection of the preferred alternative from those listed above involved scoring non-monetary factors relating to treatment ability, plant resiliency, constructability, and operability among others. These scores were divided by the 30-year life cycle cost to identify a 'benefit-to-cost' ratio and to identify the most beneficial alternative. Table 1-1 summarizes this analysis, with **Alternative 2B** (new facility east of the current WTP) as the selected alternative.

Table 1-1 Summary of Alternative Scores, Costs, and Rank

Alt.	Non-Monetary Benefits Score	Construction Cost	30-Year Life Cycle (Billions)	Benefit-to-Cost Ratio	Rank
1	67.1	$121,822,000	$0.253	265	3
2A	76.9	$141,605,000	$0.238	324	2
2B	**84.6**	**$140,049,000**	**$0.231**	**366**	**1**
3	68.2	$175,599,000	$0.298	229	4

To fully implement Alternative 2B, additional project costs are expected and would include bidding, construction administration, construction inspections, material testing, legal and permitting fees, interest incurred through project financing, and related project expenses. With the addition of these requirements, the total project implementation cost is estimated to be $151.1 million. Obtaining a single loan to finance the complete project would result in a dramatic and sudden increase in utility rates. Therefore, spreading the incurred costs throughout the construction duration and obtaining smaller loans on an annual basis may offer a more financially manageable strategy.

Implementing this approach with an alternative project delivery method having a guaranteed maximum price such as a construction manager at risk or progressive design build may be more suitable than a conventional design-bid-build method. With alternative delivery, EWSU can collaborate with the contractor upfront to determine the construction schedule and lock in a guaranteed project cost. It is not recommended to bid the work as individual contracts due to the complexity of the overall project and the need for continuity from one phase of the project to the next. Bidding as separate contracts is also expected to add considerable cost and extend the construction schedule. Regarding schedule, construction of the proposed alternative is expected to reach substantial completion within approximately 3.5 years following the preparation of the site located across Waterworks Road from the existing WTP.

In summary, the existing WTP cannot reliably sustain continued operation, and major improvements are needed to avoid the risks of failure. To address this issue and ensure a safe and reliable supply of drinking water to its customers, it is proposed that EWSU abandon most of the current WTP and construct a new 50 MGD facility featuring ozone and biologically active filtration as the core treatment processes.

2.0 Introduction

The City of Evansville Water and Sewer Utility (EWSU or City) owns and operates a water treatment plant (WTP) and distribution system which has been providing drinking water to its residents and industries since the late 1800's. Water is currently delivered to over 62,000 customer accounts and serves a population of approximately 120,000 people. A comprehensive overview of the WTP and distribution system infrastructure was recently documented in the September 2016 Water Master Plan (by HNTB) and is therefore not summarized in detail within this report. The primary purpose of this report is to provide a detailed evaluation of long-term improvement solutions at the WTP (including consideration of all new infrastructure), and ultimately identify a preferred alternative for implementation. Although the WTP has undergone many improvements and expansions in its history, a brief summary of major milestones is noted below:

- 1873 to 1910: Direct river intake with minimal treatment, various improvements over these years related to pumping capacity and the river intake;
- 1912 to 1949: Construction of gravity filters at the (now) north plant in various stages ;
- 1960: New 6.5 million-gallon clearwell added to the site;
- 1967: Construction of the south plant including the PAC feed facility;
- 1980: Construction of a new river intake facility;
- 1983: Construction of a new high service pumping station;
- 1997: Plat-wide upgrades and construction of filters 33 and 34;
- 2007: Major electrical and controls upgrades, new chemical facilities, and various improvements and equipment replacement throughout plant;
- 2009: Construction of filters 35 and 36.

The WTP currently has a rated (approved) capacity of 60 MGD, although there are hydraulic restrictions which limit the maximum finished water production rate to approximately 45 to 50 MGD according to EWSU. Average daily flows typically do not exceed 30 MGD and a summary of flow data and projections are provided in Chapter 3. The facility is essentially split into a north and south plant (south is the newer of the two), with each treatment train consisting of the following processes:

- Ohio River intake with coarse screening and pumping;
- Addition of potassium permanganate, primarily for zebra mussel control;
- Optional addition of powder activated carbon (PAC);
- Coagulation and flocculation using an aluminum chlorohydrate based coagulant (Hyper Ion).
- Two-stage sedimentation;
- Conventional dual media gravity (rapid sand) filtration;
- Chlorine gas disinfection with the ability to feed ammonia for chloramines;
- Sodium hydroxide feed for pH adjustment;
- Fluoridation;
- Clearwell storage;
- High service pumping to the distribution system;
- Residuals (pretreatment sludge and filter backwash) discharged directly to the Ohio River.

Drawings relating to the existing facility and are included in Appendix A as follows:

Figure A0-1	Existing WTP Process Flow Diagram
Figure A0-2	Existing WTP Site Plan
Figure A0-3	Existing WTP Hydraulic Profile – North Plant
Figure A0-4	Existing WTP Hydraulic Profile – South Plant

Water quality of the Ohio River can change seasonally and during storm events, and taste and odor complaints throughout the City are not uncommon due to this variability. Spills do occasional occur in the river and the drainage area is susceptible to other contamination such as agricultural runoff, which can generally be mitigated with PAC addition. Disinfection byproducts are also a persistent problem due to organics in the river, which is why the WTP implemented chloramines in 1999. However, EWSU does periodically shut off ammonia in order to prevent nitrification in the system. When this occurs, the system often experiences total trihalomethanes (TTHMs) in excess of the drinking water maximum contaminant limit (MCL). Section 4 of this report gives a detailed review of water quality, but the takeaway is the existing treatment facility has limited ability to effectively address some potential water quality issues. The age and overall condition of the treatment facility is also problematic with portions of the plant being over 100 years old and much of the infrastructure not receiving any improvements for decades. Section 5 of this report provides a further condition assessment of the plant. As a summary, portions of the plant are abandoned, maintenance is constantly on-going, and some of the critical infrastructure is at the end of its useful life which includes vulnerable points of failure for the entire plant.

Given the issues relating to water quality and the overall WTP condition, EWSU has elected to implement major improvements (or plant replacement) to ensure a safe and reliable drinking water supply for its customers. AECOM was retained by EWSU in late 2019 to investigate alternatives for these plant improvements in this report. These alternatives consider rehabilitating the existing facility, construction of a new facility, investigating the use of groundwater, and evaluating many treatment technologies focused on providing superior water quality with attention to operational flexibility and reliability, capital and life-cycle costs, operational safety, and other criteria.

3.0 Population Projections and Water Demand

Currently, the WTP has a rated capacity of 60 MGD and customer water demand in the service area averages approximately 22 MGD. This section looks at factors affecting current and future demand including population growth and land use to identify a plant capacity for all treatment alternatives.

3.1 Population Projections

The June 2016 Evansville-Vanderburgh County Comprehensive Plan (Plan) provides historical population trends and forecasts for growth through 2035, and this data summarized herein. Table 3-1 shows the Vanderburgh County historical population data for each decade between 1960 and 2010, and the percent change between years.

Table 3-1 Vanderburgh County and Evansville Historical Population Data

Year	County Population	City Population	County % Change	City % Change
1960	165,794	141,543	-	-
1970	168,772	138,764	1.8%	-1.95%
1980	167,515	130,496	-0.7%	-5.96%
1990	165,058	126,272	-1.5%	-3.24%
2000	171,922	121,582	4.2%	-3.71%
2010	179,703	117,429	4.5%	-3.42%

Source: 2016 Evansville-Vanderburgh County Comprehensive Plan, Evansville-Vanderburgh County Area Plan Commission

Evansville's population decreased over the 50-year period between 1960 and 2010, while Vanderburgh County's population has generally increased. The overall change in population of the two is a net loss of approximately 10,000 people during this period. However, there has been growth in more recent years within Vanderburgh county, and there appears to have been an uptick in Evansville's population since 2010. In July 2018, the US Census Bureau reported an estimated City population of 117,963, which is an increase of about 0.5% since 2010. A subsequent estimate in July 2019 estimated 117,979 people, indicating stability. The Comprehensive Plan included a section about future capacity needs of the WTP and recommended an annual population growth rate of about 7% through 2035. However, this is a very aggressive growth model and can yield an unnecessarily large facility. Based on the historical data summarized above, it is recommended to utilize a lower and more representative rate of population growth to not drastically oversize the facility. This report considers an annual population growth rate of 1.5% through 2050 for future plant capacity.

3.2 Current Water Use and Demand

In addition to population trends, historical and projected land use should be considered for the capacity, as differing land uses yield differing water demands. The Comprehensive Plan breaks down 2015 land use both Vanderburgh County and the City of Evansville and is summarized in Table 3-2.

Table 3-2 2015 Land Use Breakdown

Land Use Category	Evansville % Use	Vanderburgh County % Use
Agricultural	7.1%	61.5%
Commercial	14.0%	0.8%
Forest	4.4%	10.8%
Government and Institutional	6.4%	1.2%
Industrial	5.5%	1.1%
Infrastructure and Utilities	6.3%	0.4%
Other	0.8%	1.2%
Parks and Open Spaces	10.8%	2.5%
Residential	41.7%	19.3%
Undeveloped	3.1%	1.3%

Source: 2016 Evansville-Vanderburgh County Comprehensive Plan, Evansville-Vanderburgh County Area Plan Commission,

Residential is the largest land use category within the City, while agricultural is the largest in the county. EWSU also tracks the number of water service accounts and classifies them as either residential, commercial, industrial, or public authority. The maximum number of accounts for each category for years 2014 through 2017 is listed in Table 3-3, and a slight increase in total accounts has been observed during this period. EWSU also tracks the volume of water sold to each of the categories, which is provided in Table 3-4 (volume in billions of gallons).

Table 3-3 EWSU Maximum Water Customer Account History

Category	2014	2015	2016	2017
Residential	59,137	58,684	59,245	59,465
Commercial	3,741	3,550	3,575	3,570
Industrial	133	119	110	128
Public Authority	212	211	217	236
TOTAL	63,223	62,564	63,147	63,399

Source: Evansville Water and Sewer Utility

Table 3-4 Water Usage (Billion Gallons Annually) by Customer Category

Customer Types	2014	2015	2016	2017	Average	% of Total
Residential	2.68	2.61	2.54	2.50	2.58	39%
Wholesale	0.77	0.77	0.80	0.75	0.77	12%
Commercial	1.85	1.94	1.83	1.82	1.86	28%
Public Authority	0.37	0.36	0.31	0.33	0.34	5%
Industrial	0.96	1.07	1.03	1.00	1.01	15%
Total	6.62	6.74	6.50	6.41	6.57	-

Source: Evansville Water and Sewer Utility

Note that Table 3-4 includes a wholesale category, which represents bulk sale of potable water to Gibson Water, German Township, and the Town of Elderfeld. EWSU also has a fourth wholesale account with Indiana American Water but this account utilizes no potable water. The wholesale accounts have experienced an increase in water usage since 2018 and metering data from October 2019 through September 2020 reports a total supplied volume of 0.828 billion gallons (up from the average 0.77 billion gallons shown in Table 3-4). Furthermore, a recent wholesale account agreement allows for an increased supply of water and is estimated to result in an additional average demand of 600,000 gallons per day (0.219 billion gallons per year). As such, for the basis of the demand estimates, an initial annual wholesale demand of 1.05 billion gallons is considered.

Water conservation has been trending nationwide as more residents, commercial, and industrial water users adapt the use low flow and efficient fixtures and appliances including dishwashers, washing machines, toilets, shower heads, and rain barrels among others. For example, although the number of residential accounts increased by 328 units from 2014 to 2017 (increase of 0.55%), the annual volume of water sold decreased by 18 million gallons during that same time (reduction of nearly 7%). Decades ago, a typical residential water use may have been 100 to 120 gallons per day per person. Now, that value is closer to 60 to 75 gallons per day per person due to water conservation trends. This trend extends beyond residential users and is also seen in many commercial and industrial facilities including hotels and manufacturing plants. To estimate per capita and per category use, the 2017 data from the previous two tables was combined and is summarized in Table 3-5 (wholesale values are updated per previous discussion).

Table 3-5 2017 Individual Category Daily Water Use

Category	# of accounts or units	Annual Use (Billion Gal)	Average Use (gal/day/unit)
Residential	59,465	2.50	115
Person (estimated)	117,500	2.50	58
Commercial	3,570	1.82	1,397
Industrial	128	1.00	21,404
Public Authority	236	0.33	3,831
Wholesale	4	1.05	719,178
Total Demand	-	6.70	18,356,000

Raw water flow delivered to the WTP and finished water flow pumped into the distribution system spanning the years 2014 through 2018 is shown in Figure 3-1.

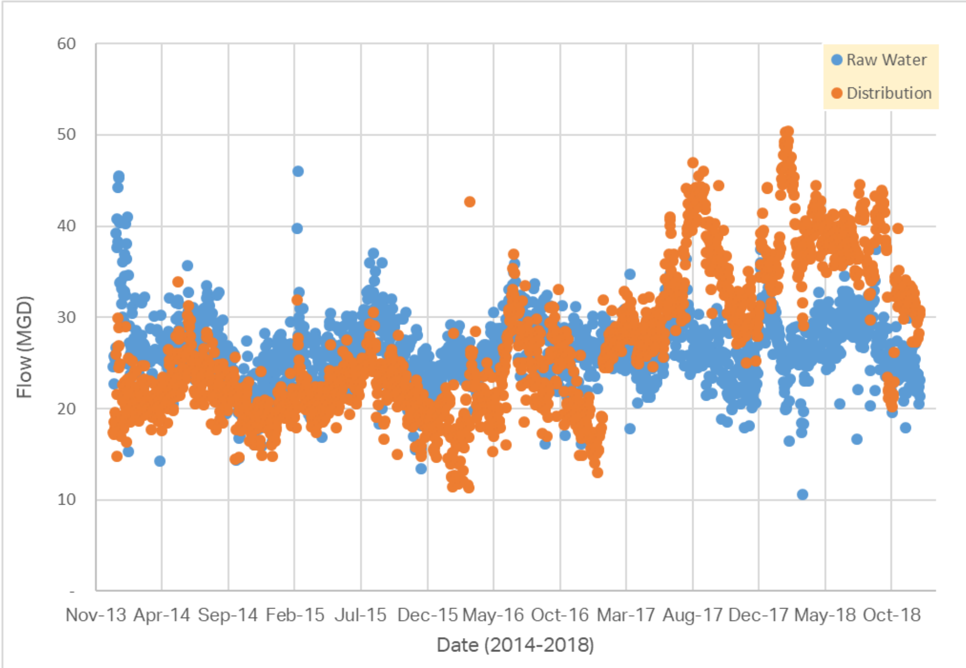


Figure 3-1 Pumped Water Flow

Figure 3-1 indicates the WTP delivered about 15 to 30 MGD (average of 22 MGD) to the distribution system from the beginning of this period through 2016. However, the data indicates the finished water flow experienced a sustained increase beginning in early 2017. This specifically includes numerous recorded flows in excess of 45 MGD. Not only has customer billing use not reflected this trend, but the amount of raw water supplied to the plant did not increase. Since it is not possible to treat more water than supplied, this data is not considered valid. EWSU uses insertion and transit-time ultrasonic type meters on its finished water systems, which can quickly lose accuracy and should be replaced with more reliable equipment such as magnetic or differential pressure flow meters. A further statistical summary of raw and finished water demands from 2014 through 2016 (prior to the metering error) is presented in Table 3-6.

Table 3-6 Statistical Summary of WTP Flow Data from 2014-2016

Flow Description	2014	2015	2016
Average Finished Water Flow (MGD)	22.32	22.12	22.57
Finished Flow 10th Percentile (MGD)	18.64	18.77	16.98
Finished Flow 90th Percentile (MGD)	26.28	25.59	29.07
Finished Flow 98th Percentile (MGD)	29.90	27.99	32.78
Finished Flow Standard Deviation (MGD)	3.12	2.82	5.08
Peak Factor (98th Percentile: Average)	1.34	1.27	1.45
Average Raw Water Flow (MGD)	26.08	25.89	26.44
% of Raw Flow to Residuals	14.4%	14.6%	14.6%

The average finished water flow value of 22 MGD is greater than 18.4 MGD sold to customers noted in Table 3-5 (difference of 3.6 MGD). This is assumed to be water lost through leaks, breaks and other undocumented water usages such as hydrants and storage tank overflows. This difference translates to a 16% loss of finished water, which is a high rate. EWSU is currently undertaking substantial waterline improvement and replacement projects and this loss is expected to decline.

3.3 Proposed Plant Capacity

The WTP currently has a rated capacity of 60 MGD; although this flow cannot reliably be sustained due to hydraulic limitations in the aging plant. Demand projections are extrapolated through the year 2050 for this analysis, and a summary of the assumptions are as follows:

- Initial City population of 118,000 people and a per capita a demand of 70 gal/day/person, or 8.26 MGD (higher than the per capita estimate of 58 gal/day/person).
- City population growth rate of 1.5% per year, maintaining the same per capita demand through 2050.
- Initial wholesale demand of 2.88 MGD with a flow increase of 0.75% per year.
- Initial industrial demand of 3.0 MGD with a flow increase of 2.5% per year.
- Initial commercial demand of 5.0 MGD and a growth rate of 2.0% per year.
- Initial public authority demand of 1 MGD and a growth rate of 0.25% per year.
- Initial leaks and losses volume of 3.50 MGD remaining the same through 2050.
- Peak day demand factor of 1.4 times the average demand.

Using the factors and assumptions listed above, the average and peak water demand through the year 2050 is presented in Table 3-7.

Table 3-7 Projected Average and Peak Water Demand through 2050

Demand Source	2020 Demand (MGD)	2050 Demand (MGD)
Average Residential	8.26	12.91
Average Industrial	3.00	6.29
Average Commercial	5.00	9.05
Average Wholesale	2.88	3.60
Average Public Authority	1.00	1.08
Average Leaks and Losses	3.50	3.25
Average Day Demand	**23.6**	**36.4**
Peak Day Demand	**31.7**	**49.4**

As indicated in the table, the projected average day demand by 2050 is 36.2 MGD with a peak day demand of 49.4 MGD. Based on this projection, it is proposed to consider a firm capacity of 50 MGD for the new or upgraded WTP. Although this capacity is right at the peak demand, the City currently has approximately 37 million gallons in storage throughout the distribution system and plant clearwells, which will balance the available plant capacity during extremely high peak days or peak hour flows in excess of 50 MGD. Additionally, the alternatives evaluated in this report consider expansion capabilities should flows increase considerably before the end of the life cycle.

4.0 Water Quality

The Ohio River is the sole source of water for the WTP and is pumped directly to the treatment processes without storage in a reservoir. Water shortage is not a concern as the river experiences median flows through the City of Evansville in excess of 23,000 ft^3/sec. Although groundwater is not currently utilized, there have been several hydrogeological studies to investigate conveying it to the WTP for use as a secondary source. This section provides a summary of current water quality data and identifies goals.

4.1 Surface Water Quality

Ohio River water quality is variable due to the large drainage area and subsequent variations in flows and runoff conditions. The City trends several river water quality parameters through a combination of online analyzers and manual measurement. This information was collected in daily increments from the City's SCADA server spanning 2014 through 2018 and is shown in Table 4-1.

Table 4-1 Raw Surface Water Quality Data

Parameter	Units	Average	10th Percentile	90th Percentile
Turbidity	NTU	54	14	110
Suspended Solids	mg/L	72	15	158
Total Organic Carbon	mg/L	3.8	2.8	4.7
Iron	mg/L	0.29	0.09	0.55
Manganese	mg/L	0.19	0.07	0.34
Calcium	mg/L	37	31	44
Magnesium	mg/L	10	7	13
Total Hardness	mg/L $CaCO_3$	130	107	154
Alkalinity	mg/L $CaCO_3$	88	74	104
pH	S.U.	7.78	7.63	7.93
Atrazine	ug/L	0.33	BDL	0.90
Chloride	mg/L	16	10	22
Sulfate	mg/L	38	27	52
Phosphorus	mg/L	0.18	0.09	0.27
Silica	mg/L	3.9	1.5	6.2
Total Dissolved Solids	mg/L	242	184	308
Total Coliforms	CFU/100 mL	6,125	687	15,531
e. coli	CFU/100 mL	176	5	403
CSMR	None	0.43	0.26	0.63
LSI	None	-0.35	-0.64	-0.02

4.1.1 Turbidity and Total Suspended Solids

Turbidity and total suspended solids (TSS) concentrations vary with runoff events with values for turbidity throughout the year ranging from less than 20 NTU to over 300 NTU. Similarly, TSS concentrations are reporting as ranging from less than 10 mg/L to over 500 mg/L. Figure 4-1 presents turbidity and TSS concentrations from 2014 through 2018 (turbidity on primary Y axis and TSS on secondary Y axis).

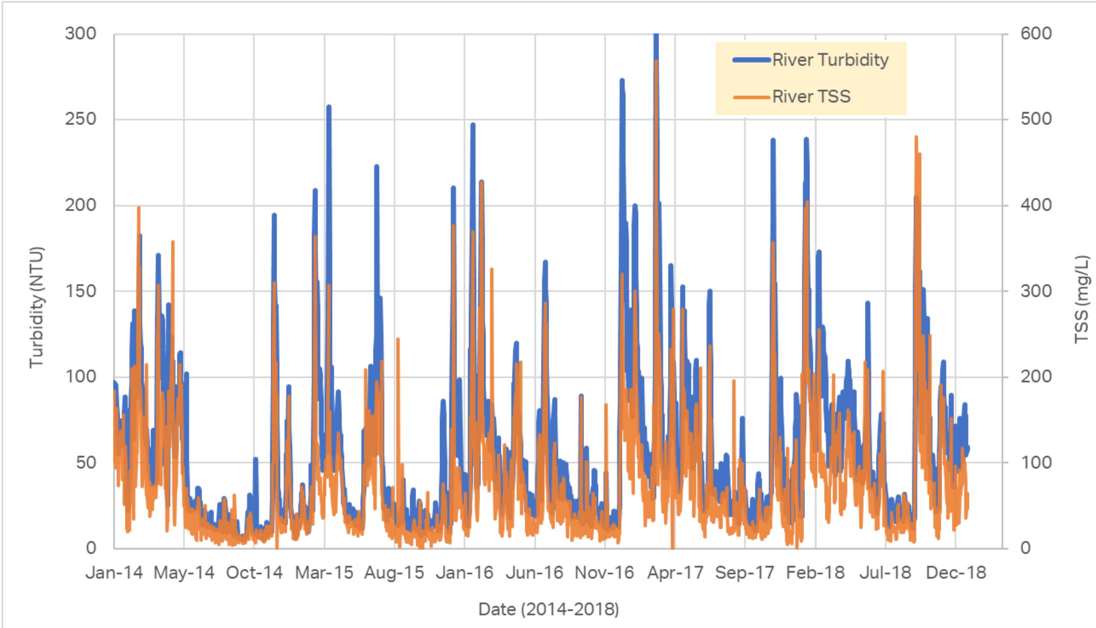


Figure 4-1 River Turbidity and Total Suspended Solids

The WTP implements rapid mixing, flocculation and coagulation, two-stage sedimentation, and rapid sand filtration for the reduction and removal of turbidity and TSS. Hyper$^+$Ion® 4064 is currently used for coagulant, which is an aluminum chloride-based chemical. Coagulant is a major operational expense at $50,000 to $60,000 per month (which is almost half the cost of the formerly used poly-aluminum chloride). More detail on the plant performance relating to turbidity is presented in Chapter 5. Overall, settled water from the north and south plants is consistently low in turbidity (1 to 3 NTU) despite changing river conditions.

Reduction and removal of turbidity and TSS is a primary objective of surface water treatment facilities. As far as goals, achieving a settled water turbidity like the current 1 to 3 NTU range are considered a good benchmark. Filtered water turbidity must meet the USEPA's surface water treatment rule and maintained below 0.3 NTU in 95% of the monthly measurements. Additional treatment credits are given if the combined filter effluent turbidity is maintained below 0.15 NTU. Maintaining consistent filtered water turbidity of 0.15 NTU or less is therefore considered the goal for the treatment alternatives.

4.1.2 Total Organic Carbon and Disinfection Byproducts

The presence of total organic carbon (TOC) is a prevalent issue with many surface water treatment facilities. Reaction with chlorine can lead to formation of disinfection byproducts (DBP). As such, removal of TOC prior to chlorination is a key step in reducing DBP formation potential. The existing WTP achieves a TOC removal rate of nearly 50%. However, this is likely due to a large portion of raw water TOC being suspended or bound to other solids and removed through the physical sedimentation and filtration processes. The WTP has little ability to reduce dissolved TOC. Figure 4-2 presents raw and finished water TOC data from 2014 through 2018.

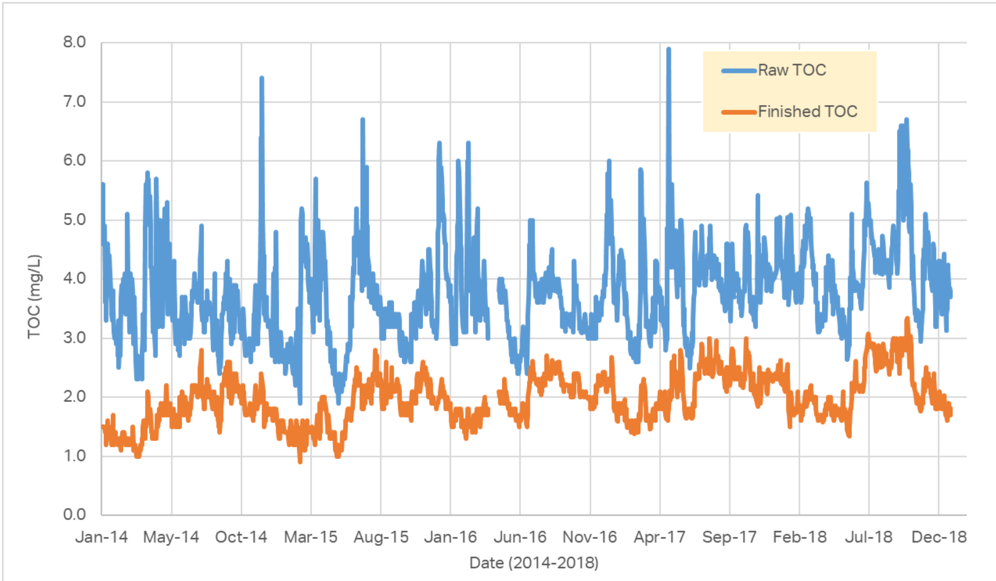


Figure 4-2 River and Finished Water TOC

To mitigate DPB, EWSU has been feeding ammonia to form chloramines since 1999. At least once per year, the plant turns off the ammonia and disinfects only with chlorine. This typically occurs for one continuous month near the beginning and/or end summer. When this occurs, a corresponding spike in DBP formation occurs. With chloramines, TTHM concentrations are low in winter months and start to increase in warmer months with rising water temperature and TOC levels. Since EWSU typically switches from chloramines to chlorine in the summer months, the issue of DBP formation is compounded. As a result, it is not uncommon for the City to experience exceedances of the drinking water MCL of 80 µg/L for TTHM. Even with the use of chloramines, TTHM levels can exceed this value. Therefore, removal of TOC is a major consideration for alternatives.

Figure 4-3 presents TTHM species concentration from 2014 through 2018. EWSU does not typically experience elevated levels of haloacetic acids (HAA) and the primary concern are the total trihalomethanes (TTHM). The species included in the figure are chloroform ($CHCl_3$), bromodichloromethane ($CHBrCl_2$), dibromochloromethane ($CHBr_2Cl$), and bromoform ($CHBr_3$). The figure also indicates when chlorine was used as the disinfectant (chloramines were used otherwise).

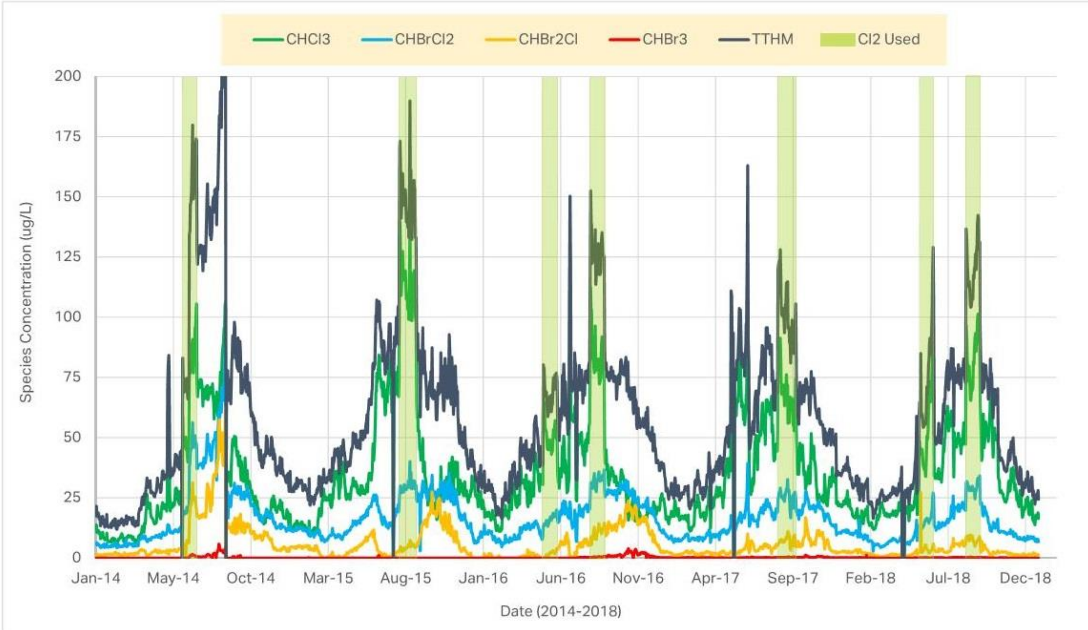


Figure 4-3 Finished Water TTHM by Speciation

4.1.3 Iron and Manganese

The river naturally contains iron and manganese at levels typically above the secondary drinking water standards of 0.3 mg/L for iron and 0.05 mg/L for manganese. However, these metals are oxidized in the river and easily removed with sedimentation and filtration. Historic levels for iron and manganese in the river are provided in Figure 4-4, and finished water levels are typicall below detection limits.

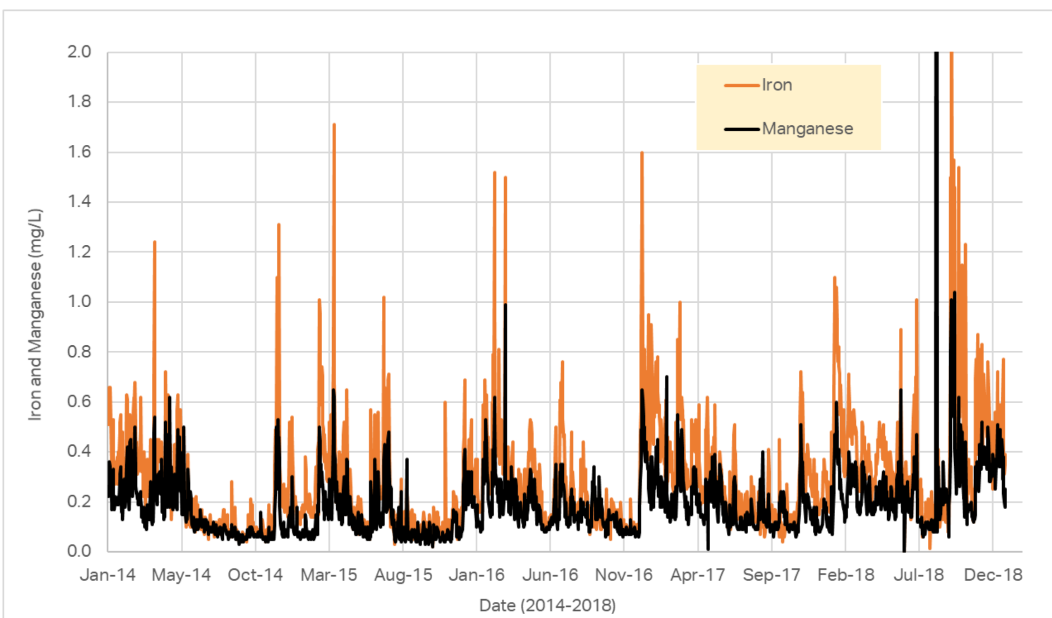


Figure 4-4 River Iron and Manganese Concentrations

The presence of iron and manganese in its oxidized form does not pose a concern for alternatives utilizing media filtration. However, it can be problematic for membranes if not properly removed upstream. In any case, the water quality objective would be to maintain iron and manganese comfortably below secondary standards for all evaluated alternatives.

4.1.4 Hardness

EWSU does not implement softening as the river hardness is consistently low enough to not warrant the additional expense or effort. Ideal levels of hardness are subjective, but source guidelines generally suggest target value between 50 and 150 mg/L as calcium carbonate ($CaCO_3$). Although there is variability in the river and occasional hardness spikes, the total hardness is usually below 160 mg/L as $CaCO_3$. Therefore, it is not considered cost effective to add softening if the Ohio River is used as the source of water. Figure 4-5 presents the historical river water hardness from 2014 through 2018 including the calcium and magnesium content.

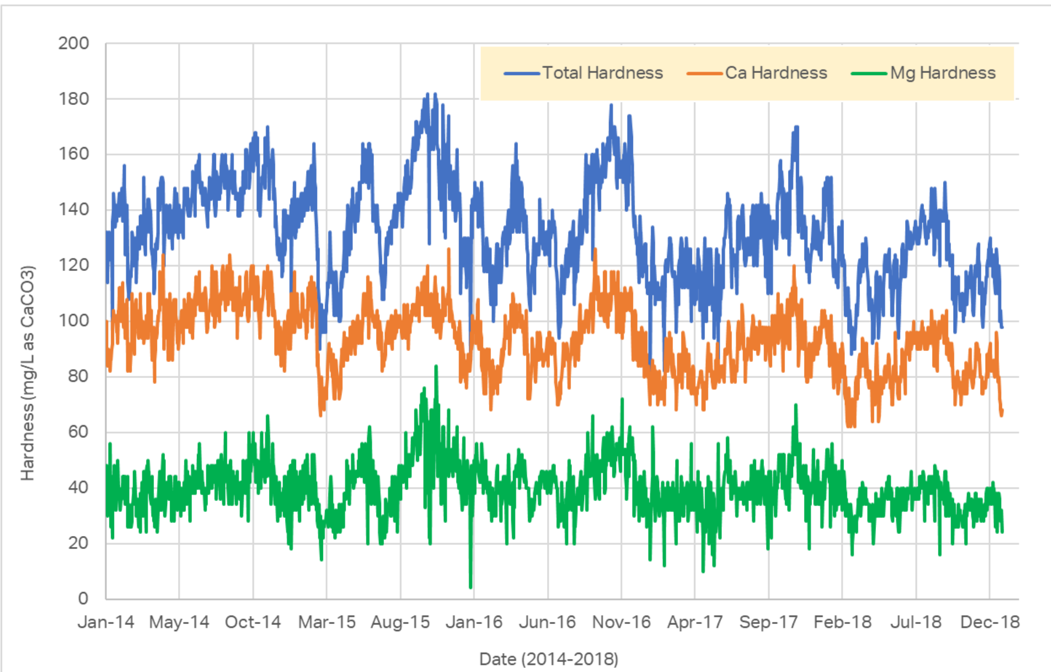


Figure 4-5 River Hardness

4.1.5 pH and Alkalinity

River pH and alkalinity are monitored daily and a relatively stable pH is experienced throughout the year with alkalinity typically being higher in the summer. Water pH is depressed by the treatment process (primarily due to the use of chlorine gas) and is raised with addition of sodium hydroxide. Figure 4-6 presents the raw water pH and alkalinity data from 2014 through 2018.

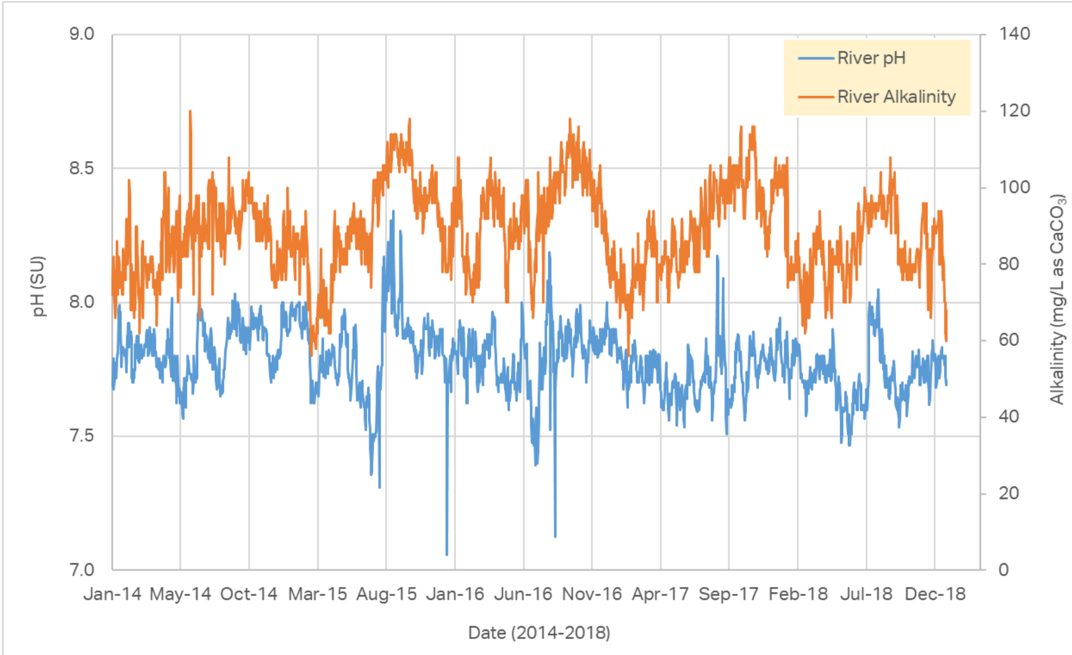


Figure 4-6 River pH and Alkalinity

4.1.6 Agricultural Runoff

Much of the Ohio River drainage basin in Indiana and Kentucky is subject to agricultural runoff. EWSU monitors for atrazine (herbicide) and phosphorus (used in fertilizers). The City also monitors for total and fecal coliforms which are often attributed to agricultural runoff. Although phosphorus does not have a drinking water MCL, it can result in algal blooms and subsequent algal toxins during warm months. EWSU has not had a history of algal blooms thus far. Atrazine does have a regulated MCL of 3 µg/L. Atrazine can effectively be removed with PAC in addition to other technologies including reverse osmosis (RO) and advanced oxidation. Nitrate is another regulated contaminant associated with agricultural runoff and has an MCL of 10 mg/L as NO_3. However, EWSU has not historically had issues with nitrates approaching the MCL and values reported on consumer confidence reports are typically less than 2 mg/L as NO_3. Figure 4-7 presents the raw water atrazine and phosphorus data from 2014 through 2018. Note that EWSU only monitors for atrazine in summer months and that phosphorus does not have much seasonal variability as atrazine.

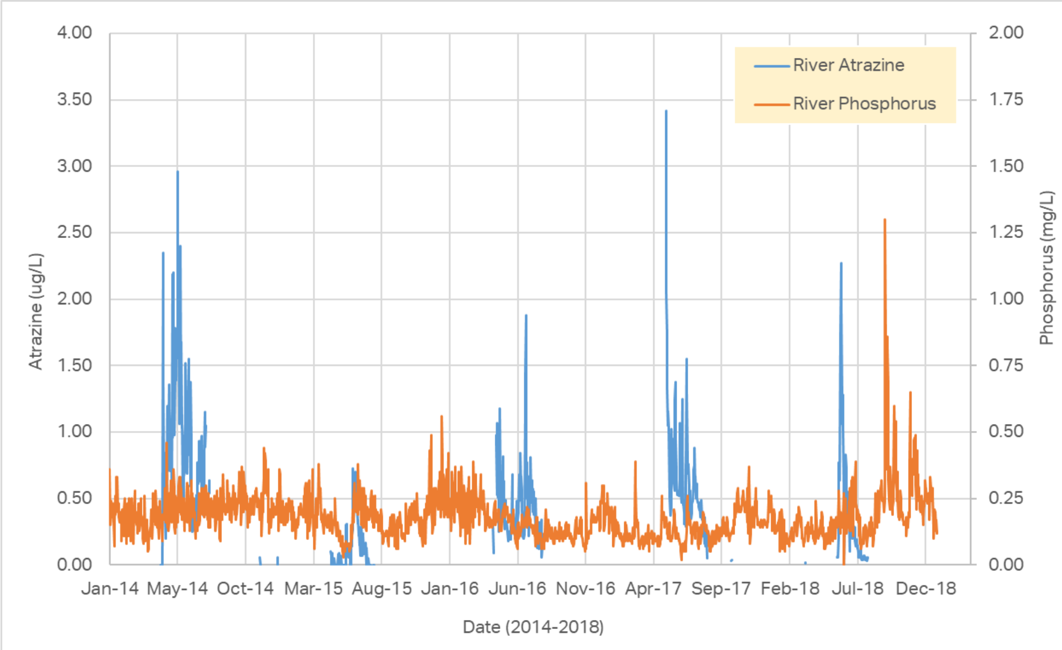


Figure 4-7 River Atrazine and Phosphorus

4.1.7 Corrosion Indices

Several indices can be calculated from water quality parameters to give a quantitative indication of water corrosivity. A common index includes the Langelier saturation index (LSI). LSI is a representation of a water's ability to form scale or be corrosive, with negative values indicating corrosiveness and positive values indicating scale potential. Ideally, an LSI of 0 would be a good balance of preventing both corrosion and excessive scale formation. Although published guidelines are not well established for preferred LSI values, widely accepted goals generally range between -0.3 and +0.5. River LSI is typically negative and occasionally below -0.5. The simplest way to raise the LSI is with the addition of a base such as sodium hydroxide.

Another common index is the chloride-to-sulfate mass ratio (CSMR). Research has shown that CSMR values greater than 0.6 can lead to an increase in corrosion of steel or iron pipes. CSMR of the river is typically around 0.5 although it does tend to spike to values of 1 or more during the winter, possibly due to salt runoff from road de-icing which increases chloride levels. Little can be done lower the value of CSMR, as adding excessive sulfate or reducing chloride without also reducing sulfate is not practical. Figure 4-8 presents calculated LSI and CSMR values from 2014 to 2018.

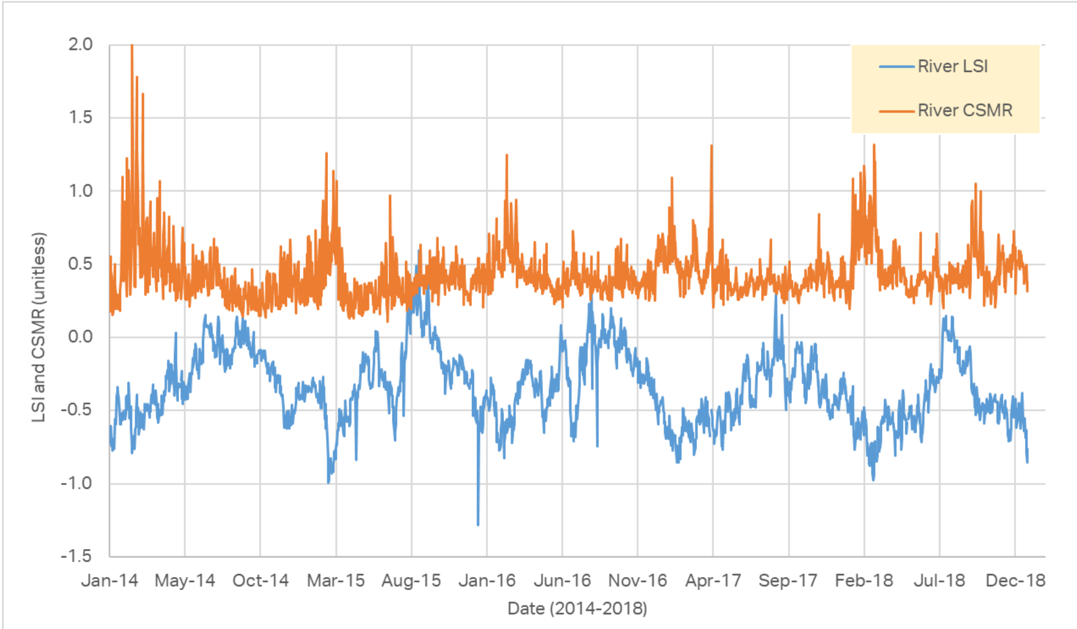


Figure 4-8 River LSI and CSMR

4.2 Groundwater Quality

Groundwater test borings were recently performed and included water quality sampling. A detailed presentation of groundwater quality is provided in Chapter 6.

4.3 Finished Water Quality Goals

Regardless of the source and quality of the raw water, there are numerous finished water quality goals that the considered alternatives must meet. A summary of the proposed finished water quality goals along with a brief indication of potential treatment technologies need to obtain these goals is provided in Table 4-2.

Table 4-2 Summary of Water Quality Goals

Constituent	Unit	Goal	Possible Treatment Strategy
Turbidity (pre-filtration)	NTU	< 3	Conventional pretreatment, ballasted flocculation
Turbidity (post-filtration)	NTU	< 0.15	Proper pretreatment and monitoring filtration, low pressure (UF) membranes
Total Organic Carbon	mg/L	< 2	Pretreatment, GAC contactors, biofiltration with ozone, RO membranes
TTHMs	µg/L	< 80	TOC reduction (noted above), use of chloramines, lowering pH
Total Hardness	mg/L as $CaCO_3$	100-150	Lime / soda ash softening, RO membranes, ion exchange
pH	S.U.	> 7.7	Caustic Addition (to raise)
Alkalinity	mg/L as $CaCO_3$	> 50	Caustic Addition (to raise)

Constituent	Unit	Goal	Possible Treatment Strategy
Iron	mg/L	< 0.2	Oxidation, detention, filtration, (if unoxidized before filtration)
Manganese	mg/L	< 0.05	Oxidation, detention, filtration, (if unoxidized before filtration)
Atrazine	µg/L	< 3.0	Addition of PAC, GAC contactors, RO membranes, advanced oxidation
Nitrates	mg/L as NO_3	< 8	RO membranes, Anion exchange
Arsenic	µg/L	< 10	Conventional Pretreatment, Lime softening, RO membranes
River Chemical Spill	-	BDL	Dependent on spill: Addition of PAC, GAC contactors, RO membranes, Ozone, Advanced Oxidation, etc.
***Cryptosporidium* and *Giardia* Log Credits**	LOG	≥ 4	Conventional pretreatment and filtration, turbidity monitoring, Chlorine contact, UV Disinfection, Ozone, low pressure (UF) membranes
Taste and Odors	-	Minimal complaints	Dependent on source: ozone, advanced oxidation, other pre-oxidation, PAC addition, RO membranes, etc.

5.0 Treatment Plant Condition and Performance Assessment

Many EWSU plant condition assessments have documented through various reports with the most recent being the 2015 master plan by HNTB. This section summarizes many of these previous findings along with findings of new investigations to develop a basis for the improvements.

5.1 Critical Treatment Equipment Infrastructure

Although major upgrades are planned following recommendations of this report, there remains critical infrastructure nearing the point of failure. The improvements will take several years to implement, and such equipment may not last until this project is completed. Critical infrastructure was therefore evaluated to identify smaller and fast-tracked improvements to help ensure operation. HNTB performed these critical infrastructure studies and are provided into two memoranda: one for treatment equipment and one for the electrical and I&C systems. These documents are included in Appendix C (Treatment Equipment) and Appendix D (Electrical Systems) and the key recommendations are summarized Table 5-1.

Table 5-1 Summary of Recommended Critical Improvements for Continued Operation

Priority	Area	Description
Critical	Switchgear	Install new main plant switchgear with existing to serve as backup
Critical	SCADA	Provide SCADA & RTU emergency power / battery backups
Critical	Intake	Perform dredging of sediment around intake structure
Critical	Intake	Replace end-of-life switchgear for low service pumps
Critical	Intake	Continue intake screen rebuild cycle (one per year)
Critical	Intake	Continue low service pump rebuild cycle (2 per year)
Critical	North Primaries	Replace structural column & equip. in primary sed basin 2
Critical	North Primaries	Replace structural column & equip. in primary sed basin 2
Critical	Clearwells	Inspect 6.5 MG clearwell and repair as necessary
Critical	High Service	High service pump #5 and #10 rebuild
Critical	High Service	Full replacement existing high service station 3 switchgear
Critical	Outfalls	Extend outfalls to comply with IDEM requirements
High	SCADA	Update SCADA service and provide backup server
High	Intake	Replace pneumatic actuators with electric in intake facility
High	Intake	Replace low service pump controls with new PLC
High	Intake	Service existing transformers 3 and 4 at intake
High	Intake	Service existing MCCs at intake
High	North Primaries	Replace corroded access hatches on secondary basins
High	North Primaries	Replace corroded access hatches on north flume
High	North Primaries	Repair / replace / resurface all handrails and access bridges
High	Filters	Continue replacing media & underdrains where not yet performed
High	Filters	Relocate portion of backwash line currently under levee
High	Filters	Replace severely corroded electrical enclosures in 21-28 gallery
High	Filters	Service existing MCC in 21-28 gallery
High	Filters	Repair / resurface corroded pipes in filters 13-20 gallery
High	High Service	Replace control system in high service station 3 with new PLC
High	High Service	Service existing MCC in high service station 3
High	Clearwell	Extend 1.5 MG vent to reduce gas/moisture in gallery

Priority	Area	Description
High	Generator	Install load bank for generator testing
High	Generator	Service existing generator and subsystems annually
High	Switchgear	Service existing main plant switchgear
High	Floodwall	Repair cracking floodwall cap
High	Flood Pumps	Perform pump and motor rebuild for flood pumps
High	Various Areas	Service electrical panels PP2, P3, and PP4
Med	Intake	Add redundant sump pump to lower intake gallery
Med	Intake	Service VFD at manufacturer recommended schedule
Med	North Primaries	Replace corroded roof drains extending overhead of flume
Med	North Primaries	Inspect / repair concrete in floc & sed basins as necessary
Med	South Primaries	Replace center column motor and drive
Med	South Primaries	Inspect / repair / coat walkways and supports as necessary
Med	South Primaries	Service electrical systems in sludge pump station
Med	South Primaries	Add redundant sump pump to sludge pump station
Med	Filters	Replace ventilation & dehumidification equip. in filters 21-32
Med	Filters	Repair / resurface corroded pipes in filters 21-28 gallery
Med	Filters	Replace corroded electrical enclosures in 13-20 gallery
Med	Filters	Replace flex power cables with compliant equip in 29-32 gallery
Med	High Service	Repair / resurface piping in high service stations 2 & 3
Med	High Service	Repair / resurface handrail & stairs in high service stations 2
Med	High Service	Replace flow meter in high service station 3
Med	High Service	Service switchboards 2A and B in high service station 1
Med	High Service	Add redundant sump pump to high service station 2
Med	High Service	Repair / resurface handrail & stairs in high service station 2
Med	High Service	Replace hydraulic valve system w/ electric in high service station 2
Med	High Service	Replace VFD on high service pump #5
Med	High Service	Service panel PP1and switchboard 1 in high service station 2
Med	High Service	Add VFD or eddy current drive to high service pump #10
Med	High Service	Replace hydraulic valve system w/ electric in high service station 3
Med	High Service	Service pump 9 eddy current drive at recommended schedule
Med	High Service	Service pump 8 VFD at recommended schedule
Med	Controllers	Replace Hach SC100 units with new SC200 throughout plant
Low	Intake	Repair / resurface exterior walkway and piping at low service
Low	Intake	Repair / resurface piping inside intake facility
Low	South Primaries	Replace sludge pump station pumps
Low	South Primaries	Repair / resurface handrail and walkways at sludge pump station
Low	Filters	Replace ventilation & dehumid. equip. in filters 33-36 gallery
Low	Filters	Replace corroded electrical equipment in 13-20 & 29-32 gallery
Low	Filters	Repair / resurface piping in filters 29-36 galleries
Low	High Service	Enclose VFD & electrical equipment in high service station 2
Low	High Service	Service transformers T1 & T2 at high service station 2
Low	High Service	Repair / resurface hand and stairs in high service station 2
Low	High Service	Service VFDs on high service pumps 6 and 7

5.2 Building Systems Condition

Although the infrastructure improvements noted in the critical need memorandums are important for continued operation in terms of water treatment, there are other aspects of the facility which need considered if plant rehabilitation is employed as described in the following sections.

5.2.1 Boilers and HVAC Systems

Heating is primarily provided via a centralized natural gas boiler, although some areas rely on electric unit heaters. The existing boiler is 1976 vintage and continuous upkeep is critical for its operation. A 1963 vintage boiler sits adjacent to the operational boiler but has been decommissioned and is not planned for repairs. A total of approximately 36 electric unit heaters are installed throughout the plant. Many components of the heating system are reaching the point of failure and a major overhaul is needed for continued operation. Specifically, many of the electric unit heaters are severely corroded due to exposure to moisture and chlorine fumes, there are leaks in the steam and condensate piping throughout the plant, and the condensate pumps are corroded.

In addition to building heating systems, ventilation needs improvements. This is particularly the case where moisture from chlorinated water is present as this environment corrodes piping, valves, actuators, electrical cabinets, and instruments. The corrosion rate is further accelerated if dehumidification is not provided. There several portable dehumidifier units in areas, but it is evident that additional dehumidification could be beneficial. An example of an analyzer (located in the gallery of filters 13-20) with extensive deterioration is shown on the right.

5.2.2 Building Architectural and Structural Condition

Structural components of the WTP including basin and channel concrete, access hatches, walkways, and handrails are in poor condition need repair or replacement. Examples include corroded metal roof trusses in buildings, corroded metal staircases, columns and other structural supports, handrails, and deteriorated concrete in various locations including evidence of water intrusion. Some of these items pose a considerable safety risk. An example of a staircase where the lower supports have corroded away from the floor is shown to the right. Several of the roofing systems were replaced over the last 15 years including high service station #3 in 2019, the south plant in 2017, conference room areas in 2015, filters 33-36 building in 2009, and most of the slate

roofs on the older plant in 2006-2007. The only roofing systems that are now older and possibly in need of replacement are the intake structure, high service station #2, caustic and ammonia building, and fluoride room. Most of the above-grade interior concrete floors, walls, and columns appear to be in good condition and not in need of major repairs.

Plant-wide, there are many architectural features or areas in poor condition needing renovation. These include many of the windows and door frames, interior and exterior mortar joints, and room finishes such as floor tile, ceiling tiles, and coatings. The main conference room was recently renovated, but most of the other rooms have not been for several decades. These include restrooms, locker rooms, staff offices, control room, laboratory, break rooms, and records storage areas. If the existing plant were to undergo major rehabilitation, these areas should also be renovated to modernize the entire facility.

5.2.3 Electrical Systems

The main plant switchgear has reached the end of its useful life and is considered a critical point of failure. In addition to the main switchgear, many of the ancillary electrical and control panels, disconnects, wiring and conduit, lighting fixtures, and related systems are in poor condition and do not meet current electrical codes. These pose as both a risk of power failure and as a safety risk. An example of a panel near the point of failure is shown in the figure on the right (supported by a floor jack). If the existing plant is to be renovated, a major overhaul of nearly all electrical equipment is needed to bring the facility up to code and ensure safe and reliable operation.

5.3 Plant Performance

This section presents the overall performance of individual WTP components used to establish baseline information in considering the functionality of alternatives.

5.3.1 River Intake

The river intake was constructed in 1980 and replaced the original wet well and pump station. The condition of the structure is decent while much of the equipment has some issues due to age. Specially, the three (3) travelling screens and six (6) vertical turbine pumps require frequent rebuilds. The electrical equipment in the intake is also nearing the point of failure. A more comprehensive description of intake and deficiencies is provided in Chapter 7 of this report, which evaluates rehabilitation. Overall, the system is performing an adequate job of conveying raw water to the pretreatment systems.

5.3.2 Pretreatment System Performance

The north and south plants each feature two trains for coagulant mixing, flocculation, and two-stage sedimentation. Coagulant is mixed in the north plant via a single mechanical rapid mixer and the south plant utilizes a static mixer. The two plants also differ in flocculation and sedimentation tank geometry. The north plant has three-stage flocculation in square basins followed by primary and secondary sedimentation in square basins; whereas the south plant has single stage flocculation in a circular tank followed by primary and secondary sedimentation in circular basins. Although the pretreatment systems differ, their ultimate performance and removal of turbidity and suspended solids is about the same.

Average settled water turbidity in the primary basins during 2018 was 1.46 NTU and 1.97 for the north and south plants, respectively. Secondary basin effluent averaged 1.39 NTU and 1.66 NTU for the north and south plants, respectively. Although both are performing similarly, the north plant achieves slightly better results, likely due to mechanical mixing and multi-stage flocculation. Regardless, it is apparent that very little reduction in turbidity is gained with the second stage of sedimentation and turbidity out of the primary basins is suitable for filtration. However, higher flows may warrant the use of secondaries.

Figure 5-1 presents the raw and settled water turbidities taken for the effluent of the north plant primary and secondary settling basins in 2018. This is followed by Figure 5-2, which presents the raw and settled water turbidities taken for the effluent of the south plant primary and secondary settling basins in 2018. Raw water turbidity is displayed on the secondary axis and is in logarithmic scale.

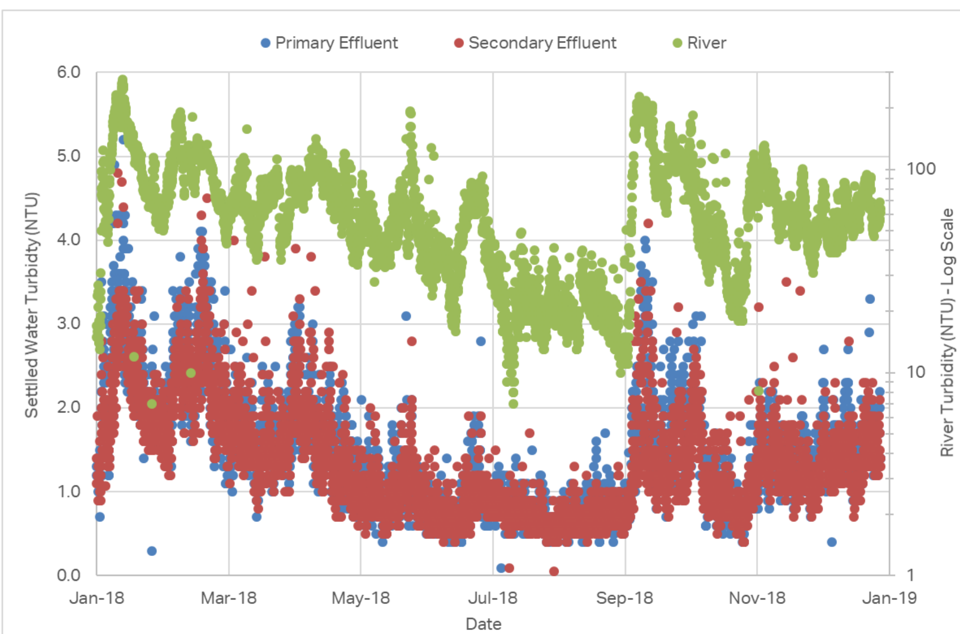


Figure 5-1 North Plant Sedimentation Basin Performance

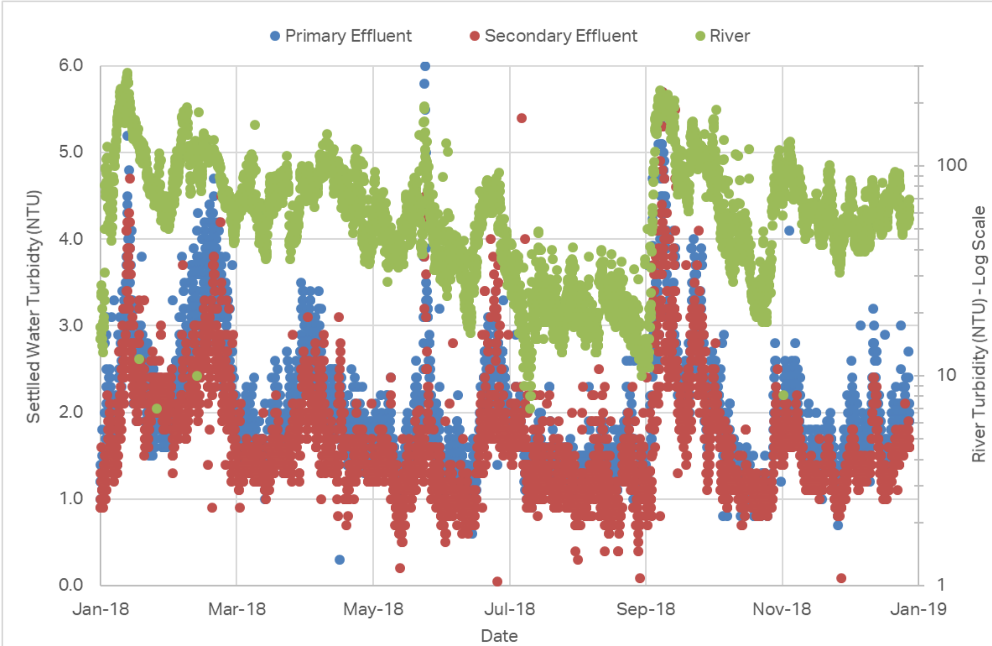


Figure 5-2 South Plant Sedimentation Basin Performance

5.3.3 Filter Performance

The WTP has a total of 36 gravity filter beds, although the original 12 filters have been abandoned. Filters vary in size, age, and condition with sizes of active filters are listed below, followed by effluent turbidity data from 2014 through 2018 in Figure 5-3.

- Filters 13 through 20: 8 filters, each 550 square feet
- Filters 21 through 28: 8 filters, each 1,036 square feet
- Filters 29 through 36: 8 filters, each 1,058 square feet
- Total of 24 filters with total area of 21,152 square feet

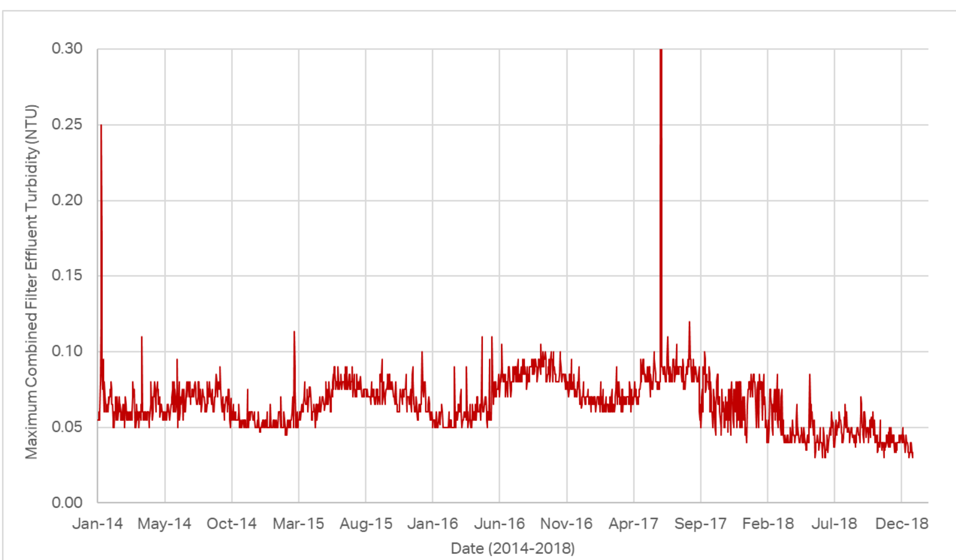


Figure 5-3 Combined Filter Effluent Maximum Daily Readings

In 2017, EWSU began gradually replacing the media and / or underdrains in several of the older filters and a slight downward trend is observed after this time in the figure. Although maximum daily values for combined filter effluent turbidity have consistently stayed at or below 0.1 NTU, there was one rare occurrence on June 15, 2017 where the maximum value was reported as 1.3 NTU and may have been due to construction activities relating to the filter bed rehab. However, was not a violation, as regulations require the 95th percentile of turbidity values to stay below 0.3 NTU.

The plant typically backwashes one filter per each 8-hour shift unless high turbidity otherwise warrants a backwash. With 24 filters, this yields three filter backwashes per day or approximately 7 to 8 days between a given filter backwash. Although this is a long run time compared to many WTPs, effluent goals are met, and this does not pose as an alarm. With a total filter surface area of about 21,152 ft^2 and an average raw water flow of 26 MGD, the average effective filter loading rate is calculated as 0.85 gpm/ft^2. Filters are typically designed to operate at 2 to 4 gpm/ft^2 and this low loading lends an explanation to the extended run times.

5.4 Chemical Facilities and Usage

Chemical use from 2016 through 2018 plant data was obtained and this section provides a summary of each.

5.4.1 Potassium Permanganate

Potassium permanganate can be fed to the screens in the river intake facility. Although use of permanganate may add benefit of pre-oxidation and help with taste and odors, its primary use in this case is for control of zebra mussels. The chemical feed equipment is a small hopper and eductor system (manufactured by Merrik) located inside the intake facility. Dry potassium permanganate crystals are stored in the intake facility in five-gallon buckets on a containment pallet and must be manually fed to the hopper. In 2018, EWSU recorded a total permanganate usage of 17,800 pounds, which equates to an average dosage of approximately 0.22 mg/L based on the recorded raw water flow rates.

5.4.2 Powder Activated Carbon

A large powder activated carbon (PAC) facility was constructed in 1967. Although EWSU does not often feed PAC, its use is beneficial for removal of short-term organic contaminants in the river. PAC can be fed at any of the following application points:

- North Plant: Upstream of the rapid mix tank
- North Plant: Between primary and secondary sedimentation basins
- South plant: Upstream of static mixer prior to primary sedimentation
- South Plant: Between primary and secondary sedimentation basins on east train;
- South Plant: Between primary and secondary sedimentation basins on west train;

PAC is an important feature to have at surface WTPs and is proposed to be included with any new improvements. EWSU did not feed PAC in 2016 or 2018, and it was only fed once in 2017 (received a delivery of 40,000 pounds). As such, a consistent historical use or typical dosage cannot be accurately identified. However, for the purposes of this report, it is assumed that EWSU will feed an average of 15,000 pounds per year of PAC. This works out to be a dosage of approximately 8 mg/L for one week a year at a plant flow of 30 MGD.

5.4.3 Chlorine Gas and Chloramines

Disinfection is accomplished with chlorine gas and the feed system consists of 1-ton cylinders and chlorinators. Chlorine can be fed to the any of the following application points:

- North Plant: Ahead of the primary sedimentation basins;
- South Plant: Ahead of the primary sedimentation basins;
- Near the entry of the 6.5 million-gallon clearwell;
- Upstream of the 1.5 million-gallon clearwell.
- Although feed points for chlorine or chlorine dioxide (no longer at the plant) used to be installed and operational at the river intake and downstream of clearwells, EWSU has indicated these application points are not currently in service.

When utilizing chloramines, EWSU feeds ammonia upstream of the filter beds (ammonia discussed in Section 5.4.5). A chlorine residual at the point of distribution entry is typically between 2.8 and 3 mg/L (whether using free chlorine or chloramines). Reactions in the sedimentation basins effectively consume free chlorine and gas usages are notably higher than this final residual. In 2018, EWSU recorded a total chlorine gas usage of 410,000 pounds, which equates to an average dosage of approximately 5.0 mg/L based on raw water flow. Feeding chlorine early in the process is a likely cause of DBPs. One strategy to minimize chlorine use and DBP formation could be to chlorinate after sedimentation and then feed ammonia near the outlet of the clearwell. However, there may not be adequate CT achieved due to flow patterns through the 1.5 and 0.5 MG clearwells to facilitate this option.

5.4.4 Coagulant

EWSU has fed different coagulants over the last decade, and currently uses Hyper⁺Ion® 4064, which is an aluminum based chemical. The coagulant feed facility is located adjacent to the chlorine building and garage and the system is relatively new and in good condition. Coagulant can be fed at any of the following application points:

- North Plant: Upstream of the rapid mix tank in the channel;
- South Plant: Upstream of the static mixer prior to primary sedimentation
- Header pipe upstream of filters 13 through 20
- Header pipe upstream of filters 21 through 28
- Header pipe upstream of filters 29 through 32
- Header pipe upstream of filters 33 through 36

In 2018, EWSU recorded a total Hyper⁺Ion® 4064 feed of over 5.8 million pounds. At an estimated 40% chemical strength, this equates to an average effective coagulant dosage of 28 mg/L based on raw water flow. EWSU does not typically vary the coagulant dose based on river turbidity; but a low settled water turbidity is consistently maintained indicating that adequate coagulant is fed. Figure 5-4 presents the Hyper⁺Ion® 4064 dosage and corresponding river water turbidity throughout 2018.

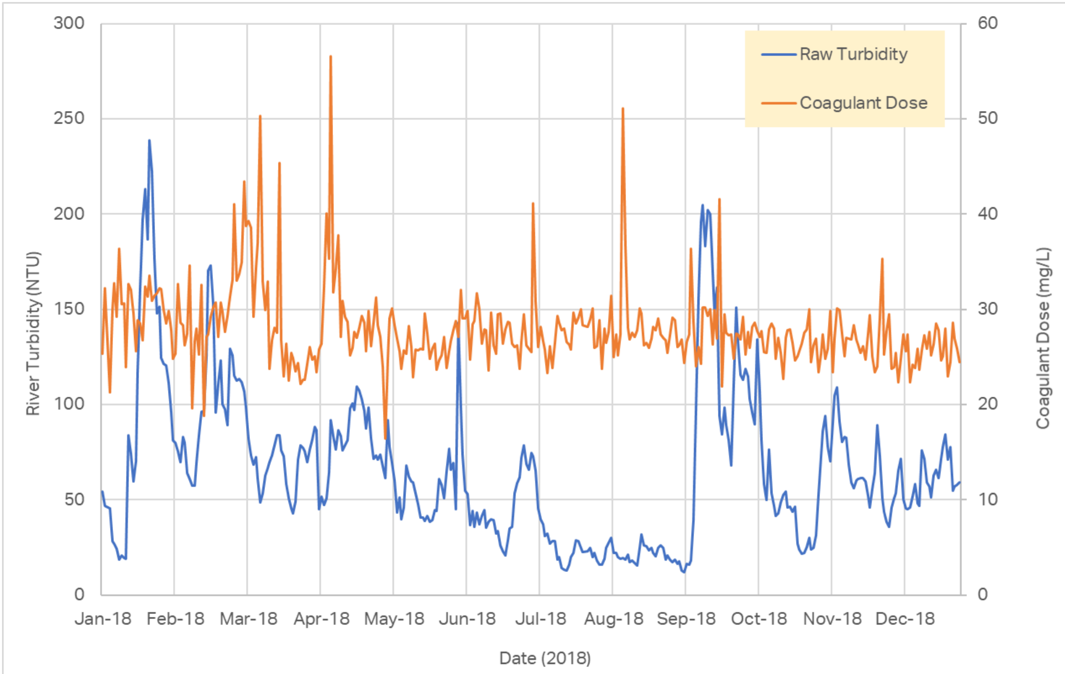


Figure 5-4 River Turbidity and Coagulant Dose

5.4.5 Ammonia

EWSU has been using chloramines since 1999 and feeds ammonia most of the year but does shut it off periodically to help prevent nitrification in the distribution system. Plant operational data indicates that EWSU fed approximately 225,000 pounds of liquid ammonia hydroxide, or aqua ammonia, from January through July of 2018 (ammonia was turned off in August that year). Assuming an effective ammonia concentration of 19% for the aqua ammonia solution, this equates to an average dosage of about 1 mg/L based on raw water flow.

5.4.6 Sodium Hydroxide

Sodium hydroxide (caustic soda) is fed to raise the pH of finished water between 7.8 to 8.0. Although a similar pH observed as the river, it is reduced through the treatment process and primarily due to the use of chlorine gas which forms hydrochloric acid in the reaction process. Sodium hydroxide can be fed at either of the following application points:

- North Plant: Downstream of the secondary sedimentation basins;
- South Plant: Downstream of the secondary sedimentation basins;

Regarding dosage, EWSU feed 25% sodium hydroxide solution and reports a total of 2.29 million pounds fed in 2018. Based on the raw water flow and chemical strength, this yields an average dosage of about 8 mg/L as chemical.

5.4.7 Fluoride

Water is fluoridated by means of hydrofluosilicic acid addition and the plant typically maintains a finished water fluoride concentration of 0.6 to 0.7 mg/L. Fluoride can be fed at any of the following application points:

- Downstream of the 6.5 million-gallon clearwell / high service pump station #3;
- Downstream of the 1.5 million-gallon clearwell / high service pump station #2.

In 2018, approximately 196,000 pounds of liquid fluoride solution were fed. Assuming an average chemical concentration of 23%, this results in a dosage of 0.64 mg/L based on finished water flow and is consistent with the reported value.

5.4.8 Sulfur Dioxide

Sulfur dioxide gas is fed to the residual outfalls for dechlorination prior to discharging to the river. Sulfur dioxide can be fed to the following outfalls upstream of the discharge point:

- Outfall 002 (south plant primary and secondary sludge)
- Outfall 005 (north plant primary and secondary sludge)
- Outfall 004 (filter backwash)

In 2018, EWSU reported a total use of 15,500 pounds of sulfur dioxide. However, an accurate estimate of the average dosage could not be established as total residuals discharge is not reliably tracked. From a mass basis, it takes approximately 0.9 parts of sulfur dioxide to dechlorinate water having 1-part free chlorine. For example, if the filter backwash chlorine residual were 3 mg/L, this would require at least 2.7 mg/L of sulfur dioxide. Additional sulfur dioxide would likely need fed to account for competing oxidation reactions.

5.4.9 Chemical Costs

Chemical costs are a significant portion of the annual operational expenses for EWSU. Coagulant accounts for most of the total chemical cost, which is often the case for surface water treatment facilities. However, it should be noted that EWSU had a considerable reduction in coagulant cost since switching to Hyper$^+$Ion® 4064. In 2016, DelPAC coagulant was used and cost EWSU $250,000 more than Hyper$^+$Ion® did in 2018. Caustic soda also accounts for a large portion of the annual chemical expense. The need to raise the pH is primarily due to feeding chlorine gas, and a significant reduction (or even elimination) in annual use would be gained if the disinfectant were switched to sodium hypochlorite. Figure 5-5 provides a breakdown of 2018's chemical expenses which totaled $1.06 million. It should be noted that no PAC was fed in 2018, although this is usually a minor expense when it is fed compared to total chemical expenses.

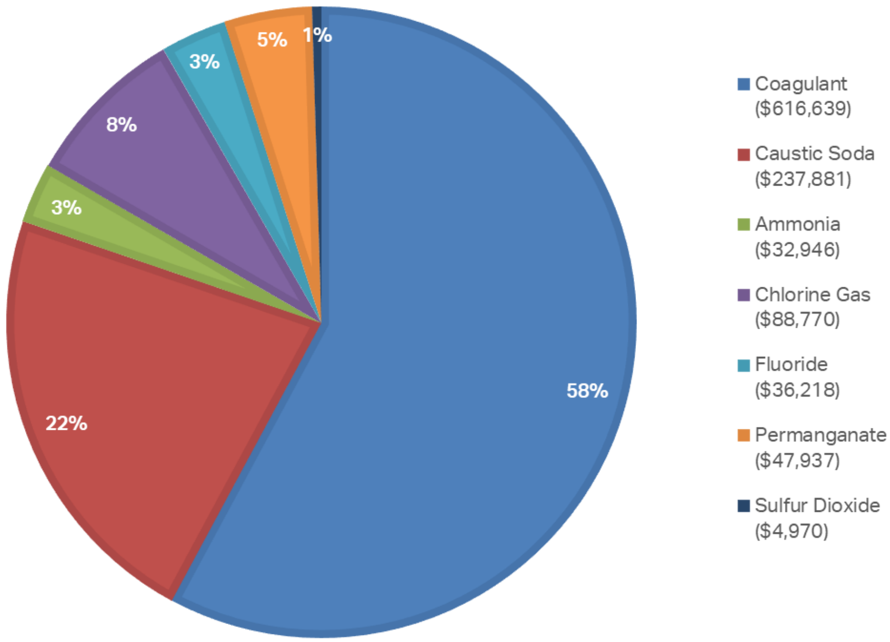


Figure 5-5 Breakdown of 2018 Chemical Expenses

5.5 Clearwells and High Service Pumps

The plant features three (3) clearwells with volumes of 0.5 MG, 1.5 MG, and 6.5 MG. Splitting of flows between these tanks is not easily controlled or tracked. All flow from filters 21-28 is diverted through the 0.5 MG clearwell below these filters and all three are hydraulically connected with a 60-inch interconnect pipe running between the 6.5 MG clearwell and a channel which connects the 0.5 and 1.5 MG tanks. IDEM gives disinfection credits for chlorination in the sedimentation basins, so the clearwells do not necessary need to be relied upon for CT. However, they do provide storage needed for 'buffering' flows either coming into the tanks from the filters or being pumped out by the high service pumps. All three tanks are in poor condition and are generally not able to be taken out of service without drastically interrupting operations. The 6.5 MG clearwell will occasionally experience turbidity spikes, which may be resultant from water intrusion from cracks our other unknow infiltration sources such as groundwater pressure relief valves.

The plant has two high service pump stations; namely high service station #2 and #3 (#1 has been abandoned). Although clearwells are hydraulically connected, station #2 effectively pulls water from the 0.5 and 1.5 MG clearwells whereas station #3 effectively pulls from the 6.5 MG clearwell. Station #2 utilizes horizontal split case pumps and station #3 features vertical turbine pumps. The condition of each pump is variable, as rebuilds or replacements have been performed in the last 20 to 30 years. Overall, it would be extremely beneficial if EWSU had better control over diversion of flows between clearwells and pump stations; and the ability to take clearwells out of service for inspection and repair.

5.6 Residuals Management

EWSU does not currently implement any advanced residuals management at the WTP facility such as thickening or dewatering. All treatment residuals, including sludge blow-down from sedimentation basins, filter backwash, and process tank drains are sent directly to the Ohio River via four (4) permitted outfalls. These are identified as Outfalls 002, 003, 004, and 005 and the residuals stream(s) corresponding to each outfall is noted below:

- Outfall 002: Sludge from the south plant primary and secondary settling basins.
- Outfall 003: Basin drain outlet which is rarely used.
- Outfall 004: Filter backwash and stormwater collected onsite.
- Outfall 005: Sludge from the north plant primary and secondary settling basins.

There is also technically an outfall at raw water intake structure, as water used to backwash screens discharges into the river.

6.0 Groundwater Supply Investigations

Numerous hydrogeological studies have been conducted for EWSU over the past decades to investigate an alternative (or supplemental) source of raw water. This includes investigating both groundwater and Riverbank Filtration (RBF) with considerations for horizontal collector and traditional vertical wells. Therefore, considerations for groundwater are included in this report. This chapter provides a brief summary of these recent investigations and implications for potential use in treatment.

6.1 Test Borings and Groundwater Production

Although original hydrogeologic studies date back over 60 years, Granite Construction (formerly Layne) conducted the most recent study between 2017 and 2019. This effort included drilling a total of 15 test borings in proximity to the WTP. The locations of these borings are shown in Figure 6-1 and follow a test bore (TB) naming convention of: "TB"(*year performed)*–(*sequential number)*.

Figure 6-1 Map of Recent Groundwater Test Bores

6.2 Groundwater Production

Borings 1 through 10 were conducted between 2017 and 2018 along Waterworks Road (south and east of the WTP). Since capacities observed at these borings were less than desired, test borings 11 through 15 were performed in 2019 adjacent to the river with the hope that higher transmissivity and yields would be observed. A summary of all 15 test borings are given in Table 6-1.

Table 6-1 Summary of Groundwater Test Bore Characteristics

Test Bore Identification	Estimated Hydraulic Conductivity (gal/day/ft^2)	Estimated Transmissivity (gal/day/ft)	Estimated Production (MGD)
TB 2017 - 1	1,400	116,000	5
TB 2017 - 2	1,600	113,000	6
TB 2017 - 3	1,400	94,000	3.4
TB 2017 - 4	1,900	101,000	3.2
TB 2017 - 5	3,800	241,000	11
TB 2017 - 6	3,000	143,000	5.3
TB 2018 - 7	500	34,000	1.6
TB 2018 - 8	2,000	90,000	2.2
TB 2018 - 9	1,600	113,000	6.2
TB 2018 - 10	Shallow Bedrock	-	-
TB 2019 - 11	1,400	110,000	6.5 to 9.8
TB 2019 - 12	1,500	111,000	6.6 to 10.0
TB 2019 - 13	1,400	116,000	6.3 to 9.5
TB 2019 - 14	980	73,000	7.3 to 11.0
TB 2019 - 15	1,200	90,000	5.5 to 8.4

Overall, the estimated production of many of the newly tested borings were not as promising as those originally performed in the 1950's. Those earlier borings estimated a single collector well in this area could yield approximately 15 MGD. Recent tests indicate that most of the wells would not reliably produce much more than 5 to 6 MGD per well. In order to achieve a WTP capacity of 50 MGD, it is estimated that at least 60 MGD would be required to account for losses through the softening and metals removal processes needed for groundwater treatment (described in the next section). As a result, approximately 10 to 12 collector wells with capacities of at least 5 to 6 MGD would be needed. Therefore, additional sites of adequate yield beyond those already tested would need to be identified. The resultant number of wells and potential distance from the WTP to achieve this becomes cost prohibitive and generally impractical. Therefore, exclusively using groundwater to meet the demands of EWSU is not considered a viable option. However, using a 50/50 blend of groundwater and surface water is further evaluated in the alternatives.

6.3 Groundwater Quality and Treatment Requirements

Water pumped from the noted test bores was analyzed for all EPA-regulated drinking water constituents with results summarized in Table 6-2, followed by a discussion of treatment requirements. The testing did include volatile organic compounds and radionucleotides. However, none of these were detected and are therefore not listed in the table. Also note that this table only pertains to wells which were identified as having higher yields (TB 2, 5, 9, 11, 12, 13, 14, 15), as collector wells of lesser capacity are not considered viable for further use in a groundwater treatment plant scenario.

Table 6-2 Groundwater Quality Data

Constituent	Units	TEST BORE ID SUFFIX								
		2	5	9	11	12	13	14	15	Avg
Tested Depth	Feet	95	95	85	95	85	60	75	75	-
Alkalinity (total)	mg/L $CaCO_3$	270	350	380	370	350	380	280	310	336
Arsenic	µg/L	8	8	ND	9	13	15	7	6	< 9
Barium	mg/L	ND	0.32	0.32	ND	ND	0.32	ND	ND	<0.2
Calcium	mg/L	120	166	149	144	141	114	84.2	101	127
Chloride	mg/L	17	43	9.6	33	29	27	14	14	23
Hardness (carb)	mg/L $CaCO_3$	270	350	380	370	350	380	280	310	336
Hardness (noncarb)	mg/L $CaCO_3$	150	240	160	150	170	60	50	60	130
Hardness (total)	mg/L $CaCO_3$	420	590	540	520	520	440	330	370	466
Iron (total)	mg/L	3.38	4.46	5.17	3.44	3.5	7.9	2.6	4.7	4.4
Magnesium	mg/L	28.5	42.5	41.1	40.2	41.4	37.5	28.0	30.0	36.2
Manganese (total)	mg/L	0.40	0.36	2.44	0.50	0.5	2.3	1.8	2.7	1.4
pH	S.U.	6.8	6.9	6.6	7.2	7.1	7.6	7.6	7.5	7.2
Total Diss. Solids	mg/L	480	700	580	620	590	490	370	400	529
Silica	mg/L	18.5	18.3	20.3	21	22	17	14	15	18
Sodium	mg/L	9	10	10	25	20	11	7	7	12
Strontium	mg/L	0.16	0.21	0.25	0.20	0.18	0.26	0.19	0.24	0.21
Sulfate	mg/L	120	200	110	130	120	40	48	49	102
LSI*	-	-0.21	+0.12	-0.18	+0.39	+0.26	+0.72	+0.47	+0.49	+0.26
Precipitation Potential*	mg/L	-29.8	+20.3	-40.8	+53.7	+36.9	+69.9	+31.9	+41.8	+23.0
Chloride to Sulfate Ratio	-	0.14	0.22	0.09	0.25	0.24	0.68	0.29	0.29	0.28

* Values reported are greatly pH dependent which may be influenced by the presence of carbon dioxide

6.3.1 Iron and Manganese Removal

Iron and manganese were both detected above the secondary drinking water MCL values (0.3 mg/L for iron and 0.05 mg/L for manganese). It should also be noted that manganese may also be under consideration for a primary MCL below 0.05 mg/L in upcoming USEPA regulations. These metals are expected to be under anoxic conditions (dissolved form) in the groundwater, which differs from the oxidized metals present in the river and requires additional treatment steps for removal. There are essentially three treatment strategies for removal of these anoxic metals as follows:

- Oxidation of the metals by means of either physical aeration or the addition of an oxidizing chemical (chlorine, ozone, permanganate) followed by up to 30 minutes of detention and filtration with a granular media;
- Chemical precipitation of metals using conventional lime and/or soda ash softening;
- Removal of metals in their anoxic state with high pressure membranes (i.e. RO or nanofiltration (NF)). However, at the elevated levels seen here, this poses risk for operation of the membrane system and would not be recommended.

6.3.2 Softening

Groundwater hardness is considerably higher than levels found in the Ohio River and are beyond what would be considered desirable. Softening would therefore be recommended for any alternative utilizing groundwater. Three common softening methods are as follows:

- Lime and/or soda ash softening. Note this process would concurrently remove iron and manganese and not require pre-filtration, but effluent from the softening clarifiers would be filtered.
- RO or NF membrane softening. For this option, it is recommended to first remove metals in an oxidation/detention/filtration process ahead of the membranes. Permeate from the membrane process would not need to be filtered.
- Ion exchange softening is an option but is done more frequently at smaller facilities. The resultant salt usage and residuals generated at EWSU would lead to this option being problematic and is not recommended.

6.3.3 Arsenic Removal

Arsenic levels above the drinking water MCL of 10 µg/L were identified in two of the wells (13 and 15 µg/L), and arsenic removal or dilution would be needed if the combination of wells feeding the plant exceeded the MCL. Arsenic can be removed via methods including enhanced conventional treatment, adsorptive media, ion exchange, or RO. However, given that surface water will be used for blending (ratio of 50:50 proposed), the final level would be maintained below the MCL with just dilution and not require a designated treatment process.

6.3.4 Other Groundwater Quality Parameters

There are additional considerations for water quality given the results of the testing. One is that silica is at elevated concentrations with an average of 18 mg/L. Although silica is not an issue from a public health perspective, it does create treatment limitations for RO or NF membranes. High levels of silica limit the recovery, and this will ultimately waste more groundwater. Removal of silica is generally not practical for RO pretreatment, and the best strategy is to feed antiscalant specifically formulated for control of silica fouling.

A second consideration are corrosion indices. These are largely dependent on pH as seen in Table 6-2 (i.e. precipitation potential of -40 at pH of 6.6 and +70 at pH of 7.6) as well as hardness. Low pH may be explained by the presence of carbon dioxide in groundwater which should be removed through aeration as a preliminary step in the process. With carbon dioxide removed, these indices are rather high and may lead to excessive scaling within pipes and pumps. The finished water would target more ideal values for these indices with the addition of softening, but there may be some risk of scaling pipes and pumps located between the wellfield and the softening process.

6.4 Groundwater Use Benefits

The constituents noted in the previous section are considered disadvantages of groundwater due to additional treatment processes. However, there would be some benefits to its use and are described in this section.

- **Reduced TOC**: Very little TOC is expected to be present in groundwater if there is limited influence from the river. The advantage of lower TOC is mitigating DPBs. With a 50/50 blend, the levels may even drop to the point where EWSU could discontinue use of chloramines.
- **Taste and Odors**: Taste and odor complaints normally stem from the presence of organic matter such as geosmin which are prevalent in surface waters. Groundwater would dilute these compounds and may therefore lessen the frequency of such customer complaints.
- **Lower Chlorine Demand**: With a reduction in organics, another benefit of the blend would be a reduction in the amount of chlorine required to maintain a given residual. This not only saves chemical costs but also further reduces the formation potential of DBPs.
- **More Stable Temperature**: Groundwater has a more stable temperature throughout the year which can have benefits including more consistent chemical reaction kinetics, possibly reducing waterline breaks caused by thermal expansion and contraction, and cooler water temperatures will help mitigate DPB formation (more prone to form in warm water).
- **Mitigate Short-Term River Contamination**: In the event of short-term river contamination via a chemical spill, agricultural runoff, or harmful algal blooms, groundwater helps mitigate these impacts. If water demand is low enough, it may be possible to utilize 100% groundwater during these events. Even with the blend of surface water, the use of groundwater will dilute any such contaminant.

7.0 Surface Water Treatment Alternatives

This Chapter presents options for improving the surface water treatment infrastructure. Rather than evaluating a fixed number of full plant alternatives, individual components are first considered, including the river intake, pretreatment, filtration, and chlorine delivery method. Alternatives are then scored based on performance criteria with final plant-wide alternatives presented in Chapter 9.

7.1 Baseline and Cost Considerations

An average daily flow of 30 MGD was utilized to estimate annual operational costs. The quantity of consumables (energy, chemicals, etc.) varies at stages in the treatment process due to water losses, and a summary of the expected flows are summarized in Table 7-1. For reference, the current plant operates at an overall recovery of about 85%. Table 7-2 presents baseline operational costs which carry through most alternatives.

Table 7-1 Baseline Plant Flows and Recovery

Parameter	Design Basis	Average Condition
Finished Water Flow	50 MGD	30 MGD
Filtration Overall Recovery	92%	92%
Settled Water Flow	54.3 MGD	32.6 MGD
Pretreatment Overall Recovery	95%	95%
Raw Water Flow	57.2 MGD	34.3 MGD
Overall Plant Recovery	87.4%	87.4%

Table 7-2 Baseline Unit Operational Costs

Parameter	Unit	Unit Cost	Notes
Electricity	kWh	$0.08	
Potassium Permanganate	Pounds	$3.00	In crystal form
PAC	Pounds	$0.60	Bulk delivery of powder
Hyperlon Coagulant	Pounds	$0.30	$0.12 / lb delivered at 40% Strength
Chlorine Gas	Pounds	$0.22	1-Ton Cylinders
12.5% Hypochlorite	Pounds	$0.81	$1.00 per gal delivered at 12.5% Strength
Food Grade Salt	Pounds	$0.19	
Liquid Oxygen	Tons	$180	
Sodium Hydroxide	Pounds	$0.36	$0.09 per lb delivered at 25% Strength
Aqua Ammonia	Pounds	$0.47	$0.09 per lb delivered at 19% Strength
Fluoride	Pounds	$0.78	$0.18 per lb delivered at 23% Strength
Sulfur Dioxide	Pounds	$0.35	

7.2 Design Considerations

Indiana is included in the Great Lakes Upper Mississippi River Board (GLUMRB or 10 State Standards). As such, design criteria as outlined in the 2018 edition of *Recommended Standards for Water Works* is used as the basis for these treatment components as applicable. There are several technologies that likely require piloting and approval through IDEM in order to establish design criteria and performance. In these cases, practical design assumptions are applied based on previous experience, existing installations, and information from manufacturers.

7.3 Alternatives Scoring

Non-monetary scoring criteria and effective weights for these alternatives were established through meetings with AECOM and EWSU. The full scoring criteria matrix and subsequent weight is presented in Table 7-3. Many alternatives do not consider every factor listed if the criteria are not applicable, in which case weights are redistributed to the included factors.

Table 7-3 Scoring Criteria Matrix

CATEGORY	CATEGORY WEIGHT	APPLIED WEIGHT	NOTES AND CONSIDERATIONS
Process Robustness	**20%**		**Needs to produce consistent water and adequately meet challenges of source water**
Turbidity Spikes	25%	5.0%	Mainly applies to pre-treatment systems ahead of filtration
Spills in the River or Recurring / Future Contaminants	30%	6.0%	Could include HABs, atrazine, other unregulated organic contaminants
Taste and Odor Control	20%	4.0%	This is a primary source of customer complaints
Organics Removal & Disinfection Byproducts	25%	5.0%	A current challenge for EWSU even with use of chloramines
Operational Considerations	**20%**		**Day-to-day operations at the facility**
Mechanical Complexity	30%	6.0%	Overall moving parts, complexity of system, ability for staff to repair in-house
Monitoring & Reporting Requirements	20%	4.0%	Instruments to calibrate and replace, operational alarms to acknowledge, regulatory reporting.
Operational "Forgiveness"	50%	10.0%	Adapt to changing water quality, flow variability, short term component downtime
Residuals & Environmental	**15%**		**Will residuals be manageable in the future, sustainability**
Residuals Quantity & Ability to Continue River Discharge	80%	12.0%	Limiting residuals and continue to discharge to the river would be major savings
Energy Use Efficiency / Greenhouse Gases	20%	3.0%	Note that energy is also accounted for in Operational Costs (hence low score weight)
Social Impacts	**15%**		**How will the public perceive the project if there are any issues after improvements**
System Resiliency: Natural Disasters or other Failures	40%	6.0%	Redundancy in treatment trains and main process equipment, limiting other failure risks
Plant or System Expandability	40%	6.0%	Can plant be easily expanded if needed to accommodate growth, will operation be similar
Distribution System Impacts	20%	3.0%	Water stability treatment requirements, water temperature consistency
Health and Safety	**15%**		**Operator safety as well as the general public**

CATEGORY	CATEGORY WEIGHT	APPLIED WEIGHT	NOTES AND CONSIDERATIONS
Health Hazards	40%	6.0%	Presence or use of highly hazardous chemicals/gasses, confined spaces
Ergonomic & Accessibility Factors	30%	4.5%	Manual labor effort, ease of access for maintenance
Truck Traffic during Operations	30%	4.5%	Resultant from additional chemical delivery, residuals hauling, future conditions, etc.
Construction Sequencing	**15%**		**Challenging construction for rehabilitation options**
Construction Layout and Sequence Ability	80%	12.%	Ability to keep plant operational during construction and minimize downtime
Retirement / Demolition of Abandoned Infrastructure	20%	3.0%	Eliminate existing infrastructure and reduce overall site footprint

7.4 River Intake Alternatives

Two alternatives for the intake are considered in this section and include rehabilitation of the existing intake and construction of a new facility.

7.4.1 River Intake Alternative 1: Rehabilitation

In this scenario, the river intake will receive major rehabilitation and continue to serve as the source of raw water. The intake facility was constructed in 1980 and appears to be in fair condition from a structural standpoint. However, the process equipment, electrical systems, HVAC, and ancillary building systems are not in good condition. EWSU performs frequent rebuilds of screens and pumps and much of this major equipment is beyond its useful life. This alternative considers a major overhaul of most of these systems while generally keeping the structure intact.

Screens: Screen are about 40 years old and are considered beyond their useful life and should be replaced. This includes full replacement of the ancillary backwash water supply piping and control valves. New control valves will feature electric operators. Due to limitations of the existing intake channel geometry, the style of the screens would need to be like the existing ones. However, there have been advancements in the design and of these types of travelling screens in the last 40 years such as an easier ability to adjust drive chain tension and eliminating sprockets or other maintenance items. Physical installation of the screens may be challenging and may need constructed in sections. EWSU has indicated that they are able to remove and replace pumps and screens using the existing AASHTO-rated bridge, and do not require a barge crane for delivery.

Pumps: The six (6) low service pumps are on a rebuild schedule of two per year, which effectively rebuilds a given pump once every three years. At this point, the pumps feature a mix of different motor manufacturers, condition of pump internals, condition and age of electrical switchgear, drives, and feeders. Two of the pumps are 480V power and on VFDs (#1and #6) and the remaining four are fixed speed drives utilizing 4160V power. It is recommended to completely replace all pumps, motors, and drives to provide consistency through the system, extend equipment life without frequent rebuilds, and improve overall operational efficiency. Use of VFDs on each pump is recommended to provide turndown, as EWSU currently has some difficulty adapting to low flows. Improvements will include controls to allow multiple pumps to run at the same hertz to avoid pumping against each other.

Valves: Most of the larger diameter valves in the lower gallery are in decent condition and can remain, although costs are included for minor rehabilitation. It is recommended to remove the upper level hydraulic control valves at the discharge of each pump and replace these with smaller footprint check and butterfly valves. The use of VFDs for all pumps also effectively eliminates the need for these hydraulic valves during pump startup/shutdown.

Piping: The large diameter piping can generally be reused but it is recommended to perform some rehabilitation including rust removal and other surface preparation and application of new coatings. This is especially the case for the more vulnerable exposed headers installed along the exterior walkway. The smaller diameter piping associated with the process water, plumbing, and chemical supplies has undergone many tie-ins over the years. It is proposed to replace all such piping to give a cleaner installation and eliminate piping no longer in use. Scope of the new small diameter piping includes:

- Plant water supply (with new backflow preventer) for raw water screen backwash routed to each screen; pump seal water routed to each pump; and for other general uses such as hose bibs;
- Potassium permanganate piping routed to each screen intake.

Potassium Permanganate System: Operation of the existing potassium permanganate system is problematic as operators must carry 55-pound containers of permanganate crystals into the intake and manually load these into a hopper. In 2018, almost 16,000 pounds of permanganate was used and equates to nearly one container per day. The feed system also has little automation or trending ability and chemical use is not easily monitored. It is recommended to completely upgrade this system and locate a new feeder onshore with solution fed to the intake. This includes a modernized and less labor-intensive loading method such as eductors or a sack feeder. Such systems would not only reduce operator physical requirements but would also provide more automation and monitoring to allow better use and benefit of the chemical.

Electrical Switchgear: Most of the electrical switchgear and related feeders are original to the intake construction and are subsequently in poor condition and non-code compliant. Pump drives also differ, with pump 1 and pump 6 on VFDs, and the remainder as constant speed. It is proposed to provide consistency across all pumps in terms of feeders and drives and utilize VFDs. The upgrades would also include added switchgear serviceability by providing at least two main power supply disconnects (for example two disconnects each feeding three pump starters). Ancillary electrical systems including transformers and local disconnects are also in poor condition and are recommended for replacement. The power supply is fed via the main plant through conduits supported from the walkway bridge, and any new cabling would be suspended from the bridge as well.

Instrumentation and Controls: With upgrades to the electrical and mechanical systems, the controls would also be replaced. This includes a new PLC at the intake and new analytical instruments for monitoring pump status. The raw water flow meters are located outside of the station and should be replaced but are not considered part of this alternative given their location. Refer to plant-wide alternatives (Chapter 9) for locations of raw water meters.

HVAC and Plumbing: Most of the intake HVAC is original to the construction and has reached the end of its useful life. It is recommended to overhaul the HVAC system and provide new exhaust fans, heaters, louvers, and replace much of the ductwork. The building space can remain without air conditioning, but all VFDs should include designated air conditioning units within their enclosure. It is also recommended to utilize mobile dehumidifier units to minimize moisture and corrosion in the building. Lastly, it is recommended to add a redundant sump pump to the lower level gallery.

Structural and Architectural: The structural condition of the intake appears to be in relatively good condition and not in need of major repairs. However, it is recommended to inspect the submerged areas for any major cracks or deficiencies and repair as needed if the intake is to be used long-term. There are some apparent deficiencies in the walkways and handrail on the entrance and side access catwalk which should receive some rehabilitation. Costs are also included to upgrade some of the architectural finishes including roof replacement, painting of interior walls, and lighting upgrades.

Dredging: In the past, river dredging has been a considerable expense to remove sand dunes building up around the screen channels. If equipment is essentially replaced in kind, dredging operations may need to continue. EWSU had indicated these dunes appeared more persistent in recent years and dredging efforts are not fully removing accumulated sediment. River dredging is a considerable expense. In Fall of 2017, EWSU received a proposal from a contractor of over $230,000 to perform dredging. However, a very large nearby boat (LST Boat) was recently moved and it is believed that this will help reduce the accumulation of sediment and lead to less dredging in the future. For the 30-year life cycle analysis, it is assumed that the river will be dredged twice over this duration.

Construction Sequencing: Downtime can be minimized given the number of available pumps and screens if replaced one at a time. A longer downtime item would be replacement of the primary electrical feeders and equipment. A potential construction challenge which could delay improvements would be the method employed for removal and installation of large equipment.

Non-Monetary Score: This alternative received a non-monetary score of 7.687 as outlined in Table 7-4.

Table 7-4 River Intake Rehabilitation Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	River Intake Does Not Address these	**NA**	0.00%
Spills in the River or Recurring / Future Contaminants	30%	River Intake Does Not Address these	**NA**	0.00%
Taste and Odor Control	20%	River Intake Does Not Address these	**NA**	0.00%

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Organics Removal & Disinfection Byproducts	25%	River Intake Does Not Address these	NA	0.00%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Screens are mechanically cleaned which adds some complexity	8	9.16%
Monitoring & Reporting Requirements	20%	Same for either alternative intake option - NA	NA	0.00%
Operational "Forgiveness"	50%	Robust system but some issues being offshore	7	15.27%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	Minimal, but screen backwash is from finished water supply discharge to river	9	18.32%
Energy Use Efficiency / Greenhouse Gases	20%	About the same for either intake option - NA	NA	0.00%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Fairly susceptible due to being offshore	6	9.16%
Plant or System Expandability	40%	Opportunity to install larger pumps	8	9.16%
Distribution System Impacts	20%	Not applicable for intake - NA	NA	0.00%
Health and Safety	**15%**			
Health Hazards	40%	Minimal - some safety consideration for travelling screens	9	9.16%
Ergonomic & Accessibility Factors	30%	Minimal - upper and lower levels easily accessed, difficulty accessing screen drives	9	6.87%
Truck Traffic during Operations	30%	No difference in truck traffic for intake options - NA	NA	0.00%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	Sequencing not major issue, but construction somewhat difficult	7	18.32%
Retirement / Demolition of Abandoned Infrastructure	20%	Minimal opportunity to eliminate aging infrastructure	5	4.58%
Total Non-Monetary Score for Alternative			**7.687**	**100%**

Estimate of Construction and Life Cycle Cost: Work associated with rehabilitation of the existing river intake structure has an estimated construction cost of approximately $6.75 million with a summary provided in Table 7-5. The 30-year life cycle cost of this system is estimated at $19,409,000 with a detailed breakdown of the estimate provided in Appendix B.

Table 7-5 Cost Estimate for River Intake Rehabilitation

Description	Estimated Cost
Demolition Work	$75,000
Roof Repair / Replacement (3,000 sf)	$60,000

Description		Estimated Cost
Doors & Hardware Rehab		$13,000
Building Finishes & Specialties		$35,000
Structure and Walkway Rehabilitation		$50,000
Process Piping and Accessories		$209,000
Pump Replacement (6 units)		$1,336,000
Intake Screens (3 units)		$1,300,000
Potassium Permanganate System (1 unit)		$400,000
HVAC Replacement (3,000 sf)		$115,000
Misc. Electrical (MCC Upgrades are Underway)		$150,000
Instrumentation		$100,000
Subtotal		**$3,843,000**
Estimating Contingency	30%	$1,152,900
Escalation to Midpoint	3%	$115,290
Construction Subtotal		**$5,111,190**
Contractor General Conditions	10%	$511,119
Contractor Overhead and Profit	12%	$613,343
Construction Contingencies	5%	$255,560
Allowance: Dredge River		$260,000
Grand Total Cost		**$6,752,000**

7.4.2 River Intake Alternative 2: New Construction

In this scenario, a new river intake is constructed with the existing facility demolished or abandoned. To avoid potential sediment accumulation, vulnerability of collision with a watercraft, and further vulnerability of suspending piping and electrical systems from the access bridge, it is recommended this new facility be located on the riverbank or slightly inland. One concept would be a concrete intake channel between the river and pumping station featuring bottom intake pipes and pneumatically cleaned screens. Other concepts may include an open channel with wet pit pumps and buried intake lines.

The original EWSU WTP had an inland pump station with multiple river intake pipes supplying water. However, flushing these intake lines to remove sediment was difficult and required a complete plant shut down to reverse the flow. The new intake would consist of a more modern design to address these issues. Conceptual drawings are provided in Appendix A as listed below, followed by a description of the components.

- Figure A1-1: New River Intake: Flow Diagram and Plan View
- Figure A1-2: New River Intake: Section View

Intake Channel: The concrete intake channel would be cut into the bank of the river and extended to provide adequate submergence over the intake screen during low flow conditions. The bottom of the channel would feature three (3) 42-inch intake pipes with a pneumatically cleaned screen. Design and construction of the intake needs to be closely coordinated with the Army Corps of Engineers to ensure the structural integrity of the bank.

Screens: A pneumatically cleaned perforated screen is proposed on the end of each intake pipe. Each screen features a dedicated 6-inch compressed air line for its backwash function with air supplied from a large receiver and dual-motor compressor located onshore.

Potassium Permanganate Feed System: Potassium permanganate would be fed at the screen to inhibit growth of zebra mussels. The location of this facility would vary depending on the selected location of the intake.

Pump Facility: Intake pipes enter a lower floor with the suction of the pump cans. The upper level floor is at grade and features six (6) vertical turbine can pumps, discharge piping and valves, air compressor, and a separate room for the electrical and controls systems. A staircase (with appropriate landings conforming to building code) would traverse the entire depth of the facility, which is anticipated to be nearly 60 feet. Pump installation and removal access would be provided by roof hatches located over each pump.

Construction Sequencing: Given new construction, down-time of existing operations would be minimal or non-existent. Depending on the plant-wide alternative selected, there may be some minimal downtime associated with tying in pump discharge piping. The more difficult and time-consuming task may be permitting and coordination with the US Army Corps of Engineers or other regulatory authorities associated with construction within the Ohio River.

Non-Monetary Score: This alternative received a non-monetary score of 8.595 as outlined in Table 7-6.

Table 7-6 River Intake New Construction Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	River Intake Does Not Address these	**NA**	0.00%
Spills in the River or Recurring / Future Contaminants	30%	River Intake Does Not Address these	**NA**	0.00%
Taste and Odor Control	20%	River Intake Does Not Address these	**NA**	0.00%
Organics Removal & Disinfection Byproducts	25%	River Intake Does Not Address these	**NA**	0.00%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Air compressor system a little less complex than mechanical screen	**9**	9.16%
Monitoring & Reporting Requirements	20%	Same for either alternative - NA	**NA**	0.00%
Operational "Forgiveness"	50%	Robust system and eliminate offshore concerns	**8**	15.27%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	No water returned to river	**10**	18.32%

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Energy Use Efficiency / Greenhouse Gases	20%	About the same for either intake option - NA	**NA**	0.00%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Located onshore and less susceptible - good amount of redundancy	**7**	9.16%
Plant or System Expandability	40%	Opportunity to install larger pumps	**8**	9.16%
Distribution System Impacts	20%	Not applicable	**NA**	0.00%
Health and Safety	**15%**			
Health Hazards	40%	Minimal - but very low-level access	**9**	9.16%
Ergonomic & Accessibility Factors	30%	Lower level requires a lot of stairs to be traversed	**6**	6.87%
Truck Traffic during Operations	30%	Not applicable for either	**NA**	0.00%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	No issues with construction, but some excessive permitting required	**9**	18.32%
Retirement / Demolition of Abandoned Infrastructure	20%	Can eliminate old infrastructure associated with raw water	**10**	4.58%
Total Non-Monetary Score for Alternative			**8.595**	**100%**

Estimate of Construction and Life Cycle Cost: Work associated with construction of a new river intake facility as shown on the drawings and described within this section has an estimated capital construction cost of approximately $12.98 million with a summary provided in Table 7-7. The 30-year life cycle cost of this system is estimated at $25,404,000 with a detailed breakdown provided in Appendix B.

Table 7-7 Cost Estimate for New River Intake Pump Station

Description	Estimated Cost
Intake Building (3,400 sf) & Structure	$1,089,000
Dredging & Subsurface Work	$350,000
Levee Foundation and Inland Earthwork	$986,000
Levee Construction	$1,000,000
COE Requirements for New Intake Structure	$500,000
Misc. Site Improvements	$25,000
Process Piping	$410,000
Valves, Meters, Etc.	$298,000
Pumps and VFD (6 units)	$1,327,000
Intake Screens (3 units)	$850,000
Potassium Permanganate System (1 unit)	$400,000
Hydroburst System (1 unit)	$137,000
Plumbing	$50,000
HVAC	$175,000
Electrical	$400,000

Description		Estimated Cost
Instrumentation & Controls		$311,000
Subtotal		**$8,308,000**
Estimating Contingency	20%	$1,661,600
Escalation to Midpoint	3%	$249,240
Construction Subtotal		**$10,218,840**
Contractor General Conditions	10%	$1,021,884
Contractor Overhead and Profit	12%	$1,226,261
Construction Contingencies	5%	$510,942
Grand Total Cost		**$12,978,000**

7.5 Pretreatment Alternatives

Pretreatment is referring to the processes ahead of filtration and consist of combinations of pre-oxidation, PAC addition, coagulation, flocculation, and sedimentation. An overview of the existing infrastructure and the evaluated technology is first presented.

Pretreatment Capacity: A raw water flow of at least 57 MGD is estimated to be needed to achieve a consistent finished water flow of 50 MGD. Since this raw water is sent through pretreatment the design flow of the system is taken as 60 MGD.

Pre-Oxidation and PAC Contact: Although pre-oxidation (with permanganate) has little benefit in alternatives utilizing ozone, it needs fed at the intake for zebra mussel control. PAC is also proposed for any alternative to give better ability to combat river contamination. The WTP does not have dedicated contact tanks for these processes. Rather, the chemicals are fed prior to mixing with contact time occurring in the flocculation and sedimentation basins or influent conduits. Although this is generally effective, it is advantageous to provide approximately 10 minutes of contact time prior to the coagulation process (420,000 gallons at the design flow).

Rapid Mixing: The north plant utilizes a conventional rapid mix chamber and mixer, whereas the south plant utilizes a static mixer in a 42-inch raw water line. Static mixing has limitations in that varied flow causes inconsistent mixing energy and are not recommended for coagulants. Therefore, if re-use of the south plant is considered, it is recommended to either replace this static mixer with an inline dynamic mixer (jet system or mechanical mixer) or construct a conventional rapid mix chamber.

Flocculation: The north plant features two parallel flocculation trains, each 3-stage (series) with one vertical flocculator per stage. Flocculation at the south plant is accomplished via two parallel reaction-type clarifiers featuring a center flocculation tank and outer sedimentation tank. 10-States recommends a minimum flocculation hydraulic retention time of 30 minutes and a flow through velocity of 0.5 to 1.5 feet per minute. Based on these standards, the maximum recommended capacity of the existing north and south flocculation basins are as follows:

- North Plant: 30 min detention time yields a flow of 28.8 MGD, although the flow through velocity is high at over 5 feet per minute due a basin width of 27 feet.

- South Plant: 30 min detention time yields a flow of 30.4 MGD (flow through velocity is not a valid calculation for a circular center-feed tank).

Sedimentation: The north and south plants have two-stage sedimentation. As noted in Chapter 5, the second stage of sedimentation adds very little benefit in terms of turbidity reduction. However, the plant is not run at capacity and if stressed to flows in excess of 50 MGD, the second stage of sedimentation may be needed. 10-States recommends a minimum sedimentation time of four (4) hours and a maximum overflow weir loading rate of 20,000 gallons per day per foot of weir length. Table 7-8 summarizes the tank capacities based on these standards.

Table 7-8 Characteristics of Existing Pretreatment Components

Basin	4-Hour Detention Time Capacity	20,000 gpd/ft Weir Loading Capacity
North Plant: Primary	15.3 MGD	16.0 MGD
North Plant: Secondary	12.5 MGD	NA*
North Plant: Combined	27.8 MGD	NA*
South Plant: Primary	20.9 MGD	15.4 MGD
South Plant: Secondary	8.9 MGD	10.6 MGD
South Plant: Combined	29.8 MGD	26.0 MGD
Total Capacity (all basins)	50.7 MGD	NA*

** North plant secondaries do not have weirs and flow exits basins via gates*

The combined capacity of all sedimentation basins is limited to approximately 50 MGD if meeting these guidelines. Although the basins could be rehabilitated and high-rated, a better solution would be retrofit basins with plate or tube settlers to reduce the required footprint and eliminate the second stage (and reduce the amount of sludge collection equipment). Stainless steel plate settlers are recommended, as tube settlers are typically PVC which will degrade when exposed to sunlight. 10-States specifies a maximum plate loading rate of 0.5 gpm/ft^2 of plate area and a settling efficiency of 80% (essentially requiring a loading 0.4 gpm/ft^2). For a 60 MGD capacity, this equates to an effective plate area of about 105,000 square feet.

Ballasted flocculation: The previous descriptions pertain to a conventional pretreatment system with the addition of plate settlers. Ballasted flocculation is being considered which utilizes a fraction of a conventional system footprint by achieving high-rate sedimentation involving recycling sludge to the process along with the addition of polymer, microsand, and coagulant. Large spikes in feed water turbidity are handled well and low turbidity in the effluent is consistently maintained. A general process illustration of a ballasted flocculation unit (Actiflo®) including component descriptions is shown in Figure 7-1.

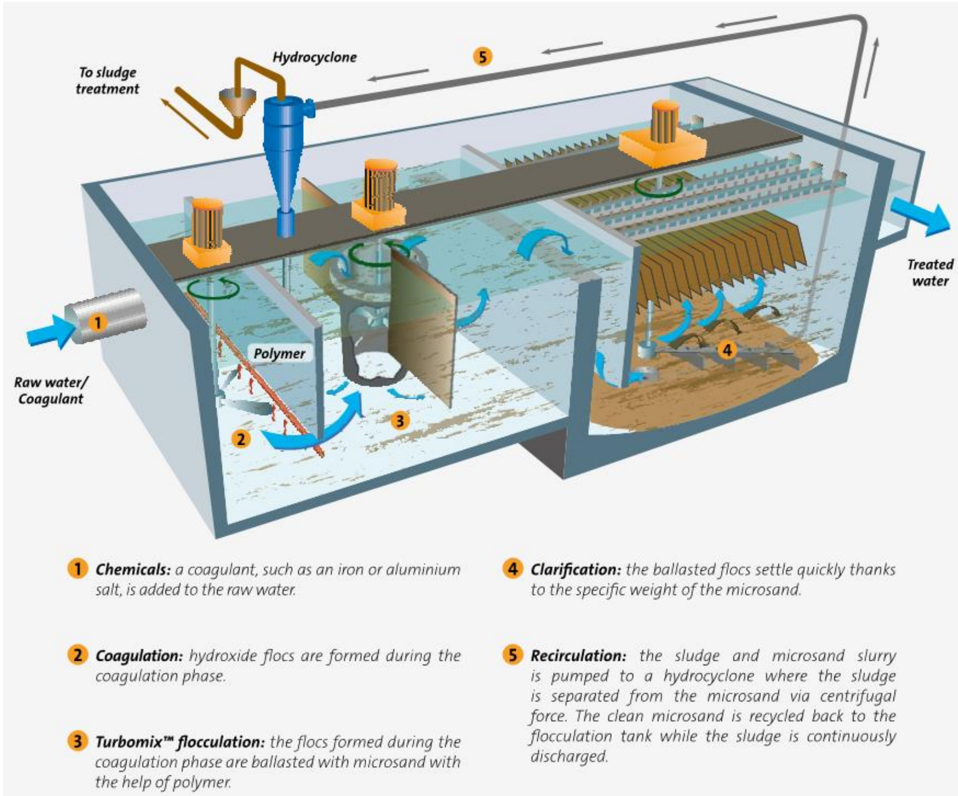


Figure 7-1 Actiflo® Ballasted Flocculation System Illustration (Source: Veolia)

Although these systems have the benefit of a small footprint and excellent turbidity reduction, there are some drawbacks. One disadvantage is the amount of additional mechanical equipment which needs to be maintained compared to a conventional system. Conventional pretreatment features rapid mixers, flocculators, and sludge collectors; whereas ballasted flocculation requires all those components plus sludge recycle pumps, a (non-mechanical) hydrocyclone and control valves to separate return and waste sludge, and additional chemical inputs of polymer and microsand. The additional chemicals fed to the system also yield higher operational costs and produce larger volumes of residual sludge compared to conventional pretreatment.

7.5.1 Pretreatment Alternative 1: Conventional with Rehabilitation

This alternative considers conventional pretreatment by upgrading existing infrastructure. The north and south plants were both evaluated for reuse, and although the south plant is a newer facility, its configuration does not lend itself well to a retrofit. However, a flow of 60 MGD can be accomplished using only the north plant pretreatment infrastructure. This will effectively leave the entire south plant site for repurposing or demolition with the available space used for future expansion or another treatment process. Reasons for not considering the use of the south plant for pretreatment are summarized below:

- The design flow can be achieved in the north plant. Eliminating the south plant for pretreatment will save considerable construction costs and ongoing maintenance efforts by minimizing the amount of equipment.
- The circular, single-stage flocculation basins have limited capacity and cannot be retrofitted for multi-stage flocculation to enhance performance. The north plant (and retrofit) uses 3-stage flocculation which can achieve better coagulation and process control.
- The circular sedimentation basins at the south plant are not ideal for retrofitting with plate settlers, which is proposed for the improvements to eliminate the secondary basins. Retrofitting the south plant with plates was evaluated, and a drawing of the retrofit is shown in Figure A2-3 of Appendix A. The length of the plate settler frame is limited due to the sludge collection system and must be installed via cantilevered supports. Doing so greatly limits the amount of capacity that can be achieved in a single basin.
- The south plant static mixer is not ideal for coagulant, and improvements would propose to replace this with a jet or mechanical mixer.
- Eliminating the south plant pretreatment process (and the north plant secondary basins) can eliminate Outfall 002 and help mitigate pending IDEM requirements to relocate all discharges further into the river.

The north plant retrofit will consist of six (6) parallel trains, each with a peak hydraulic capacity of 10 MGD. Descriptions of individual components of the system are provided in the following sections, and conceptual drawings are in Appendix A as follows:

- Figure A2-1: Conventional Pretreatment Retrofit - Overall Plan
- Figure A2-2: Conventional Pretreatment Retrofit - Enlarged Plan and Section
- Figure A2-3: South Plant Plate Settler Retrofit (Not Recommended)

Permanganate and PAC Contact: Potassium permanganate will continue to be fed for zebra mussel control and the added benefit of pre-oxidation. The upgraded plant will continue to have the ability to feed PAC ahead of pretreatment with contact time occurring in the existing tankage (no dedicated contact tank).

Influent Channel: Water pumped from the river intake will enter the existing north plant raw water channel and flow to the basins as it does now. The influent channel is located on top of the settled water channel. The channels are in poor condition and significant rehabilitation work is included for this option. This includes replacement of handrails and grating, storm discharge piping (roof gutters which currently discharge to the channel), and concrete repair. At the inlet of the sedimentation basin, partial demolition of the existing channel walls is required as illustrated on the drawings.

Rapid Mix: The existing rapid mix chamber will be demolished for installation of a new flow splitting channel between the east and west basins. Each of the six parallel trains will feature a new (concrete) 6’x6’x’6’ rapid mix chamber with a variable speed mixer and inlet gate for isolation of individual trains. Coagulant storage tanks and pumps are in relatively good condition, although most of the feed piping should be replaced with these improvements.

Flocculation: As shown on the drawings, the first stage of flocculation for each of the six parallel trains can be constructed within the existing flocculation basins. This includes cutting openings in the existing wall to feed the second stage of flocculation. The second and third stages will be inside of the existing primary settling basin and feature diffuser walls for separation. Each stage will have a vertical flocculator with variable speed drive. The basin geometry yields just over 30 minutes of hydraulic retention time at flow of 10 MGD per train.

Sedimentation and Sludge Collection: Each of the six trains will feature plate settler frames and travelling sludge collectors with drives. Each basin will house approximately 18,000 square feet of plates to maintain an effective loading below 0.4 gpm/ft^2. The effluent launders are in poor condition replacement is included with this alternative. Plate effluent collection troughs will be built into the new effluent launders, with settled water flowing out of the basins to the existing channel as it does now. The next downstream process would vary by plant-wide alternative but could include settled water flowing to the existing secondary basin as it does now for ozone contact, a new ozone basin, or the filter beds retrofitted with membrane gravity filtration. Each train will also feature a new concrete valve pit on the north end to house a sludge blow-off valve. A scum or other floatables removal system would not work with plate settlers, but such a feature could be including in the flocculation basins if desired.

General Basin Modifications: A considerable amount of work within the existing basins is needed to facilitate this alternative. To accommodate the system as shown on the drawings and described above, major modifications are summarized as follows:

- Demolishing existing infrastructure including rapid mix concrete walls, all existing mixers / flocculators and drivers, internal flocculation diffuser walls, all settling basin sludge collection drives, walkways and scraper units, effluent launder, cutting into the existing settling basin wall and launder, removal of electrical systems, and partial abandonment / plugging of sludge piping.
- Pouring new concrete inside existing basin to add divider walls between each parallel train, filling the existing sloped basins floors to achieve a level surface for sludge collection equipment, and pouring all new walls and launders.
- Installation of new structural supports (horizontal beams) for the plate settlers and equipment drives; and installation of walkway grating and handrail (generally not shown on the drawings) for operator access to all equipment.

Construction Sequencing: During construction of the retrofit, the south plant must remain fully operational. Improvements to the north basins should be performed one basin at a time, but there will inevitably be periods (possibly up to two weeks) when both north basins are inoperable due to influent channel modifications. If reliance on only the south plant is not desired during this time, temporary piping / pumping installed at ground level can be used to bypass the raw water channel while performing influent modifications.

Non-Monetary Score: This alternative received a non-monetary score of 7.169 as outlined in Table 7-9.

Table 7-9 Conventional Pretreatment Rehabilitation Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	3-stage floc, peak loading of <.4 gpm/ft2 on plates (robust for turbidity)	**8**	5.81%
Spills in the River or Recurring / Future Contaminants	30%	Minimal stand-along PAC contact time	**5**	6.98%
Taste and Odor Control	20%	Minimal stand-alone PAC and pre-oxidation contact time	**5**	4.65%
Organics Removal & Disinfection Byproducts	25%	Minimal applicability - all pretreatment options may remove some organics	**NA**	0.00%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Minimal mechanical parts and simple operation	**9**	6.98%
Monitoring & Reporting Requirements	20%	Minimal instruments / equipment to monitor	**10**	4.65%
Operational "Forgiveness"	50%	Fairly robust and can handle swings in flows	**8**	11.63%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	Very similar to current quantity/quality of residuals	**9**	13.95%
Energy Use Efficiency / Greenhouse Gases	20%	Low energy and minimal motors (with variable speeds)	**10**	3.49%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Features 6 parallel trains and minimal points of failure	**9**	6.98%
Plant or System Expandability	40%	This is maxed out at about 60 MGD and limited expansion opportunity adjacent	**4**	6.98%
Distribution System Impacts	20%	Not applicable for all pretreatment	**NA**	0.00%
Health and Safety	**15%**			
Health Hazards	40%	No health hazards for any pretreatment alternative (NA)	**NA**	0.00%
Ergonomic & Accessibility Factors	30%	Fairly accessible - does have confined area for sludge control valve	**8**	5.23%
Truck Traffic during Operations	30%	Minimal and just coagulant / PAC (as it is now)	**9**	5.23%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	Some difficulty in staging work - reliance on south plant for short periods	**3**	13.95%
Retirement / Demolition of Abandoned Infrastructure	20%	Can eliminate south pretreatment	**8**	3.49%
Total Non-Monetary Score for Alternative			**7.169**	**100%**

Estimate of Construction and Life Cycle Cost: Work associated with modifying the existing north plant to achieve up to 60 MGD of conventional pretreatment as described in this section has an estimated construction cost of approximately $13.61 million with a summary provided in Table 7-10. The 30-year life cycle cost of this system is estimated at $40,503,000 with a detailed breakdown provided in Appendix B.

Table 7-10 Cost Estimate for Conventional Pretreatment by Rehabilitation

Description		Estimated Cost
Demolition Work		$90,000
Modify Existing Structure & Services		$2,307,000
Flow Control Diffuser Wall SS 304		$347,000
Process Piping and Valves		$150,000
Coagulant Injection Improvements		$75,000
Flocculators & Mixers w/VFD (24 units)		$922,000
Plate Settlers & Sludge Collection		$3,399,000
Slide Gate w/ Operator (6 units)		$180,000
Electrical (8% Equip Cost)		$361,000
Instrumentation & Controls (5% Equip Cost)		$226,000
Subtotal		**$8,057,000**
Estimating Contingency	30%	$2,417,100
Escalation to Midpoint	3%	$241,710
Construction Subtotal		**$10,715,810**
Contractor General Conditions	10%	$1,071,581
Contractor Overhead and Profit	12%	$1,285,897
Construction Contingencies	10%	$535,791
Grand Total Cost		**$13,610,000**

7.5.2 Pretreatment Alternative 2: Conventional with New Construction

This alternative is like the pretreatment system described in the previous retrofit option but instead considers completely new construction. Since new construction would not be bound by the existing basin dimensions, the overall layout differs slightly. Rather than six parallel trains of 10 MGD, this considers four parallel trains of 15 MGD. Descriptions of components are provided in the following sections, and conceptual drawings of a new conventional pretreatment system are in Appendix A as follows:

- Figure A2-4: Conventional Pretreatment – New Construction Plan
- Figure A2-5: Conventional Pretreatment – New Construction Sections

Influent Channel: Water pumped from the river intake will enter a new influent channel (or pipe) where it can be diverted into PAC contact basins ahead of each rapid mixer. The inlet to each PAC basin is via a submerged pipe with a 36-inch isolation gate to shut off flow to an individual train.

Permanganate and PAC Contact: Potassium permanganate will continue to be fed for zebra mussel control at the intake and a designated PAC contact tank will be provided at the head of each train to provide approximately 10 minutes of contact time at design flows prior to coagulant addition. Two (2) constant-speed mechanical mixers are provided in each PAC basin for suspension of PAC, and do not need to run unless PAC is fed.

Rapid Mix: Each train features a 6.5'x6.5'x6' depth chamber with a variable speed rapid mixer. Coagulant is injected directly into the chamber to achieve adequate separation of the coagulant from the PAC contact tank.

Flocculation: Three stages of flocculation are proposed and separated by diffuser walls. Each stage features two variable speed flocculators. This layout offers a much lower flow-through velocity compared to the previous retrofit and approximately 30 minutes of flocculation time is achieved at the design flow of 15 MGD per train.

Sedimentation and Sludge Collection: Each of the four parallel trains will feature plate settlers and two (2) travelling sludge collectors with drives. Each basin will house approximately 27,000 square feet of plates to maintain an effective loading below 0.4 gpm/ft^2 at peak design flows. Settled water from the plate effluent collection troughs is directed to a new channel for final conveyance to the downstream process. Each sludge collector drive will also feature a new concrete valve pit beyond the effluent channel to house an automatic sludge blow-off valve.

Other Basin Features: As the drawings are conceptual, numerous details are not fully developed and the new pretreatment system will have additional features including:

- Basin drains via mud valves, giving the ability to drain PAC contact basins, flocculation stage basins (all three stages simultaneously through one drain) and the sedimentation basins.
- Aluminum grating and handrail spanning the basins in multiple directions for access to all mixers, gate and mud valve actuators, and sludge collection drives, including maintenance considerations for motors/gearbox and plate settler equipment. Routine plate settler maintenance typically includes lowering the basin water level and spraying down the plates and troughs. As such, easily accessible yard hydrants would be included in the design.
- A total of two control panels (2 basins controlled from a single panel) for control of mixer and flocculator speeds and sludge collection operations.

Construction Sequencing: Given this is new construction, down-time of existing operations would be minimal or non-existent. Depending on the plant-wide alternative selected, there may be some minimal downtime associated with tying the influent and effluent connections. However, coordination would be needed if the basins were constructed in the location of the existing north or south plant. Cost estimates in this section assume the basin will be constructed on a 'greenfield' site, and any additional costs for coordination and shutdowns of the existing facility are included in plant-wide alternatives.

Non-Monetary Score: This alternative received a non-monetary score of 8.959 as outlined in Table 7-11.

Table 7-11 Conventional Pretreatment New Construction Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	3-stage floc, peak loading of <.4 gpm/ft2 on plates (robust for turbidity)	**8**	5.81%
Spills in the River or Recurring / Future Contaminants	30%	Providing 10 min of PAC/pre-oxidation contact time	**9**	6.98%
Taste and Odor Control	20%	Providing 10 min of PAC/pre-oxidation contact time	**9**	4.65%
Organics Removal & Disinfection Byproducts	25%	Minimal applicability - all pretreatment options may remove some organics	**NA**	0.00%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Minimal mechanical parts and simple operation	**9**	6.98%
Monitoring & Reporting Requirements	20%	Minimal instruments / equipment to monitor	**10**	4.65%
Operational "Forgiveness"	50%	Fairly robust and can handle swings in flows	**8**	11.63%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	Very similar to current quantity/quality of residuals	**9**	13.95%
Energy Use Efficiency / Greenhouse Gases	20%	Low energy and minimal motors (with variable speeds)	**10**	3.49%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Features 4 parallel trains and minimal points of failure	**8**	6.98%
Plant or System Expandability	40%	Opportunity to add additional trains depending on construction location	**9**	6.98%
Distribution System Impacts	20%	Not applicable for all pretreatment	**NA**	0.00%
Health and Safety	**15%**			
Health Hazards	40%	No health hazards for any pretreatment alternative (NA)	**NA**	0.00%
Ergonomic & Accessibility Factors	30%	Fairly accessible - does have confined area for sludge control valve	**8**	5.23%
Truck Traffic during Operations	30%	Minimal and just coagulant / PAC (as it is now)	**9**	5.23%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	New construction - no major issues anticipated	**10**	13.95%
Retirement / Demolition of Abandoned Infrastructure	20%	Can eliminate all north and south pretreatment system/basins	**10**	3.49%
Total Non-Monetary Score for Alternative			**8.959**	**100%**

Estimate of Construction and Life Cycle Cost: Work associated with construction of a new conventional pretreatment system as shown on the drawings and described within this section has an estimated construction cost of approximately $17.38 million and a summary provided in Table 7-12. The 30-year life cycle cost of this system is estimated at $44,472,000 with a detailed breakdown provided in Appendix B.

Table 7-12 Cost Estimate for New Conventional Pretreatment

Description		Estimated Cost
Building & Structure		$2,446,000
Site Dewatering		$195,000
Foundation and Earthwork		$1,923,000
Baffle Walls		$530,000
Process Piping, Valves, Meters, Etc.		$500,000
Flocculators & Mixers w/VFD (36 units)		$1,300,000
Plate Settlers & Sludge Collection		$3,390,000
Slide Gate w/ Operator (4 units)		$118,000
Electrical (10% Equip Cost)		$481,000
Instrumentation & Controls (5% Equip Cost)		$241,000
Subtotal		**$11,124,000**
Estimating Contingency	20%	$2,225,000
Escalation to Midpoint	3%	$334,000
Construction Subtotal		**$13,683,000**
Contractor General Conditions	10%	$1,368,000
Contractor Overhead and Profit	12%	$1,642,000
Construction Contingencies	5%	$684,000
Grand Total Cost		**$17,377,000**

7.5.3 Pretreatment Alternative 3: Ballasted Flocculation with Rehabilitation

This alternative considers use of a ballasted flocculation system inside one of the existing north primary sedimentation basins. Retrofitting the south plant was not evaluated due to the circular tank geometry. Table 7-13 provides a design summary of the proposed ballasted flocculation retrofit.

Table 7-13 Ballasted Flocculation Rehabilitation

Component	North Plant
Number of Parallel Trains	4 trains
Capacity per Parallel Train	15 MGD
Design Hydraulic Capacity	60 MGD
Coagulant Tank Hydraulic Retention Time	2.2 min
Maturation Tank Hydraulic Retention Time	4.7 min
Effective Settling Loading Rate at Design Flow	30 gpm/ft^2

Descriptions of the components are provided in this section, and conceptual drawings of retrofitting a north sedimentation basin with ballasted flocculation are provided in Appendix A as follows:

- Figure A2-6: Ballasted Flocculation Retrofit Plan
- Figure A2-7: Ballasted Flocculation Retrofit Section

Influent Channel: For optimum performance, the depth of water in the basin needs to be at least 20 feet. As a result, the upstream hydraulic grade must be raised. One option is to raise channel walls, which has some impracticality due to concrete walkaways above the channel. The proposed solution is to install a new 60-inch influent pipe from the river intake. The location of the new line may be inside the existing channel or adjacent depending on obstacles. Either alignment could pose sequencing issues and this alternative likely would require temporary piping to minimize downtime. Regardless of alignment, the pipe discharge will be hydraulically split into two parallel PAC contact basins as shown on the drawings.

Permanganate and PAC Contact: Potassium permanganate will continue to be fed for zebra mussel control at the intake and retrofitting the basins with ballasted flocculation allows for adequate space upstream of the initial coagulation tank for new PAC contact. The walls of the existing basin will need raised approximately three (3) feet for the PAC basins and the basins would provide about 6 minutes of contact time at the peak design flow with average flow conditions (30 MGD) yielding about 12 minutes of contact time. Two constant-speed mechanical mixers are provided in each basin for suspension of PAC, which do not need to run unless PAC is fed.

Ballasted Flocculation System: Each train of ballasted flocculation features a coagulation tank, maturation tank, and sedimentation tank installed in the existing basin as generally depicted on the drawings and summarized in the previous design table. All new concrete floors and walls would be poured inside the existing basin to a height of approximately 22 feet to accommodate a water depth of 20 feet. Abandoned areas of the existing flocculation and sedimentation basins can be filled with compacted engineered fill to add stability to the finished surface above, or this tank could be repurposed for another use. Several mechanical components are associated with each train, including coagulation and maturation tank mixers, control valves, a sludge scrapper system, and two sludge return pumps. An auxiliary building is proposed at the effluent side of the basin to provide access to the lower level sludge return pumps and house the polymer and microsand feed systems. Delivery of the chemicals can possibly be accomplished by modifying and utilizing the existing access drive which runs along the east side of the river or by approaching the tanks from the east. The existing coagulant feed system can generally remain as is, with new piping installed and some minor equipment modifications.

Other Basin Features: As the drawings are conceptual, numerous details are not fully illustrated and the ballasted flocculation retrofit system will have additional features to better facilitate operations, including the following:

- Aluminum grating and handrail spanning the basins in multiple directions for access to all mixer drives, gates, hydrocyclones, sludge collection drives, sludge return piping and valves, etc.
- A total of two control panels (one to control two basins) for control of mixer speeds, chemical dosages, sludge return/waste rates, polymer and micro-sand feed systems, and control valves.
- Auxiliary building to house polymer and micro-sand feed systems and lower level sludge return pumps.

Construction Sequencing: The phasing of construction may have some challenges in the case of the ballasted flocculation retrofit, and the entire north plant may be out of service for a period of several weeks. One of the more challenging aspects is construction of the new influent line as it runs in the north/south direction to the basins due to conflicts. This may require a temporary line laid on grade until the ballasted flocculation system is operational, at which point the new line can be installed in its permanent location.

Non-Monetary Score: This alternative received a non-monetary score of 5.924 as outlined in Table 7-14.

Table 7-14 Ballasted Flocculation Rehabilitation Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	Ballasted flocculation very good and handling turbidity spikes	**10**	5.81%
Spills in the River or Recurring / Future Contaminants	30%	Minimal stand-along PAC contact time, limited floc time	**3**	6.98%
Taste and Odor Control	20%	Minimal stand-along PAC contact time, limited floc time	**3**	4.65%
Organics Removal & Disinfection Byproducts	25%	Minimal applicability - all pretreatment options may remove some organics	**NA**	0.00%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Fairly complex and adding pumps, extra chemical systems, sludge return equip.	**6**	6.98%
Monitoring & Reporting Requirements	20%	Some additional monitoring compared to conventional pretreatment	**8**	4.65%
Operational "Forgiveness"	50%	Does need more immediate adjustments for swings in flow / water quality	**6**	11.63%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	Increased volume of residuals and will contain more solids plus polymer	**5**	13.95%
Energy Use Efficiency / Greenhouse Gases	20%	Higher energy than conventional due to addition of recycle pumps	**5**	3.49%
Social Impacts	**15%**			

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
System Resiliency: Natural Disasters or other Failures	40%	Features 4 parallel trains, but does have more points of failure (pumps, control valves)	**6**	6.98%
Plant or System Expandability	40%	Could leave second north basin available for future expansion	**9**	6.98%
Distribution System Impacts	20%	Not applicable for all pretreatment	**NA**	0.00%
Health and Safety	**15%**			
Health Hazards	40%	No health hazards for any pretreatment alternative (NA)	**NA**	0.00%
Ergonomic & Accessibility Factors	30%	Lower level pumps and additional chemical feed systems	**6**	5.23%
Truck Traffic during Operations	30%	Adding deliveries of polymer and microsand… possibly more if residuals need disposed	**5**	5.23%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	Some difficulty in staging work - reliance on south plant for short periods	**5**	13.95%
Retirement / Demolition of Abandoned Infrastructure	20%	Can eliminate south plant pretreatment and possibly second north basin	**9**	3.49%
Total Non-Monetary Score for Alternative			**5.924**	**100%**

Estimate of Construction and Life Cycle Cost: Work associated with retrofitting the existing north basin with ballasted flocculation as shown on the drawings and described within this section has an estimated capital construction cost of approximately $19.19 million, with a summary provided in Table 7-15. The 30-year life cycle cost of this system is estimated at $58,749,000 and a breakdown of that estimate is provided in Appendix B.

Table 7-15 Cost Estimate for Pretreatment Rehabilitation w/Ballasted Flocculation

Description	Estimated Cost
Demolition Work	$90,000
Modify Existing Structure & Services	$1,854,000
Process Piping - Pretreatment	$233,000
Valves, Meters, etc. - Pretreatment	$100,000
Flocculators & Mixers w/VFD (12 units)	$110,000
Actiflo Lamella Tube Plate Settlers (4 units)	$3,662,000
Slide Gate w/ Operator (4 units)	$120,000
Sludge Handling Building (3,623 sf)	$452,000
Site Work, Pavement	$25,000
Process Piping - Sludge	$175,000
Valves, Meters, etc. - Sludge	$30,000
Sludge Pumps and VFDs (8 units)	$586,000
Chemical System Equipment	$2,704,000

Description		Estimated Cost
Plumbing		$30,000
HVAC		$91,000
Electrical (10% Equip Cost)		$732,000
Instrumentation & Controls (5% Equip Cost)		$366,000
Subtotal		**$11,360,000**
Estimating Contingency	30%	$3,408,000
Escalation to Midpoint	3%	$340,800
Construction Subtotal		**$15,108,800**
Contractor General Conditions	10%	$1,510,880
Contractor Overhead and Profit	12%	$1,813,056
Construction Contingencies	5%	$755,440
Grand Total Cost		**$19,189,000**

7.5.4 Pretreatment Alternative 4: Ballasted Flocculation with New Construction

This alternative considers a newly constructed ballasted flocculation system, which is nearly identical to the overall layout of the retrofit option. Therefore, conceptual drawings of a new ballasted flocculation system are not provided and generally mimic the previous drawings. There are, however, a few differences in this alternative which offer a better system since it is not bound by existing conditions. These revisions include the following:

- All basins are excavated and construed with earth backfill opposed to being constructed inside the existing north primary sedimentation basin.
- An open channel can be used for supply of influent water rather than piping which would need to be constructed along or inside of the existing channel. The new channel will feature inlet gates for isolation of individual trains.
- PAC contact basins can be slightly larger to yield approximately 10 minutes of contact time at the design flow.

Construction Sequencing: Given new construction, down-time of existing operations would be minimal. Depending on the plant-wide alternative selected, there may be minimal downtime associated with tying the influent and effluent connections to processes. However, if the basins were constructed in the location of the existing north or south plant pretreatment systems, considerable coordination would be needed. Cost estimates within this section assume the system will be constructed on a 'greenfield' site, and any additional costs for major coordination or partial shutdowns of the existing facility are included in plant-wide alternatives.

Non-Monetary Score: This alternative received a non-monetary score of 7.459 as outlined in Table 7-16.

Table 7-16 Ballasted Flocculation New Construction Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	Ballasted flocculation very good and handling turbidity spikes	**10**	5.81%
Spills in the River or Recurring / Future Contaminants	30%	Providing 10 minutes of PAC / pre-oxidation contact time	**9**	6.98%
Taste and Odor Control	20%	Providing 10 minutes of PAC / pre-oxidation contact time	**9**	4.65%
Organics Removal & Disinfection Byproducts	25%	Minimal applicability - all pretreatment options may remove some organics	**NA**	0.00%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Fairly complex and adding pumps, extra chemical systems, sludge return equip.	**6**	6.98%
Monitoring & Reporting Requirements	20%	Some additional monitoring compared to conventional pretreatment	**8**	4.65%
Operational "Forgiveness"	50%	Does need more immediate adjustments for swings in flow / water quality	**6**	11.63%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	Increased volume of residuals and will contain more solids plus polymer	**5**	13.95%
Energy Use Efficiency / Greenhouse Gases	20%	Higher energy than conventional due to addition of recycle pumps	**6**	3.49%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Features 4 parallel trains, but does have more points of failure (pumps, control valves)	**6**	6.98%
Plant or System Expandability	40%	Can easily be expanded with new construction	**10**	6.98%
Distribution System Impacts	20%	Not applicable for all pretreatment	**NA**	0.00%
Health and Safety	**15%**			
Health Hazards	40%	No health hazards for any pretreatment alternative (NA)	**NA**	0.00%
Ergonomic & Accessibility Factors	30%	Lower level pumps and additional chemical feed systems	**6**	5.23%
Truck Traffic during Operations	30%	Adding deliveries of polymer and microsand… possibly more if residuals need disposed	**5**	5.23%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	New construction - no major issues anticipated	**10**	13.95%
Retirement / Demolition of Abandoned Infrastructure	20%	Can eliminate all north and south pretreatment system/basins	**10**	3.49%
Total Non-Monetary Score for Alternative			**7.459**	**100%**

Estimate of Construction and Life Cycle Cost: Work associated with construction of a new ballasted flocculation system as shown on the drawings and described within this section has an estimated construction cost of approximately $24.04 million, with a summary provided in Table 7-17. The 30-year life cycle cost of this system is estimated at $63,604,000 and a detailed estimate is provided in Appendix B.

Table 7-17 Cost Estimate for New Pretreatment w/Ballasted Flocculation

Description		Estimated Cost
Pretreatment Building & Structure		$1,327,000
Site Dewatering		$195,000
Foundation and Earthwork		$1,109,000
Process Piping - Pretreatment		$233,000
Valves, Meters, etc. - Pretreatment		$100,000
Flocculators & Mixers w/VFD (12 units)		$110,000
Actiflo Lamella Tube Plate Settlers (4 units)		$3,662,000
Slide Gate w/ Operator (4 units)		$120,000
Sludge Handling Building (3,623 sf)		$452,000
Foundation, Sitework		$80,000
Process Piping - Sludge		$175,000
Valves, Meters, etc. - Sludge		$30,000
Pumps and VFDs (8 units)		$586,000
Chemical System Equipment		$2,704,000
Plumbing		$30,000
HVAC		$91,000
Electrical		$732,000
Instrumentation & Controls		$3,656,000
Subtotal		**$15,392,000**
Estimating Contingency	20%	$3,078,400
Escalation to Midpoint	3%	$461,760
Construction Subtotal		**$18,932,160**
Contractor General Conditions	10%	$1,893,216
Contractor Overhead and Profit	12%	$2,271,859
Construction Contingencies	5%	$946,608
Grand Total Cost		**$24,044,000**

7.6 Filtration Alternatives

Filtration alternatives include rehabilitation and new construction of three options: conventional filtration, biologically active filtration (BAF) with ozone, and membrane gravity filtration (MGF). For alternatives involving rehabilitation, it is important to first define the characteristics of the filter beds, which are summarized in Table 7-18. Rehabilitation of the currently abandoned filters 1-12 is not considered viable and these are not included in the table.

Table 7-18 Characteristics of Existing Filters

Filter Bay	Filter Size (ft x ft)	Surface area per Filter (ft^2)	Total Bed Depth (ft)[i]	Trough Height (ft)[ii]
13 through 20	22 x 25	550	8	5.17
21 through 28	28 x 37	1,036	12	8
29 through 32	23 x 46	1,058	11.5	7.67
33 through 36	23 x 46	1,058	11.5	7.67

i measured from top of filter bed concrete floor to top of filter bed wall
ii measured from top of filter bed concrete floor to top of wash water trough

Filter media profiles generally consist of a gravel base (estimated depth of 10 to 12 inches) with approximately 22 inches of sand and an anthracite cap of 6 to 8 inches. Underdrain styles vary throughout the filter bays and some older beds have received new Leopold underdrains within the last 10 years. The following descriptions give a brief overview of the three filtration methods evaluated in this report.

Conventional Filtration: For alternatives considering conventional filtration, very little would be fundamentally different than the current operation. Use of the newer Leopold (or equivalent) underdrains which EWSU has recently been installing can continue and media profiles would be similar. All filters would feature a filter-to-waste process (as they do now), and it is proposed to add air scour to reduce the volume of backwash water and increase overall plant water efficiency. Use of air scour can effectively replace the surface sweep feature and air scour grids can be installed without removal of filter media. For construction of new filters, media retaining underdrains are considered to eliminate the need for gravel.

Biologically Active Filtration: BAF coupled with ozone is gaining popularity throughout the United States at surface water plants due to its ability to remove organic constituents. This subsequently reduces DBP formation and other befits may include improving taste and odors, limiting the amount of chlorine needed, and removal / destruction of trace organic contaminants. Following the ozone process, BAF is like conventional filtration, with the key differences being water is unchlorinated and the media profile is different. Ideally, the profile features a small layer of sand (6 to 12 inches) and capped with a deep layer of granular activated carbon (GAC) having a depth of three (3) feet or more.

Ozone Addition for BAF: Although a filter can technically operate biologically without ozone addition, the primary benefit of organics reduction is not nearly as pronounced. Use of ozone ahead of BAF breaks larger (molecular size) compounds into smaller fractionalized compounds that are more readily consumed/removed within the BAF beds. The main components of a complete ozone system include the source of oxygen, ozone generation equipment, ozone injection system, ozone contact tanks or pipe, and the ozone destruction and quenching systems.

- **Oxygen Supply**: Oxygen needed for generation of ozone can be from ambient air or using high purity oxygen. Ambient air systems typically produce 1 to 4% by weight ozone whereas high purity oxygen feed produce 10% to 15% ozone. Given the size of the project and subsequent generators, it is recommended to utilize high purity oxygen. For high purity oxygen supply, it is recommended to utilize liquid oxygen (LOX) delivered and stored onsite opposed to onsite oxygen generation, as these systems add another layer of complication to the already-complex ozone system.

- **Ozone Generation**: There are numerous manufacturers of ozone generators and these systems are generally provided as complete equipment packages for field installation. The main components include the power supply, ozone generators, cooling water system, and nitrogen boost system. The cooling water system is assumed to be an open loop type configuration with heated water discharge sent to the river or returned to the head of the treatment process during cooler water conditions.
- **Ozone Injection**: Generated ozone can be delivered to the treatment process using bubble diffusers or dissolving the gas into a small side stream for injection into contact tanks or pipe (referred to as side-stream injection or pressurized solution feed). For EWSU, the side-stream injection method is recommended over bubble diffusion, as it maximizes transfer efficiency, alleviates issues associated with in-tank diffuser, and reduces foaming in the tank. A pilot study would typically be needed to determine ozone dosages and decay rates. However, for the purposes of this evaluation, it is proposed to inject ozone into settled water at a range of approximately 1 to 4 mg/L.
- **Ozone Contact Tanks**: After injection, detention of the ozonated water is provided ahead of filtration. A pilot study is typically performed to establish contact times, but for the purposes of this evaluation, approximately 20 minutes is proposed at the design flow. Ozone basins must be covered and sealed in order to prevent release of hazardous ozone gas and the tanks would include internal baffling to eliminate short circuiting.
- **Ozone Destruct and Quenching**: As inhalation of ozone is hazardous, air is continuously drawn from the top of the ozone basin with vacuum piping and sent to an ozone destruct system. Similarly, the presence of ozone in a BAF bed effectively inhibits biological performance, so it must be removed (quenched) ahead of the process. To do so, a reducing chemical such as sodium bisulfite or calcium thiosulfate is continuously fed to the outlet of the contact tank.

Membrane Gravity Filtration: Use of low-pressure microfiltration (MF) or ultrafiltration (UF) membranes is employed at many municipal surface water treatment plants in lieu of media filtration. Some benefits of membranes include higher log removal of cryptosporidium and giardia, consistently low (< 0.05 NTU) filtered water turbidity, and a smaller footprint than conventional filtration if operated at typical fluxes. However, the main drawback is increased operation and maintenance efforts and costs stemming from chemical cleaning, membrane fiber breaks requiring manual repair, membrane integrity testing, and high cost of membrane replacement with typical membrane life expectancies less than 10 years. Because of these reasons, a typical pressurized or vacuum driven membrane system is not proposed. Rather, the use of membrane gravity filtration (MGF) operating at lower flux is considered. Although MGF requires a larger footprint and greater number of membranes than pressurized systems, the same water quality benefits are gained. With lower flux, the benefits are infrequent chemical cleaning, low occurrence of fiber breaks, and longer membrane life.

Regarding MGF operation, it is comparable to a conventional gravity filter arrangement with the main difference being granular media is replaced with membranes. The MGF filter face piping is be like gravity filter face piping and is the reason why MGF is a good candidate for retrofitting existing beds. Although most of the process flows operate the same, the backwash waste is typically drained out the bottom of the bed rather than through upper backwash troughs. In this case, troughs are not needed to can be abandoned or removed, and part of the retrofit would include core drilling a lower-level outlet pipe and control valve to drain the bed to the waste gullet. Air scour also must be provided for MGF.

7.6.1 Filtration Alternative 1: Conventional with Rehabilitation

In this alternative, the existing filter beds and ancillary systems will be rehabilitated and essentially continue to operate as they do now. As discussed in Chapter 5, the existing filters are underloaded and rapid sand gravity filters are typically designed to operate at loading rates between 2 and 4 gpm/ft^2. Based on these typical loading rates, the potential capacities of existing filters (assuming all filters in service) is presented in Table 7-19.

Table 7-19 Potential Capacities of Existing Filters

Filter Bay	Area per Bed (ft^2)	Total Area in Bay (ft^2)	Capacity at 2 gpm/ft^2 (MGD)	Capacity at 4 gpm/ft^2 (MGD)
13 to 20	550	4,400	12.7	25.3
21 to 28	1,036	8,288	23.9	47.7
29 to 36	1,058	8,464	24.4	48.8
Total	-	21,152	61.0	121.8

It is noted that other hydraulic limitations exist within the plant which would inhibit these flows. However, from the perspective of just the filters, flows far in excess of 50-60 MGD could be achieved at rates above 2 gpm/ft^2, even considering multiple beds out of service for backwashing or maintenance. Furthermore, the design capacity can be easily met when eliminating filters 13 through 20. Since these filters are beyond their useful life and considered in too poor of condition for rehabilitation, this alternative only considers reusing filters 21 through 36. Some of these filter beds have recently received new underdrains which are proposed to remain in place as part of these improvements. Work associated with each filter bay is summarized below. Conceptual drawings are not provided for this alternative, as they would generally mimic the existing infrastructure.

Filters 1 through 12 and 13 through 20: It is proposed to demolish filters 1 through 20 and the 1.5 MG clearwell below. The upper floor could be rehabilitated if desired and would include removing piping in the lower levels and creating an upper level finished space by covering filter beds with a concrete slab. Most of the interior wall paint contains lead and remedial costs are expected. Possible uses of this space include new chemical feed, maintenance or storage area, control and records room, laboratory, offices, locker rooms, or break rooms. Costs presented in this alternative do not consider renovation of the final space, but such costs are included in plant-wide alternatives.

Filters 21 through 28: These south plant filters were commissioned in 1970 but have undergone improvements over the decades. Beds which have received new underdrains and media within the last 15 years include filters 21, 23, 24, 27, and 28. Nearly all valves, actuators, and controls were replaced in 2008 and are not considered at the end of their useful life. Filter to waste piping was also added in the late 1990s and is still in good condition. Proposed improvements in this filter bay include the following:

- Remove and replace approximately 90 cubic yards of gravel, 215 cubic yards of filter sand and 58 cubic yards of anthracite in existing filters 22, 25, and 26.
- Demolish old underdrains and install approximately 3,108 square feet of new underdrains in filter beds 22, 25, and 26.
- Although filter-to-waste piping is in good condition, it is recommended to rehabilitate all other piping by means of surface preparation to remove rust and old coatings, followed by application of a corrosion resistant primer and a high-performance coating system.
- Replacement of individual filter effluent and combined effluent turbidimeters.
- Replacement of individual filter effluent flow meters.
- Walls in the lower gallery need rehabilitation including concrete and crack repair, new waterproofing, and coatings. There is a bulge in the existing west wall will need to be addressed by means of grout fill and anchoring.
- Electrical improvements in the lower level are proposed to provide better support and alignment for wiring and conduits.
- The HVAC system in this building needs completely replaced with a more modern system.
- Existing filters include non-structural aluminum store-front type windows to ‘encase’ the filter beds in the upper level to provide better humidity control. The store-front enclosures should be retained as part of filter rehabilitation.
- Miscellaneous building improvements including new coatings in the upper level walls and ceilings, replacement of lighting systems, and replacement of minor architectural features such as corroded door hardware.
- Improvements to the clearwell associated with these filters would also be proposed but is not included in this section and is discussed in sections evaluating clearwells.

Filters 29 through 32: These north plant filters and ancillary systems are in relatively poor condition and need rehabilitation. Recent improvements include new underdrains and media in filter 29, and replacement of all valves, actuators, and controls in 2008. The work considered for these filters includes the following:

- Remove and replace approximately 90 cubic yards of gravel, 215 cubic yards of filter sand and 65 cubic yards of anthracite in existing filters 30, 31, and 32.
- Demolish old underdrains and install approximately 3,174 square feet of new underdrains in filter beds 30, 31, and 32.
- Rehabilitate filter to waste piping and control valves. This would be like the retrofit previously performed at filters 21 through 28.

- All piping in the lower gallery is in poor condition and needs robust restoration including surface preparation and application of a high-performance coating. Nuts, bolts, and washers on flanged fittings are corroded and should be replaced. Further inspection of piping would likely lead to replacement of some fittings, and additional cost to account for this is included.
- Replacement of individual filter effluent and combined effluent turbidimeters.
- Replacement of individual filter effluent flow meters.
- Walls in the lower gallery are in very poor condition, bowing, and even have leaks from the filter bed into the gallery. These walls need major concrete and crack repair, new waterproofing, and coatings.
- Electrical improvements are proposed in the lower level to provide better support and alignment for wiring and conduits.
- The HVAC system needs completely replaced with a more modern system.
- Provisions for better humidity control will be performed by construction of new non-structural walls to 'encase' the filter beds. These would be primarily aluminum store-front type windows like those installed in other filters. However, the upper area requires carpentry or other specialty insulation to avoid the ceiling trusses.
- Miscellaneous building improvements including new coatings in the upper level walls and ceilings (ceiling is heavily rusted), replacement of lighting systems, and replacement of minor architectural features such as corroded door hardware.

Filters 33 through 36: Filters 33 and 34 were added to the north plant in the late 1990s and filters 35 and 36 were constructed in 2007. The filters therefore feature newer underdrains and controls and the existing infrastructure is in good condition. The building HVAC is also adequate compared to other bays and beds are enclosed to minimize humidity. For these filter bays, very little work is proposed other than minor piping touch-up in rusted areas.

Construction Sequencing: Sequencing of construction would require some coordination. To minimize impacts, it is proposed to limit the number of filter beds out of service for rehabilitation. Although this extends the construction schedule and adds some cost, the flexibility is needed to ensure continued operation.

Non-Monetary Score: This alternative received a non-monetary score of 6.601 as outlined in Table 7-20.

Table 7-20 Conventional Filtration Rehabilitation Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	Mainly dependent on pretreatment, but least capable of the 3 filter options	**7**	5.32%
Spills in the River or Recurring / Future Contaminants	30%	No real ability provided with conventional filters	**1**	6.38%
Taste and Odor Control	20%	No real ability provided with conventional filters	**1**	4.26%

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Organics Removal & Disinfection Byproducts	25%	No real ability provided with conventional filters	**1**	5.32%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Very Simple - Least Complex of the 3	**10**	6.38%
Monitoring & Reporting Requirements	20%	Limited need for monitoring and reporting - turbidity monitoring	**9**	4.26%
Operational "Forgiveness"	50%	Robust and forgiving - handles swings in flow but not water quality	**8**	10.64%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	No change from current process	**10**	12.77%
Energy Use Efficiency / Greenhouse Gases	20%	Very low energy	**9**	3.19%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Robust system with limited points of failure - same for all filter evaluations (NA)	**NA**	0.00%
Plant or System Expandability	40%	Can add additional filters but would have another 'bay' located elsewhere	**4**	6.38%
Distribution System Impacts	20%	No improvements for disinfection byproducts in system	**5**	3.19%
Health and Safety	**15%**			
Health Hazards	40%	No outstanding issues	**10**	6.38%
Ergonomic & Accessibility Factors	30%	Easily accessed, some limitations by modifying ex. pipe galleries	**9**	4.79%
Truck Traffic during Operations	30%	No chemical deliveries for conventional Filtration	**10**	4.79%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	Must limit to 1 or 2 filters at a time, long construction duration - some tie-in issues	**4**	12.77%
Retirement / Demolition of Abandoned Infrastructure	20%	Eliminating filters 13-20	**5**	3.19%
Total Non-Monetary Score for Alternative			**6.601**	**100%**

Estimate of Construction and Life Cycle Cost: Work associated with rehabilitating filters described within this section has an estimated construction cost of approximately $17.12 million, with a summary provided in Table 7-21. The 30-year life cycle cost of this system is estimated at $29,038,000 with a detailed breakdown provided in Appendix B.

Table 7-21 Cost Estimate for Conventional Filter Rehabilitation

Description	Estimated Cost
Demolition & Media Removal	$732,000
Filters 21-28 Concrete Repair	$81,000
Filters 29-32 Concrete Repair	$450,000

Description		Estimated Cost
Pipe Resurfacing & Paint Finishes		$524,000
Pipe Replacement		$238,000
Filtration Equipment, Media & Valves		$3,100,000
Storefront Walls (Filters 29-32) & Arch. Improvements		$551,000
Air Scour Grids		$1,440,000
Air Scour Blowers (4 ea.)		$850,000
HVAC Improvements		$880,000
Electrical & I&C Improvements		$1,292,000
Subtotal		**$10,138,000**
Estimating Contingency	30%	$3,041,400
Escalation to Midpoint	3%	$304,140
Construction Subtotal		**$13,483,540**
Contractor General Conditions	10%	$1,348,354
Contractor Overhead and Profit	12%	$1,618,025
Construction Contingencies	5%	$674,177
Grand Total Cost		**$17,125,000**

7.6.2 Filtration Alternative 2: Conventional with New Construction

A new conventional filtration system is considered here which would provide one centralized filter building rather than multiple filter bays. This would facilitate operational improvements including a better flow balance to filters and clearwells, minimizing the number of chemical feed injections, minimizing the number of control panels and other instrumentation, and generally 'clean up' the site with less buried utilities for chemical, electrical, and control systems. The system would also provide a consistent filter design spanning all filters giving commonality amongst valve sizes, process pipes or channels, types of instruments and controls, filtration and backwash rates, etc. For conceptual design purposes, the geometry of the filter beds would match that of existing filter beds 33 through 36. Conceptual drawings of the new filter system are provided in Appendix A as follows:

- Figure A3-1 Conventional Filtration Conceptual Plan Process Flow Diagram
- Figure A3-2 Conventional Filtration Conceptual Plan Lower Level
- Figure A3-3 Conventional Filtration Conceptual Building Upper Level Plan

The design summary of a conceptual new filtration system is provided in Table 7-22, followed by a list of the key components and features.

Table 7-22 Design Summary of New Conventional Filters

Filter Component	Units	Value
Number of Filters	Each	12
Filter Bed Width (Each)	Feet	46

Filter Component	Units	Value
Filter Bed Length (Each)	Feet	23
Filter Surface Area (Each)	Each	1,058
Total Design Flow	MGD	50
Loading w/ all Filters in Service @ Design Flow	gpm/ft^2	2.73
Loading w/ 1 Filter out of Service @ Design Flow	gpm/ft^2	2.98
Loading w/ 2 Filters out of Service @ Design Flow	gpm/ft^2	3.28
Loading w/ 3 Filters out of Service @ Design Flow	gpm/ft^2	3.65
Loading w/ 4 Filters out of Service @ Design Flow	gpm/ft^2	4.10
Underdrain Style	-	Media Retaining
Filter Sand Depth	Inches	22
Filter Anthracite Depth	Inches	8

- 12 new filter beds matching the geometry of existing filters 33-36 and arranged in four parallel bays of three filters per bay.
- Upper level of filters enclosed in a glass storefront window for humidity control.
- Lower piping gallery with all valves and piping. Electrically operated butterfly valves associated with each filter includes (1) 20-inch influent valve, (1) 24-inch wash water outlet valve, two (2) 24-inch valves for common effluent and wash water supply, one (1) 16-inch effluent control valve, (1) 12-inch filter to waste outlet valve, and one (1) 6-inch air supply valve.
- A new 26,000 square foot filter building with associated mechanical, electrical, and plumbing systems.
- 12,696 square feet of filter underdrains; approximately 940 cubic yards of filter sand; and 235 cubic yards of anthracite media.
- Three (3) 250 HP positive displacement blowers to facilitate air scour. The blowers are sized such that one blower can perform air scour of one filter bed.
- Four filter control panels.
- Instruments for each filter including a level transmitter, turbidimeter, and flow meter.
- A new clearwell is not specifically included with this alternative but consideration for clearwell(s) is provided in any plant-wide alternative.

Construction Sequencing: Given that these are newly constructed filters, down-time of existing facilities would be limited. Depending on the plant-wide alternative, there may be minimal downtime associated with tying in connections. However, if the filters were constructed in the location of existing infrastructure, coordination would be needed with demolition of such areas. Costs for this alternative assume the filters will be constructed on a 'greenfield' site, and any additional costs for major coordination or partial shutdowns of the existing facility are included in plant-wide alternatives.

Non-Monetary Score: This alternative received a non-monetary score of 8.000 as outlined in Table 7-23.

Table 7-23 Conventional Filtration New Construction Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	Mainly dependent on pretreatment, but least capable of the 3	**7**	5.32%
Spills in the River or Recurring / Future Contaminants	30%	No real ability provided with conventional filters	**1**	6.38%
Taste and Odor Control	20%	No real ability provided with conventional filters	**1**	4.26%
Organics Removal & Disinfection Byproducts	25%	No real ability provided with conventional filters	**1**	5.32%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Very Simple - Least Complex of the 3 options	**10**	6.38%
Monitoring & Reporting Requirements	20%	Limited need for monitoring and reporting - turbidity monitoring	**9**	4.26%
Operational "Forgiveness"	50%	Robust and forgiving - easily handles swings in flow but not water quality	**9**	10.64%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	No change from current process	**10**	12.77%
Energy Use Efficiency / Greenhouse Gases	20%	Very low energy	**9**	3.19%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Robust system with limited points of failure - same for all filter evaluations (NA)	**NA**	0.00%
Plant or System Expandability	40%	Can leave room for additional filters in same bay	**9**	6.38%
Distribution System Impacts	20%	No improvements for disinfection byproducts in system	**5**	3.19%
Health and Safety	**15%**			
Health Hazards	40%	No outstanding issues	**10**	6.38%
Ergonomic & Accessibility Factors	30%	Easily accessed, no considerable issues	**10**	4.79%
Truck Traffic during Operations	30%	No chemical deliveries for conventional Filtration	**10**	4.79%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	New construction	**10**	12.77%
Retirement / Demolition of Abandoned Infrastructure	20%	Eliminates all old filters	**10**	3.19%
Total Non-Monetary Score for Alternative			**8.000**	**100%**

Estimate of Construction and Life Cycle Cost: Work associated with construction of a new conventional filtration system as shown on the drawings and described within this section has an estimated construction cost of approximately $31.60 million, with a summary provided in Table 7-24. The 30-year life cycle cost of this system is estimated at $39,127,000 with a detailed breakdown provided in Appendix B.

Table 7-24 Cost Estimate for New Conventional Filtration

Description		Estimated Cost
Filter Building and Structure (25,300 sf)		$5,214,000
Site Dewatering		$213,000
Foundation and Earthwork		$2,081,000
Process Piping		$2,800,000
Valves, Meters, Etc.		$1,666,000
Hoists & Cranes		$147,000
Filtration Equipment (12 units)		$4,820,000
Plumbing		$102,000
HVAC		$911,000
Air Scour Blowers		$850,000
Electrical		$925,000
Instrumentation & Controls		$480,000
Subtotal		**$20,209,000**
Estimating Contingency	20%	$4,041,800
Escalation to Midpoint	3%	$606,270
Construction Subtotal		**$24,857,070**
Contractor General Conditions	10%	$2,485,707
Contractor Overhead and Profit	12%	$2,982,848
Construction Contingencies	5%	$1,242,854
Grand Total Cost		**$31,569,000**

7.6.3 Filtration Alternative 3: Ozone & Filtration with Rehabilitation

Given the depth limitations, an effective BAF operation could not be achieved in the existing beds. However, there are still benefits of adding ozone and this alternative considers such an option. Therefore, for the improvements described in the conventional filtration rehabilitation alternative are virtually the same including costs, and this section focuses on the ozone system. The rehabilitated filters could technically be operated biologically but may have minimal benefit. Since this alternative considers rehabilitation of existing infrastructure, it is proposed to utilize the north plant secondary sedimentation basins as the ozone contact tanks. Descriptions of the components are provided in this section, and conceptual drawings of the ozone system are in Appendix A as follows:

- Figure A3-4: Conceptual Ozone System Process Flow Diagram
- Figure A3-5: Conceptual Ozone System Retrofit Overall Plan
- Figure A3-6: Conceptual Ozone System Retrofit Section
- Figure A3-7: Conceptual Ozone System LOX System Plan

Ozone Generation System: The ozone generation building would consist of mostly new construction, although there may be an opportunity to reuse an existing building. The system would feature two generators whose total production could provide a transferred dose of 3 to 4 mg/L of ozone at a flow of 50 MGD. The exact size of the generators is not identified at this time, as equipment manufacturers offer different capacities for their standard models. The system is not designed for full redundancy, as it is not proposed for disinfection. Other components of the ozone generation system (shown on the drawings) include liquid oxygen (LOX) storage tanks and vaporizers, a nitrogen boost system, equipment for control and monitoring of gas flow and pressure, generator cooling water equipment, ozone destruct units, sampling stations, and power supply units. The LOX system is shown as a separate drawing from the ozone generation building, although it would ideally be near the generators to minimize piping runs. The final location of the LOX system would ultimately depend on the ability for delivery trucks to reach the storage tanks.

Ozone Delivery and Contact System: Settled water from the pretreatment basins would flow by gravity to ozone contact basins. For this rehab option, it is proposed to utilize the existing secondary basins at the north plant. Although these will require substantial rehabilitation, only basins #1 is needed for contact time. Work associated with rehabilitation includes installation of new concrete on walls and slabs to add structural integrity and protect rebar from oxidation, installation of new gas-tight manways, reinforcing the existing columns, extending existing baffle walls to separate the tank into two (2) basins, addition of new baffles, addition of sample piping, new ozone quench chemical feed systems, ozone injectors, foam suppression spray, and air piping with ozone destruct units. Adjacent basins #2 through 5 will be abandoned and are proposed to be modified to support the building housing ozone equipment. Modifications include removal of the existing top slabs, filling the basins with engineered fill to support a new concrete slab at grade level, and constructing the new ozone building.

Construction Sequencing: Construction of this alternative would be challenging. The secondary sedimentation basins need bypassed for the entire construction duration which might pose some short-term coordination issues. However, discontinuing use of these basins is not expected to pose as a treatment issue. Filter construction sequencing is not considered a major obstacle if beds are rehabilitated one or two at a time.

Non-Monetary Score: This alternative received a non-monetary score of 7.218 as outlined in Table 7-25.

Table 7-25 Ozone and Filtration Rehabilitation Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	Mainly dependent on pretreatment, some ozone benefit	**8**	5.32%
Spills in the River or Recurring / Future Contaminants	30%	Ozone can mitigate most organics, not full benefit without BAF	**9**	6.38%
Taste and Odor Control	20%	Ozone is excellent at controlling T&O	**10**	4.26%

Organics Removal & Disinfection Byproducts	25%	Not significant without proper BAF conditions, some destruction	**6**	5.32%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Ozone system relatively complex	**7**	6.38%
Monitoring & Reporting Requirements	20%	Some additional monitoring of ozone system	**9**	4.26%
Operational "Forgiveness"	50%	Like gravity filters but some risk of ozone overfeeds, etc.	**9**	10.64%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	No change from current process	**10**	12.77%
Energy Use Efficiency / Greenhouse Gases	20%	Relatively high energy consumption	**6**	3.19%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Robust system with limited points of failure - same for all filter evaluations (NA)	**NA**	0.00%
Plant or System Expandability	40%	Limited ability to expand ozone or filters with plant retrofit	**3**	6.38%
Distribution System Impacts	20%	No major improvements, possible ozone byproducts	**6**	3.19%
Health and Safety	**15%**			
Health Hazards	40%	Ozone gas is a slight safety concern	**8**	6.38%
Ergonomic & Accessibility Factors	30%	Easily accessed, no considerable issues other than infrequent basin access	**9**	4.79%
Truck Traffic during Operations	30%	Liquid oxygen delivery requirement	**8**	4.79%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	Difficult rehabbing secondary basin, converting filters slowly	**3**	12.77%
Retirement / Demolition of Abandoned Infrastructure	20%	Eliminating filters 13-20, re-using secondary basins	**4**	3.19%
Total Non-Monetary Score for Alternative			**7.218**	**100%**

Estimate of Construction and Life Cycle Cost: Work associated with construction of a new ozone building and LOX system, retrofitting the existing north secondary sedimentation basins for ozone contact, and rehabilitating gravity filters as shown on the drawings and described within this section has an estimated capital cost of approximately $34.06 million, with a summary provided in Table 7-26. The 30-year life cycle cost of this system is estimated at $51,306,000 with a detailed breakdown is provided in Appendix B.

Table 7-26 Cost Estimate for Ozone and Filter Rehabilitation

Description	Estimated Cost
Rehab North Secondary Basins	
Demolition Work	$309,000
Basin Modifications	$897,000

Description		Estimated Cost
Ozone Corrosion Additives		$100,000
Basin Abandon, Structural Backfill		$543,000
Process Piping		$100,000
Access Hatches (8 units)		$120,000
Ozone Facility		
Building Structure (5,712 sf)		$365,000
Process Piping		$299,000
Sampling System (pumps, piping, Analyzers)		$100,000
Valves, Meters, etc.		$155,000
Ozone System, quench, destruct (2 units)		$4,498,000
Plumbing (5,740 sf)		$75,000
HVAC (5,740 sf)		$259,000
Electrical		$900,000
Instrumentation & Controls (5 % Equip Cost)		$225,000
LOX Equipment		
Equipment Pad (1,462 sf)		$35,000
Misc. Site and Access Improvements		$25,000
Process Piping		$29,000
Valves, Meters, etc.		$42,000
LOX Vaporizer, Tank, Station (2 units)		$891,000
Electrical (5% Equip Cost)		$45,000
Instrumentation & Controls (1.5% Equip Cost)		$14,000
Filter Rehabilitation Base Cost		$10,138,000
Subtotal		**$20,164,000**
Estimating Contingency	30%	$6,049,200
Escalation to Midpoint	3%	$604,920
Construction Subtotal		**$26,818,120**
Contractor General Conditions	10%	$2,681,812
Contractor Overhead and Profit	12%	$3,218,174
Construction Contingencies	5%	$1,340,906
Grand Total Cost		**$34,060,000**

7.6.4 Filtration Alternative 4: Ozone & BAF with New Construction

The filter design in this alternative is nearly the same as presented in the new conventional filtration option with the difference being a deeper bed media profile. In this case, filters feature media retaining underdrains, 6 inches of sand, and 36 inches of GAC. Since operation of the filters are nearly the same as previously presented, this section focuses on the new ozone basins and delivery system. Conceptual drawings of the ozone system are in Appendix A as follows:

- Figure A3-8: Conceptual New Ozone System: Lower Level Plan
- Figure A3-9: Conceptual New Ozone System: Upper Level Plan
- Figure A3-10: Conceptual New Ozone System: Section

Note the ozone process flow diagram (Figure A3-4) and the LOX system overall plan (Figure A3-7) would be the same as those presented in the previous retrofit alternative.

Ozone Generation System: The ozone generation system would consist of a new building to house all components. The system would feature two generators whose total production could provide a transferred dose of 3 to 4 mg/L of ozone at a flow of 50 MGD. The system is not intended for disinfection credits, and therefore does not require full redundancy. Other components of the generation system include LOX storage tanks and vaporizers, a nitrogen boost system, equipment for control and monitoring of gas flow and pressure, cooling systems, sampling stations, and ancillary equipment.

Ozone Delivery and Contact System: Settled water from the pretreatment basins would flow to two ozone contact basins. Ozone would be fed using a side-stream injection at the head of the basins. Each basin has a volume of at least 350,000 gallons to yield a contact time of 20 minutes at design flows. Basin concrete construction would feature a crystalline admixtures and use of epoxy coated rebar to inhibit impacts of residual ozone. The interior of the basin would feature baffling, ozone injectors, quenching chemical injectors, foam suppression, and sample piping ports. Other features include a center injection and sampling pipe gallery between basins and a multi-level building housing ozone generators, process water pumps, and destruct units. Carrier water for the side stream injection and cooling water could be pulled from filter effluent or settled water channels. It is proposed to locate the LOX system adjacent to the new ozone facility.

Construction Sequencing: With new construction, downtime of existing facilities would be minimal although some may be experienced depending on the overall layout and sequencing of the entire plant. However, if the filters or ozone building were constructed in the location of existing infrastructure, considerable coordination would be needed. Costs for this alternative assume all infrastructure will be constructed on a 'greenfield' site, and any additional costs for major coordination or partial shutdowns of the existing facility are included in plant-wide alternatives.

Non-Monetary Score: This alternative received a non-monetary score of 9.027 as outlined in Table 7-27.

Table 7-27 Ozone and Biologically Active Filtration New Construction Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	Mainly dependent on pretreatment, some ozone benefit, deeper filter bed	**9**	5.32%
Spills in the River or Recurring / Future Contaminants	30%	Ozone can mitigate most organics, BAF has added benefit too	**10**	6.38%
Taste and Odor Control	20%	Ozone is excellent at controlling T&O	**10**	4.26%

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Organics Removal & Disinfection Byproducts	25%	Good removal of TOC	**10**	5.32%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Ozone system relatively complex	**7**	6.38%
Monitoring & Reporting Requirements	20%	Some additional monitoring of filter growth, ozone system	**8**	4.26%
Operational "Forgiveness"	50%	Like gravity filters but some risk of ozone overfeed, etc.	**8**	10.64%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	No change from current process	**10**	12.77%
Energy Use Efficiency / Greenhouse Gases	20%	Relatively high energy consumption	**6**	3.19%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Robust system with limited points of failure - same for all filter evaluations (NA)	**NA**	0.00%
Plant or System Expandability	40%	Easily expandable with new construction	**10**	6.38%
Distribution System Impacts	20%	Do have disinfection byproduct improvement, possible ozone byproducts	**9**	3.19%
Health and Safety	**15%**			
Health Hazards	40%	Ozone gas is a slight safety concern	**8**	6.38%
Ergonomic & Accessibility Factors	30%	Easily accessed, no considerable issues other than infrequent basin access	**9**	4.79%
Truck Traffic during Operations	30%	Liquid oxygen delivery requirement	**8**	4.79%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	Difficult rehabbing secondary basin, converting filters slowly/long construction	**10**	12.77%
Retirement / Demolition of Abandoned Infrastructure	20%	Eliminating considerable infrastructure	**10**	3.19%
Total Non-Monetary Score for Alternative			**9.027**	**100%**

Estimate of Construction and Life Cycle Cost Work associated with construction of the new ozone system and BAF facility has an estimated construction cost of $53.63 million, with a summary provided in Table 7-28. The 30-year life cycle cost of this system is estimated at $67,424,000 with a detailed breakdown provided in Appendix B.

Table 7-28 Cost Estimate for New Ozone and BAF System

Description	Estimated Cost
Ozone Facility w/ Contact Basins	
Site Dewatering	$213,000

Description		Estimated Cost
Ozone Contact Basins		$2,524,000
Access Hatches (8 units)		$120,000
Foundation and Earthwork		$1,502,000
Building Structure (7,834 sf)		$497,000
Process Piping		$377,000
Sampling System (pumps, piping, Analyzers)		$100,000
Valves, Meters, etc.		$155,000
Ozone System, quench, destruct (2 units)		$4,498,000
Plumbing		$75,000
HVAC		$353,000
Electrical		$900,000
Instrumentation & Controls (5% Equip Cost)		$225,000
LOX Equipment Base Cost		$1,081,000
BAF System Base Cost		$21,709,000
Subtotal		**$34,329,000**
Estimating Contingency	20%	$6,865,800
Escalation to Midpoint	3%	$1,029,870
Construction Subtotal		**$42,224,670**
Contractor General Conditions	10%	$4,222,467
Contractor Overhead and Profit	12%	$5,066,960
Construction Contingencies	5%	$2,111,234
Grand Total Cost		**$53,626,000**

7.6.5 Filtration Alternative 5: MGF with Rehabilitation

In this alternative, a portion of the existing filter beds are retrofitted with MGF. Like the other filter rehabilitation alternatives, filters 13-20 will be discontinued. MGF offers a reduction in footprint compared to conventional filtration, and additional filters can be decommissioned. Since filters 29-32 are in the worst condition, it is proposed to discontinue their use. Overhead space in all filter buildings is limited and it is not considered viable to provide an overhead crane for removal of membrane racks. Instead, the membranes are proposed to be arranged in rows with adequate space between to allow for an operator to walk within and remove or install membranes from the side. Design of the MGF retrofit was coordinated with Suez and for recommendations of design flux and overall arrangement, and a summary of the design is provided in Table 7-29.

Table 7-29 Design Summary of MGF Retrofit

Component Description	Value
Target Flux Rate	8.0 gal/day/ft^2
Layers of Membranes per Row	2 Layers
Filters 21-28: Number Membranes per Filter Bed	896 membranes

Component Description	Value
Filters 33-36: Number of Membranes per Filter Bed	960 membranes
Total Membranes Provided	11,008 membranes
Max Capacity at Flux Rate	61.6 MGD
Capacity: 1 Bed out of Service in Bay 21-28	56.6 MGD
Capacity: 1 Bed out of Service in Bay 33-36	56.3 MGD
Capacity: 1 bed out of Service in each filter bay	51.25 MGD

The proposed flux of 8 GFD is conservative and membranes can likely operate at higher rates if needed, especially in warmer water conditions. Design parameters such as flux would need to be verified with a pilot study but are assumed for this evaluation. Descriptions of the construction requirements are provided in this section, and conceptual drawings of the MGF retrofit are in Appendix A as follows:

- Figure A3-11: Filters 21-28 MGF Retrofit Process Flow Diagram
- Figure A3-12: Filters 33-36 MGF Retrofit Process Flow Diagram
- Figure A3-13: Filters 21-28 MGF Retrofit Plan
- Figure A3-14: Filters 33-36 MGF Retrofit Plan

Filters 1-12 and 13-20: As noted, these filters are not considered for the MGF retrofit. The building and associated equipment should be repurposed and/or demolished as generally described in the alternative considering rehabilitation of gravity filters.

Filters 21-28: Improvements proposed at this filter bay include the following:

- Remove approximately 614 cubic yards of filter sand, 155 cubic yards of anthracite, and 155 cubic yards of gravel from all filter beds.
- Demolish approximately 8,288 square feet of filter underdrains in all filter beds.
- Demolish the surface sweep piping.
- Install membrane racks in each filter bed/cell as shown in the drawings. Each bed receives a total of 896 membranes which are arranged in eight (8) rows of 112 membranes per row. The rows are comprised of a two-stack layer with 56 membranes per layer.
- Install new air scour system consisting of two (2) 250 HP blowers and air piping manifolds routed to membrane racks. Each blower would be capable of backwashing the membranes in one filter bed.
- Install new piping manifolds and necessary fittings and valves for connection to existing filter piping including (2) filtered water pipes, backwash supply, and backwash drain (filter influent will remain as it currently operates).
- Provide modifications to the center waste gullet wall to allow filter beds to drain during a backwash cycle.
- All existing piping besides filter-to-waste piping needs rehabilitation including surface preparation to remove rust and old coatings, followed by application of a corrosion resistant primer and high-performance coating system.
- Existing Walls in the lower gallery need rehabilitation including concrete and crack repair, new waterproofing, and coatings.

- Electrical improvements in the lower level to provides better support for wiring and conduits. New controls are included with the MGF system.
- HVAC system in this building needs replaced with a more modern system.
- Miscellaneous building improvements including new coatings in the upper level walls and ceilings, replacement of lighting systems, and minor architectural features.
- Improvements to the clearwell area also needed but are not included in this section.

Filters 29-32: As noted, these filters are not required for the MGF retrofit. The building and associated equipment should be repurposed and/or demolished.

Filters 33-36: Improvements proposed with this alternative include the following:

- Remove approximately 313 cubic yards of filter sand, 79 cubic yards of anthracite, and 79 cubic yards of gravel in all filter beds.
- Demolish approximately 4,232 square feet of filter underdrains in all filter beds.
- Demolish the surface sweep piping.
- Install membrane racks in each filter cell as shown in the drawings. Each bed receives a total of 960 membranes which are arranged in 10 rows of 96 membranes each (two layers of 48 membranes).
- Install new air scour system consisting of two (2) 250 HP blowers and air piping manifolds routed to membrane racks.
- Install new piping manifolds and necessary fittings and valves for connection to existing filter piping including (2) filtered water pipes, backwash supply, and backwash drain (filter influent will remain as it currently operates).
- Provide modifications to the center waste gullet wall to allow filter beds to drain during a backwash cycle.
- New controls for the MGF system.
- Existing piping is in good condition but is assumed to receive some minor repairs.

Construction Sequencing: Sequencing of construction would require some coordination but can generally be accomplished by limiting the number of filter beds taken out of service. Filters which are ultimately being decommissioned should continue to operate as the beds being retrofitted are brought online. Given this flexibility, there are not major obstacles anticipated if the number of filter beds simultaneously upgraded is limited.

Non-Monetary Score: This alternative received a non-monetary score of 6.840 as outlined in Table 7-30.

Table 7-30 Membrane Gravity Filtration Rehabilitation Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	Mainly dependent on pretreatment, but most capable of the 3	**10**	5.32%
Spills in the River or Recurring / Future Contaminants	30%	No major advantage for MGF, but do have higher log removal credits	**5**	6.38%
Taste and Odor Control	20%	No real ability provided with MGF	**2**	4.26%

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Organics Removal & Disinfection Byproducts	25%	Slightly better than conventional filtration with good pretreatment	**3**	5.32%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Comparable to conventional filtration, some added complexity	**9**	6.38%
Monitoring & Reporting Requirements	20%	Increased monitoring / report for integrity tests and TMPs	**7**	4.26%
Operational "Forgiveness"	50%	Fairly forgiving and redundant, some risk of fouling membranes	**8**	10.64%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	Occasional chemical cleans requiring waste disposal and/or neutralization	**8**	12.77%
Energy Use Efficiency / Greenhouse Gases	20%	Very low energy	**10**	3.19%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Robust system with limited points of failure - same for all filter evaluations (NA)	**NA**	0.00%
Plant or System Expandability	40%	Could use filters 29-32 beds but generally not more expandable without another bay	**5**	6.38%
Distribution System Impacts	20%	Same impact as conventional filters	**5**	3.19%
Health and Safety	**15%**			
Health Hazards	40%	No major issues, occasional chemical cleans with acid / high chlorine	**9**	6.38%
Ergonomic & Accessibility Factors	30%	Do need to access lower level areas of membranes for maintenance	**8**	4.79%
Truck Traffic during Operations	30%	No appreciable truck traffic with MGF	**10**	4.79%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	Must limit to 1 or 2 filters at a time, long construction duration - some tie-in issues	**4**	12.77%
Retirement / Demolition of Abandoned Infrastructure	20%	Eliminating filters 13-20 and 29-32	**8**	3.19%
Total Non-Monetary Score for Alternative			**6.840**	**100%**

Estimate of Construction and Life Cycle Cost: Work associated with rehabilitating filters to an MGF system described within this section has an estimated construction cost of $48.03 million, with a summary provided in Table 7-31. The 30-year life cycle cost of this system is estimated at $66,999,000 with a detailed breakdown provided in Appendix B.

Table 7-31 Cost Estimate for Converting Existing Filters to MGF

Description	Estimated Cost
Demolition Work	$921,000
Patch Cracks and Resurface Concrete	$269,000
Paint Finishes	$375,000

Description		Estimated Cost
Ultrafiltration Membranes (50 MGD firm)		$20,588,000
Process Piping		$473,000
Misc. Filter Modifications & Accessories		$2,500,000
Air Scour Blowers (4 units)		$888,000
HVAC Improvements		$880,000
Electrical Improvements		$804,000
Instrumentation & Controls (3 % Equip Cost)		$734,000
Subtotal		**$28,432,000**
Estimating Contingency	30%	$8,529,600
Escalation to Midpoint	3%	$852,960
Construction Subtotal		**$37,814,560**
Contractor General Conditions	10%	$3,781,456
Contractor Overhead and Profit	12%	$4,537,747
Construction Contingencies	5%	$1,890,728
Grand Total Cost		**$48,025,000**

7.6.6 Filtration Alternative 6: MGF - New Construction

This alternative generally follows the MGF concept but optimizes space layout with the advantage of not being limited to existing filter bed geometry, water depth, and other obstacles. With new construction, the footprint can be further reduced and mitigate costs and operational issues. In this case, a single building would contain all, membranes, blowers, and ancillary MGF equipment. A design summary is presented in Table 7-32.

Table 7-32 Design Summary of New MGF System

MGF Component Description	Value
Target Flux Rate	8.0 gal/day/ft^2
Layers of Membranes per Row	3 Layers
Number of New Filter Beds	12 Beds
Number Membranes per Filter Bed	864 membranes
Total Membranes Provided	10,368 membranes
Max Capacity at Flux Rate	58.1 MGD
Capacity w/ 1 Bed out of Service	53.2 MGD
Flux at 50 MGD w/ 2 Beds out of service	8.27 gal/day/ft^2
Flux at 50 MGD w/ 3 Beds out of service	9.19 gal/day/ft^2

A normal operating flux of 8 GFD is still proposed for the new system. However, filter beds will be construed deeper than the existing beds, allowing for additional head and higher flux rates. Conceptual drawings of the new MGF system are presented as follows in Appendix A:

- Figure A3-15 New MGF System Process Flow Diagram

- Figure A3-16: New MGF System Lower Filter Plan

The system features 12 filter beds arranged in two parallel six-bed rows. Each bed features six rows of membranes, with each row having three layers of 48 membranes per layer (144 membranes per row). Other features of the system are summarized below:

- A new 16,000 square foot building including all mechanical, electrical, and plumbing systems. Upper level features filter bays, electrical room, and blower room.
- Two (2) 250 HP positive displacement blowers to facilitate air scour. The blowers are sized such that one blower can perform air scour of one bed of membranes.
- One control panel for each filter on the upper level.
- Instrumentation and controls for each filter with instruments including level transmitters, turbidimeters, flow meter, and integrity testing pressure transmitters.
- Lower piping gallery centered between the two rows of filters with all common valves and piping. The layout of the pipe gallery is assumed to be like that of the MGF retrofit for existing filters 33-36.

Construction Sequencing: Given these are newly constructed filters, down-time of existing facilities and operation would be minimal. However, if the filters were to be constructed in the location of existing treatment infrastructure, considerable coordination would be needed with demolition of such areas. Costs for this alternative assume the new MGF building will be constructed on a 'greenfield' site, and any additional costs for major coordination or shutdowns of the existing facility are included in plant-wide alternatives.

Non-Monetary Score: This alternative received a non-monetary score of 8.037 as outlined in Table 7-33.

Table 7-33 Membrane Gravity Filtration New Construction Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	Mainly dependent on pretreatment, but most capable of the 3	**10**	5.32%
Spills in the River or Recurring / Future Contaminants	30%	No major advantage for MGF, but do have higher log removal credits	**5**	6.38%
Taste and Odor Control	20%	No real ability provided with MGF	**2**	4.26%
Organics Removal & Disinfection Byproducts	25%	Slightly better than conventional filtration with good pretreatment	**3**	5.32%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Comparable to conventional filtration, some added complexity	**9**	6.38%
Monitoring & Reporting Requirements	20%	Increased monitoring / report for integrity tests and TMPs	**7**	4.26%
Operational "Forgiveness"	50%	Fairly forgiving and redundant, some risk of fouling membranes	**8**	10.64%
Residuals and Environmental	**15%**			

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Residuals Quantity & Ability to Continue River Discharge	80%	Occasional chemical cleans requiring waste disposal and/or neutralization	**8**	12.77%
Energy Use Efficiency / Greenhouse Gases	20%	Very low energy	**10**	3.19%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Robust system with limited points of failure - same for all filter evaluations (NA)	**NA**	0.00%
Plant or System Expandability	40%	Easily expandable - could leave additional depth for another layer	**10**	6.38%
Distribution System Impacts	20%	Same impact as conventional filters	**5**	3.19%
Health and Safety	**15%**			
Health Hazards	40%	No major issues, occasional chemical cleans with acid / high chlorine	**9**	6.38%
Ergonomic & Accessibility Factors	30%	Can design for overhead bridge crane to remove membranes	**9**	4.79%
Truck Traffic during Operations	30%	No appreciable truck traffic with MGF	**10**	4.79%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	New construction - no major challenges	**10**	12.77%
Retirement / Demolition of Abandoned Infrastructure	20%	Eliminating all old filter bays	**10**	3.19%
Total Non-Monetary Score for Alternative			**8.037**	**100%**

Estimate of Construction and Life Cycle Cost: Work associated with construction of a new MGF system has an estimated construction cost of $50.82 million, with a summary provided in Table 7-34. The 30-year life cycle cost of this system is estimated at $69,814,000 with a detailed breakdown provided in Appendix B.

Table 7-34 Cost Estimate for New MGF

Description	Estimated Cost
Filter Building and Structure (15,395 sf)	$2,774,000
Site Dewatering	$213,000
Foundation and Earthwork (12 filters)	$1,404,000
Process Piping	$2,190,000
Valves, Meters, Etc.	$966,000
Hoists & Cranes	$438,000
Ultrafiltration Membranes (50 MGD firm)	$20,588,000
Misc. Process Accessories	$1,000,000
Air Scour Blowers (2 units)	$444,000
Plumbing	$62,000
HVAC	$693,000

Description		Estimated Cost
Electrical (5% Equip Cost)		$1,102,000
Instrumentation & Controls (3 % Equip Cost)		$661,000
Subtotal		**$32,535,000**
Estimating Contingency	20%	$6,507,000
Escalation to Midpoint	3%	$976,050
Construction Subtotal		**$40,018,050**
Contractor General Conditions	10%	$4,001,805
Contractor Overhead and Profit	12%	$4,802,166
Construction Contingencies	5%	$2,000,903
Grand Total Cost		**$50,823,000**

7.7 Disinfection Alternatives

Any alternative will require the use of chlorine, although the amount may vary depending on the treatment process. For instance, using ozone will reduce the total chlorine demand due to destruction of otherwise chlorine-consuming organics. In this section, chlorine gas, bulk delivery of liquid sodium hypochlorite, and onsite generation of low-strength liquid sodium hypochlorite alternatives are considered. For any option, the use of ammonia to form chloramines can continue if desired by EWSU, as it does not impact the selected chlorine delivery method. Descriptions of the individual technologies are provided within each section, but an overview of the capacity and use of each system (for life cycle cost comparisons) is summarized below:

- Typical dosage: 5 mg/L based on current usage
- Peak hydraulic flow: 60 MGD (50 MGD rated plant capacity)
- Average design flow: 30 MGD
- Daily chlorine usage at peak flow conditions: 2,500 PPD
- Daily chlorine usage at average conditions: 1,250 PPD

Regarding costs, each alternative considers a new building as part of the estimate. Although a new building may not be needed (depending on the final plant-wide alternative), inclusion of a building provides a reference for comparison purposes.

7.7.1 Disinfection Alternative 1: Chlorine Gas

EWSU currently uses 1-ton gas cylinders and chlorinators, and a similar system is considered herein. As EWSU is familiar with this process, a limited discussion is provided. However, conceptual drawings consisting of a flow diagram and overall plan are presented in Figure A4-1 of Appendix A for purposes of cost estimating and comparison to other delivery methods. A summary of the primary components of the system is as follows:

- Four (4) vacuum operated chlorinators with automatic switchover. Each chlorinator would be rated for a maximum of 1,000 pounds per day;

- Two (2) chlorine gas manifolds with venting, each connected to three (3) 1-ton cylinders. Each manifold would supply chlorine gas to two (2) 1,000 PPD chlorinators;
- Six (6) 1-ton cylinder weigh scales;
- Gas eductors and carrier water piping routed to injection points throughout the plant;
- Overhead bridge crane with electric trolley and hoist for removing and placing 1-ton cylinders on scales or into empty / reserve storage areas;
- Chlorine ventilation and scrubber system with low-level HVAC intake ducts, related gas detectors, alarms and controls.

Although chlorine gas is a low-cost alternative for disinfection, the health and safety risks can be tremendous. A chlorine gas release can be deadly and is not limited to the WTP footprint since gas can spread for miles during a significant release. Furthermore, transport of chlorine cylinders through the City (and neighboring communities) along road and rail systems expand the reach of this risk. Over the last twenty years, many large water and wastewater treatment utilities throughout the country have replaced chlorine gas with a safer liquid sodium hypochlorite system despite gas offering a lower cost.

Non-Monetary Score: This alternative received a non-monetary score of 4.755 as outlined in Table 7-35.

Table 7-35 Chlorine Gas Disinfection Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Spills in the River or Recurring / Future Contaminants	30%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Taste and Odor Control	20%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Organics Removal & Disinfection Byproducts	25%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Simple system with limited parts, EWSU familiar with process	**9**	12.77%
Monitoring & Reporting Requirements	20%	Limited system monitoring but major Risk Management Reporting requirements	**3**	8.51%
Operational "Forgiveness"	50%	Easily adjusts to higher or lower demands but small leaks are big issue	**6**	21.28%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Energy Use Efficiency / Greenhouse Gases	20%	Very low energy usage	**9**	6.38%
Social Impacts	**15%**			

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
System Resiliency: Natural Disasters or other Failures	40%	Major implications for a failure of this system (thousands or affected residents)	**1**	12.77%
Plant or System Expandability	40%	All options are easily expanded - NA	**NA**	0.00%
Distribution System Impacts	20%	Requires additional feed of caustic to maintain higher pH	**6**	6.38%
Health and Safety	**15%**			
Health Hazards	40%	Very dangerous for operators even for very small release	**1**	12.77%
Ergonomic & Accessibility Factors	30%	Some physical labor required for positioning / activating cylinders	**5**	9.57%
Truck Traffic during Operations	30%	Moderate amount of chlorine delivery traffic, delivery trucks risk to public	**4**	9.57%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Retirement / Demolition of Abandoned Infrastructure	20%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Total Non-Monetary Score for Alternative			**4.755**	**100%**

Capital costs associated with such a chlorine gas system are estimated to be $1.62 million and a detailed estimate is provided in Table 7-36. The 30-year life cycle cost for the chlorine gas system is estimated to be $13,026,000 with a detailed breakdown is provided in Appendix B. The primary components of the life cycle costs are chlorine gas and sodium hydroxide. Sodium hydroxide is included at a dosage of 8 mg/L for pH adjustment (sodium hypochlorite alternatives do not require chemical pH adjustment).

Table 7-36 Cost Estimate for New Chlorine Gas Disinfection

Description		Estimated Cost
Chlorine Building (1,372 sf)		$262,000
Control Room (250 sf)		$88,000
Process Piping		$27,000
Hoists & Cranes		$114,000
Chlorination Equipment (4 units)		$142,000
Gas Scrubber System		$100,000
Fire Protection (Wet System)		$22,000
Plumbing		$16,000
HVAC		$62,000
Electrical		$129,000
Instrumentation & Controls		$72,000
Subtotal		**$1,034,000**
Estimating Contingency	20%	$206,800

Description		Estimated Cost
Escalation to Midpoint	3%	$31,020
Construction Subtotal		**$1,271,820**
Contractor General Conditions	10%	$127,182
Contractor Overhead and Profit	12%	$152,618
Construction Contingencies	5%	$63,591
Grand Total Cost		**$1,616,000**

7.7.2 Disinfection Alternative 2: Bulk Delivery of Sodium Hypochlorite

Liquid sodium hypochlorite is commonly used at treatment facilities and is delivered at a strength of 12.5% to 15%. The primary components of a feed system are bulk storage tanks, day tank, chemical metering pumps, and related piping, instruments, and controls. Use of softened carrier water is often employed for larger systems, as hypochlorite at this strength can have issue with gasket failures and crystallizing inside fittings and valves. Other design considerations address chemical off-gassing and degradation. Off-gassing creates a corrosive environment and must be addressed with adequate ventilation and suitable materials for electrical cabinets, pipe hangers and supports, and architectural finishes such as door hardware and handrails. Chemical degradation is also an issue as strength can degrade to 10% or less within two or three weeks, especially in warmer conditions. Strategies to mitigate degradation include receiving smaller deliveries in warm months, conditioning the storage space, or ramping up pump speeds as the chemical degrades.

Based on 30-days of chemical storage at the average conditions of 1,250 pounds per day, a total storage volume of approximately 30,000 gallons is proposed. Peristaltic type metering pumps are also recommended over diaphragm due to issues with off-gassing. Conceptual drawings of full-strength liquid sodium hypochlorite system, including a flow diagram and plan view is shown in Figure A4-2 of Appendix A. The major components of the hypochlorite feed system are summarized below:

- Three (3) 10,000-gallon storage tanks with space for a fourth tank and containment;
- One (1) 1,500-gallon day tank and weigh scale;
- Up to eight (8) peristaltic type chemical metering pumps. The actual number of pumps may vary depending on selected alternative and associated delivery points;
- Carrier water softening system consisting of ion exchange vessels and related piping and controls;
- Accessories relating to the liquid chemical system including piping, valves, controls, and instrumentation.

Non-Monetary Score: This alternative received a non-monetary score of 8.340 as outlined in Table 7-37.

Table 7-37 Liquid Sodium Hypochlorite Disinfection Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Spills in the River or Recurring / Future Contaminants	30%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Taste and Odor Control	20%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Organics Removal & Disinfection Byproducts	25%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Simple system with limited parts, EWSU familiar with process (other liquid feed)	**9**	12.77%
Monitoring & Reporting Requirements	20%	Limited monitoring (scales, pumps, etc.). No gas monitoring	**8**	8.51%
Operational "Forgiveness"	50%	Easily adjusts to higher or lower demands - some minor issues w/ crystallizing	**9**	21.28%
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Energy Use Efficiency / Greenhouse Gases	20%	Very low energy usage	**9**	6.38%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Providing redundancy in tanks, pumps and feed points	**8**	12.77%
Plant or System Expandability	40%	Same for all options	**NA**	0.00%
Distribution System Impacts	20%	Does not require additional chemical for adjustment of corrosion indices	**10**	6.38%
Health and Safety	**15%**			
Health Hazards	40%	Relatively hazardous for local exposure	**8**	12.77%
Ergonomic & Accessibility Factors	30%	Very limited physical labor or difficult access	**8**	9.57%
Truck Traffic during Operations	30%	Moderate amount of chlorine delivery traffic (slightly more than gas)	**6**	9.57%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Retirement / Demolition of Abandoned Infrastructure	20%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Total Non-Monetary Score for Alternative			**8.340**	**100%**

Capital costs associated with a bulk liquid sodium hypochlorite system are estimated to be $2.09 million and a detailed estimate is provided in Table 7-38. The 30-year life cycle cost for the bulk hypochlorite option is estimated to be $13,943,000, with a detailed breakdown provided in Appendix B.

Table 7-38 Cost Estimate for Liquid Hypochlorite Disinfection

Description		Estimated Cost
Building Structure (1,819 sf)		$382,000
Process Piping		$53,000
Pumps (carrier, transfer, metering)		$300,000
Liquid Chemical Feed Equipment		$179,000
Fire Protection (Wet System)		$29,000
Plumbing		$21,000
HVAC		$110,000
Electrical		$170,000
Instrumentation & Controls		$95,000
Subtotal		**$1,339,000**
Estimating Contingency	20%	$267,800
Escalation to Midpoint	3%	$40,170
Construction Subtotal		**$1,646,970**
Contractor General Conditions	10%	$164,697
Contractor Overhead and Profit	12%	$197,636
Construction Contingencies	5%	$82,349
Grand Total Cost		**$2,092,000**

7.7.3 Disinfection Alternative 3: Onsite Generation of Sodium Hypochlorite

Another chlorine alternative is to generate low strength (0.8%) sodium hypochlorite onsite. This process is referred to as onsite generation (OSG) and requires inputs of salt, electricity and softened water. To generate one pound of hypochlorite, the required inputs are approximately three pounds of salt, 1.9 kWh of electricity, and 15 gallons of softened water. The other primary consumable of the system are electrolytic cells which need periodic cleaning and replacement.

A complete system consists of brine storage tank(s), hypochlorite generators, liquid hypochlorite storage and pumping equipment, water conditioning equipment which may include combinations of softeners and heaters/chillers, and provisions for hydrogen gas ventilation. OSG systems are also typically designed to receive deliveries of full-strength hypochlorite in case the generation system is inoperable, or salt is unavailable. Unlike delivered hypochlorite, 30 days of storage is not required since the chemical is continuously generated. Rather, 30-days of salt storage is needed, and systems typically do not provide more than three days of liquid storage. Since the generated chemical is about 1/15th the strength of delivered hypochlorite, the overall footprint of the storage tanks is similar for either alternative. Conceptual drawings of an OSG system including a flow diagram and layout are provided in Figure A4-3 of Appendix A. The main components of the system are:

- 30-days of salt storage accomplished in two (2) brine tanks. This brine solution also serves as the ion exchange softening resin regeneration brine;
- Two (2) hypochlorite generators, each rated for 1,500 PPD. Units are designed with internal redundancy in 500 PPD increments, yielding a firm capacity of 2,500 PPD;
- Three (3) 10,000-gallon polyethylene liquid hypochlorite storage tanks. Future conditions can rely on the same number of tanks;
- Up to eight (8) hose pumps for chemical feed. Final number of pumps may vary based on final alternative and chlorine application points;
- Two (2) water heaters, as generators cannot operate below ambient surface water temperatures during cold conditions;
- One (1) full-strength hypochlorite dilution panel for emergency use;
- Hydrogen gas ventilation piping and gas detector with alarms and controls.

OSG has several benefits compared to higher strength bulk hypochlorite. It does not pose as a significant health hazard as the chemical is rather inert in short-term contact. The lower strength solution also eliminates the issues with corrosion of materials since the chemical will not experience excessive off-gassing. The solution will also not crystalize in piping, and special provisions such as carrier water and vented valves or pumps are not needed. Lastly, the amount of delivery truck traffic is typically less as deliveries consist of longer lasting salt instead of liquid hypochlorite. The main disadvantages of the system are the higher capital cost of the installation and the additional equipment which requires maintaining.

Non-Monetary Score: This alternative received a non-monetary score of 8.223 as outlined in Table 7-39.

Table 7-39 Onside Generation of Sodium Hypochlorite Disinfection Alternative Scoring

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Process Robustness	**20%**			
Turbidity Spikes	25%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Spills in the River or Recurring / Future Contaminants	30%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Taste and Odor Control	20%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Organics Removal & Disinfection Byproducts	25%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Operational Considerations	**20%**			
Mechanical Complexity	30%	Complex with generators, brine system, water system etc.	**6**	12.77%
Monitoring & Reporting Requirements	20%	Additional instruments compared to other Cl options	**6**	8.51%
Operational "Forgiveness"	50%	Easily adjusts to higher or lower demands	**10**	21.28%

CATEGORY	CATEGORY WEIGHT	NOTES AND CONSIDERATIONS	SCORE (1-10)	EFFECTIVE WEIGHT
Residuals and Environmental	**15%**			
Residuals Quantity & Ability to Continue River Discharge	80%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Energy Use Efficiency / Greenhouse Gases	20%	Relatively high energy use	**7**	6.38%
Social Impacts	**15%**			
System Resiliency: Natural Disasters or other Failures	40%	Providing redundancy in tanks, pumps and feed points	**8**	12.77%
Plant or System Expandability	40%	Same for all options	**NA**	0.00%
Distribution System Impacts	20%	Does not require additional chemical for adjustment of corrosion indices	**10**	6.38%
Health and Safety	**15%**			
Health Hazards	40%	Non-hazardous chemicals utilized	**10**	12.77%
Ergonomic & Accessibility Factors	30%	Very limited physical labor or difficult access, some labor	**7**	9.57%
Truck Traffic during Operations	30%	Lesser amount of salt delivery compared to others	**8**	9.57%
Construction & Sequencing	**15%**			
Construction Layout and Sequence Ability	80%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Retirement / Demolition of Abandoned Infrastructure	20%	Does not change with form of chlorine fed to water (NA)	**NA**	0.00%
Total Non-Monetary Score for Alternative			**8.223**	**100%**

Capital costs associated with an OSG system are estimated to be $5.60 million, and a detailed estimate is provided in Table 7-40. The 30-year life cycle cost for the system is estimated to be $16,539,000, with a detailed breakdown provided in Appendix B.

Table 7-40 Cost Estimate for On-site Hypochlorite Generation and Disinfection

Description		**Estimated Cost**
Building Structure (2,200 sf)		$463,000
Process Piping		$119,000
Pumps (metering)		$300,000
Hypochlorite Generation Equipment		$2,117,000
Fire Protection (Wet System)		$31,000
Plumbing		$25,000
HVAC		$99,000
Electrical (15% Equip Cost)		$318,000
Instrumentation & Controls		$114,000
Subtotal		**$3,586,000**
Estimating Contingency	20%	$717,200
Escalation to Midpoint	3%	$107,580

Description		Estimated Cost
Construction Subtotal		**$4,410,780**
Contractor General Conditions	10%	$441,078
Contractor Overhead and Profit	12%	$529,294
Construction Contingencies	5%	$220,539
Grand Total Cost		**$5,602,000**

7.8 Clearwell(s) and UV Disinfection Considerations

USEPA requires differing levels of disinfection for surface water treatment plants depending on their source water. The EWSU facility is currently classified as Bin 1 which requires 3 log (99.9%) removal / inactivation of cryptosporidium and giardia, and 4 log (99.99%) removal / inactivation of virus. For 'conventional treatment' (as the plant current operates) credits of 3-log for cryptosporidium, 2.5-log for giardia, and 2-log for virus are achieved prior to any disinfection. Disinfection credits are subsequently gained with the addition of chlorine for the additional 0.5 log for giardia and 2-log for virus. CT requirements will vary with chlorine dose, pH, and temperature. For example, the required CT considering a residual chlorine concentration of 2.5 mg/L, water pH of 8, and cold water at 1 deg C are:

- CT required for 0.5 log inactivation of giardia: 60 mg/L*min
- CT required for 2.0 log inactivation of virus: CT of 6 mg/L*min

As seen above, giardia is the governing CT factor and virus inactivation can easily be achieved at short contact times. In that example, 24 minutes of contact time is needed for giardia and only 2.4 minutes for virus if a baffling factor of 1.0 is considered. Baffling factors are typically less than 1.0, and subsequently increase time. For example, a baffling factor of 0.5 in this case would require 48 minutes of contact time.

Chloramines are not effective at inactivation of virus and giardia, and adequate contact time must be achieved prior to addition of ammonia when using chloramines. IDEM calculates CT based on the presence of chlorine anywhere in the plant and not just clearwells. When EWSU is using chloramines, ammonia is fed after the secondary sedimentation basins. Water in these basins is chlorinated and hours of contact time are provided at design flows, eliminating the need for further disinfection in clearwells.

The surface water treatment alternatives presented thus far have varying levels of disinfection credits. For example, MGF is often approved as 4-log for cryptosporidium and over 3-log for giardia upon pilot approval. Use of ozone may be another candidate for higher credit if the system is designed with redundancy. Because of the variability of these factors, individual alternatives are not evaluated in detail in this section (i.e. new clearwells, UV disinfection, etc.). Rather, they are applied to plant-wide alternatives. Below is a brief summary of the considerations made in the plant-wide alternatives relating to clearwells or final disinfection.

New Clearwell: The existing 6.5 MG clearwell is heavily relied upon for storage and operational flow 'buffering' prior to pumping to the distribution system and generally cannot be taken out of service without a major disruption in capacity. Since this clearwell is in poor condition and in need of inspections and repairs, one solution can be to construct a new larger clearwell for additional storage while giving the ability to take this clearwell out of service. If the 6.5 MG can be taken out of service for rehabilitation, an option could be to provide a center dividing wall and split this into two 3.25 MG clearwells.

The clearwells would need to be as deep as the existing tanks due to filter elevations, and pile foundations are included in estimated clearwell costs. Some reduction in cost may be gained if the clearwell is constructed directly beneath the filters as common concrete wall and slab construction can occur. The actual location of a new clearwell will depend on the selected plant-wide alternative, although options could include in place of the south pretreatment basins (following demolition) and across Waterworks Road on the south side of Sunset Park.

UV Disinfection: UV is effective at inactivation of giardia and cryptosporidium, although it does little for virus inactivation. Implementation of UV is common at municipal treatment plants whose source waters are in a higher Bin classification than Bin 1. It may also be helpful where removing a clearwell from service results in the inability to achieve the required log inactivation. As EWSU's source water is Bin 1 and IDEM gives chlorine disinfection credits ahead of the clearwell, the use of UV for disinfection does not appear to be warranted at this time and is not further evaluated.

Advanced Oxidation: Although UV may not be beneficial for EWSU in terms of disinfection, use of higher energy output UV in conjunction with an oxidizing chemical (hydrogen peroxide or ozone) to facilitate advanced oxidation may be worth considering. Advanced oxidation can effectively destroy potential surface water contaminants including pesticides, solvents, pharmaceuticals, cyanotoxins, and other organic compounds. Although consistent destruction of such compounds may not be warranted at this time, the systems are relatively compact, and it may be wise to leave space for a future advanced oxidation facility with any considered surface water alternative.

7.9 High Service Pumps

Like the clearwell considerations, the high service pumps are also best suited for individual plant-wide alternatives rather than stand-alone processes. Any alternative will require high service pumping, and the ultimate pump configuration will vary upon the final plant-wide improvement alternative. Options for high service pumps generally include rehabilitation of existing pump stations #2 and / or #3, and / or construction of a new high service pump station.

7.10 Other Improvements

The treatment systems discussed in this section are just the major components of the plant. Numerous ancillary systems need to be considered for the plant-wide improvements including electrical and control systems, sitework and stormwater utilities, chemical feed facilities, process residuals disposal, potential re-use or abandonment/demolition of buildings, and systems like the central boiler system. Each of these components are unique to plant-wide alternatives and further consideration is given in the plant-wide alternatives in Chapter 9.

7.11 Summary

Alternatives for the river intake, pretreatment, filtration, and chlorine delivery systems were evaluated in the previous sections. Table 7-41 provides a summary of the non-monetary score, capital cost, and 30-year life cycle cost for each option.

Table 7-41 Overall Summary of Alternatives, Scoring, and Costs

Treatment Alternative	Score	Construction Cost	30-Year Life Cycle
1.a River Intake Rehab	7.687	$6,752,000	$19,409,000
1.b. River Intake New	8.595	$12,978,000	$25,404,000
2.a Pretreatment Rehab	7.169	$13,610,000	$40,503,000
2.b Pretreatment New	8.959	$17,377,000	$44,472,000
3.c Ballasted Floc Rehab	5.924	$19,189,000	$58,749,000
3.d Ballasted Floc New	7.459	$24,044,000	$63,604,000
4.a Filter Rehab	6.601	$17,125,000	$29,038,000
4.b Filters New	8.000	$31,569,000	$39,127,000
4.c Ozone with Filter Rehab	7.218	$34,060,000	$51,306,000
4.d Ozone & BAF New	9.027	$53,626,000	$67,424,000
4.e MGF Rehab	6.840	$48,025,000	$66,999,000
4.f MGF New	8.037	$50,823,000	$69,814,000
5.a Chlorine Gas	4.755	$1,616,000	$13,026,000
5.b Sodium Hypochlorite	8.340	$2,092,000	$13,943,000
5.c Onsite Generation	8.223	$5,602,000	$16,539,000

7.12 Surface Water Treatment Recommendations

River Intake: Although construction of a new intake scored more favorably than rehabilitation, the existing structure is in good condition and conveniently located assuming the plant will remain at or near the existing site. Given these considerations and the higher cost of new construction, rehabilitation of the river intake (alternative 1.a) is recommended for any plant-wide alternative.

Pretreatment: Ballasted flocculation is not recommended due to low scores and higher costs than conventional pretreatment. Costs associated with rehabilitation and construction of new conventional pretreatment are comparable to each other, and new construction has scored higher. Therefore, new construction of a conventional system with plate settlers is the preferred alternative (alternative 2.b). However, the final plant alternatives also consider a rehabilitation option, where alternative 2.a. is considered.

Filtration: MGF did not favor well in both costs and scoring and these alternatives (4.e and 4.f) are therefore not considered for further evaluation. Additionally, construction of new conventional filters (4.b) is not recommended over a new BAF option (4.d) due to limited treatment efficacy.

Straight rehabilitation of the conventional filters (4.a) is a low-cost option but gives very little benefit in terms of long-term operation and resiliency of a surface water facility (as reflected by the score). The final plant alternatives therefore consider two options in this category: providing ozone with filter rehabilitation (alternative 4.c) and construction of the new ozone and BAF facility (alternative 4.d).

Chlorination: Although chlorine gas was the lowest overall cost, liquid sodium hypochlorite (alternative 5.b) is recommended for all plant-wide alternatives due to reduced risks associated with chlorine gas. OSG did not score as favorably due to added complexity, and the relatively low cost of hypochlorite available to Evansville makes bulk liquid hypochlorite a good option.

Other Systems: There are numerous other plant systems included in the integration of the plant. These include, but are not limited to, site utilities, other chemical feed systems, clearwells, high service pumps, building renovations and/or new building construction, building mechanical (HVAC and plumbing) systems, and plant-wide electrical and controls infrastructure. Consideration for such systems, including additional costs, are provided for each of plant-wide alternatives presented in Chapter 9.

8.0 Groundwater Treatment Alternatives

In this chapter, two options are presented for a 25 MGD capacity groundwater softening plant; namely lime softening and membrane softening. Final blending with a 25-MGD capacity surface water plant is considered in Chapter 9 as a plant-wide alternative.

8.1 New Collector Wells

A summary of the groundwater investigations and use of collector wells was presented in Chapter 6. To meet a firm treated groundwater capacity of 25 MGD, adequate raw water must be provided with the largest well out of service. Due to water losses through softening, approximately 26 to 27 MGD of raw water is required for lime softening, and membrane softening would require approximately 30 MGD of raw groundwater. For either alternative, the following wells are proposed to be developed to meet this firm capacity:

- Collector well at site TB-11 (average yield of approximately 8.1 MGD)
- Collector well at site TB-12 (average yield of approximately 8.3 MGD)
- Collector well at site TB-13 (average yield of approximately 7.9 MGD)
- Collector well at site TB-14 (average yield of approximately 9.1 MGD)
- Collector well at site TB-15 (average yield of approximately 6.9 MGD)
- Rated Firm capacity with largest well out of service: 31.2 MGD

Note that a well in the location of test bore TB-5 did indicate a high yield of 11 MGD. However, this well is located over a mile from the next closest well (and over 1.5 miles from the water plant). Developing this remote well along with others is therefore somewhat impractical and not considered. Budgetary estimates for collector wells were obtained from Layne (collector well contractor performing wellfield investigations) and are presented in Table 8-1.

Table 8-1 Budgetary Construction Costs for Horizontal Collector Wells

Well Capacity	Well Cost (caisson, seal, screens, slab)	Pumps, Controls, Piping Cost	Total Estimated Cost
6 MGD	$2,700,000	$1,000,000	$3,700,000
10 MGD	$3,200,000	$1,000,000	$4,200,000
14 MGD	$3,700,000	$1,000,000	$4,700,000

For either groundwater alternative, the total estimated construction cost to develop the five proposed wells is $38.8 million, and Table 8-2 provides a breakdown of this estimate.

Table 8-2 Cost Estimate to Develop New Wellfield

Description	Estimated Cost
Collector Wells (5 total)	$20,050,000
Raw Water Piping (11,800 ft total)	$3,188,000
Well Accessories (Access Roads, Fencing, etc.)	$589,000
Power & Communication Systems	$1,345,600

Subtotal		**$25,172,600**
Estimating Contingency	20%	$5,034,520
Escalation to Midpoint	3%	$755,178
Construction Subtotal		**$30,962,298**
Contractor General Conditions	10%	$3,096,230
Contractor Overhead and Profit	12%	$3,715,476
Construction Contingencies	5%	$1,548,115
Allowances: Final Well Testing		$750,000
Grand Total Cost		**$40,073,000**

8.2 Groundwater Alternative 1: Lime Softening

A common method of softening is chemical precipitation, or lime softening. Chemicals normally used are lime (calcium oxide {CaO} or calcium hydroxide {$Ca(OH)_2$}) and soda ash (sodium carbonate {Na_2CO_3}). Lime is used to remove carbonate hardness and soda ash removes non-carbonate hardness. As a goal for this alternative, the total groundwater hardness after softening is proposed to be 130 mg/L as $CaCO_3$. Work associated with development of the five (5) collector wells was noted previously, and other components of this alternative are as follows:

Pre-Aeration: The softening process will remove iron and manganese with or without pre-aeration and detention. However, it is recommended to provide aeration ahead of softening to remove carbon dioxide. Without aeration, carbon dioxide is consumed by lime and yields higher dosages and greater sludge production. Aeration options (using ambient air) include a cascade aerator or an induced / forced draft aerator. For a plant of this size, a multiple tray concrete aerator structure is recommended to eliminate the need for blowers or fans. Multiple tray aerators are typically designed to provide 50 square feet of tray area per MGD of capacity and this system would include approximately 1,350 square feet of tray area for 27 MGD.

Lime and Soda Ash Feed: Since groundwater is high in magnesium hardness, excess lime treatment should be employed. At average carbonate and non-carbonate values found in the raw water, soda ash may not always be needed. However, the higher range of values detected do indicate a need for soda ash, so it would be provided with the improvements. Table 8-3 summarizes the estimated lime, soda ash and carbon dioxide dosages required to achieve target levels of hardness (calculations per the AWWA RTW Softening calculator).

Table 8-3 Lime and Soda Softening Chemical Dose Design Summary

Design Parameter	Design Value
Required pH for $Mg(OH)_2$ removal	11.4 S.U.
Lime Dosage, as $CaCO_3$	580 mg/L
Lime Dosage, as Quicklime, CaO	325 mg/L
Soda Ash Dosage (max), as Na_2CO_3	15 mg/L
CO_2 Dosage, as CO_2	35 mg/L
pH after Recarbonation	8.40 S.U.
Recarbonated Alkalinity, as $CaCO_3$	37 mg/L
Magnesium Hydroxide Sludge	510 lb/MG

Design Parameter	Design Value
Calcium Carbonate Sludge	6,450 lb/MG

The proposed lime and soda ash feed system would consist of a new building to house the lower portion of dry chemical storage silos (upper portion of silos could be penetrating the roof), along with equipment including lime feeders/slakers, a soda ash feeder and slurry tank, dust collectors, and activated chemical conveying piping, pumps, or troughs. Equipment proposals for feed equipment were received and details are summarized in Table 8-4.

Table 8-4 Lime and Soda Ash Feed Equipment Design Summary

Design Parameter	Design Value
Number of Lime Silos	2
Capacity of Silo, each	10,500 ft^3
Silo Size – Diameter x Eave Height	14' x 94'
Number of Lime Feeders / Slakers	4
Lime Feeder/Slaker Capacity, each	3,000 lbs/hr
Number of Soda Ash Silos	1
Soda Ash Silo Size – Diameter x Eave Height	12' x 29'
Capacity of Silo, each	1,000 ft^3
Soda Ash Screw Feeder quantity	1
Soda Ash Screw Feeder Capacity, each	20 lbs/hr
Soda Ash solution mix tank	500 gallon

Softening Clarifiers: Following addition of lime and soda ash, the precipitative softening process is carried out in basins by a sequence of mixing, flocculation / contact, and sedimentation. Basin geometry and configuration can vary but for the purposes of this evaluation, circular solids contact clarifier reactors are considered. Proposals for such reactors were obtained and a design summary of the conceptual system is provided in Table 8-5.

Table 8-5 Solids Contact Clarifier Reactor Equipment Design Summary

Design Parameter	Design Value
Number of Units	3
Size (Diameter X SWD)	75' x 20'
Design Hydraulic Flow/Unit	8.33 MGD
Minimum Mixing / Flocculation Time	30 mins
Minimum Clarification Time	90 mins
Total Tank Detention Time	120 mins
Maximum Surface Loading Rate	1.7 gpm/ft^2

Recarbonation: Clarifier effluent pH is expected to be in excess of 11, which requires reduction prior to filtration. Use of carbon dioxide (or carbonic acid) is commonly implemented and this process is known as recarbonation. Although older systems typically bubble gaseous carbon dioxide into a large basin, the more common delivery is now a side-stream injection in which carbon dioxide is fed to a pressurized stream and then injected into a reaction basin. For a single stage softening processes, a recarbonation basin contact time of 20 minutes is required for carbon dioxide gas feed. However, this time could potentially be reduced when using the pressurized carbonic acid injection pending approval from IDEM. For the purposes of preliminary design, a 20-minute contact time is assumed. Table 8-6 provides a design summary of the recarbonation system including CO_2 storage and feed equipment.

Table 8-6 CO_2 and Recarbonation Equipment Design Summary

Design Parameter	Design Value
Number of CO_2 Storage Tanks	1
CO_2 Storage Tank Capacity	30 Tons Liquid CO_2
Vaporizer Feed Rate	350 lbs/hr minimum
Number of CO_2 Feeders	2 (duty+standby)
Maximum CO_2 Feed Rate	350 lbs/hr
Average CO_2 Feed Rate	110 lbs/hr
Side Stream Flow Rate	163 gpm @ 60 psig
Turndown	20:1
Number of Basins	2
Size of Each Basin	18' wide x 70' long x 20' SWD
Basin Detention Time (at 25 MGD)	20 mins

Gravity Filtration: Granular media filtration occurs after recarbonation. Considering a 50/50 blend with surface water, a total of 50 MGD of filters would be included whether that involves new construction or rehabilitation of the existing filters. Details for 50 MGD of filtration were presented previously in Section 7.6.1 (rehabilitating existing filters) and Section 7.6.2 (construction of new filters). Depending on the overall layout of the plant, softened groundwater and pre-treated surface water could be blended ahead of filtration, or the system could be set up such that half the filters treat groundwater and the other half treat surface water.

Residuals Handling: Based on preliminary calculations, the lime and soda ash softening process would produce approximately 7,000 pounds of sludge per million gallons of flow on a dry pound basis. Considering an average groundwater flow of 15 MGD (blended with 15 MGD of surface water), the resultant annual sludge load is nearly 20,000 tons of dry solids. If the softening residuals were 1.5% solids, the daily volume would be about 0.9 MGD. A direct discharge of sludge to the Ohio River is not considered viable, and options potentially include storing in lagoons or mechanical dewatering with final disposal by hauling to a landfill, land application, or blending with wastewater biosolids. Ten State Standards[*] recommends lime lagoons provide at least 2.5 years of storage and be sized based on 0.7 acres per MGD per 100 mg/L of hardness removed per five feet of usable depth. With approximately 330 mg/L of hardness removed, lagoons would need to be roughly 20 acres at design capacity with a usable depth of 15-ft. Locating such lagoons onsite is not feasible, and sludge would need to be pumped to remote lagoons adding further complexity and operational requirements. For these reasons, lagoon storage is not considered practical and mechanical dewatering is recommended. Options for dewatering technologies may include a plate and frame press, rotary fan press, belt filter press, or a centrifuge.

Lime Softening Alternative Summary and Costs: The lime softening system consists of five (5) new collector wells and piping to the site, a 25 MGD treatment train utilizing concrete tray aerators,

[*] Ten State Standards, paragraph 9.3.a

a lime and soda ash feed building, three (3) solids contact reactor clarifiers, a recarbonation basin with CO_2 feed equipment, gravity filtration, and a dewatering facility including short term dry cake storage. An overall flow diagram of the process in provided in Figure A5-1 of Appendix A. Costs associated raw water conveyance and filtration are common between the lime and membrane softening options and are therefore considered separately. Capital costs associated with just the lime softening system is estimated to be approximately $38.48 million, and details are summarized in Table 8-7.

Table 8-7 Lime Softening System Estimated Construction Cost

Description		Estimated Cost
Site Civil, Demo, Utilities		$5,000,000
Cascade Aeration Trays		$600,000
Lime Feed & Dewatering Building (5600 ft^2)		$2,025,000
Lime & Soda Ash Feed Equipment		$2,200,000
Dewatering Equipment		$2,500,000
Clarifiers & Splitter Box (3 units, 75' dia)		$5,324,000
Recarbonation System and Basins		$1,747,000
Dewatered Sludge Storage Pad / Pavilion		$400,000
Process Piping & Valves (25% Equipment)		$2,200,000
Electrical (20% Equipment)		$1,760,000
Instrumentation (10% Equipment)		$880,000
Subtotal		**$24,636,000**
Estimating Contingency	20%	$4,927,200
Escalation to Midpoint	3%	$739,080
Construction Subtotal		**$30,302,280**
Contractor General Conditions	10%	$3,030,228
Contractor Overhead and Profit	12%	$3,636,274
Construction Contingencies	5%	$1,515,114
Grand Total Cost		**$38,484,000**

Total costs for the 25 MGD lime softening train prior to blending with surface water would include the collector wells and filtration. Approximate total construction costs including these processes, with the option of filter rehabilitation or new construction are noted below:

- Collector wells, lime softening, and filter rehab (25 MGD): **$87.1 million**
- Collector wells, lime softening, and new filters (25 MGD): **$94.3 million**

Regarding operational costs, major components include the sludge residual, chemicals, and energy. An annual operational cost at an average flow of 15 MGD (blended with 15 MGD of surface water) is estimated as $5.58 million and is summarized in Table 8-8. This only considers the raw water and lime processes and does not include filtration or surface water treatment.

Table 8-8 Annual Lime Softening Operational Costs

Item Description	Unit	Quantity	Unit Cost	Total Cost
Wellfield Pumping Electricity	kWh	3,609,097	0.08	$289,000
Solids Contact Clarifier Electricity	kWh	294,073	0.08	$24,000
Dewatering Electricity	kWh	435,664	0.08	$35,000
Misc. Process Electricity	kWh	130,699	0.08	$10,000
Lime Chemical (Quicklime)	Tons	7,811	$140	$1,093,000
Soda Ash Chemical	Tons	114	$240	$27,000
Carbon Dioxide Chemical	Tons	841	$200	$168,000
Chemical Carrier Water	Mill. Gal.	94.61	$1,200	$114,000
Dewatered (20%) Lime Disposal	Tons	95,265	$40	$3,811,000
Misc. Equipment Maintenance	Annual	1	$10,000	$10,000
Total Annual Operating Cost				**$5,581,000**

8.3 Groundwater Alternative 2: Membrane Softening

Another viable softening option is RO or NF membranes. As with the previous alternative, this option would provide a groundwater plant with a rated capacity of 25 MGD to be blended with 25 MGD of treated surface water. The target finished water hardness of the groundwater plant is 130 mg/L as $CaCO_3$, and other contaminants such as iron and manganese would be removed in the process to meet the proposed water quality goals. Work associated with development of the five (5) collector wells was noted previously, and other components are as follows:

Pre-oxidation: Pre-oxidation (followed by detention and filtration) of dissolved metals is recommended for membrane softening pretreatment in lieu of direct anoxic metal removal using the membranes. Although direct removal can be done under carefully controlled anoxic conditions, the elevated levels in the aquifer combined with the distance between wells and the plant is considered very high risk. Furthermore, membrane concentrate would likely need additional treatment prior to disposal to the river in this case. Oxidation options include chemical addition of an oxidizing chemical such as chlorine or permanganate, or ambient oxygen aeration using a tray aerator or forced / induced draft system. Information relating to iron and manganese oxidation options is provided in Table 8-9 and are based on the maximum design raw water flow of 30 MGD and average metals concentrations found in the wells.

Table 8-9 Summary of Metal Oxidation Options

Design Parameter	Design Value
Design Flow Rate	30 MGD
Induced Draft Aeration Loading Rate	1 to 5 gpm/ft^2
Induced Draft Aeration Blower capacity	225 SCFM
Multiple Tray Aerator Loading	50 ft^2/MGD
Estimated Chlorine Demand	1,100 lb/d
Estimated Potassium Permanganate Demand	1,630 lb/d

Although use of chemicals for oxidation is somewhat common at smaller RO/NF facilities, the amount needed for EWSU would be better suited for ambient oxygen aeration. For example, use of sodium hypochlorite to oxidize metals in the groundwater is expected to have an annual cost of about $250,000 at average flows and current hypochlorite costs. A cascade type tray aerator is recommended in this case, as generally described in the lime softening alternative (for CO_2 removal). Although the primary oxidation method would be with air, it is also recommended to feed a small chlorine or permanganate residual to ensure full oxidation and keep the filter media charged (discussed in the filtration section).

Detention: Oxidation kinetics of iron are relatively fast, but manganese proceeds much slower and it is recommended to provide at least 30 minutes of detention time between the pre-oxidation and filtration processes. Table 8-10 gives the design summary of the detention tanks consider new construction.

Table 8-10 New Detention Tank Design Summary

Design Parameter	Design Value
Detention Time Required	30 minutes
Design Flow	29.6 MGD
Number of Detain Tanks	4 in parallel
Size of Each Tank	17′ wide x 68′ long x 18′ SWD
Total Volume Provided	623,000 gallons

Rather than a new tank, a viable option could be to utilize the secondary sedimentation basins of the north or south plant to serve this purpose. These provide detention times well in excess of 30 minutes, even with basins out of service. A space-saving strategy could be to install the tray aerator in the center of the south basins in lieu of a separate concrete structure.

Granular Media Gravity Filtration: Effluent from the detention tank would flow to gravity filters for removal of oxidized iron, manganese, and other suspended solids prior to membrane filtration. For filter media, the use of manganese coated synthetic greensand (with an anthracite cap) is recommend for optimum manganese removal. This media does require continuous or intermittent charging with an oxidizing chemical (permanganate or chlorine), and it is recommended to carry a small residual through the detention tanks. Options for filters include reuse of existing beds or construction of new. For a new filter scenario, a new building housing eight (8) filters is proposed, with an overall design summary of the system in Table 8-11.

Table 8-11 New NF Pretreatment Filter System Design Summary

Design Parameter	Design Value
Number of Filters Provided	8
Design Flow per Filter Bed	4.28 MGD
Design Loading Rate	3 gpm/ft^2
Required Surface Area of Each Filter	992 ft^2
Filter Dimensions (example options)	25′ x 40′ ; 32′ x 32′
Total capacity w/ 1 out of service	30 MGD

If rehabilitation and use of existing filters is to be considered, filters 21-28 would provide adequate capacity. Each of these filters is 1,036 ft^2, which is nearly same as the eight filters noted in the table above. Furthermore, if the south detention basins are used for pre-oxidation, use of these filters would work well with the current configuration of the south plant. A break tank is also proposed to store filtered water prior to feeding the membranes and should provide approximately 20 minutes or more of storage at the design flows. If filters 21-28 were utilized, the existing 0.5 million-gallon clearwell could serve as this tank and provide up to 25 minutes of storage at peak design flows.

Membrane Softening: Effluent from the gravity filters would flow to a holding tank as noted and subsequently be pumped to the NF/RO system. Prior to the membranes, final pretreatment steps including cartridge filtration and addition of antiscalant. A reducing chemical such as sodium bisulfite would also be fed ahead of membranes to dechlorinate filter effluent. A chemical analysis of the feedwater with antiscalant projections indicated that the overall membrane recovery could be pushed to 85%. However, for the basis of design, a more conservative estimate of 80% recovery is used. Also, for the purposes of preliminary design, Dow/Filmtec NF90 membrane elements were considered. A summary of the NF softening system is provided in Table 8-12.

Table 8-12 Nanofiltration System Design Summary

Parameter	Units	Value
Total Softened Groundwater Flow	MGD	25
Total Membrane Permeate Flow	MGD	18.4
Total Membrane Bypass Flow	MGD	6.6
Total Membrane Concentrate (Residuals) Flow	MGD	4.6
Total Membrane Feed Flow	MGD	23.0
Total Filtered Water Flow Required	MGD	29.6
Final Softened Groundwater Hardness	mg/L $CaCO_3$	130
Number of Membrane Skids	Each	10
Permeate Flow per Membrane Skid	MGD	1.84
Proposed Membrane Skid Configuration	-	30:15x7m
Proposed Operating Recovery	%	80
Proposed Operating Flux	gal/day/ft^2	14.6
Number of Cartridge Filters	Each	10
Projected Antiscalant Dosage	mg/L	2.5

Post Membrane Treatment: Following membranes, a re-stabilization process is commonly implemented by releasing dissolved gasses (such as CO_2 or H_2S) and pH adjustment. Groundwater will be aerated prior to membrane filtration, generally eliminating the need to perform this step post-membranes. The estimated pH of the membrane permeate is 6.7. After blending with the aerated bypass (bypass pH of 7.8) at the proposed blend ratio, the final softened groundwater pH is estimated to be 7.3. This stream is blended with surface water (surface water pH of 7.8) to reach a final estimated blended water pH of 7.6. To match the currently supplied finished water pH of 8, a caustic dose of approximately 8 mg/L as chemical is estimated. Additional caustic would be required if utilizing chlorine gas for disinfection.

Residuals Handling: Although there are no solid residual streams with NF softening (as there are with lime softening), NF does produce a liquid residual in the form of membrane concentrate which requires disposal. Considering 80% recovery and the bypass flow, the proposed system would produce a concentrate stream of approximately 4.6 MGD at the design capacity of 25 MGD. In the case of the evaluated membranes, this waste stream has a projected total dissolved solids (TDS) concentration of 3,400 mg/L (compared to the raw groundwater TDS of 730 mg/L). Higher recovery and 'tighter' RO membranes would result in a higher TDS concentration. Disposal of membrane concentrate can often be a challenge at treatment facilities which do not have an adequate receiving stream due to these elevated TDS concentrations. Disposal of this stream directly to the Ohio River via a permitted outfall is not anticipated to be a major hurdle due to the size of the river, but preliminary discussions on allowable TDS limits have not been held with IDEM to verify this assumption. Furthermore, the concentrate will help dilute the mercury in the existing surface water residuals stream which could help EWSU in long-term compliance. However, this volume of dilution is not expected to bring levels down to concentrations needed to waive the mercury variance altogether.

The other two primary residuals to consider are groundwater filter backwash and membrane cleaning chemicals. Filter backwash would contain elevated levels of iron and manganese, and direct disposal to the Ohio River may not be a viable option. If surface water discharge is not viable, this stream may have to be sent to EWSU's wastewater treatment plant, or red water filters could be constructed. At an estimated filter recovery of 95%, this would result in about 1.5 MGD of backwash at design capacity, or about 0.9 MGD at average flows. NF cleaning does not need to occur frequently but does result in a chemical waste requiring disposal. Chemical neutralization and a surface water discharge may be viable, but an easier solution is to send this directly to the sanitary sewer given the low volumes and infrequent occurrence.

Membrane Softening Alternative Summary and Costs: The 25 MGD membrane softening system consists of five (5) new collector wells with raw water piping, concrete tray aerators, a detention basin with at least 20 minutes of contact time, eight (8) gravity filters, a filtered water break tank, six (6) low pressure transfer pumps to feed the cartridge filters and membrane bypass, ten (10) cartridge filter housings, ten (10) high pressure membrane feed pumps, ten (10) membrane softening skids with appurtenances including a cleaning system, and chemical feed systems. A concentrate stream of 4.6 MGD is anticipated at the design flows and is proposed to be discharged to the Ohio River.

There may be some opportunities to rehabilitate portions of the south plant for the process. This includes using secondary settling tanks as detention basins, filters 21-28 for membrane pre-filtration, and the 0.5 MG clearwell for a break tank. Regardless of any reuse, a new building to house the membranes and related systems would be provided. An overall flow diagram of this alternative (with new or reuse options) is provided in Figure A5-2 of Appendix A. A conceptual layout of the membrane building is also provided in Appendix A as Figure A5-3.

The base capital costs associated with the membrane system building is estimated at $32.3 million and is summarized in Table 8-13. However, this does not reflect complete system costs including the collector wells, cascade aerators, detention tanks, filters, and break tanks, as those have numerous options relating to new construction or rehab. A cost matrix of complete softening system options is therefore presented in Table 8-14.

Table 8-13 Cost Estimate for Membrane System Building

Description		Estimated Cost
Membrane Equipment		$6,350,000
Feed Pumps & Cartridge Filters		$2,500,000
Chemical Feed Systems		$750,000
Membrane Building (Upper Shell)		$2,380,000
Membrane Building (Lower Level & Foundation)		$1,700,000
Civil & Utilities Work		$1,200,000
Process Piping and Valves (25% Equipment)		$2,583,000
Electrical (20% Equipment)		$2,066,000
Instrumentation (10% Equipment)		$1,033,000
Subtotal		**$20,562,000**
Estimating Contingency	20%	$4,112,400
Escalation to Midpoint	3%	$616,860
Construction Subtotal		**$25,291,260**
Contractor General Conditions	10%	$2,529,126
Contractor Overhead and Profit	12%	$3,034,951
Construction Contingencies	5%	$1,264,563
Grand Total Cost		**$32,120,000**

Table 8-14 Cost Estimates for Complete Membrane Softening Options

Description	Estimated Cost
Wells and Transmission Main (Alt 1 & 2)	$40,073,000
Aerators (Alt 1 & 2)	$937,000
New Detention Basins (Alt 1)	$1,317,000
Rehab South Plant for Detention (Alt 2)	$253,000
Construct New Filters (Alt 1)	$15,784,500
Rehab Filters 21-28 (Alt 2)	$8,562,500
Construct New Break Tank (Alt 1)	$1,250,000
Rehab 0.5 MG Clearwell (Alt 2)	$253,000
Membrane Building (Alt 1 & 2)	$32,120,000
Alternative 1 Cost (New)	**$91,481,500**
Alternative 2 Cost (Rehab)	**$82,198,500**

Major operational cost components for membrane softening are pumping energy, chemicals, and membrane replacement / cleaning. Annual operational costs for membrane softening, based on an average finished groundwater plant flow of 15 MGD (blended with 15 MGD of surface water) is $1.74 million and is summarized in Table 8-15.

Table 8-15 Annual Membrane Softening Operational Costs

Item Description	Unit	Quantity	Unit Cost	Total Cost
Wellfield Pumping Electricity	kWh	4,210,613	$0.08	$337,000
Membrane Feed Pumping Electricity	kWh	5,888,121	$0.08	$471,000
Misc. Process Electricity	kWh	130,699	$0.08	$10,000
Chlorine Chemical	Pounds	126,026	$0.81	$102,000
Antiscalant Chemical	Pounds	105,021	$2.80	$294,000
Sodium Bisulfite Chemical	Pounds	26,885	$0.65	$17,000
Sodium Hydroxide Chemical	Pounds	365,292	$0.36	$132,000
Annualized Membrane Replacement	$/Year	1	$247,500	$248,000
Membrane Cleaning (ea. skid)	#/Year	15	$7,500	$113,000
Misc. Equipment Maintenance	$/Year	1	$15,000	$15,000
Annual Operating Cost				**$1,739,000**

8.4 Groundwater Summary and Recommendations

The use of groundwater has some benefits relating to water quality and offers a semi-redundant water source. However, it does introduce some treatment complexity and higher capital costs given the available supply is inadequate (utilizing a practical number of wells) to meet the total water demand and surface water is still needed. Two primary treatment options for groundwater include lime softening and membranes. Both options have some ability to reuse existing infrastructure, although the membrane option is better suited for this. A summary of options is shown in Table 8-16.

Table 8-16 Summary of Groundwater Softening Costs

Cost Item (25 MGD GW Only)	Lime Softening	Membrane Softening
New Facility Costs	$94,341,500	$91,481,500
Rehabbed Facility Cost	$87,119,500	$82,198,500
Annual Operational Cost	$5,581,000	$1,739,000

Although capital construction costs are comparable for the lime and membrane systems, the operational cost of lime due to residuals disposal is substantially higher. Residuals management of the membrane option does have increased residuals handling compared to current operation but is much less extensive than the lime option. The membrane concentrate could even potentially dilute surface water residuals (mercury) which may offer a net benefit. As such, the membrane softening option is recommended if groundwater is to be considered. Note the costs above do not include the 25 MGD surface water treatment system. Chapter 9 presents a plant-wide improvements alternative which utilizes the groundwater / surface water blending scenario and includes these complete project costs.

9.0 Plant-Wide Alternatives

Chapters 7 and 8 presented options for the major components of the WTP liquid stream systems. This chapter combines these components into three (3) plant-wide alternatives including two (2) surface water alternatives and (1) one featuring a blend of groundwater and surface waters. An overview of the three options is in Table 9-1, with descriptions in the subsequent sections. All alternatives consider a finished water capacity of 50 MGD. A 'do nothing' option is also discussed at the end of this section.

Table 9-1 Plant-Wide Alternatives Treatment Summary

Component	Alternative 1	Alternatives 2a & 2b*	Alternative 3
Surface water only	Yes	Yes	No
50/50 ground/surface water blend	No	No	Yes
River Intake	Rehab	Rehab	Rehab 25 MGD
Conventional Pretreatment w/ Plates	Rehab North	New Basins	Rehab ½ North
Ozone Feed and Contact	Rehab North	New Basins	No
Biologically Active Filters	No	New Filters	No
Conventional Gravity Filters	Rehab 21-36	No	Rehab 21-36
Membrane Softening	No	No	Yes
Liquid Sodium Hypochlorite	Yes	Yes	Yes
New Clearwell	Yes	Yes	Yes

*2a considers construction at the existing property and 2b considers construction primarily to the east of Waterworks Road

9.1 Plant Alternative 1 – Rehabilitate Existing Plant

This considers rehabilitation of the existing plant along with a lesser extent of new construction. Drawings associated with the proposed improvements are provided in Appendix A and listed below, followed by descriptions of the components.

New drawings specific to plant-wide system:
Figure A6-1: Plant Alternative 1 Process Flow Diagram
Figure A6-2: Plant Alternative 1: Demolition and Phasing Plan
Figure A6-3: Plant Alternative 1: Proposed Site Plan

Drawings related to alternative and presented previously in this report:
Figure A2-1: Conventional Pretreatment Retrofit – Overall Plan (North Basins)
Figure A2-2: Conventional Pretreatment Retrofit – Enlarged Plan and Section (North Basins)
Figure A3-4: Conceptual Ozone System Process Flow Diagram
Figure A3-5: Conceptual Ozone System Retrofit Overall Plan
Figure A3-6: Conceptual Ozone System Retrofit Section
Figure A3-7: Conceptual Ozone System LOX System Plan
Figure A4-2: Chlorine Alternative 2: Liquid Sodium Hypochlorite

River Intake: The river intake will be rehabilitated as described in Section 7.4.1 and includes complete replacement of all pumps and screens along with ancillary improvements such as building renovation and a new onshore potassium permanganate feed system. The location of the chemical system is assumed to be inside the building formerly housing high service pump station number 1.

Pretreatment: Pretreatment improvements were presented in Section 7.5.1. and include construction of new concrete walls and equipment inside the north plant primary settling basins to facilitate six (6) parallel trains of rapid mixing, three-stage flocculation and sedimentation with inclined plate settlers. PAC would be fed ahead of pretreatment and additional costs for major rehabilitation of the existing PAC system and feed lines are included in the estimates. Other pretreatment improvements include rehabilitation of the raw and settled water channels and replacement of coagulant piping.

Ozone Addition: Water from the pretreatment basins will be dosed with ozone and detained prior to filtration. Ozone is included to provide the ability to improve taste and odors and reduce levels of organic contaminants in the river such as atrazine or other potential chemical spills. Although the existing filters could technically be operated biologically, the limited depth is not expected to result in optimal performance, and biofiltration is not the primary intent of including ozone. The ozone feed system and contact basin are described in Section 7.6.3 and includes partially reusing the north secondary basin for ozone contact, although most of the basins would be filled in or demolished. The location of the ozone generators and liquid oxygen delivery station is proposed to be within the footprint of existing filters 1-20 and is identified on the site plan, although an alternative location could be on top of the secondary basins which are being backfilled.

Filtration: Existing filters 21-36 will be rehabilitated as described in Section 7.6.1. The filter bays have varying levels of condition with some requiring very few improvements and others extensive rehabilitation. Work associated with filter improvements include replacement of underdrains and media, new air scour grids and blowers, partial piping and valve replacement, new instrumentation, and general rehabilitation. Filters 13-20 would be decommissioned as part of these improvements.

Chlorine Disinfection: Bulk liquid sodium hypochlorite will replace chlorine gas as the mechanism of disinfection. The system is described in Section 7.7.2 and includes chemical storage tanks and a series of metering pumps servicing locations throughout the plant similar to other liquid feed systems at the WTP. For this alternative, it is proposed to retrofit the existing chlorine gas room with the new liquid feed system.

Clearwells: This alternative includes construction of one new clearwell in the location of the existing south pretreatment basins. This will need to be built as a later phase of construction following completion of the pretreatment improvements and decommissioning of the south settling basins. The new clearwell will have an effective volume of 6.0 MG and consists of two parallel 3.0 MG clearwells. The existing 1.5 MG clearwell will be decommissioned as part of these improvements and the existing 0.5 MG clearwell beneath filters 21-28 will remain in service and will be given the ability to flow to the new clearwell or the existing 6.5 MG clearwell. Following construction of the new clearwell, it is proposed to rehabilitate the 6.5 MG clearwell and provide a new center divider wall to convert this basin into two parallel 3.25 MG clearwells.

High Service Pumps: This alternative includes rehabilitating and utilizing high service pump stations #2 and #3. All three vertical turbine pumps in pump station #3 are proposed to be replaced. In pump station #2, two pumps are relatively new and only minor work is assumed for those, with the other two replaced. In both stations, other rehabilitation work such as replacement of valves, electrical improvements, and piping improvements is included. This alternative also includes new transfer piping from the new clearwell to the existing high service pump station #2.

Residuals: No new residuals are created with these improvements and disposal of process waste streams are proposed to remain as discharges to the Ohio River. Work associated with extending the outfalls further into the Ohio River to conceal the visibility of the discharge plumes is included in the cost estimates to meet IDEM requirements. Outfall 002 can be eliminated once the south plant pretreatment system is decommissioned.

Other Features: Other WTP features include additional site development to accommodate the new processes with interconnecting utilities, roads, and drainage systems, renovations throughout the existing buildings and building mechanical systems upgraded to more modern facilities (offices, break rooms, laboratory, maintenance areas, replacement of boilers with updated HVAC, etc.), various demolition work, and plant-wide treatment upgrades for ancillary systems including chemical feed and common electrical infrastructure.

Costs: The estimated construction costs associated with the work described in this section and is estimated at $121.8 million, and a summary is provided in Table 9-2. The 30-year life cycle costs are estimated to be $253.3 million and a summary is provided in Table 9-3.

Table 9-2 Plant Alternative 1 Total Estimated Construction Cost

Component Description	Cost
Civil Site Work (Roads, Drainage, Fencing etc.)	$3,500,000
Rehabilitate River Intake	$6,752,000
North Plant Pretreatment Improvements	$13,610,000
North Plant Ozone System Retrofit	$16,935,000
Rehabilitate Gravity Filters	$17,125,000
New Sodium Hypochlorite System	$2,092,000
PAC Feed Improvements	$1,000,000
Other Chemical Improvements (4 at $300k ea.)	$1,200,000
Demolish South Plant	$1,066,000
Construct New 6 MG Clearwell	$10,960,000
Rehabilitate Existing 6.5 MG Clearwell	$734,000
Rehabilitate High Service Pump Stations #2, #3	$8,733,000
Extend 3 Plant Outfalls ($750k ea.)	$2,250,000
Building Renovations	$4,000,000
Interconnecting Site Utility / Electrical Work	$3,500,000
Other Demolition Work Throughout Plant	$2,000,000
Subtotal	**$95,457,000**
Additional Construction Contingencies (15%)	$14,319,000
Other Misc. Plant-Wide Improvements (5%)	$4,773,000
Phasing & Sequencing Plant Outages (5%)	$4,773,000
Remediation & Hazardous Martials	$1,000,000

Component Description	Cost
Allowances	$500,000
Startup and Commissioning	$1,000,000
Total Estimated Construction Cost	**$121,822,000**

Table 9-3 Plant Alternative 1 30-Year Life Cycle Cost

Component Description	Cost
Initial Construction Cost	$121,822,000
River Intake 30-Year O&M Cost	$12,657,000
Pretreatment, PAC, & Coagulant 30-Year O&M Cost	$26,893,000
Ozone & Filtration 30-Year O&M Cost	$17,246,000
High Service Pumping 30-Year O&M Cost	$17,973,000
Sodium Hypochlorite 30-Year O&M Cost	$11,851,000
Sodium Hydroxide & Fluoride 30-Year O&M Cost	$6,450,000
Ammonia 30-Year O&M Cost	$1,200,000
Misc. Maintenance of New Infrastructure 30-Year Cost	$240,000
Misc. Maintenance of Existing Infrastructure 30-Year Cost	$37,000,000
Total 30-Year Life Cycle Cost	**$253,332,000**

9.2 Plant Alternative 2A – New Surface Water Treatment Facility on Current Plant Property

This alternative considers primarily new construction of a surface water ozone and BAF facility at the existing site, although some portions of the existing plant are proposed for re-use as noted herein. Drawings associated with the proposed improvements are provided in Appendix A and listed below, followed by descriptions of the components.

New drawings specific to plant-wide system:
Figure A6-4: Plant Alternative 2A: Process Flow Diagram
Figure A6-5: Plant Alternative 2A: Demolition and Phasing Plan
Figure A6-6: Plant Alternative 2A: Proposed Site Plan

Drawings related to alternative and presented previously in this report:
Figure A2-4: Conventional Pretreatment New Construction Plan
Figure A2-5: Conventional Pretreatment New Construction Sections
Figure A3-1: Conventional Filtration Conceptual Plan Process Flow Diagram
Figure A3-2: Conventional Filtration Conceptual Plan Lower Level
Figure A3-3: Conventional Filtration Conceptual Plan Upper Level
Figure A3-4: Conceptual Ozone System Process Flow Diagram
Figure A3-7: Conceptual Ozone System LOX System Plan
Figure A3-8: Conceptual New Ozone System Lower Level Plan
Figure A3-9: Conceptual New Ozone System Upper Level Plan
Figure A3-10: Conceptual New Ozone System Section

Figure A4-2: Chlorine Alternative 2: Liquid Sodium Hypochlorite

River Intake: The river intake will be rehabilitated as described in Section 7.4.1 and includes replacement of pumps and screens along with building renovation and a new onshore potassium permanganate feed system. The location of the chemical system is assumed to be inside the building formerly housing high service pump station number 1.

Pretreatment: Pretreatment improvements were presented in Section 7.5.2 and include construction of four (4) new parallel trains of PAC contact, rapid mixing, three-stage flocculation and sedimentation with inclined plate settlers. PAC would be fed ahead of pretreatment and additional costs for major rehabilitation of the system and feed lines are included in the estimate. Coagulant would be fed to each rapid mix chamber and feed piping modifications are included. Other improvements include new raw water piping from the intake, sludge piping to the outfall, and accessories such as grating and handrail, lighting, and relocation of the access road. The location of the new basins is proposed to be on the far south end of the property in place of one a south plant pretreatment train. This would require one south plant pretreatment train to be out for the entire duration of construction. The pretreatment basin hydraulic grade would be several feet above the current south plant to accommodate the new biological filters.

Ozone Addition: Water from the new pretreatment basins will be sent to an adjacent contact tank and dosed with ozone. The new ozone feed system and contact basins are described in Section 7.6.4 and include two parallel contact tanks with the ozone generation, delivery and destruct systems integral to the tank. The location of this system is in place of the second south pretreatment train with the liquid oxygen storage area near the access road.

Filtration: As the existing filters are not suited for BAF, a new filter building featuring 12 filters is proposed. The features and conceptual drawings relating to the biological filters were described in Section 7.6.4 and they generally function the same as the current gravity filters. New filters will be at a higher elevation than existing filters to accommodate deeper beds while maintaining the current clearwell depth. To facilitate this, the hydraulic grade of the pretreatment and ozone basins will be raised several feet above the current south plant pretreatment hydraulic grade.

Chlorine Disinfection: Bulk liquid solidum hypochlorite will replace chlorine gas cylinders. The overall system is described in Section 7.7.2 and includes a new room with chemical storage tanks and metering pumps servicing locations throughout the plant. The location of the new building is near the new filter building as shown on the conceptual site plan, although the final location is flexible. As for the existing chlorine gas room, it is proposed to repurpose this for fluoride feed as the existing fluoride room will be demolished for the new clearwell.

Clearwells: This alternative will include construction of one new clearwell with an effective volume of 6 MG (two parallel 3 MG clearwells). Use of the existing 1.5 MG and 0.5 MG clearwells would be discontinued with this alternative. The location of the new clearwell is preliminarily shown in place of filters 29-32 and high service station #2 on the conceptual site plans. However, if this location proves to be challenging in terms of construction phasing, other locations onsite could include beneath the new filters or within the general footprint of the north primary settling basins. A third option could even be the south end of Sunset Park across Waterworks Road. Regardless of location, the new clearwell would feature a new high service pump station as noted in the next section. Following completion of the new clearwell, it is proposed to rehabilitate the existing 6.5 MG clearwell including construction of a new center divider wall to convert this basin into two parallel 3.25 MG clearwells.

High Service Pumps: This alternative includes construction of a new high service pump station adjacent to the new clearwell. The new pump station is proposed to feature four (4) vertical turbine pumps in a new building. The high service building will also feature a lower level with diversion valves to direct water between the new and existing clearwells. Additionally, full replacement of pumps and accessories in existing pump station #3 is proposed with this alternative.

Residuals: No new residuals are created with these improvements and disposal of waste streams are proposed to remain as a discharge to the Ohio River. With the amount of new construction, it is proposed to eliminate three of the existing outfalls and extend only one discharge to the river which will collect all process residuals. This common outfall will extend below the visible pool of the Ohio River in order to meet IDEM requirements.

Other Features: There are numerous other areas throughout the plant which would be renovated and/or repurposed. This includes the existing administration areas to provide a more modern space, new HVAC and plumbing systems, various demolition, upgrading the remaining chemical feed systems, and providing new interconnecting utilities throughout the plant including process piping, access roads, storm sewers, and electrical infrastructure.

Costs: The estimated construction costs associated with the work described in this section is $141.6 million and a summary is provided in Table 9-4. The 30-year life cycle costs are estimated to be $237.6 million and a summary is provided in Table 9-5.

Table 9-4 Plant Alternative 2A Total Estimated Construction Cost

Component Description	Cost
Civil Site Work (Roads, Drainage, Fencing etc.)	$3,500,000
Rehabilitate River Intake	$6,752,000
Raw Water Piping, Metering Vault	$900,000
New Conventional Pretreatment System	$17,377,000
New Ozone Facility (Generation, Basin, LOX)	$19,630,000
New Biologically Active Filters & Building	$33,912,000
New Sodium Hypochlorite System	$2,092,000
PAC Feed Improvements	$1,000,000
Other Chemical Improvements (4 at $300k ea.)	$1,200,000
Demolish South Plant	$1,066,000
New 6 MG Clearwell	$10,960,000
New High Service Pump Station	$7,870,000
Rehabilitate Existing 6.5 MG Clearwell	$734,000
Rehabilitate High Service Pump Station #3	$5,718,000
Extend 1 Plant Outfall	$750,000
Building Renovations	$2,000,000

Component Description	Cost
Interconnecting Site Utility / Electrical Work	$3,500,000
Other Demolition Work Throughout Plant	$2,000,000
Subtotal	**$120,961,000**
Additional Construction Contingencies (10%)	$12,096,000
Other Misc. Plant-Wide Improvements (2%)	$2,419,000
Phasing & Sequencing Plant Outages (3%)	$3,629,000
Remediation & Hazardous Materials	$1,000,000
Allowances	$500,000
Startup and Commissioning	$1,000,000
Total Estimated Construction Cost	**$141,605,000**

Table 9-5 Plant Alternative 2A 30-Year Life Cycle Cost

Component Description	Cost
Initial Construction Cost	$141,605,000
River Intake 30-Year O&M Cost	$12,657,000
Pretreatment, PAC, & Coagulant 30-Year O&M Cost	$27,095,000
Ozone & BAF System 30-Year O&M Cost	$13,798,000
High Service Pumping 30-Year O&M Cost	$17,973,000
Sodium Hypochlorite 30-Year O&M Cost	$11,851,000
Sodium Hydroxide & Fluoride 30-Year O&M Cost	$6,450,000
Ammonia 30-Year O&M Cost	$600,000
Misc. Maintenance of New Infrastructure 30-Year Cost	$300,000
Misc. Maintenance of Existing Infrastructure 30-Year Cost	$5,240,000
Total 30-Year Life Cycle Cost	**$237,569,000**

9.3 Plant Alternative 2B – New Surface Water Treatment Facility on New Property

This alternative features the same fundamental treatment process as Alternative 2A, with the key difference being plant location. In this case, a new site will be developed, and re-use of any existing plant infrastructure will be limited (exception of river intake and possibly residuals management facilities if required). The major benefit of an Alternative on a new site is no special phasing is needed for construction other than several short-duration tie-ins to raw water, finished water, and other temporary utilities. As such, the existing plant can remain operational while the new WTP is built. Doing so can accelerate the construction schedule, eliminate risks associated with plant outages, and even save cost depending on the required level of rehabilitation of an existing facility. Three potential sites were evaluated for the new plant. The first site is directly east of the existing WTP across Waterworks Road (shown in Figure 9-1 as Option 1). The second site is approximately 2.4 miles southeast of the plant and near the intersection of Kentucky Ave and Veterans Memorial Parkway (shown in Figure 9-2 as Option 2). The third site is approximately 2900 feet south of the plant along Waterworks Road near LST Drive (Shown in Figure 9-3 as Option 3).

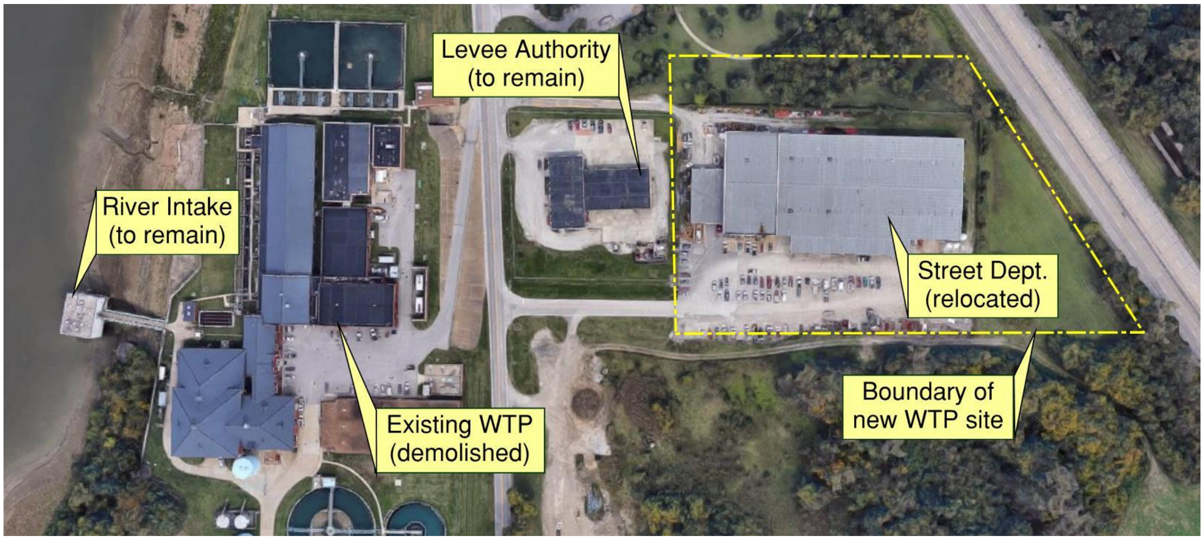


Figure 9-1 New WTP Site Option 1 Overview

Figure 9-2 New WTP Site Option 2 Overview

Figure 9-3 New WTP Site Option 3 Overview

Site Option 1 Discussion: This property is presently occupied by the Evansville Levee Authority and the City of Evansville street maintenance facility. Relocating the Levee Authority was investigated by EWSU but was determined to not be practical. However, the footprint of the maintenance facility alone is large enough for the new plant and EWSU can relocate this facility. The primary advantage of this site is the proximity to the existing river intake, Ohio River, and to the existing high service distribution waterlines. The disadvantage of this option is the cost and schedule delay associated with relocation of the maintenance facility, which is estimated to add $13.7 million to the project and a breakdown of the estimate is in Table 9-6.

Table 9-6 Plant Alternative 2B Site Option 1

Cost Description	Unit	Quantity	Unit Cost	Total Cost
Ex. Maintenance Building Demolition	SF	62,400	$10	$624,000
New Building - Office Area	SF	15,000	$144	$2,160,000
New Building - Warehouse Area	SF	70,000	$92	$6,440,000
Earthwork and Site Paving	LS	1	$710,000	$710,000
Site Stormwater Pond	CF	10,000	$19	$190,000
New Maintenance Building Fencing	LF	2,010	$90	$180,900
Miscellaneous Sitework	LS	1	$75,000	$75,000
Subtotal				**$10,379,900**
Land Acquisition	LS	1	$167,000	$167,000
Surveying, Legal Fees	LS	1	$30,000	$30,000
Architectural / Engineering Design	5%	of subtotal		$519,000
Estimating Contingency	25%	of subtotal		$2,595,000
Total Estimated Cost				**$13,690,900**

Site Option 2 Discussion: This property is presently a surface parking lot and is the closest site to the WTP which is in City limits, large enough for the new plant, undeveloped, and not located in a floodplain or wetlands. The main advantage of this site is the available area is more than option 1, offering a less compact layout for the new WTP. In terms of cost, utilizing this site is estimated to add $29.5 million to the project cost as summarized in Table 9-7. Most of this cost is due to the need to install large diameter raw and dual finished water lines between the two sites, which are located approximately 2.4 miles from each other along a potential pipe alignment following Memorial Parkway. Another disadvantage is this location adds operational complexity to the WTP as the existing river intake (or if any other infrastructure is reused) requires routine monitoring and inspection by plant personnel.

Table 9-7 Plant Alternative 2B Site Option 2

Cost Description	Unit	Quantity	Unit Cost	Total Cost
42-Inch Raw Waterline	LF	12,700	$550	$6,985,000
36-Inch Waterline	LF	25,400	$400	$10,160,000
16-Inch Residuals Pipeline	LF	12,700	$250	$3,175,000
Site Restoration / Landscaping	SY	42,300	$8	$338,400
Road and Utility Crossings	LS	1	$500,000	$500,000
Maintenance of Traffic	LS	1	$250,000	$250,000
Miscellaneous Sitework and Demo	LS	1	$50,000	$50,000
Subtotal				**$21,458,400**
Land Acquisition	LS	1	$800,000	$800,000
Survey, Easements, Legal Fees	LS	1	$125,000	$125,000
Engineering	5%	of subtotal		$1,072,900
Waterline Inspection	3%	of subtotal		$643,800
Estimating Contingency	25%	of subtotal		$5,364,600
Total Estimated Cost				**$29,464,700**

Site Option 3 Discussion: This property is presently a vacant and undeveloped lot with adequate land availability and offers a site closer to the existing WTP than option 2. However, the entire area is in the regulatory floodway of the Ohio River and is not protected by the existing levee. Developing such a property would therefore require extensive work. Realignment of the existing levee is not considered feasible as doing so would require filling Eagle Creek and interrupting the current drainage route to the Ohio River. The other option would be placing fill on the site to raise the area approximately 14 feet and above the flood elevation, which would require approximately 900,000 cubic yards of suitable fill material. Doing so is not believed to be viable from a permitting standpoint due to being in the floodway but is considered for the purposes of this exercise. Like option 2, this site would involve installation of large diameter utility lines between the two sites but is much less and estimated at 2,900 feet. The site has no electric, natural gas, or sanitary sewer utilities and those would need extended approximately 1,900 feet to the site. Altogether, these costs are estimated to add approximately $31.7 million to the project cost as described in Table 9-8. This of course, assumes this site is even feasible from a regulatory standpoint.

Table 9-8 Plant Alternative 2B Site Option 3

Cost Description	Unit	Quantity	Unit Cost	Total Cost
42-Inch Raw Waterline	LF	2,900	$550	$1,595,000
36-Inch Waterline	LF	5,800	$400	$2,320,000
16-Inch Residuals Pipeline	LF	2,900	$250	$725,000
Medium Voltage Powerlines	LF	1,900	$300	$570,000
Natural Gas Pipeline	LF	1,900	$120	$228,000
Sanitary Sewer Extension	LF	1,900	$500	$950,000
Suitable Soil Fill, Compaction, Grading	CY	903,000	$20	$18,060,000
Subtotal				**$24,448,000**
Land Acquisition	LS	1	$22,000	$22,000
Survey, Easements, Legal Fees	LS	1	$50,000	$50,000
Engineering (Site Fill / Permitting)	LS	1	$500,000	$500,000
Engineering (Waterline & Utility)	5%	of utility Cost		$319,400
Waterline & Sewer Inspection	3%	of waterline & sewer cost		$279,500.0
Estimating Contingency	25%	of subtotal		$6,112,000
Total Estimated Cost				**$31,730,900**

Recommended Site: Option 1 is a clear choice for an alternative location to develop the new WTP site due to substantially lower cost than the other options. The site also offers the greatest plant operational benefits due to its proximity to the river intake and existing plant. Furthermore, Option 3 is likely not feasible from a permitting standpoint due to being in a regulated floodway.

Proceeding with site option 1, drawings associated with the proposed improvements in this alternative are provided in Appendix A and listed below, followed by descriptions of the components.

New drawings specific to plant-wide system:
Figure A6-7: Plant Alternative 2B: Process Flow Diagram
Figure A6-8: Plant Alternative 2B: Proposed Site Plan

Drawings related to alternative and presented previously in this report:
Same as those noted in Alternative 2A.

River Intake: The river intake improvements are the same as described in Alternative 2A.

Pretreatment: Other than location (indicated on the site plan), the pretreatment system is the same as described in Alternative 2A.

Ozone Addition: Other than location (indicated on the site plan), the ozone system is the same as described in Alternative 2A.

Biologically Active Filtration: Filters are like those noted in Alternative 2A, with the key differences being location and having provisions for clearwells beneath the beds to help reduce overall plant footprint on the new site. Otherwise, the functionality and general configuration of the filters are the same.

Chlorine Disinfection: Bulk liquid solidum hypochlorite will replace chlorine gas. The setup for the hypochlorite room would vary slightly from that described in Section 7.7.2, as a wing of new chemical feed facilities would be constructed adjacent to the new filters in this alternative. The location of this chemical facility along with other new ones are shown on the conceptual site plan.

Clearwells: The existing 6.5 MG clearwell cannot be reused effectively due to hydraulics, as the elevation of the new site is over 10 feet lower than the existing site. This alternative will therefore include construction of a new clearwell with an effective volume of 5 MG (two parallel 2.5 MG clearwells). In this case, the clearwells would be located beneath the new filters rather than a stand-alone structure. Although a separate structure is more convenient, this is the only viable way to proceed on this site given the area restraints.

High Service Pumps: This alternative includes construction of a new high service pump station in the location shown on the conceptual site plan. The pump station would feature vertical turbine pumps to minimize the footprint and will pull water directly from the new clearwells. Existing pump stations #2 and #3 would not be re-used in this alternative.

Residuals: No new residuals are created with these improvements and disposal of all waste streams are proposed to remain as a discharge to the Ohio River. However, given the lower elevation of the new site, it is unlikely that the residuals will have the ability to drain by gravity to the river, especially in high river conditions. Therefore, a residuals pump station with forcemain discharge to the river is included with this alternative. The existing outfalls can be abandoned and/or removed, and this new outfall will extend further into the Ohio river to conceal the visible discharge plume as required by IDEM.

Other Features: This alternative includes new construction of many components which were otherwise reused in the previous alternative. One of the more substantial features is a new administration and maintenance building on the site. Other improvements include all new chemical feed facilities, residuals pump station, backwash supply holding tank, and other new infrastructure to develop the new site.

Costs: Although this option features more new construction compared to the last, there are some cost saving opportunities. For instance, the project implementation and sequencing efforts are far less with the new site, avoiding temporary systems and plant downtimes which ultimately add cost. There are also less unknowns with new construction. Lastly, some of the new construction is estimated to be lower cost than rehabilitation. For example, a new administration and maintenance building is estimated to be lower cost than renovation of the existing buildings given the smaller square footage, limited remediation costs, and not having to gut interiors and replace major equipment such as boilers. The total estimated construction cost for this alternative is $140.0 million and is summarized in Table 9-9. The 30-year life cycle costs are estimated to be $230.9 million and a summary is provided in Table 9-10.

Table 9-9 Plant Alternative 2B Total Estimated Construction Cost

Component Description	Cost
Civil Site Work (Roads, Drainage, Fencing etc.)	$2,853,000
Rehabilitate River Intake	$6,752,000

Component Description	Cost
Raw Water Piping, Metering Vault	$1,610,000
New Conventional Pretreatment System	$17,377,000
New Ozone Facility (Generation, Basin, LOX)	$19,630,000
New Biologically Active Filters & Building	$33,912,000
New Chemical Facilities (all)	$6,612,000
New 5 MG Clearwell	$8,804,000
New High Service Pump Station	$11,130,000
Residual Pump Station Forcemain	$1,575,000
Filter Wash water Tank	$950,000
New Administration Building	$1,810,000
New Maintenance Building	$1,040,000
Interconnecting Site Utility / Electrical Work	$3,500,000
New Electric service entrance	$1,000,000
New Generator (2,000 KW)	$1,500,000
Subtotal	**$120,055,000**
Additional Construction Contingencies (3%)	$3,602,000
Other Misc. Plant-Wide Improvements (1%)	$1,201,000
Allowances	$500,000
Maintenance Building Relocation	$13,691,000
Startup and Commissioning	$1,000,000
Total Estimated Construction Cost	**$140,049,000**

Table 9-10 Plant Alternative 2B 30-Year Life Cycle Cost

Component Description	Cost
Initial Construction Cost	$140,049,000
River Intake 30-Year O&M Cost	$12,657,000
Pretreatment, PAC, & Coagulant 30-Year O&M Cost	$27,095,000
Ozone & BAF System 30-Year O&M Cost	$13,798,000
High Service Pumping 30-Year O&M Cost	$17,973,000
Sodium Hypochlorite 30-Year O&M Cost	$11,851,000
Sodium Hydroxide & Fluoride 30-Year O&M Cost	$6,450,000
Ammonia 30-Year O&M Cost	$600,000
Misc. Maintenance of New Infrastructure 30-Year Cost	$450,000
Total 30-Year Life Cycle Cost	**$230,923,000**

It should be noted that limited information on subsurface conditions beneath the maintenance building is available, and there could be some risk of soil contamination due to the nature of this facility. Additional costs have not been included for removal / remediation of soils, which can be highly variable depending on conditions. However, over 80,000 cubic yards of soil is anticipated to be disturbed in this alternative. For example, at a cost of $30 per cubic yard, the total additional cost would be $2.4 million.

Another variable cost component is work associated with the existing WTP which is no longer needed following completion of the new plant (other than the river intake). In the previous alternative, costs for demolition and other rehabilitation work was included since such work needed to occur for the improvements. In this case, the fate of the existing WTP is unknown and could go one of several ways. A brief summary and magnitude of costs are as follows:

- **Demolition for redevelopment with park or recreational space**: If the site is to be slated for a City Park or other waterfront development not featuring major buildings, the cost for demolition can be kept relatively low and would consist of removing structures to several feet below grade and backfilling with suitable construction debris or other fill materials. At the current plant, above-ground buildings account for approximately 120,000 square feet and tanks are 130,000 square feet. At an estimated demolition cost of $\$8/ft^2$ for buildings and $\$4/ft^2$ for tanks (plus 20% for additional restoration), the total cost is approximately $1.8 million.
- **Demolition for site residential or commercial redevelopment**: If the site is to be slated for new development involving buildings, a more thorough level of demolition is needed to remove structures and properly prepare the site. Most of the construction debris would need removed (hauled to a landfill) and suitable materials would be brought in for backfill. This would drive demolition costs to be based on total tons (or cubic yards). Landfill disposal is estimated to be $50 per ton (additional for hazardous materials), and complete demolition, hauling, and final restoration is estimated to be $60 to $75 per ton. Based on preliminary estimates of total construction materials present at the WTP, full demolition would likely range between $4 and $6 million.
- **Renovation for commercial development**: Another option may be for EWSU to sell the water treatment plant (or portions of the plant) directly to a developer for commercial renovation and re-use. The older plant buildings have historic significance and architectural features which may appeal to developers depending on the industry. However, this scenario is unpredictable without first identifying a potential developer. Ultimate costs or revenue for this option would be variable, as the market value of the buildings is unknown and some of the infrastructure would need demolished regardless of the final development.

The unknown risk of site contamination and fate of the existing WTP could impact costs, tacking another $2 to $8 million onto the base project cost. In any case, it is recommended to not decide the fate of the existing WTP at this time. The existing WTP would stay operational during the construction of the new facility, which may be 4 to 5 years away from the start of new plant construction. The fate of the existing WTP should be determined and subsequently financed through a separate project following new plant construction.

9.4 Plant Alternative 3 – New Ground Water Blended Treatment Facility

This alternative consists of a 50/50 blend of ground and surface waters. The groundwater train will feature south plant rehabilitation and construction of a new membrane softening facility with the north plant undergoing improvements surface water treatment. Drawings associated with the improvements are provided in Appendix A and listed below, followed by a description of the individual components.

New drawings specific to plant-wide system:
Figure A6-9: Plant Alternative 3 Process Flow Diagram
Figure A6-10: Plant Alternative 3: Demolition and Phasing Site Plan
Figure A6-11: Plant Alternative 3: Proposed Site Plan

Drawings related to alternative and presented previously in this report:
Figure A2-1: Conventional Pretreatment Retrofit – Overall Plan (North Basins)
Figure A2-2: Conventional Pretreatment Retrofit – Enlarged Plan and Section (North Basins)
Figure A4-2: Chlorine Alternative 2: Liquid Sodium Hypochlorite
Figure A5-3: Groundwater Softening Membrane Building Plan

River Intake: The river intake will be rehabilitated as described in Section 7.4.1 but in this case would only include replacement of two (2) screens and three (3) low service pumps to meet the proposed surface water capacity of 25 MGD. Other improvements include building renovation and a new onshore potassium permanganate system located in the area of pump station #1.

Surface Water Pretreatment: North plant pretreatment improvements were presented in Section 7.5.1. For the blended water plant option, only half of the previously described improvements are necessary and pretreatment improvements therefore include new concrete walls and equipment inside one of the north primary basins to facilitate (3) parallel trains of rapid mixing, three-stage flocculation and sedimentation with inclined plate settlers. PAC would be fed ahead of pretreatment. Other pretreatment improvements include rehabilitation of the raw and settled water channels and replacement of coagulant piping. Surface water ozonation is not proposed with this alternative.

Surface Water Filtration: The filtration alternative described in Section 7.6.1 included rehabilitation of existing filters 21-36. However, for this alternative, it is proposed to utilize filters 21-28 for groundwater filtration ahead of membrane softening, which leaves filters 29-36 available for surface water filtration. Although only six of these eight filters would be needed to meet a surface water capacity of 25 MGD, it is proposed to rehabilitate all eight for redundancy. Filters 33-36 require very little rehabilitation effort. Filters 13-20 and the existing 1.5 MG clearwell would be decommissioned as part of these improvements.

Groundwater Collector Wells: Five new collector wells would be constructed for groundwater supply as described in Section 8.1. These provide water for the membrane softening trains which require approximately 30 MGD to meet a firm softened water capacity of 25 MGD. Approximately 12,000 ft of raw watermains are included in this alternative.

Groundwater Pretreatment: Iron and manganese oxidation, detention and gravity filtration provide pretreatment for the membranes. Oxidation is performed using new concrete tray aerators built in the south secondary settling basins as shown on the site plans. The basins would provide adequate detention time prior to filtration, and the existing sludge collection systems would serve as metal sludge collection equipment. However, this residual may have limited ability to discharge to the Ohio River and metal sludges would likely need to be sent to the sanitary sewer or directed to new red water filters prior to a river discharge.

Groundwater Filtration: The filtration alternative described in Section 7.6.1 included rehabilitation of existing filters 21-36. Filters 21-28 would be used for groundwater filtration and filters 29-36 would be used for the surface water train. Effluent from the south secondary tanks would therefore continue to flow to these rehabilitated filters as it does now and the existing 0.5 MG clearwell below would be used as a break tank prior to membrane softening.

Groundwater Membrane Softening: Membrane softening would be the final process in the groundwater train prior to blending with filtered surface water. A detailed discussion of the membrane softening alternative was provided in Section 8.3 and the improvements generally consist of a new building housing transfer pumps a membrane a bypass, cartridge filtration, high pressure membrane feed pumps, and ten (10) membrane skids. The location of the new membrane building is proposed to be in place of the existing south primary settling basins as shown on the conceptual drawings.

Chlorine Disinfection: The combined flow from the ground and surface water trains would be disinfected with chlorine prior to clearwell storage and high service pumping. Bulk liquid sodium hypochlorite will replace chlorine gas cylinders and the overall system is described in Section 7.7.2. Like plant alternative 1, it is proposed to retrofit the existing chlorine gas room with the new bulk hypochlorite feed facility.

Clearwells: This considers construction of a new 6 MG clearwell consisting of two parallel 3.0 MG tanks. The existing 1.5 MG clearwell will be decommissioned and the existing 0.5 MG clearwell beneath filters 21-28 will be repurposed as a membrane system feed tank. A potential location for the clearwell is identified on the site plan and is adjacent to the existing 6.5 MG clearwell, although an alternative location could be across Waterworks Road in Sunset Park. Following construction of the new clearwell, the existing 6.5 MG clearwell would be rehabilitated and include an interior baffle wall to create two parallel 3.25 MG clearwells.

High Service Pumps: The high service pump improvements for Plant Alternative 3 are proposed to be the same as previously described for Plant Alternative 1. This includes rehabilitating high service pump stations #2 and #3 for water supply to the distribution system.

Residuals: The surface water train would produce approximately half the residual volume as the plant does now with little or no anticipated variation in content concentration. The groundwater train will produce new residual streams which may need special considerations beyond a river discharge. As a benefit, the membrane concentrate could offer dilution of mercury in the surface water residuals and disposal (although likely not low enough to waive the mercury variance). This is, of course, assuming the higher TDS concentration discharge is permitted by IDEM. However, a major drawback is the amount of metals present in groundwater basin sludge and filter backwash. These may not have the ability to be sent directly to the river and could require either conveyance to the wastewater treatment plant or new red water filters prior to a liquid stream river discharge.

If EWSU is to seriously consider this plant alternative, further discussions with IDEM are recommended to identify implications of these additional residuals having high concentrations of TDS and metals. The cost estimate for this alternative does not include special residuals treatment or disposal and these may be significant.

Costs: The estimated construction costs associated with work described in this section and is estimated at $175.6 million, and a summary is provided in Table 9-11. The 30-year life cycle costs are estimated to be $297.6 million and a summary is provided in Table 9-12.

Table 9-11 Plant Alternative 3 Total Estimated Construction Cost

Component Description	Estimated Cost
Civil Site Work (Roads, Drainage, Fencing etc.)	$3,500,000
Rehabilitate River Intake	$4,823,000
North Plant Pretreatment Improvements	$7,163,000
Rehabilitate Gravity Filters	$9,013,000
Groundwater Wells and Conveyance	$40,073,000
GW Pretreatment (oxidation, detention)	$1,422,000
GW Pretreatment (filtration)	$9,013,000
GW Membrane Softening Facility	$35,979,000
New Sodium Hypochlorite System	$2,092,000
PAC Feed Improvements	$800,000
Other Chemical Improvements (4 at $300k ea.)	$1,200,000
Demolish South Plant Primaries	$693,000
Construct New 6 MG Clearwell	$10,960,000
Rehabilitate Existing 6.5 MG Clearwell	$734,000
Rehabilitate High Service Pump Stations #2, #3	$8,733,000
Extend 3 Plant Outfalls ($750k ea.)	$2,250,000
Building Renovations	$4,000,000
Interconnecting Site Utility / Electrical Work	$3,500,000
Other Demolition Work Throughout Plant	$2,000,000
Construction Subtotal	**$147,948,000**
Additional Construction Contingencies (10%)	$14,795,000
Other Misc. Plant-Wide Improvements (2%)	$2,959,000
Phasing & Sequencing Plant Outages (5%)	$7,397,000
Remediation & Hazardous Martials	$1,000,000
Allowances	$500,000
Startup and Commissioning	$1,000,000
Total Estimated Construction Cost	**$175,599,000**

Table 9-12 Plant Alternative 3 30-Year Life Cycle Cost

Component Description	Cost
Initial Construction Cost	$175,599,000
GW & Membrane System 30-Year O&M Cost	$52,170,000
River Intake 30-Year O&M Cost	$6,328,500
SW Pretreatment 30-Year O&M Cost	$13,446,500
Conventional Filtration 30-Year O&M Cost	$11,913,000
High Service Pumping 30-Year O&M Cost	$17,973,000
Sodium Hypochlorite 30-Year O&M Cost	$11,851,000
Fluoride & Corrosion Inhibitor 30-Year O&M Cost	$3,450,000
Ammonia 30-Year O&M Cost	$600,000
Misc. Maintenance of New Infrastructure 30-Year Cost	$300,000
Misc. Maintenance of Existing Infrastructure 30-Year Cost	$3,930,000
Total 30-Year Life Cycle Cost	**$297,561,000**

9.5 'Do Nothing' Alternative

A final option is a 'do nothing' alterative in which the WTP continues to operate without any major planned capital improvement project(s). In this case, equipment at the end of its useful life would continue to fail and be replaced on an emergency basis. From a life cycle perspective, this alternative would be comparable to the surface water treatment plant alternatives, since much of the existing equipment and structures are nearing the end of their useful. In other words, nearly every aspect of the plant would need improvements within a 30-year cycle. However, costs aside, the potential risks and consequences associated with taking a 'do nothing' approach could be severe and as follows:

1. **River intake**: Pumps and screens will need to remain on the same rebuild schedule which has considerable cost. The screens and the electrical infrastructure are nearly at the end of their useful life and are a vulnerable point of failure, requiring replacement soon regardless of a major plant improvement. Redundancy is available in the screens and pumps and the plant can get by with loss of one, but electrical equipment failure would result in the complete inability to provide water.
2. **Pretreatment Basins**: A north basin clarifier recently failed and was replaced as an emergency project. Both south basin clarifier systems are approaching the end of their useful life and failures of these mechanisms are imminent, resulting in a loss of at least 25% of the plant capacity. There are also numerous safety concerns with handrail and grating covering raw water channels and pretreatment basins, posing hazards to plant staff.
3. **Filters**: Filters 13-20 have nearly reach the point of failure and need to be decommissioned. This is further compounded by introduction of corrosive chlorine fumes in the piping gallery. Ongoing filter improvements involving replacement of underdrains will need to continue periodically on older filters, as many have failed. There are also visible deficiencies in the

condition of structural components throughout the filter galleries, and major rehabilitation will be needed to prevent a failure.

4. **Clearwells**: The clearwells pose as a major obstacle for long-term operation of the plant. The 6.5 MG clearwell has integrity issues relating to infiltration and the plant is unable to operate without this tank in service. Failure of this clearwell would result in a long-term inability for the plant to reliably produce water. Such a scenario could only rely on the 0.5 and 1.5 MG clearwells and high service pump station #2, which would reduce plant capacity significantly.
5. **High Service Pumps**: Some of the high service pumps have useful life remaining and could continue to operate with occasional rebuilds as they do now. However, the electrical equipment feeding these pumps is a vulnerable point of failure and needs upgraded soon to avoid a temporary inability to provide finished water to the distribution system.
6. **Chemical Feed Systems**: Most of the chemical feed systems are in reasonable condition although some components are expected to experience occasional failures and the need for repairs. The chlorine gas facility poses as a major health and safety risk to not only plant staff, but to the City of Evansville.
7. **Residuals**: IDEM will require modification of all four outfalls and other regulatory requirements if EWSU elects to not implement any major improvements.
8. **Electrical**: Most of the electrical infrastructure is beyond its useful life and poses as a major point of vulnerability for the plant. Additionally, many of the systems are non-code compliant and are therefore a health and safety risk as well.
9. **Buildings:** Many of the buildings remain structurally sound, although there certainly are deficiencies which need addressed as noted in Chapter 5. Major deficiencies lie within the mechanical components. Only one boiler is functional and is beyond its useful life. The steam system piping has leaks throughout the plant with a catastrophic failure being imminent. Other deficiencies and hazards are present throughout the buildings including the presence of lead paint, faulty handrails and gratings, inadequate ventilation, and deteriorating finishes among others.

In summary, EWSU is running a major risk if no improvements are planned at the WTP. The primary consequence is the inability to provide drinking water to the residents for an extended period. This is not tied to one or two vulnerable components of the plant but is found plant-wide in nearly every aspect. The WTP also presents several health and safety issues – not just for plant personnel but also for the general public (such as chlorine gas). Furthermore, the existing treatment process is antiquated and has limited ability to combat the challenges of the Ohio River water source. Even without implementation of a major capital improvement project, significant capital dollars will continue to be spent at the WTP on an annual basis just to keep up with replacement of failed equipment and other emergency repairs. Given the reflex reaction to address such issues, they are not always completed with due diligence and foresight, resulting in the need for further improvements and additional costs in the near-term future. Given all these considerations, a 'do nothing' alternative is not considered viable.

10.0 Recommendations

The plant-wide alternatives described in Chapter 9 are further evaluated in this section for final recommendations and project implementation strategies. As noted in that Chapter, a "Do Nothing" alternative is not considered viable and is not explored further in this section.

10.1 Recommended Alternative

Table 10-1 provides a final scoring matrix like those presented in the surface water alternatives but in this case is modified to reflect the individual plant-wide alternatives.

Table 10-1 Final Alternative Non-Monetary Scoring

	Score Weightings				Raw Scores				Net Weighted Scores			
Decision Factors	**Total**	**2nd**	**3rd**	**Net**	**Alt. 1**	**Alt. 2A**	**Alt. 2B**	**Alt. 3**	**Alt. 1**	**Alt. 2A**	**Alt. 2B**	**Alt. 3**
Technical Factors												
Process Robustness												
Turbidity Spikes in the River			25%	3%	70	80	80	90	2.1	2.4	2.4	2.7
River Spills / Contaminants		20%	25%	3%	70	90	90	90	2.1	2.7	2.7	2.7
Taste & Odor Control			25%	3%	80	90	90	90	2.4	2.7	2.7	2.7
Organics and DBP's	**60%**		25%	3%	70	90	90	90	2.1	2.7	2.7	2.7
Distribution Water Quality Impacts		15%		9%	80	90	90	70	7.2	8.1	8.1	6.3
Ease of Operation		20%		12%	80	90	90	50	9.6	10.8	10.8	6
Impacts to Operations during Const.		15%		9%	20	30	90	30	1.8	2.7	8.1	2.7
Length of Construction Period		15%		9%	40	60	70	60	3.6	5.4	6.3	5.4
Reliability & Redundancy		15%		9%	90	100	100	100	8.1	9	9	9
Social Factors												
Susceptibility to Malevolent Threats		25%		5%	90	90	90	90	4.5	4.5	4.5	4.5
Visibility from Veterans Mem. Pkwy.	**20%**	5%		1%	90	80	50	80	0.9	0.8	0.5	0.8
Beneficial Land Re-use		30%		6%	50	50	90	50	3	3	5.4	3
Flexibility for Future Expansion		40%		8%	40	70	80	40	3.2	4	6.4	3.2
Environmental Factors												
Susceptibility to Earthquake		25%		5%	70	70	80	70	3.5	3.5	4	3.5
Susceptibility to Tornado	**20%**	25%		5%	70	70	90	70	3.5	3.5	4.5	3.5
Susceptibility to Flooding		25%		5%	90	90	70	90	4.5	4.5	3.5	4.5
Potential Soil Contamination		25%		5%	100	100	60	100	5	5	3	5
Effective Score	**100%**			**100%**	**1200**	**1340**	**1400**	**1260**	**67.1**	**76.9**	**84.6**	**68.2**

For a complete assessment and evaluation of the alternatives, the life cycle cost must also be factored into scoring. This is accomplished by identifying a 'benefit-to-cost' ratio by diving the non-monetary benefit score by the 30-year life cycle cost. Life cycle costs were previously presented in Chapters 7 and 9, with further details summarized in Appendix B. These Benefit-to-Cost Ratios and supporting information are provided in Table 10-2.

Table 10-2 Final Alternatives Benefit-to-Cost Ratios and Rank

Alt.	Non-Monetary Benefits Score	Construction Cost	30-Year Life Cycle (Billions)	Benefit-to-Cost Ratio	Rank
1	67.1	$121,822,000	$0.253	265	3
2A	76.9	$141,605,000	$0.238	324	2
2B	**84.6**	**$140,049,000**	**$0.231**	**366**	**1**
3	68.2	$175,599,000	$0.298	229	4

The recommended alternative is **Alternative 2B.** This project involves construction of a new surface water treatment plant utilizing conventional pretreatment, ozone, and biologically active filtration treatment processes. The location of the new WTP is proposed to be east of Waterworks Road and very little of the existing WTP will be reused except for the river intake and low service pump station.

10.2 Scoring Considerations Discussion

Since the scores and life cycle costs for Alternatives 2A and 2B are close, additional discussion is merited to justify selection of Alterative 2B. Although the two options are fundamentally similar, there are some key differences. Reasoning to assign differing scores for individual criteria (from Table 10-1) is provided below.

1. **Impacts to Operation During Construction**: Alternative 2A requires construction within the footprint of the existing WTP site, including sequential demolition of old tankage or equipment and construction of new. It also requires extensive piping, electrical, and control tie-ins to existing facilities. This intense activity would pose an increased risk to the ability to consistently meet water demands and would inherently reduce the level of redundancy in the plant during construction. Furthermore, there is no way to construct the improvements without losing at least 25% of the capacity for months on end. The construction is also relatively complex and will require scrupulous construction sequencing to bring new process trains on-line prior to demolition of the older trains. Conversely, Alternative 2B interference with ongoing operation would be minimal with construction activities occurring across the street. Scores for Alternatives 2A and 2B were 30 and 90, respectively.
2. **Length of Construction Period**: Given the requirements of sequencing and staged demolition, the length of construction for Alternative 2A would inevitably be longer than that required for 2B. With increased construction duration comes increased total project costs,

the need for additional administration involvement with EWSU personnel, and longer occurrences of general hazards associated with an active construction site. Scores for Alternatives 2A and 2B were 60 and 70, respectively.

3. **Visibility from Veteran's Memorial Parkway**: The scoring for this factor was largely predicated on visibility of the WTP site from Veterans Memorial Parkway, which is a main artery into Evansville and has a substantially higher volume of traffic than Waterworks Road. Since a new WTP constructed under Alternative 2B would be physically adjacent to the Parkway, Alternative 2B was given a lower score than Alternative 2A, although some visual impacts could be mitigated in design through lower profile structures. Scores for Alternatives 2A and 2B were 80 and 50, respectively.

4. **Beneficial Land Reuse**: The scoring of this factor hinges primarily on the desirability of the site not used for the WTP to be developed or re-developed for beneficial land use. Given the riverfront location of the existing plant, it is assumed that eventual demolition of the existing plant (under Alternative 2B) would allow this site to be restored for potential redevelopment or park land. Alternative 2A would result in the demolition of some of the existing plant infrastructure and could free up areas at the northern end of the site, but it would be a much smaller parcel. The site east of Waterworks Road is considered far less desirable for beneficial land use as the Levee Authority and Maintenance facilities would likely remain. Scores for Alternatives 2A and 2B were 50 and 90, respectively.

5. **Flexibility for Future Expansion**: Site plans developed for both alternatives have included a space allowance for future expansion. However, Alternative 2B offers a cleaner solution and more space for additional expansion if required in the future. Scores for Alternatives 2A and 2B were 70 and 80, respectively.

6. **Susceptibility to Earthquakes and Tornadoes:** It is understood that the risk of a significant seismic event in Evansville is comparatively low, but not negligible. Tornadoes are a more probable natural disaster but would be less damaging to large structures. While the design of any new facilities would be to modern structural codes commensurate with the seismic and wind load risk in the area, it would be difficult if not impossible to sufficiently rehabilitate several of the existing facilities to bring them up to an equivalent standard from a structural perspective. Since alternative 2A features considerable re-use of existing buildings and tanks, it received a lower score in these categories. Scores for Alternatives 2A and 2B were 70 and 80 for earthquakes and 70 and 90 for tornadoes, respectively,

7. **Susceptibility to Flooding**: The existing site is considered well protected against flooding, although the existing 6.5 MG clearwell is thought to be prone to infiltration at higher river water levels. The elevation of the site for Alternative 2B is lower and may be more susceptible to surface water flooding not related to the Ohio River. Nevertheless, construction of new WTP facilities at both plant locations could be done to maximize protection against flooding including consideration of the elevations of key plant infrastructure to minimize risk. Given the additional mitigation requirements for flooding, Alternative 2B received a lower score. Scores for Alternatives 2A and 2B were 90 and 70, respectively.

8. **Potential Soil Contamination**: Although the presence of contamination in the soils is not known, there is a greater risk of this potential issue for Alternative 2B given the nature of the existing street maintenance facility which will be relocated. Having to remediate any soils could delay the project schedule and add to construction costs. Scores for Alternatives 2A and 2B were 100 and 60, respectively.

10.3 Project Implementation

A capital project of this magnitude is a major financial undertaking for EWSU and requires strategic planning. Costs that were previously presented are representative of the estimated construction costs. In order to fully implement the project, additional expenses including permitting and legal fees, bidding, construction administration, interest incurred through project financing, materials testing, and construction inspection need to be performed by parties independent of the construction contractor(s). Note that final engineering is not noted in these costs, as EWSU has already accounted for this and is financing separately of this plant cost. Table 10-3 presents the total estimated project cost for Alternative 2B.

Table 10-3 Total Estimated Project Cost of Preferred Alternative 2B

Project Cost Description	Cost
Estimated Construction Cost	$140,049,000
Construction Administration and Bidding (2.5%)	$3,501,000
Inspection and Materials Testing (2%)	$2,801,000
Interest Incurred Through Financing / Federal Regulatory (2.25%)	$3,151,000
Permitting Fees and Legal Expenses (1%)	$1,400,000
Total Estimated Project Cost	**$150,902,000**

Obtaining a single loan to finance 100% of this project cost at the beginning of the project would result in a dramatic and sudden increase in water utility rates. This would present a considerable burden to utility customers, especially given the recent rate increases to finance the major wastewater utility projects. Rather than a single loan at the start of the project, spreading the incurred costs throughout the initial preparation and construction duration may be more viable. Figure 10-1 on the following page provides a potential construction and financing schedule for the project including the sequencing of project tasks, associated costs, and approximate cost per year allocation for consideration when planning financing. The project schedule considers the relocation of the maintenance facility beginning in the third quarter of 2021.

The project delivery method has not been determined at this time. However, to help control cost escalation and give better options for project financing, a design-build type method with a guaranteed maximum price may give the most flexibility. It is not recommended to attempt to bid the work as individual contracts due to project complexity and the need for continuity between processes.

		2021				2022				2023				2024				2025			
Project Task	**Task Cost**	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Relocate Maintenance Facility	$13,691,000																				
River Intake Rehabilitation	$7,022,000																				
Earthwork / Underground Utilities	$4,007,000																				
Foundations & Concrete Work	$30,573,000																				
Filtration Equipment & Building	$26,536,000																				
High Service Equipment & Building	$8,766,000																				
Ozone & LOX Equipment & Building	$15,396,000																				
Pretreatment Equipment	$13,639,000																				
Residuals Pump Station Equipment	$882,000																				
Administration Building	$1,882,000																				
Chemical Feed Facilities	$6,876,000																				
Maintenance Building	$1,082,000																				
Wash water Tank & Piping	$1,051,000																				
Raw & Residuals Water Piping	$2,556,000																				
Final Site Civil & Building Finishes	$5,090,000																				
Substantial Completion	-																				
Plant Commissioning	$1,000,000																				
Project Implementation Costs	$10,853,000																				
Estimated Value of Work Completed Per Year		**$6,845,500**				**$19,252,083**				**$42,085,717**				**$53,517,783**				**$29,200,917**			

Figure 10-1 Potential Construction Schedule with Annual Cost Distribution

11.0 References

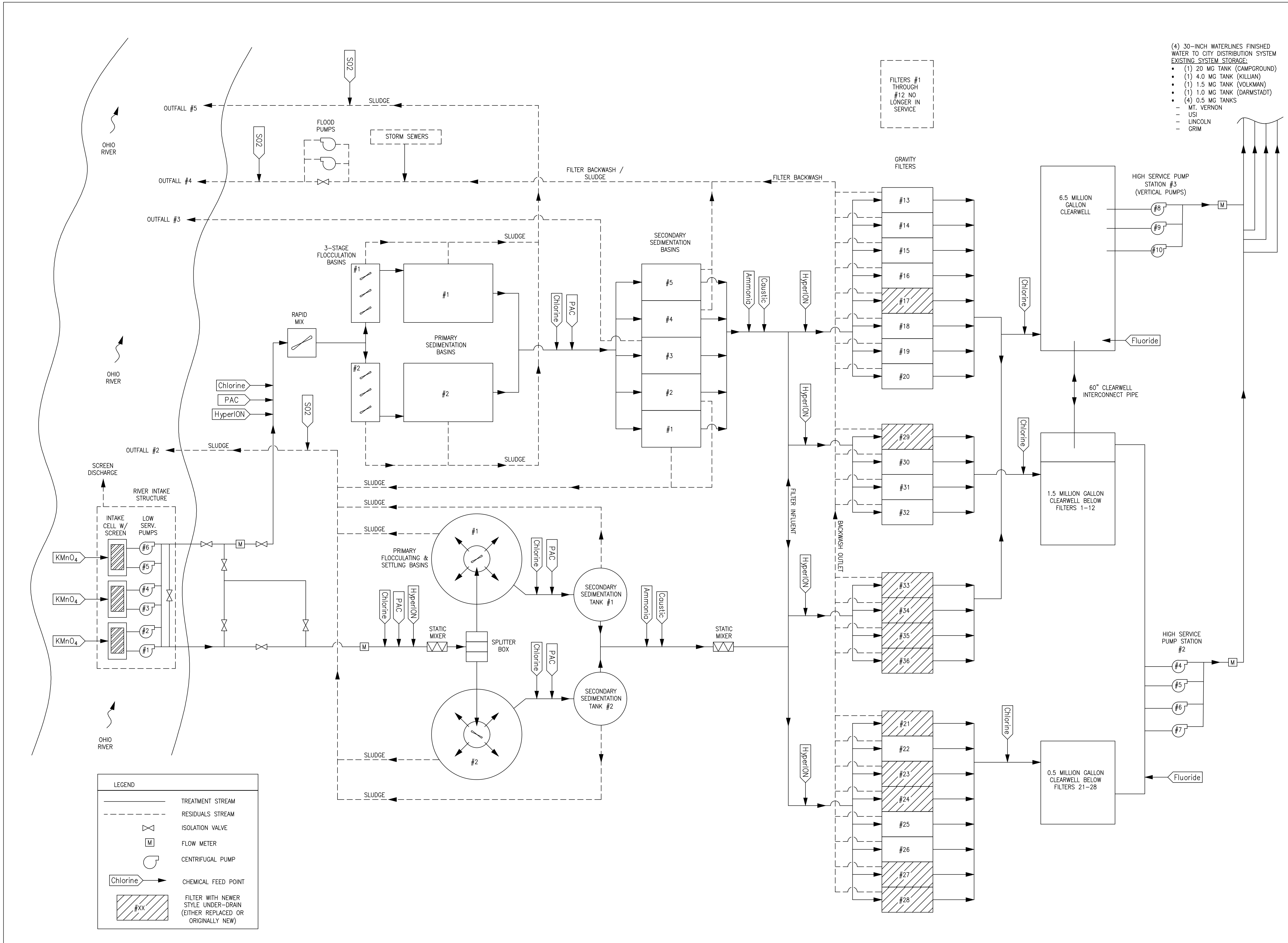
Evansville-Vanderburgh County Area Plan Commission. (2016). *Evansville-Vanderburgh County Comprehensive Plan 2015-2035.*

Great Lakes Upper Mississippi River Board. (2012). *Recommended Standards for Water Works.* Health Research Inc.

HNTB. (2016). *EWSU Water Master Plan.* Evansville Water and Sewer Utility.

APPENDIX A

DRAWINGS



ARCH D 22" x 34"

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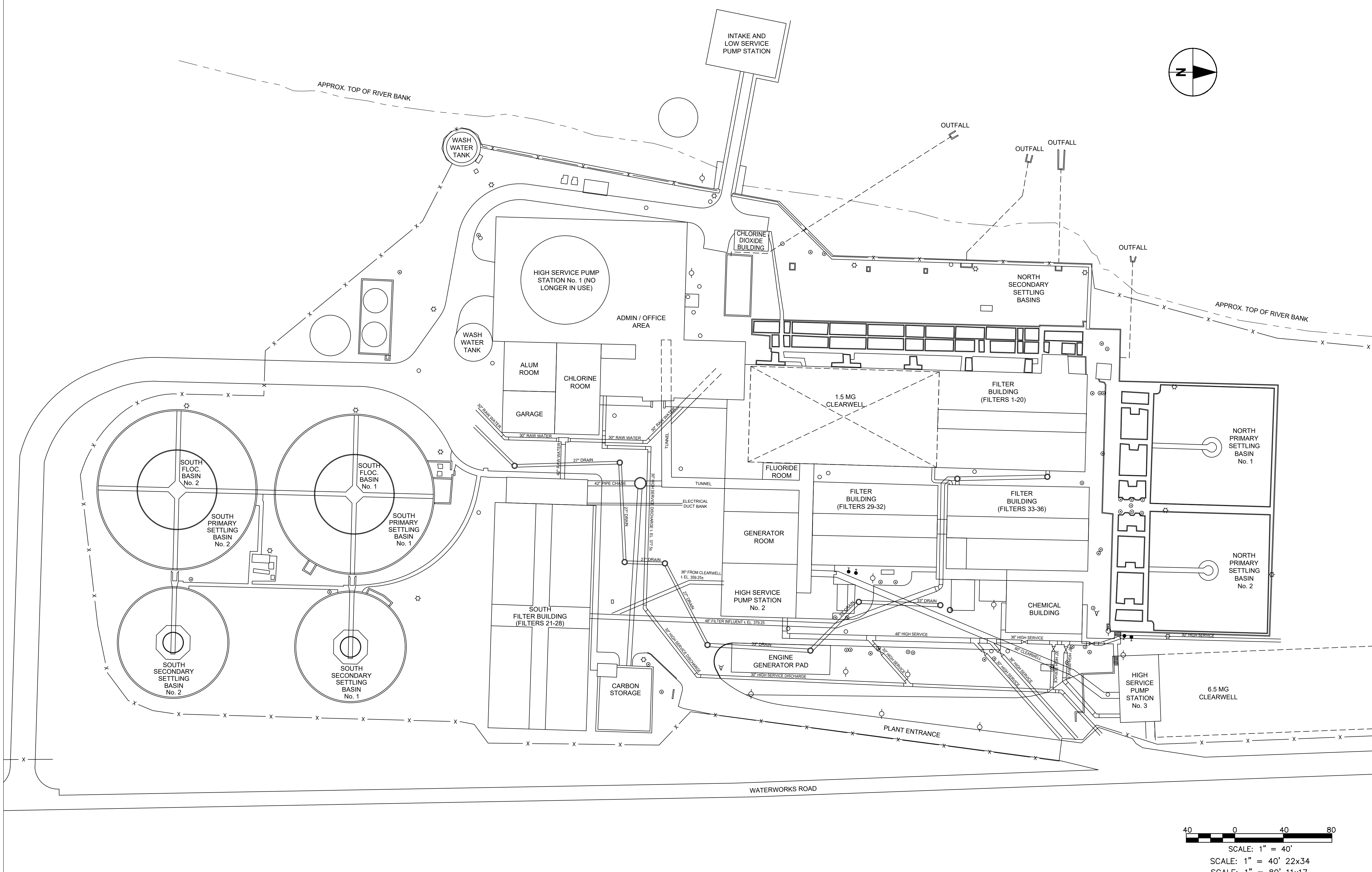
SHEET TITLE

EXISTING WTP PROCESS FLOW DIAGRAM

SHEET NUMBER

FIGURE A0-1



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EXISTING WTP
SITE PLAN

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FIGURE A0-2

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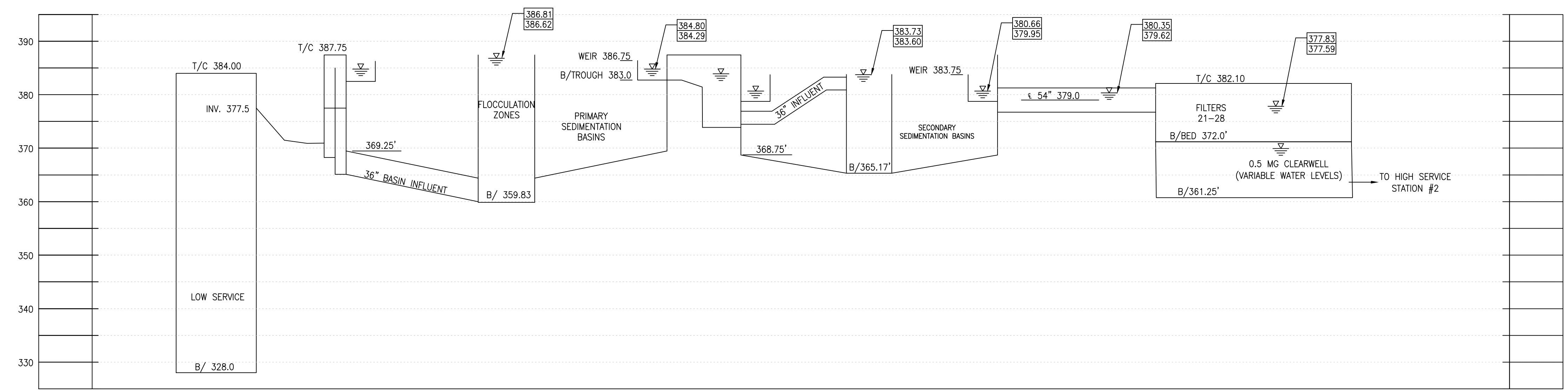

LEGENDS
XXX.XX HGL FOR 18 MGD (16 MGD IN FILTER)
XXX.XX HGL FOR 9 MGD (9 MGD IN FILTER)

3 SOUTH PLANT HYDRAULIC PROFILE: FILTERS 21-28

SCALE: NONE

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SHEET TITLE

EXISTING WTP
HYDRAULIC PROFILES
SOUTH PLANT

SHEET NUMBER

FIGURE A0-4

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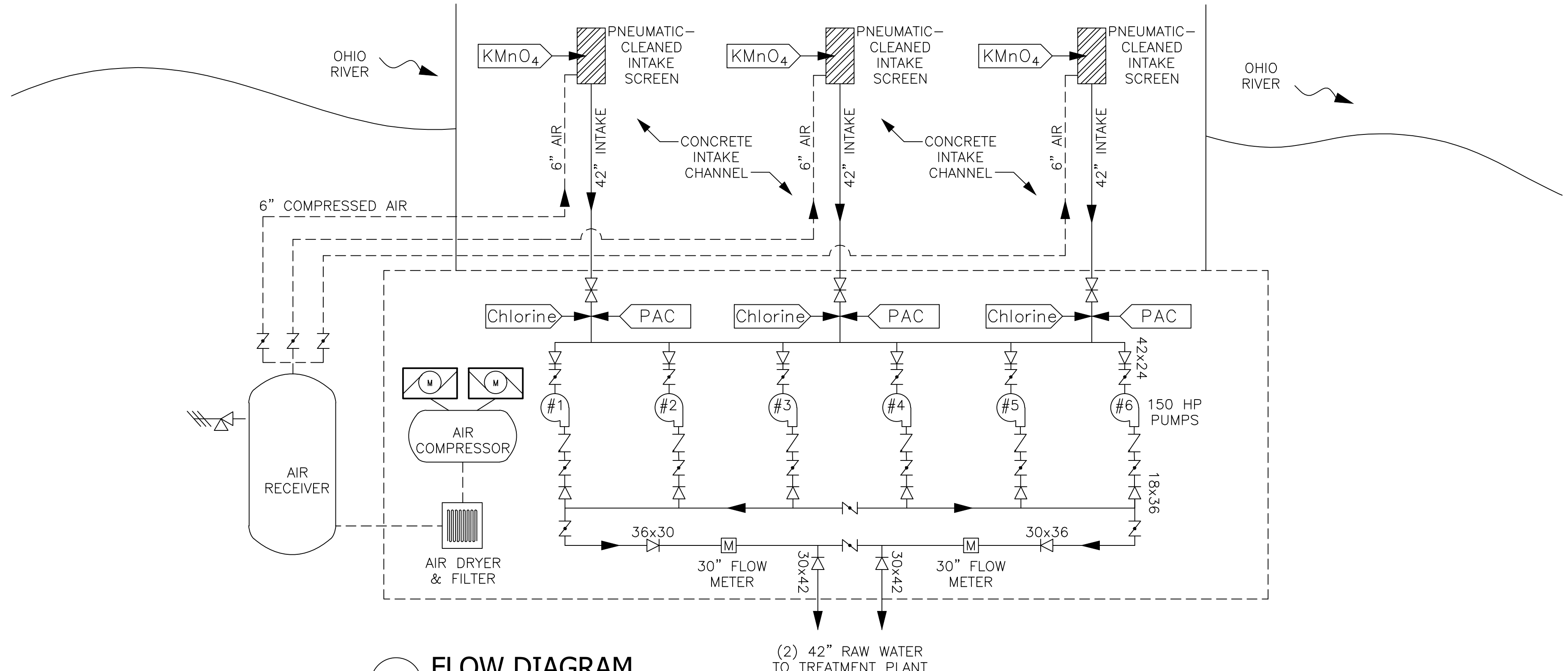

FLOW DIAGRAM

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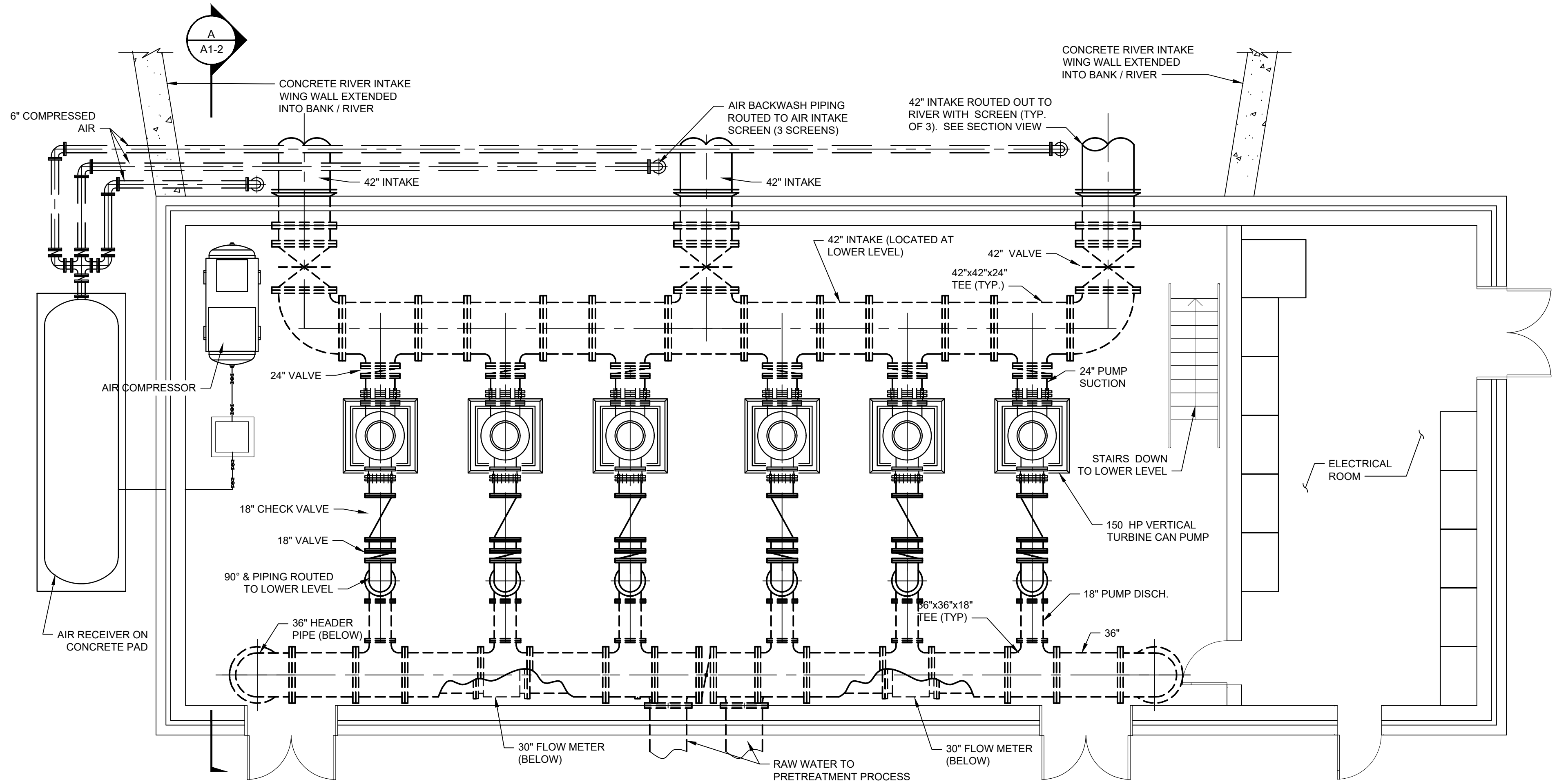

PLAN VIEW

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SCALE: 3/16" = 1'-0" 22x34
SCALE: 3/32" = 1'-0" 11x17

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SHEET TITLE

NEW RIVER INTAKE FLOW DIAGRAM AND PLAN VIEW

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FIGURE A1-1

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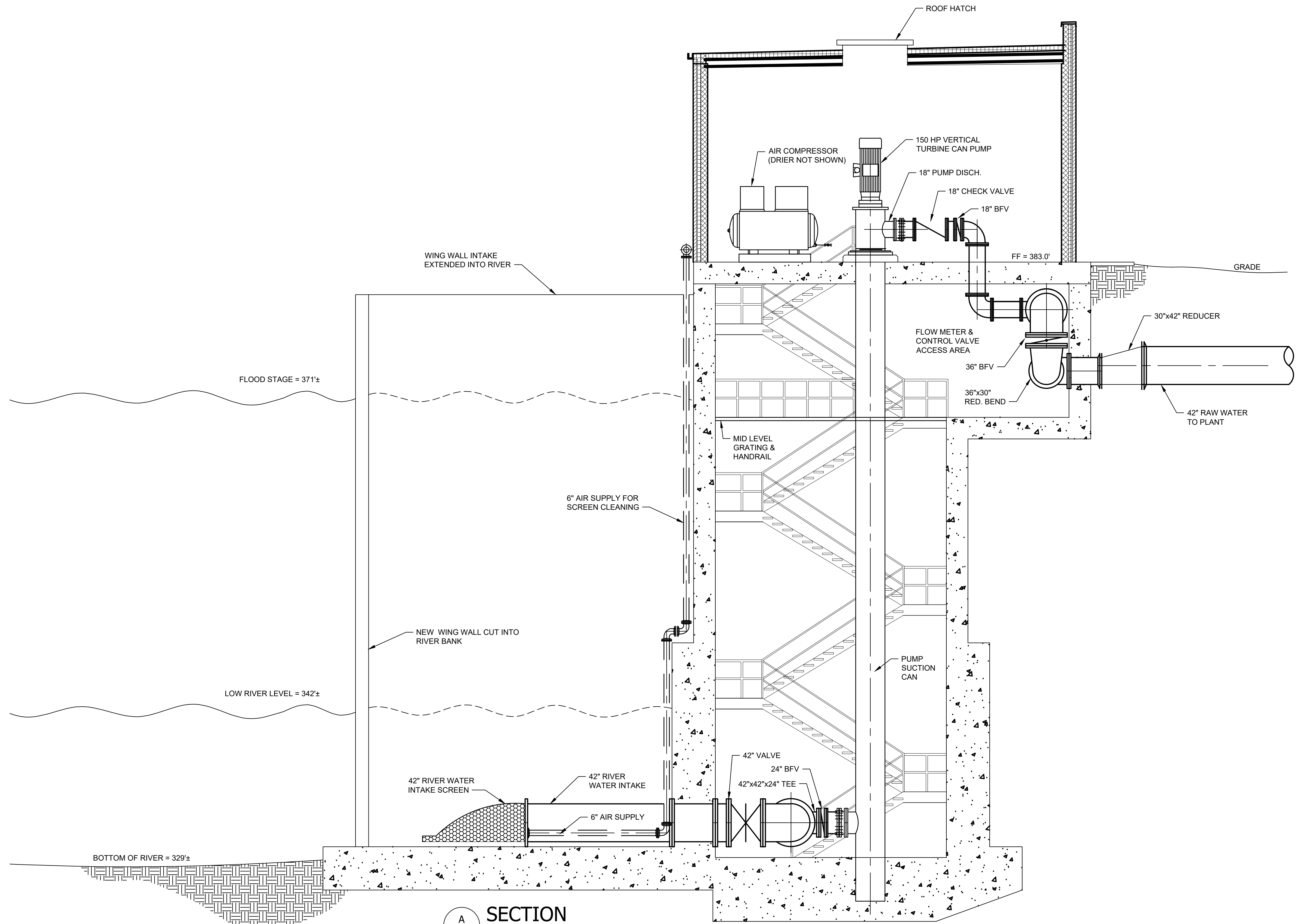

A
A1-1
SECTION
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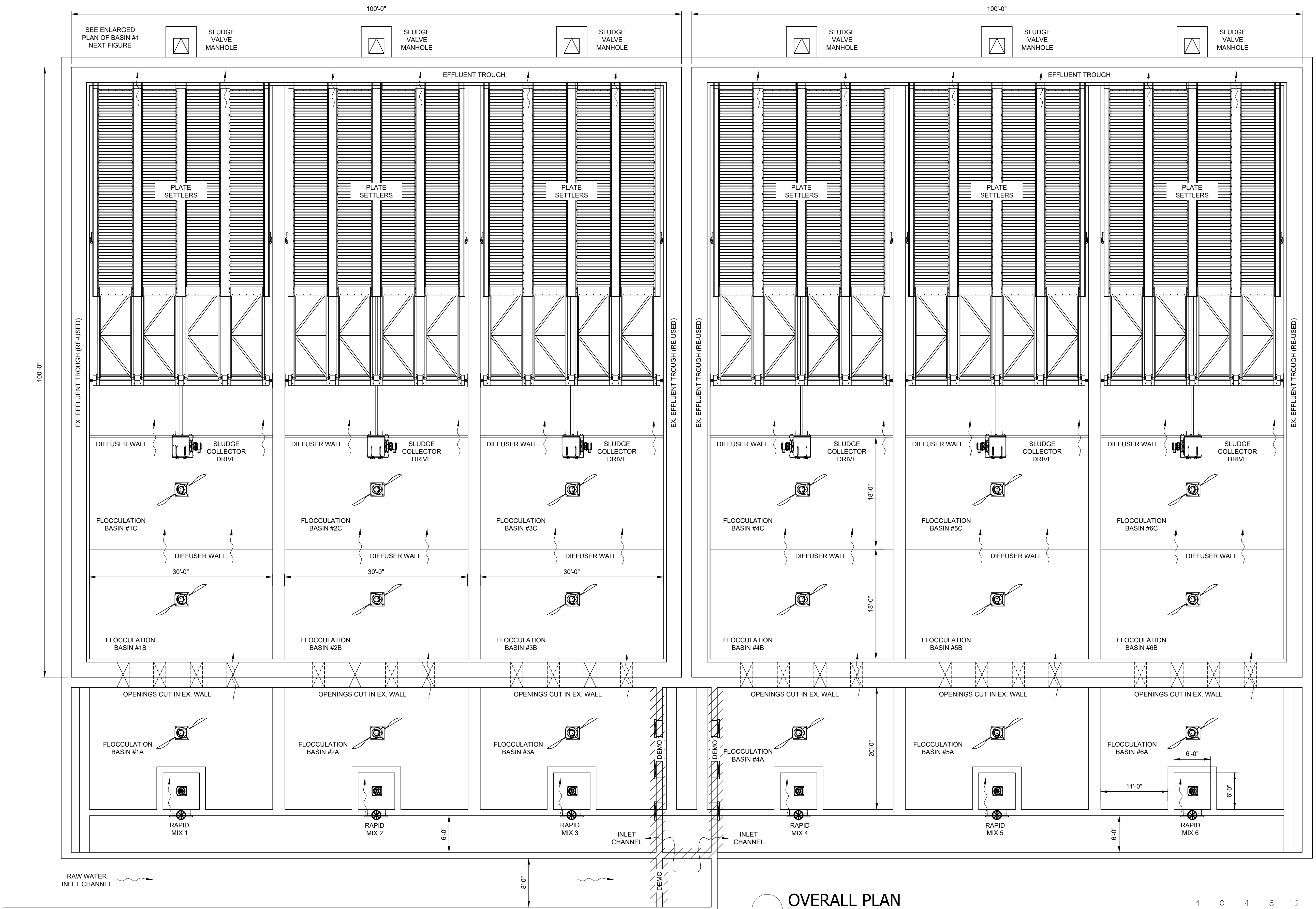
SHEET TITLE

NEW RIVER INTAKE SECTION

SHEET NUMBER

FIGURE A1-2



OVERALL PLAN

SCALE: 1/8" = 1'-0"

4 0 4 8 12
SCALE: 1/8" = 1'-0" 22x34
SCALE: 1/16" = 1'-0" 11x17

AECOM

PROJECT

EVANSVILLE WATER PLANT ADVANCED FACILITY PLAN
1301 Water Works Rd
Evansville, IN 47713

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PROJECT NUMBER

Evansville: U1032
AECOM: 60613867

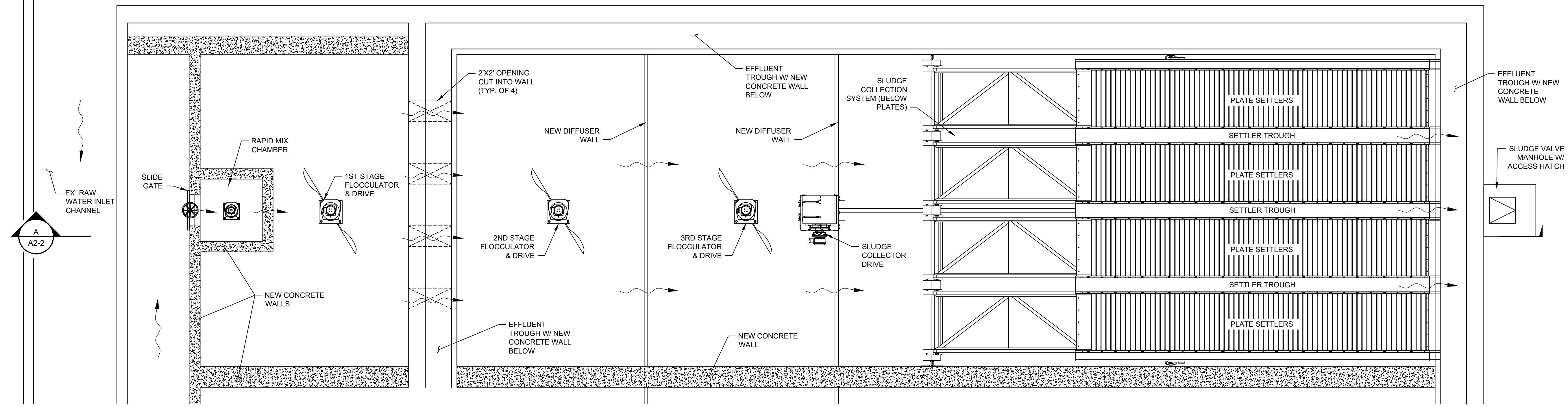
SHEET TITLE

CONVENTIONAL PRETREATMENT RETROFIT OVERALL PLAN (NORTH BASINS)

SHEET NUMBER

FIGURE A2-1

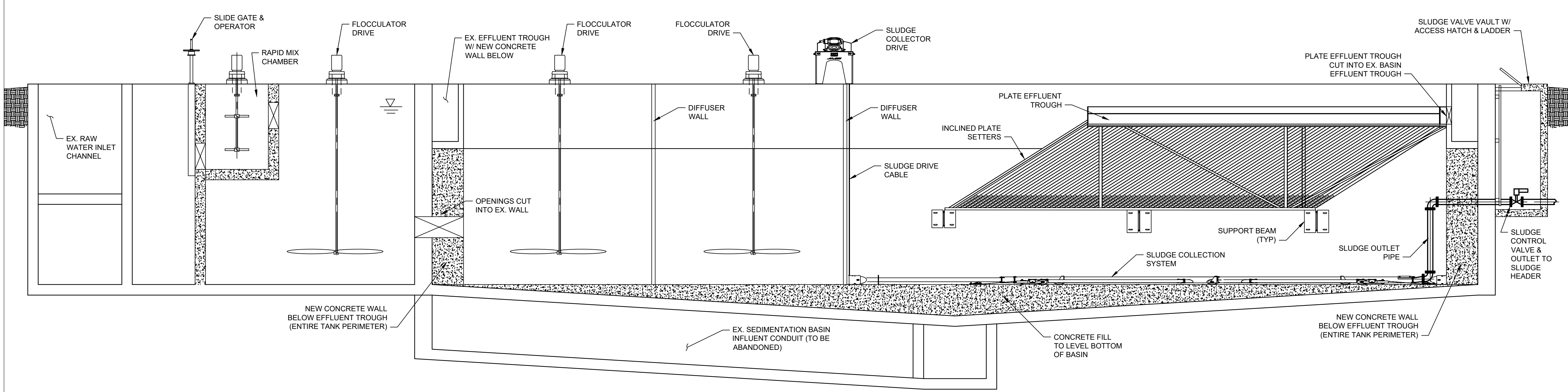
AECOM



NOTE: GRATING TO INDIVIDUAL MIXER DRIVES, INLET GATE, AND SLUDGE DRIVE TO BE PROVIDED BUT NOT SHOWN

ENLARGED PLAN

SCALE: 3/16" = 1'-0"



A
A2-2

SECTION

SCALE: 3/16" = 1'-0"

4 3 2 1 0 4 8
SCALE: 3/16" = 1'-0" 22x34
SCALE: 3/32" = 1'-0" 11x17

PROJECT

EVANSVILLE WATER PLANT ADVANCED FACILITY PLAN

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AECOM: 60613867

SHEET TITLE

CONVENTIONAL PRETREATMENT RETROFIT ENLARGED PLAN & SECTION (NORTH BASINS)

SHEET NUMBER

FIGURE A2-2

Project Management Initials: Designer: ### Checked: ### Approved: ### ARCH D 22" x 34"

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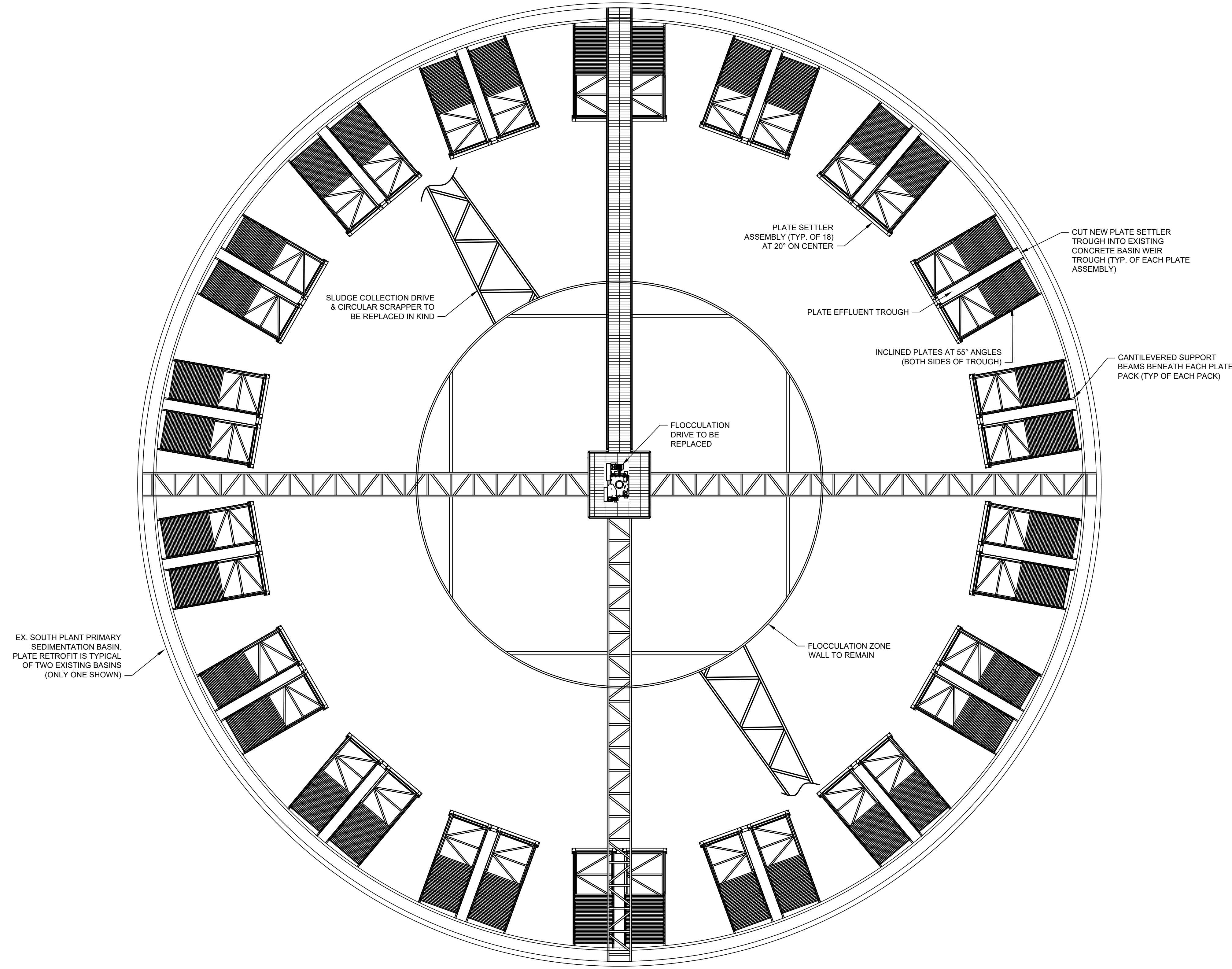

OVERALL PLAN

SCALE: 1/8" = 1'-0"

4 0 4 8 12

SCALE: 1/8" = 1'-0" 22x34
SCALE: 1/16" = 1'-0" 11x17

AECOM

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Evansville: U1032
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SHEET TITLE

SOUTH PLANT PLATE SETTLER RETROFIT PLAN (NOT RECOMMENDED)

SHEET NUMBER

FIGURE A2-3

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ARCH D 22" x 34"

Approved: ###

Checked: ###

Designer: ###

Project Management Initials:

Filename: G:\COLUMBUS\DCS\PROJECTS\WTR\60613867_EVANSVILLE\900-CAD-GIS\910-CAD\20-SHEETS\WATER\PRETREAT - NEW CONV SYSTEM.DWG
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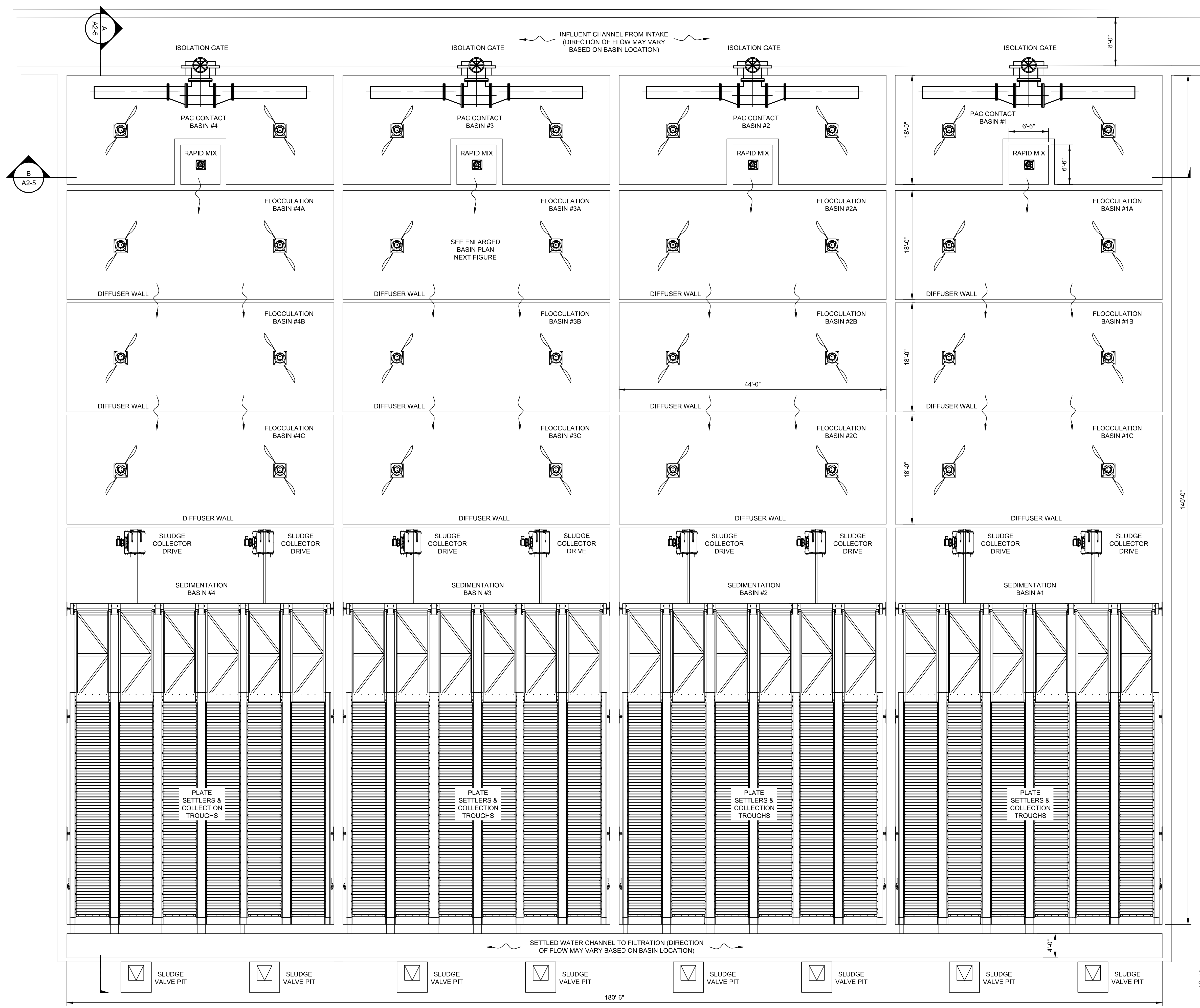

4 0 4 8 12

SCALE: 3/32" = 1'-0" 22x34
SCALE: 3/64" = 1'-0" 11x17

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PROJECT

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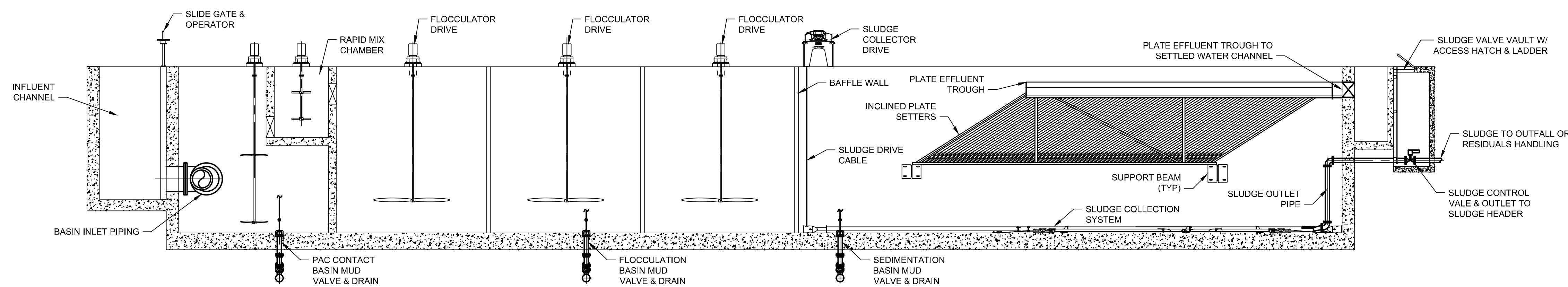
SHEET TITLE

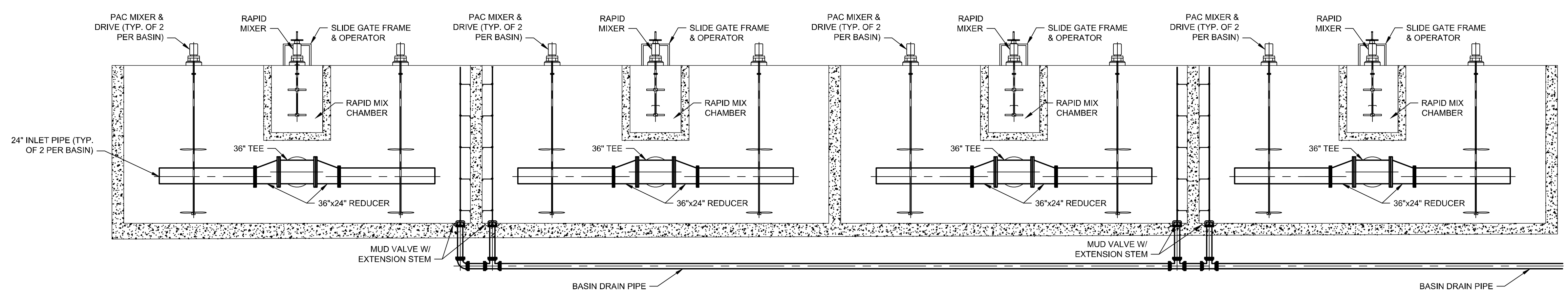
CONVENTIONAL PRETREATMENT NEW CONSTRUCTION PLAN

SHEET NUMBER

A2-4



A
2A-4
SECTION



B
2A-4
SECTION

4 0 4 8 12
SCALE: 1/8" = 1'-0" 22x34
SCALE: 1/16" = 1'-0" 11x17

ARCH D 22" x 34"
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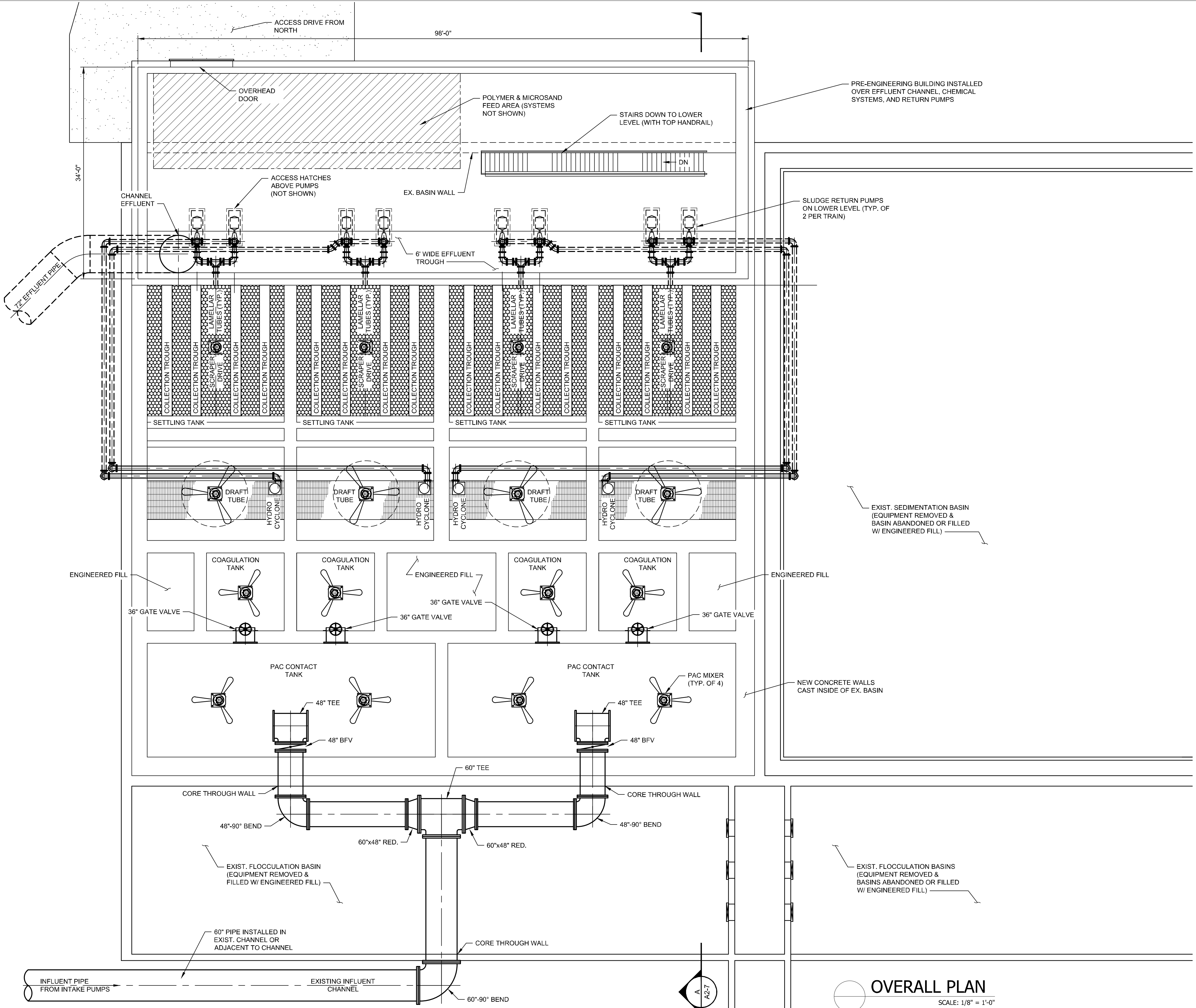
CONVENTIONAL PRETREATMENT NEW CONSTRUCTION SECTIONS

SHEET NUMBER

A2-5



OVERALL PLAN

SCALE: 1/8" = 1'-0"

4 0 4 8 12

SCALE: 1/8" = 1'-0" 22x34
SCALE: 1/16" = 1'-0" 11x17

PROJECT

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SHEET TITLE

BALLASTED FLOCCULATION RETROFIT PLAN

SHEET NUMBER

A2-6

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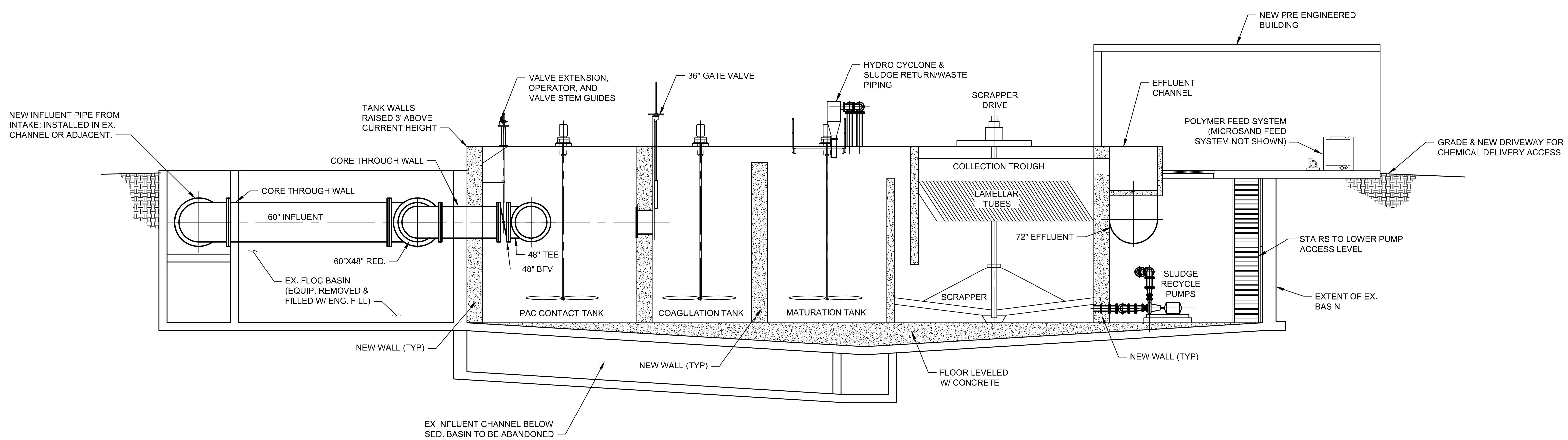
Project Management Initials: Designer: ### Checked: ### Approved: ### ARCH D 22" x 34"



A
A2-6

SECTION

SCALE: 1/8" = 1'-0"

4 0 4 8 12
SCALE: 1/8" = 1'-0" 22x34
SCALE: 1/16" = 1'-0" 11x17

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PROJECT

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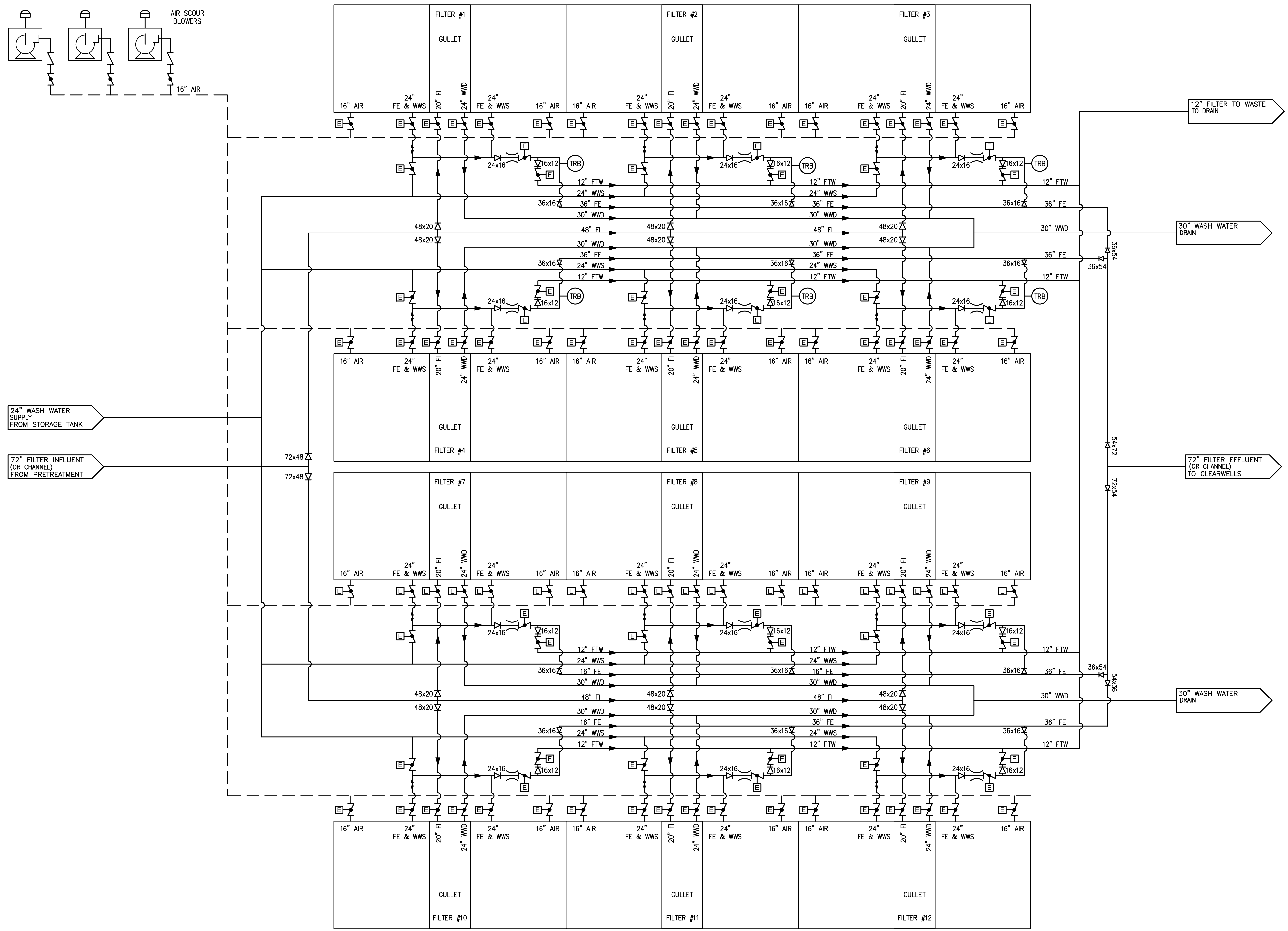
SHEET TITLE

BALLASTED FLOCCULATION RETROFIT SECTION

SHEET NUMBER

A2-7



ARCH D 22" x 34"

Approved: ###

Checked: ###

Designer: ###

Project Management Initials:

Filename: G:\COLUMBUS\DCS\PROJECTS\WTR\60613867_EVANSVILLE\900-CAD-GIS\910-CAD\20-SHEETS\WATER\FILTERS - NEW CONV FLOW DIAGRAM.DWG
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SHEET TITLE

NEW CONVENTIONAL FILTERS PROCESS FLOW DIAGRAM

SHEET NUMBER

FIGURE A3-1

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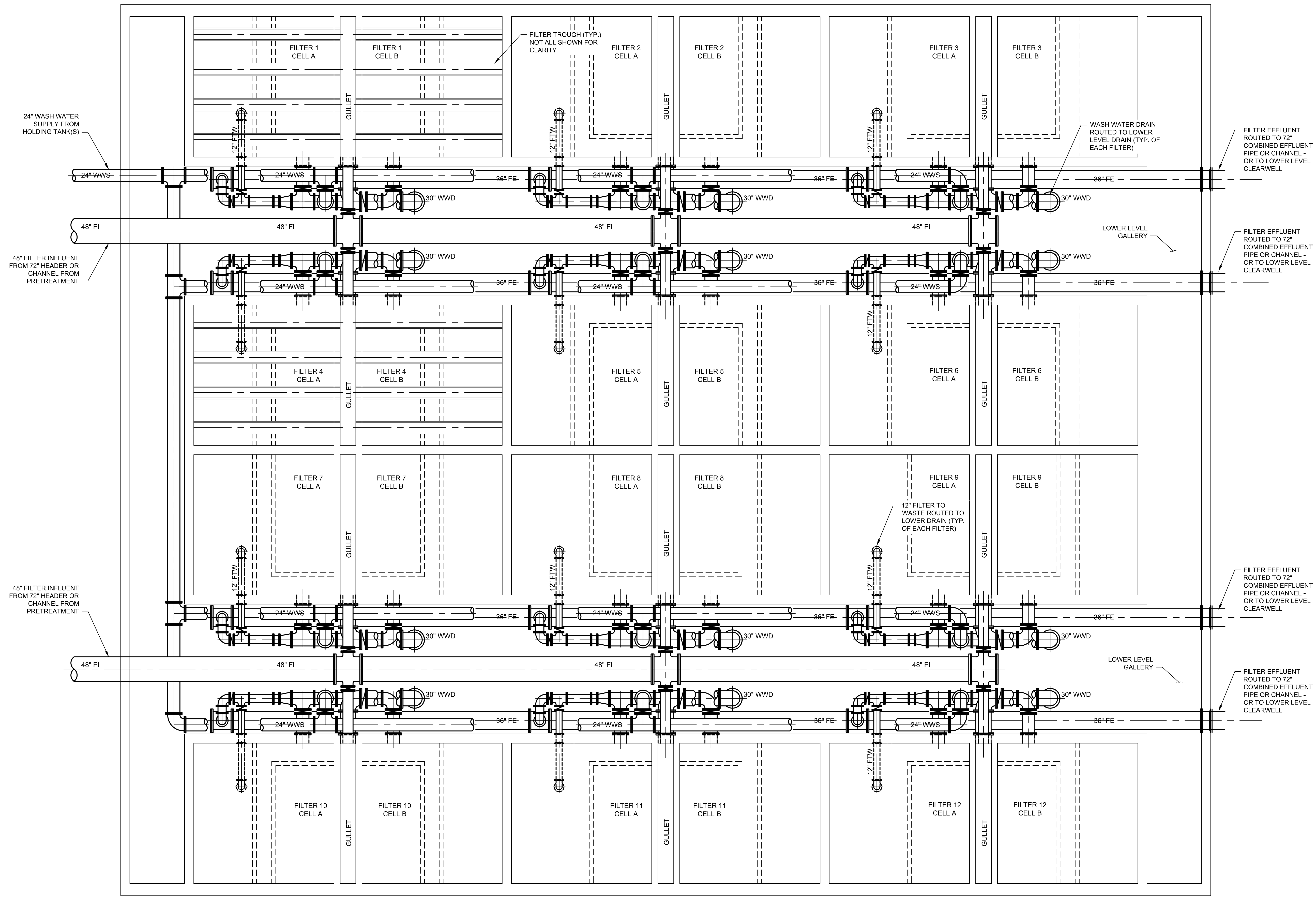

LOWER FILTER BUILDING PLAN
SCALE: 1/8" = 1'-0"

4 0 4 8 12
SCALE: $\frac{1}{8}$" = 1'-0" (22x34)
SCALE: $\frac{1}{16}$" = 1'-0" (11x17)

SHEET TITLE

NEW CONVENTIONAL FILTERS CONCEPTUAL BUILDING LOWER LEVEL PLAN

SHEET NUMBER

FIGURE A3-2

ARCH D 22" x 34"
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Designer: ###
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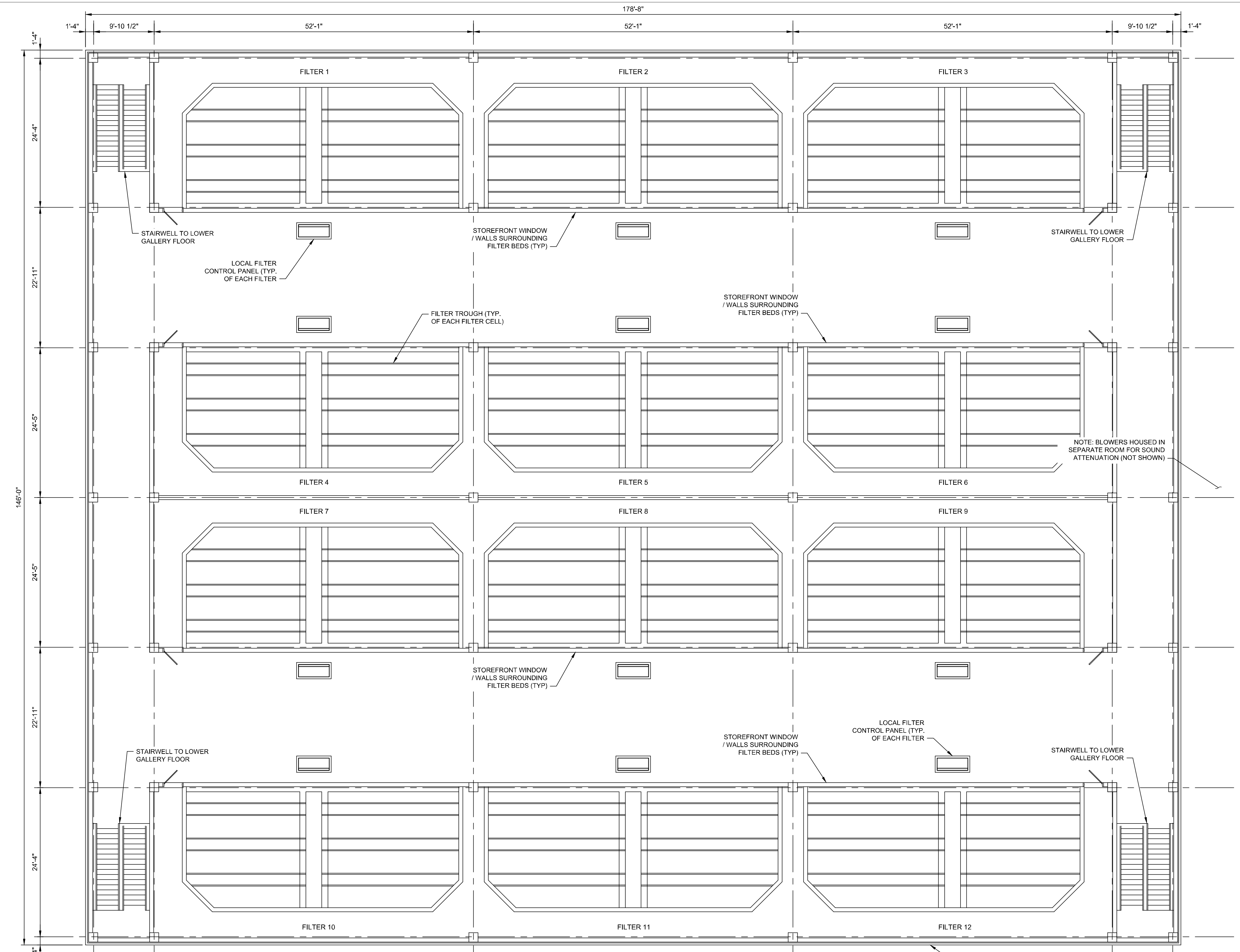
ARCH D 22" x 34"

Project Management Initials: Designer: ### Checked: ### Approved: ###



UPPER FILTER BUILDING PLAN

SCALE: 1/8" = 1'-0"

4 0 4 8 12

SCALE: $\frac{1}{8}$" = 1'-0" (22x34)
SCALE: $\frac{1}{16}$" = 1'-0" (11x17)

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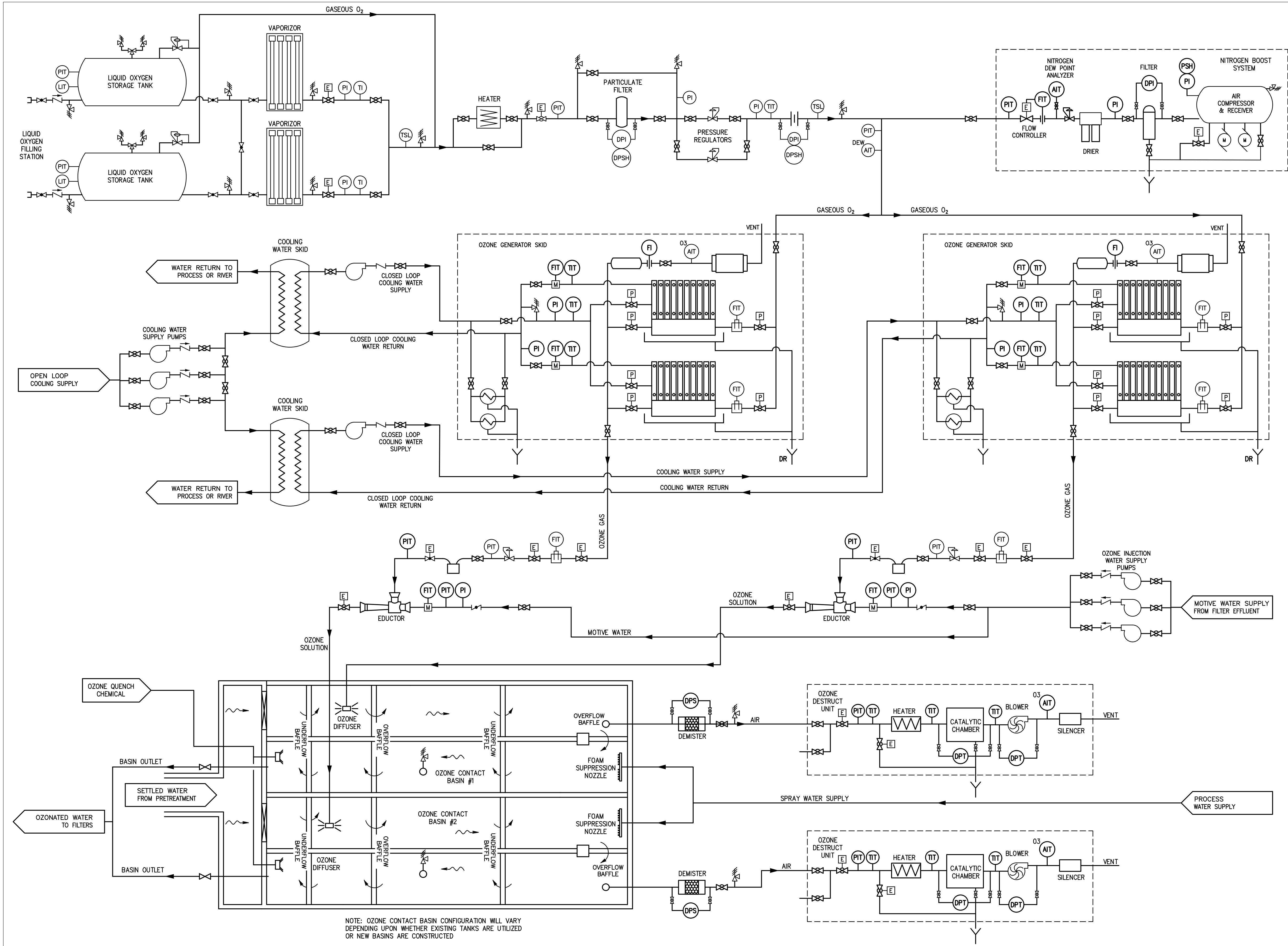
SHEET TITLE

NEW CONVENTIONAL FILTERS CONCEPTUAL BUILDING UPPER LEVEL PLAN

SHEET NUMBER

FIGURE A3-3



ARCH D 22" x 34"
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Evansville: U1032
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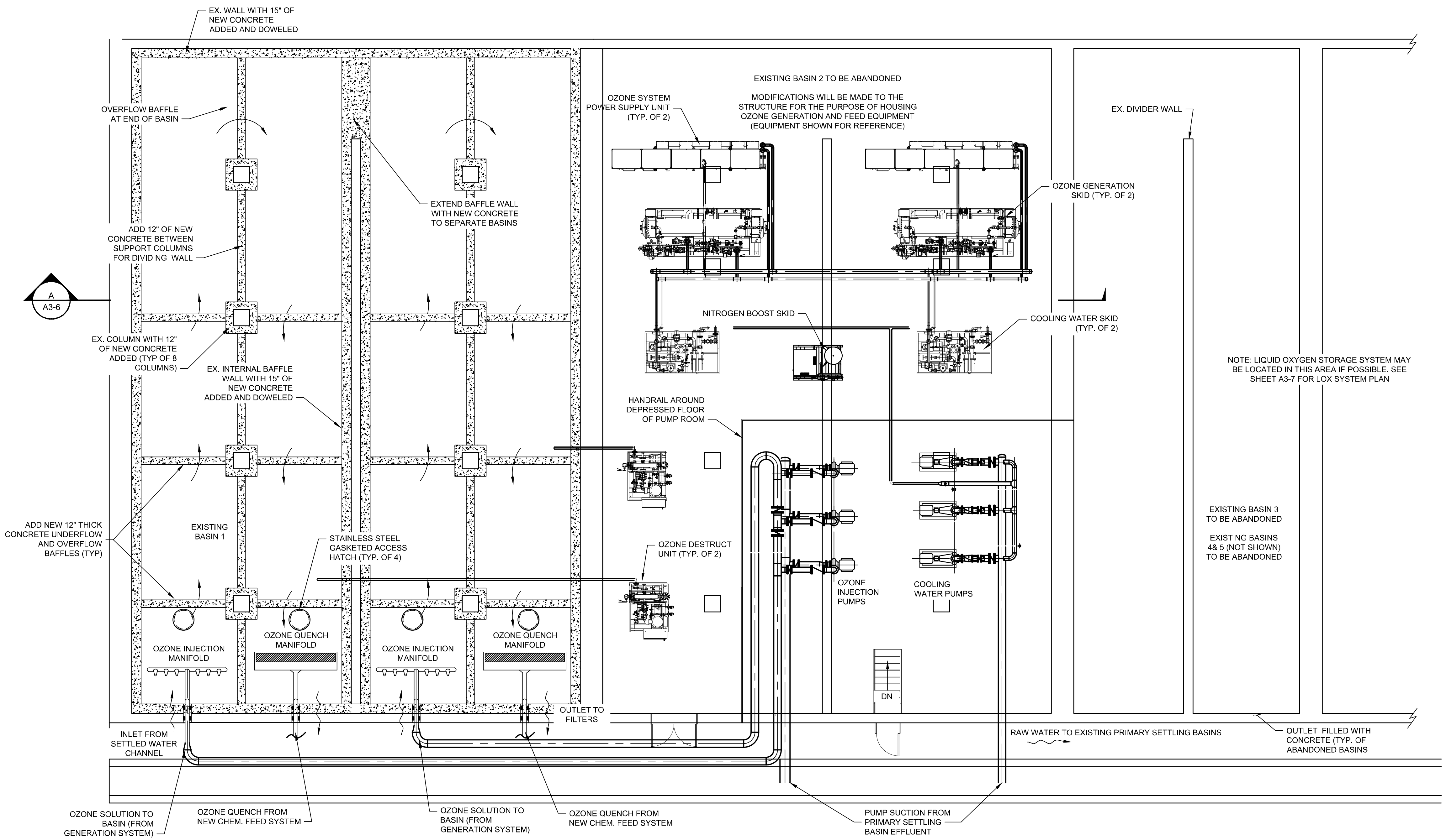
SHEET TITLE

CONCEPTUAL OZONE SYSTEM PROCESS FLOW DIAGRAM

SHEET NUMBER

FIGURE A3-4



OZONE SYSTEM PLAN

SCALE: 1/8" = 1'-0"

4 0 4 8 12
SCALE: 1/8" = 1'-0" 22x34
SCALE: 1/16" = 1'-0" 11x17

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SHEET TITLE

CONCEPTUAL OZONE SYSTEM RETROFIT OVERALL PLAN

SHEET NUMBER

FIGURE A3-5

ARCH D 22" x 34" Approved: ### Checked: ### Designer: ### Project Management Initials:

Filename: G:\COLUMBUS\DCS\PROJECTS\WTR\60613867_EVANSVILLE\900-CAD-GIS\910-CAD\20-SHEETS\WATER\OZONE - NORTH 2NDARY RETROFIT.DWG
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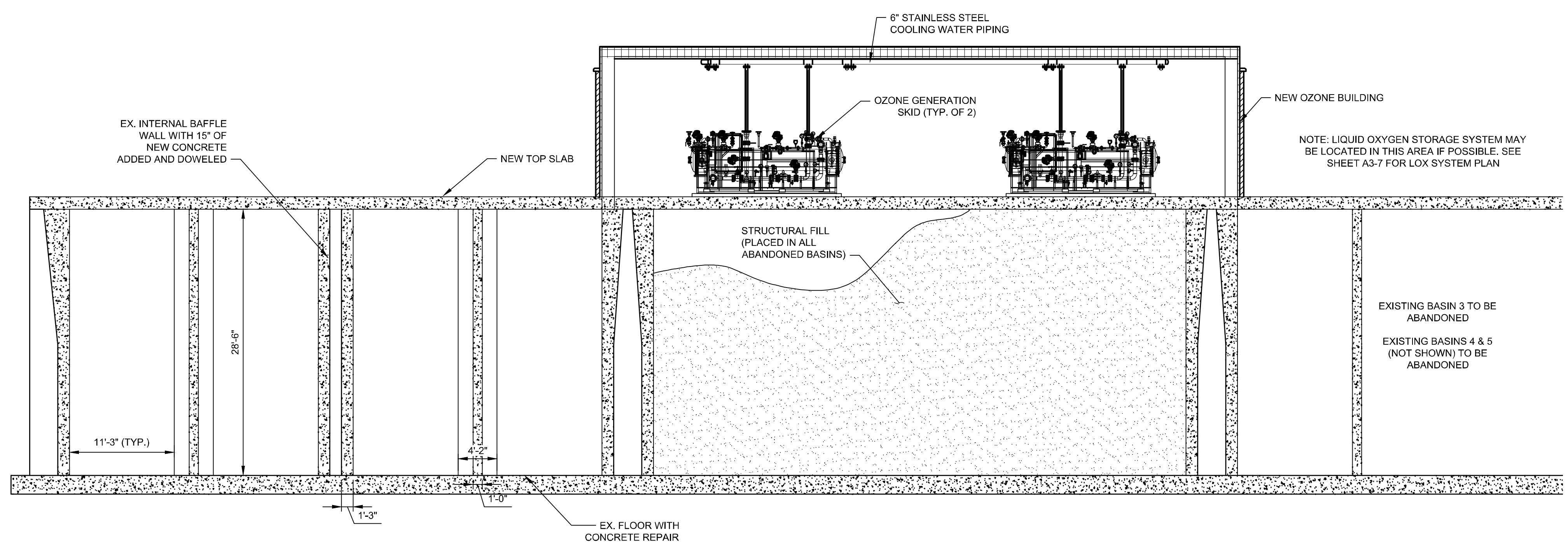

A
A3-5
SECTION
SCALE: 1/8"

4 0 4 8 12
SCALE: 1/8" = 1'-0" 22x34
SCALE: 1/16" = 1'-0" 11x17

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PROJECT

EVANSVILLE WATER PLANT ADVANCED FACILITY PLAN
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PROJECT NUMBER

Evansville: U1032
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SHEET TITLE

CONCEPTUAL OZONE SYSTEM RETROFIT SECTION

SHEET NUMBER

FIGURE A3-6

ARCH D 22" x 34"
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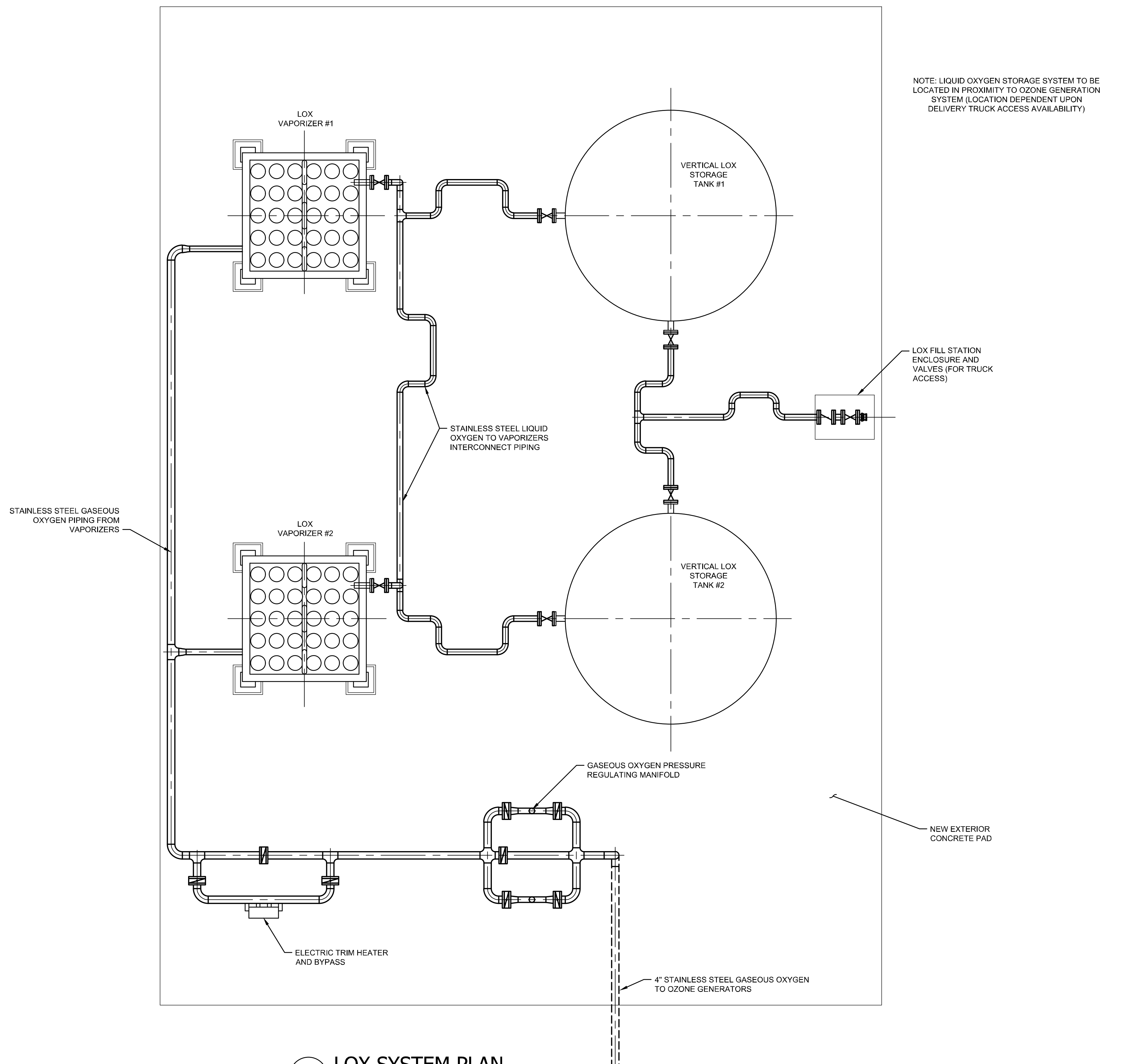
Designer: ###
Project Management Initials:
Filename: G:\COLUMBUS\DCS\PROJECTS\WTR\60613867_EVANSVILLE\900-CAD-GIS\910-CAD\20-SHEETS\WATER\OZONE - NORTH 2NDARY RETROFIT.DWG
Last saved by: MIXJ Last Plotted: 2020-07-21



LOX SYSTEM PLAN

SCALE: 3/8" = 1'-0"

2 1 0 2 4 6

SCALE: 3/8" = 1'-0" (22x34)
SCALE: 3/16" = 1'-0" (11x17)

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SHEET TITLE

CONCEPTUAL OZONE SYSTEM
LOX SYSTEM PLAN

SHEET NUMBER

FIGURE A3-7

ARCH D 22" x 34"
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Designer: ###
Project Management Initials:

Filename: G:\COLUMBUS\DCS\PROJECTS\WTR\60613867_EVANSVILLE\900-CAD-GIS\910-CAD\20-SHEETS\WATER\OZONE - LOX SYSTEM.DWG
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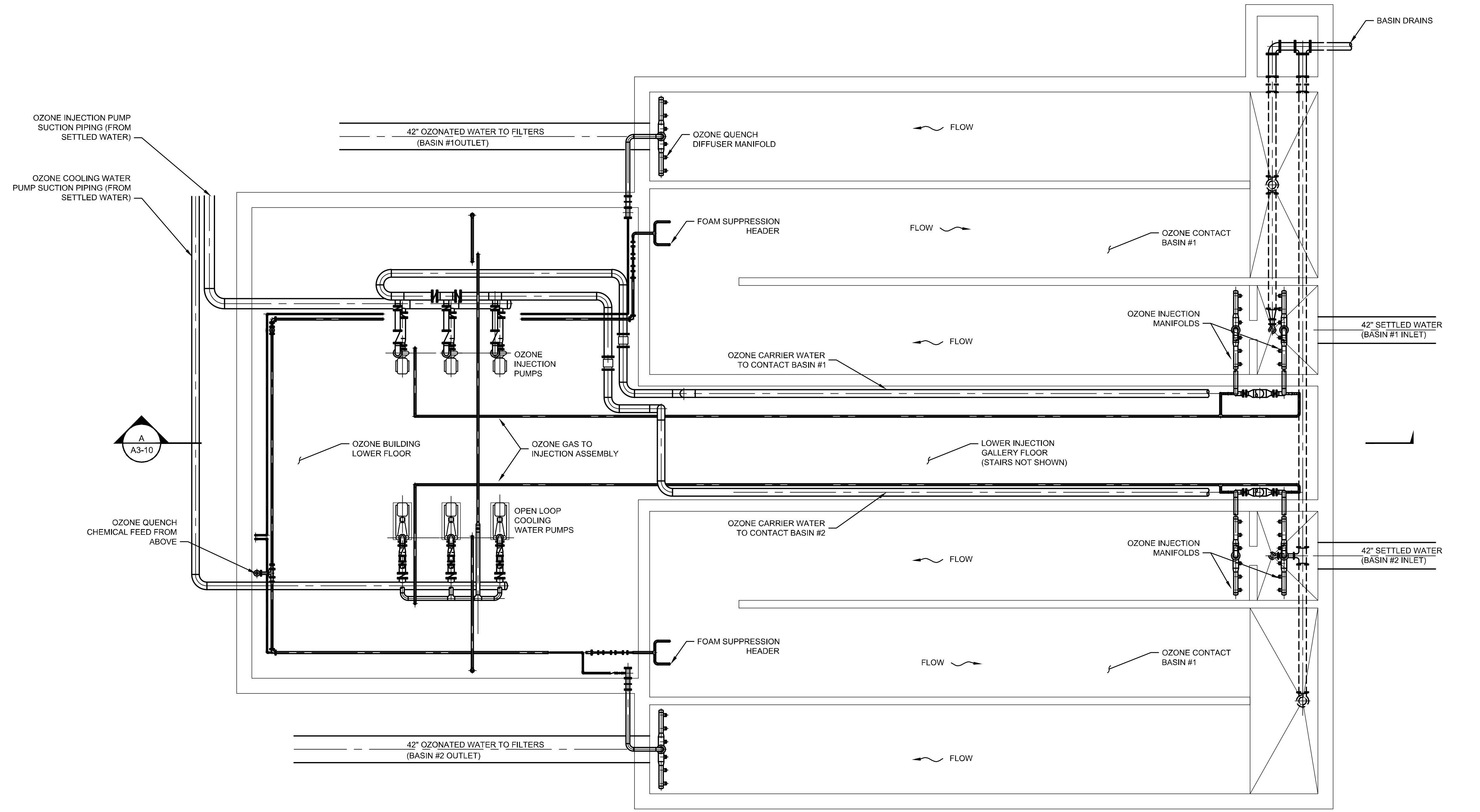
ARCH D 22" x 34"
Approved: ###
Checked: ###
Designer: ###
Project Management Initials:



OZONE SYSTEM LOWER PLAN

SCALE: 1/8" = 1'-0"

4 0 4 8 12
SCALE: 1/8" = 1'-0" 22x34
SCALE: 1/16" = 1'-0" 11x17

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PROJECT

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SHEET TITLE

CONCEPTUAL NEW OZONE SYSTEM LOWER LEVEL PLAN

SHEET NUMBER

FIGURE A3-8

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ARCH D 22" x 34"

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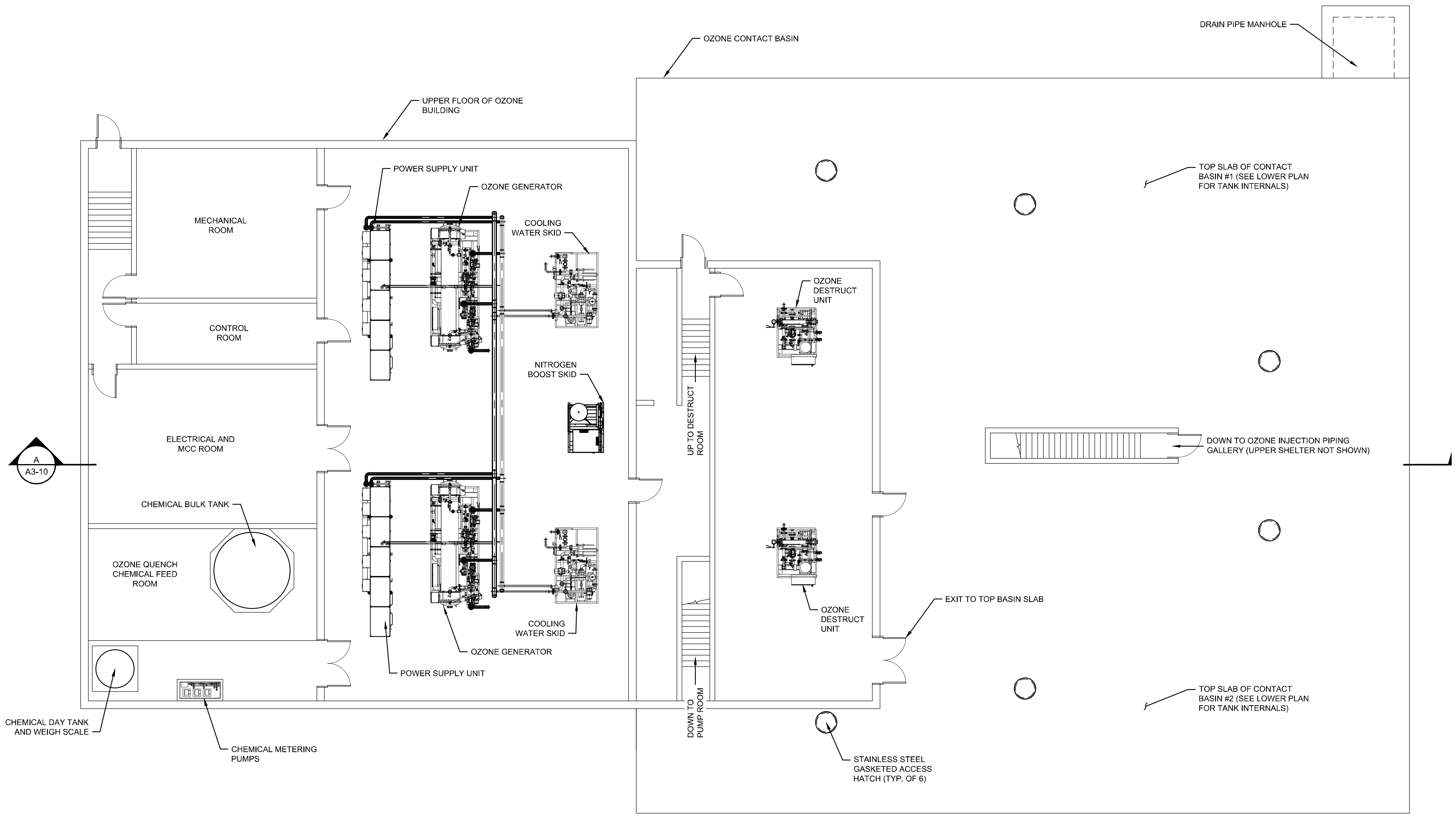

OZONE SYSTEM UPPER PLAN

SCALE: 1/8" = 1'-0"

4 0 4 8 12
SCALE: 1/8" = 1'-0" 22x34
SCALE: 1/16" = 1'-0" 11x17

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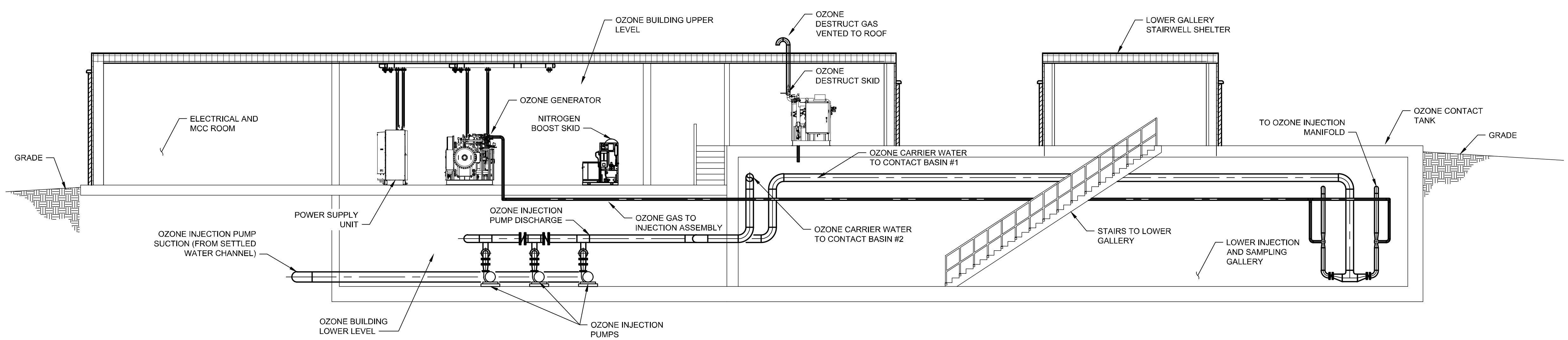
SHEET TITLE

CONEPTUAL NEW OZONE SYSTEM UPPER LEVEL PLAN

SHEET NUMBER

FIGURE A3-9



A
A3-8

OZONE SYSTEM SECTION

SCALE: 1/8" = 1'-0"

4 0 4 8 12
SCALE: 1/8" = 1'-0" 22x34
SCALE: 1/16" = 1'-0" 11x17

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PROJECT

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SHEET TITLE

CONCEPTUAL NEW OZONE SYSTEM SECTION

SHEET NUMBER

FIGURE A3-10

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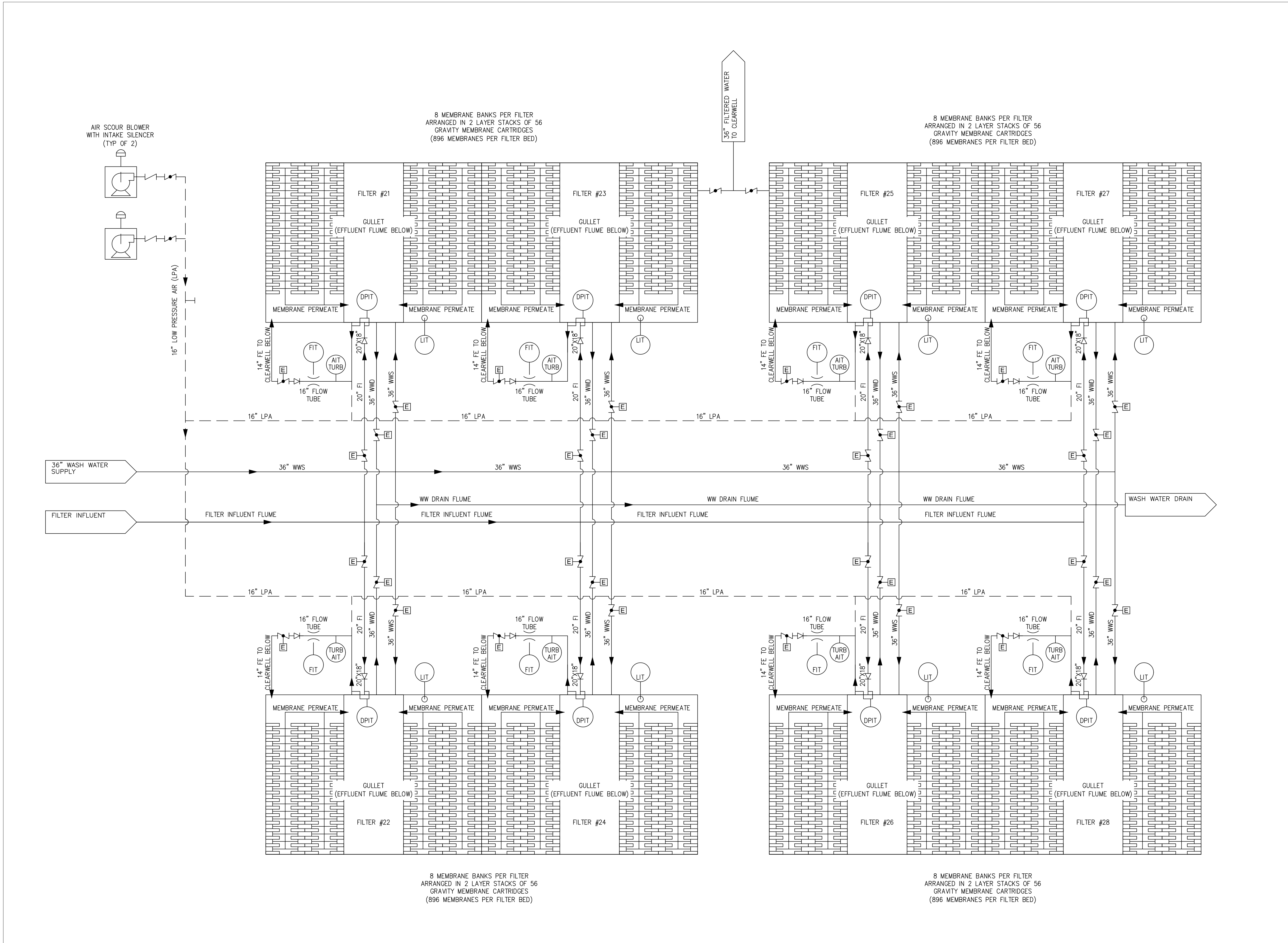

ARCH D 22" x 34"
Approved: ###
Checked: ###
Designer: ###
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Evansville: U1032
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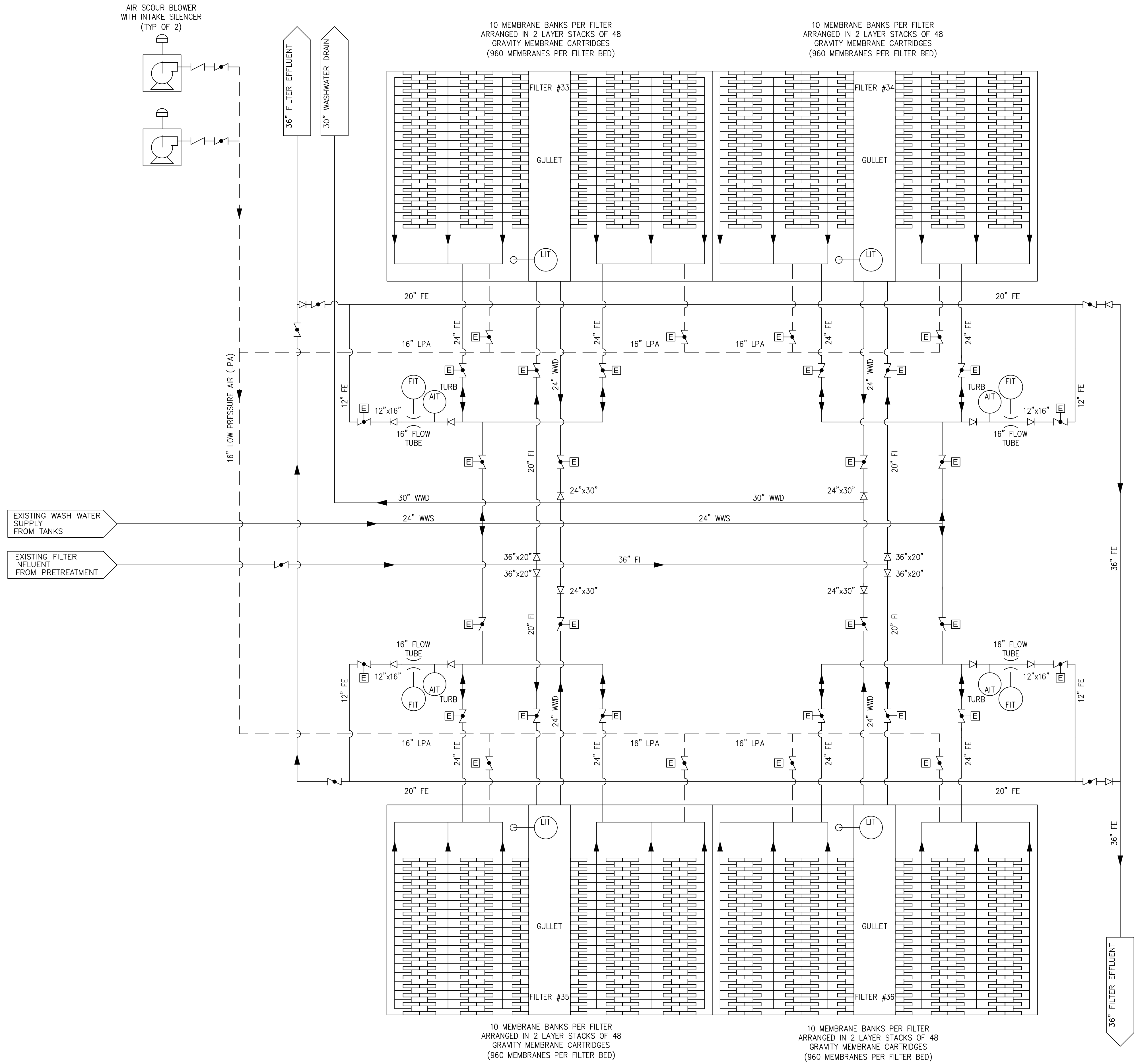
SHEET TITLE

FILTERS 21-28 MGF RETROFIT PROCESS FLOW DIAGRAM

SHEET NUMBER

FIGURE A3-11



Project Management Initials: Designer: ### Checked: ### Approved: ### ARCH D 22" x 34"

Filename: G:\COLUMBUS\DCS\PROJECTS\WTR\60613867_EVANSVILLE\900-CAD-GIS\910-CAD\20-SHEETS\WATER\MGF - REHAB FLOW DIAGRAM.DWG
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PROJECT NUMBER

Evansville: U1032
AECOM: 60613867

SHEET TITLE

FILTERS 33-36 MGF RETROFIT PROCESS FLOW DIAGRAM

SHEET NUMBER

FIGURE A3-12

ARCH D 22" x 34"

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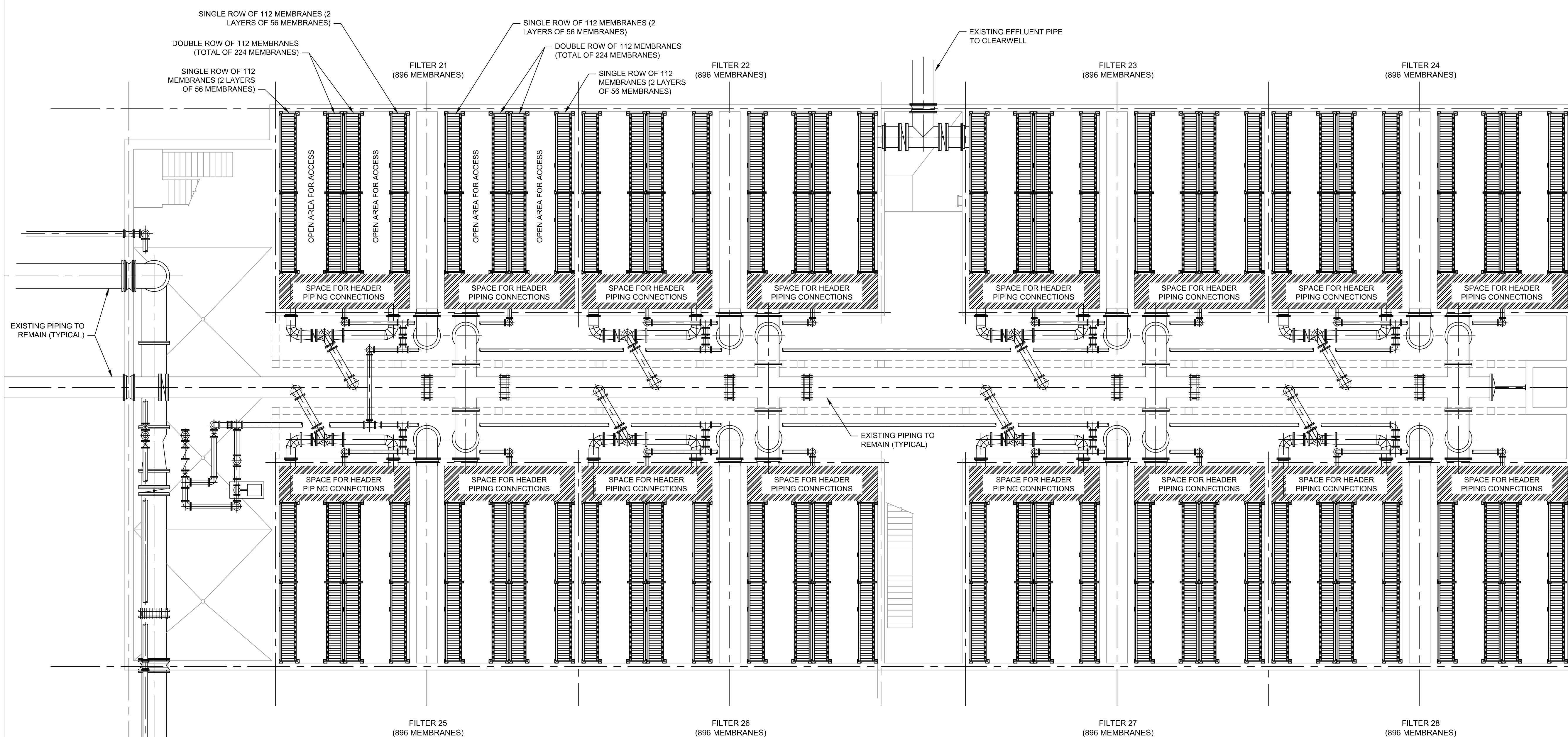
Filename: G:\COLUMBUS\DCS\PROJECTS\WTR\60613867_EVANSVILLE\900-CAD-GIS\910-CAD\20-SHEETS\WATER\MGF - RETROFIT FILTERS 21 - 28.DWG
Last saved by: MIXJ Last Plotted: 2020-07-21



MGF LOWER FILTER PLAN

SCALE: 1/8" = 1'-0"

4 0 4 8 12

SCALE: 1/8" = 1'-0" (22x34)
SCALE: 1/16" = 1'-0" (11x17)

AECOM

PROJECT

EVANSVILLE WATER PLANT ADVANCED FACILITY PLAN
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Evansville, IN 47713

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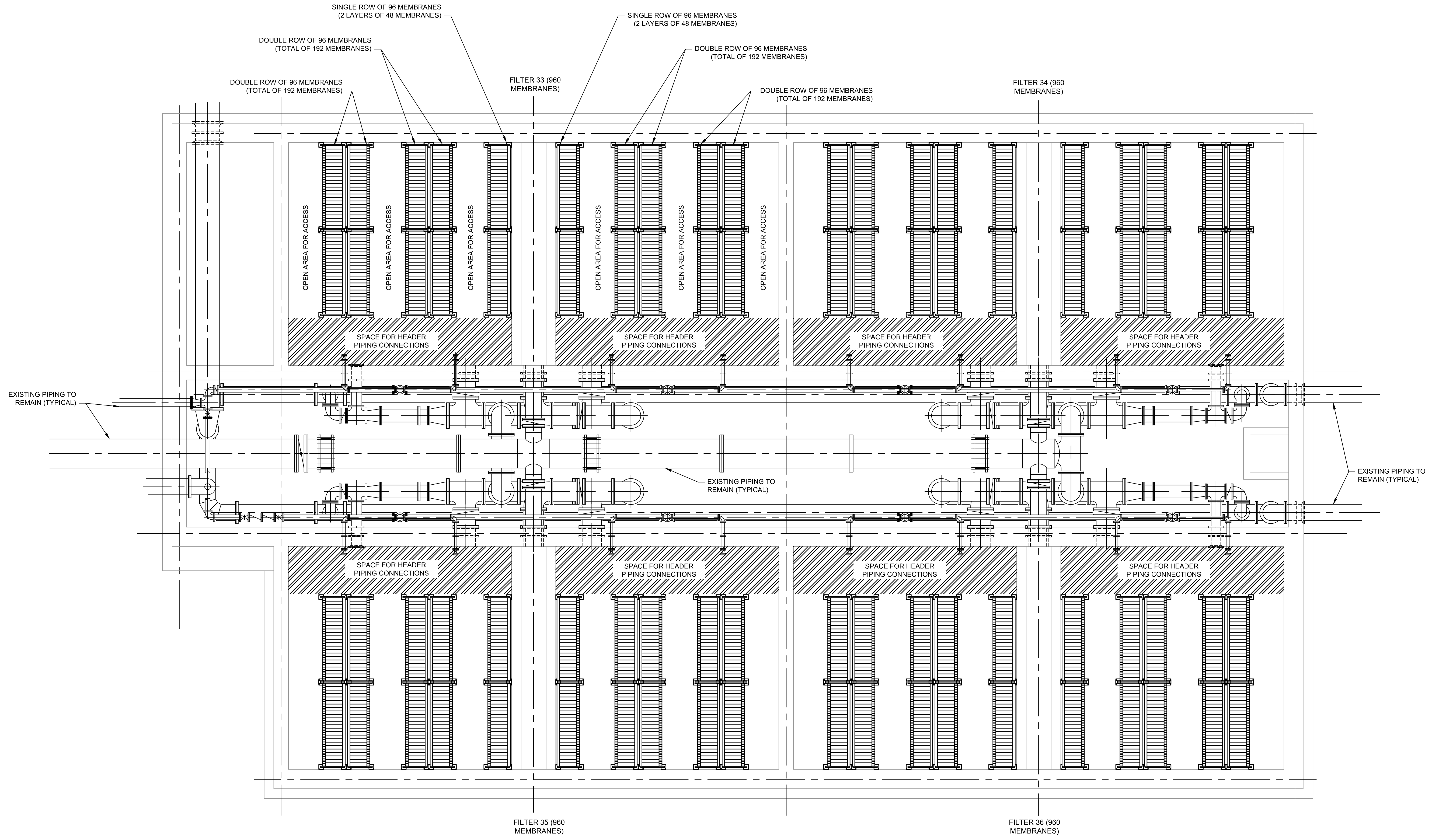
SHEET TITLE

FILTERS 21 - 28
MGF RETROFIT PLAN

SHEET NUMBER

FIGURE A3-13



MGF LOWER FILTER PLAN

SCALE: 3/16" = 1'-0"

4 3 2 1 0 4 8
SCALE: 3/16" = 1'-0" 22x34
SCALE: 3/32" = 1'-0" 11x17

PROJECT

EVANSVILLE WATER PLANT ADVANCED FACILITY PLAN
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Evansville: U1032
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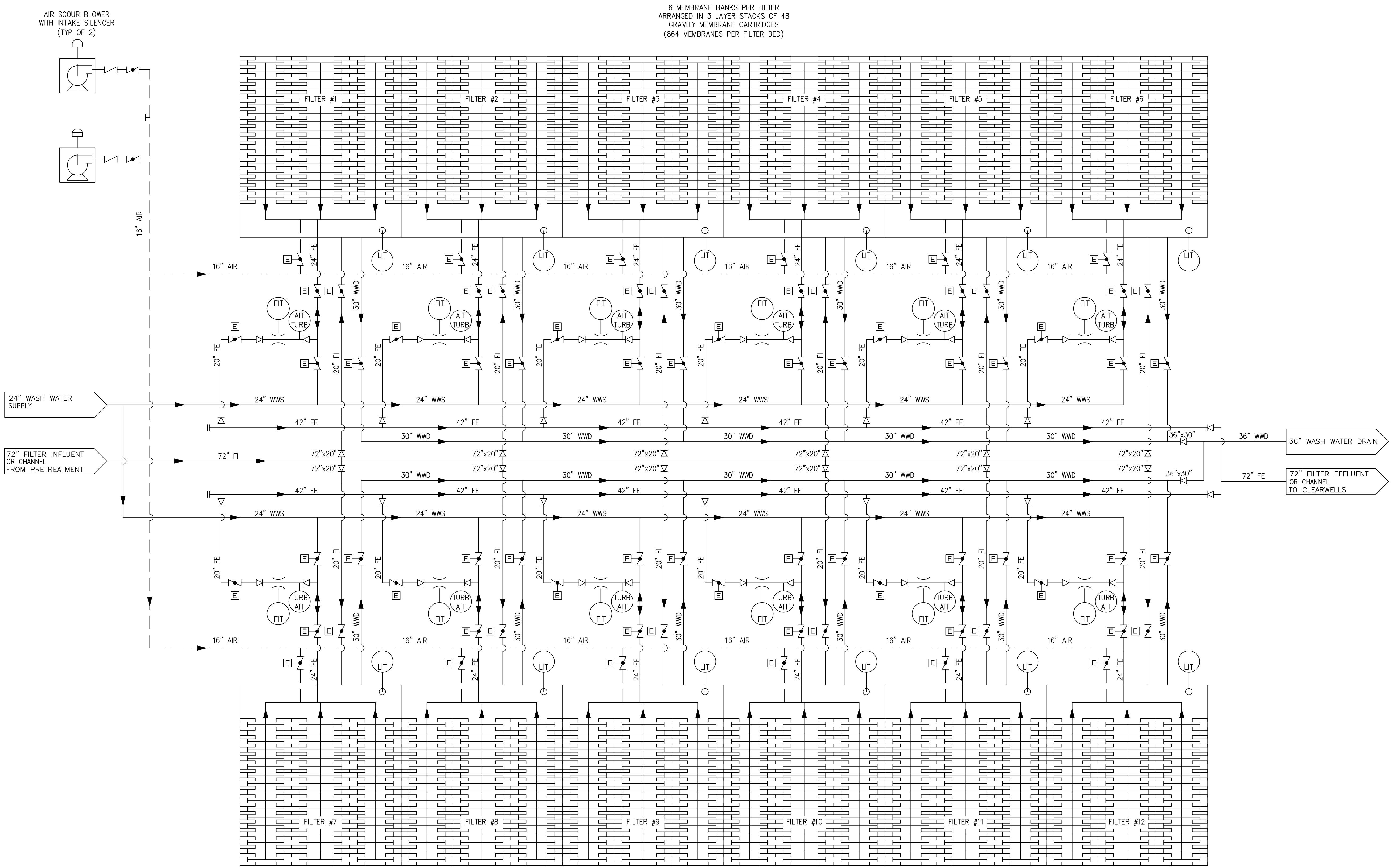
SHEET TITLE

FILTERS 33-36
MFG RETROFIT PLAN

SHEET NUMBER

FIGURE A3-14



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SHEET TITLE

NEW MGF SYSTEM
PROCESS FLOW DIAGRAM

SHEET NUMBER

FIGURE A3-15

ARCH D 22" x 34"
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Project Management Initials:

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ARCH D 22" x 34"
Project Management Initials: Designer: ### Checked: ### Approved: ###
Filename: G:\COLUMBUS\DCS\PROJECTS\WTR\60613867_EVANSVILLE\900-CAD-GIS\910-CAD\20-SHEETS\WATER\MGF - NEW CONSTRUCTION LOWER FLORR.DWG
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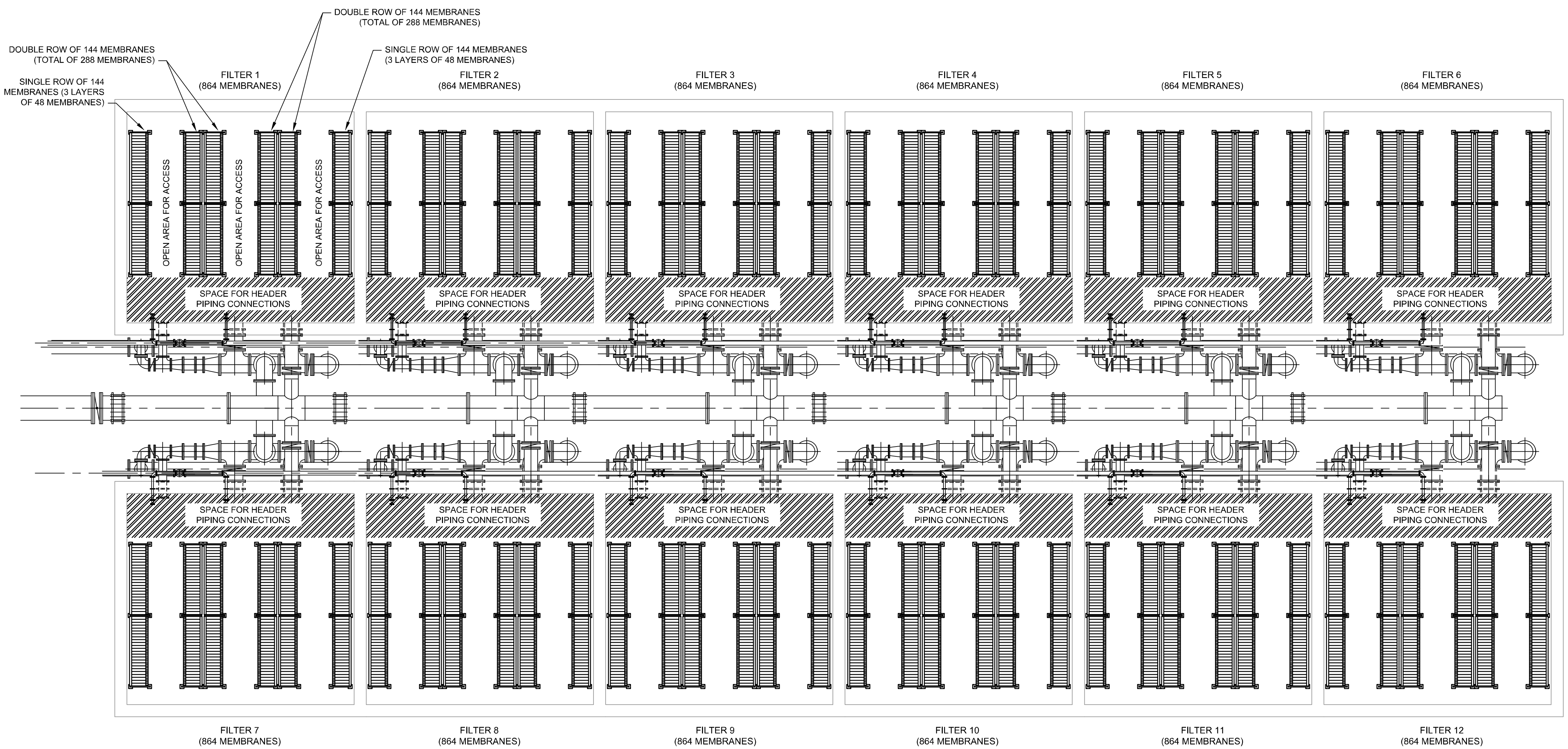

MGF LOWER FILTER PLAN

SCALE: 1/8" = 1'-0"

4 0 4 8 12

SCALE: 1/8" = 1'-0" (22x34)
SCALE: 1/16" = 1'-0" (11x17)

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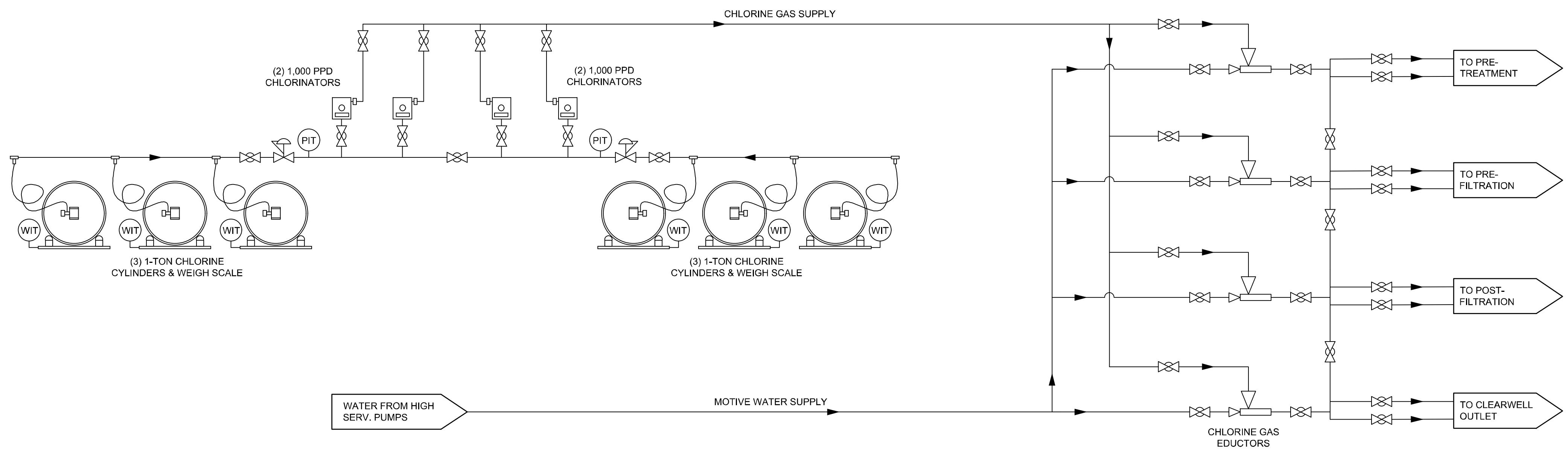
SHEET TITLE

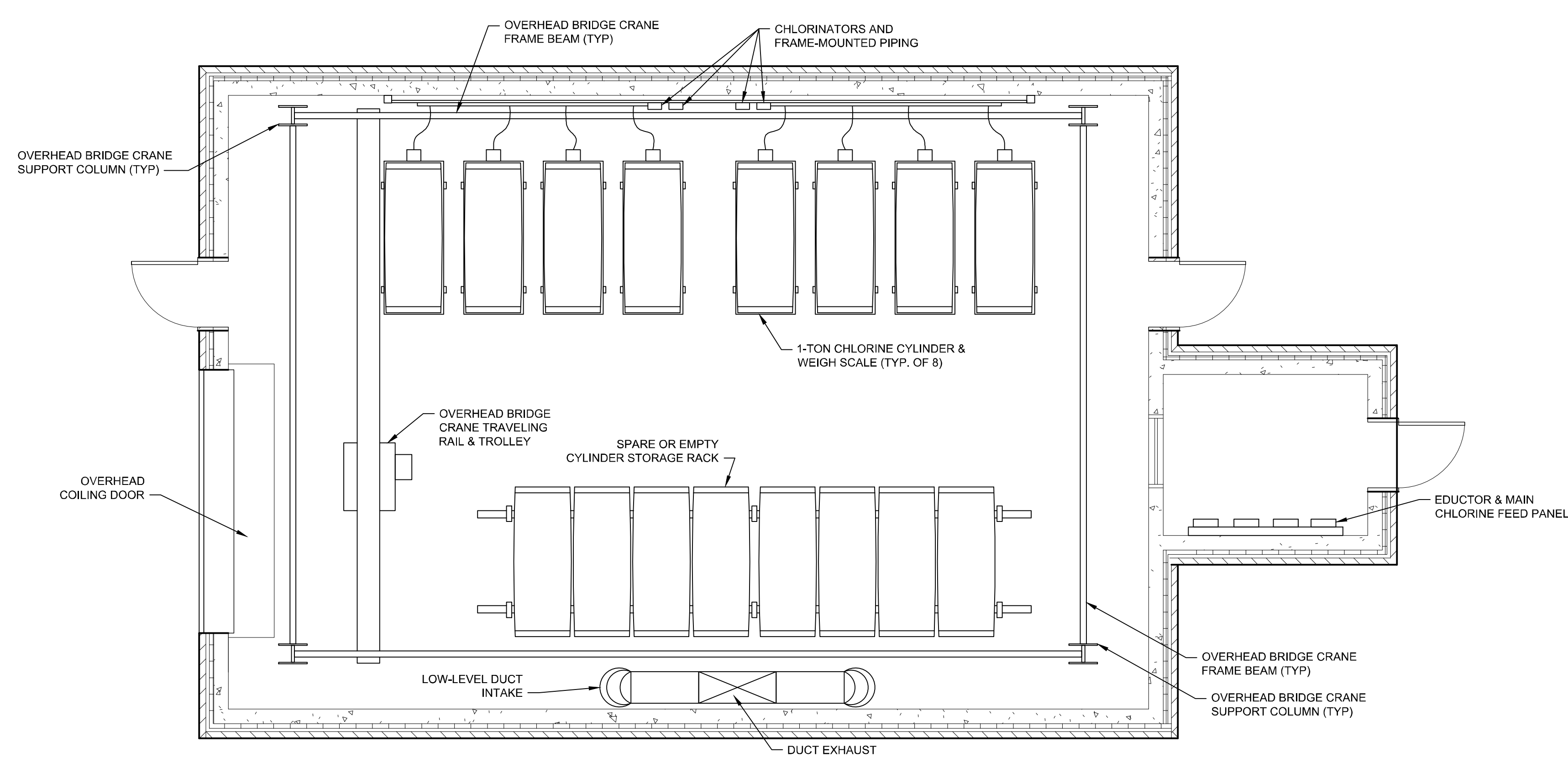
NEW MGF SYSTEM
LOWER FILTER PLAN

SHEET NUMBER

FIGURE A3-16



CHLOIRNE GAS: FLOW DIAGRAM



CHLORINE GAS: PLAN

4 3 2 1 0 4 8
SCALE: 1/8" = 1'-0" 11x17
SCALE: 1/4" = 1'-0" 22x34

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SHEET TITLE

CHLORINE GAS FLOW DIAGRAM AND CONCEPTUAL PLAN

SHEET NUMBER

FIGURE A4-1

ARCH D 22" x 34"
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Filename: G:\COLUMBUS\DCS\PROJECTS\WTR\60613867_EVANSVILLE\900-CAD-GIS\910-CAD\20-SHEETS\WATER\CHLORINE - GAS.DWG
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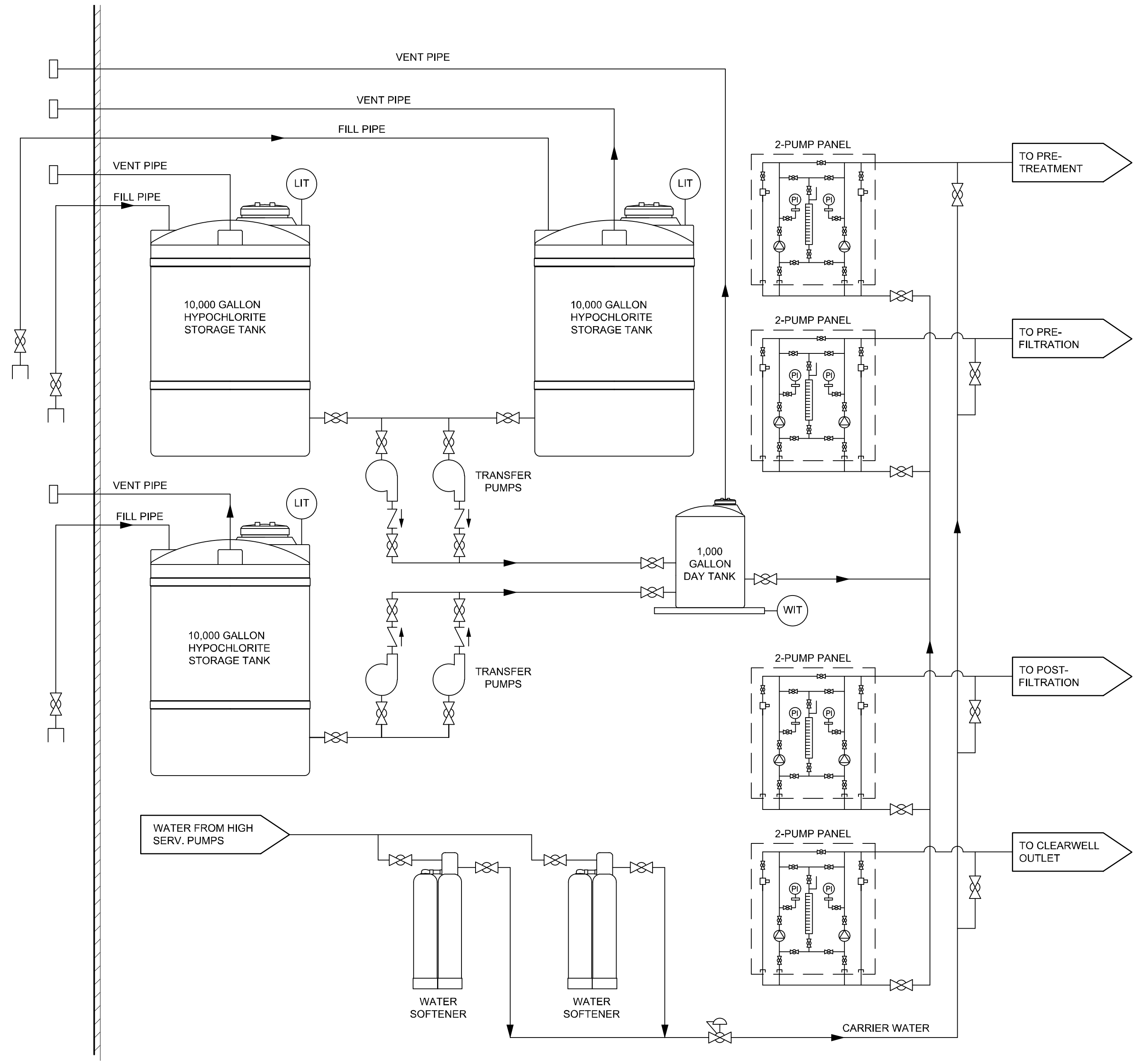
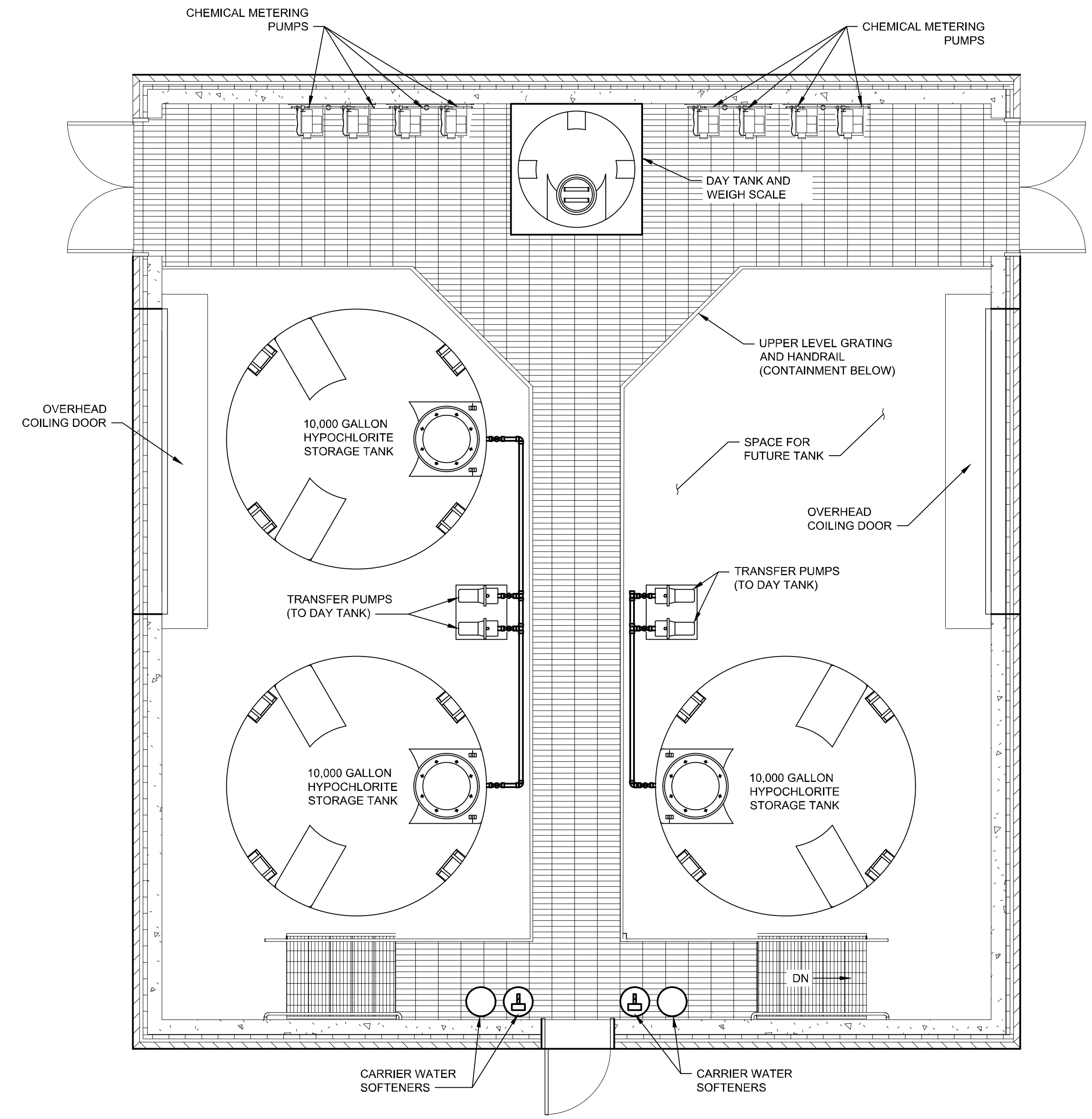


BULK HYPOCHLORITE: FLOW DIAGRAM



BULK HYPOCHLORITE: PLAN

4 3 2 1 0 4 8
SCALE: 1/8" = 1'-0" 11x17
SCALE: 1/4" = 1'-0" 22x34

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1	JULY 2020	DRAFT REPORT
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Evansville: U1032
AECOM: 60613867

SHEET TITLE

BULK SODIUM HYPOCHLORITE FLOW DIAGRAM AND CONCEPTUAL PLAN

SHEET NUMBER

FIGURE A4-2

ARCH D 22" x 34"
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Filename: G:\COLUMBUS\DCS\PROJECTS\WTR\60613867_EVANSVILLE\900-CAD-GIS\910-CAD\20-SHEETS\WATER\CHLORINE - BULK HYPOCHLORITE SYSTEM.DWG
Last saved by: MIXJ Last Plotted: 2020-07-21

ARCH D 22" x 34"
Approved: ###
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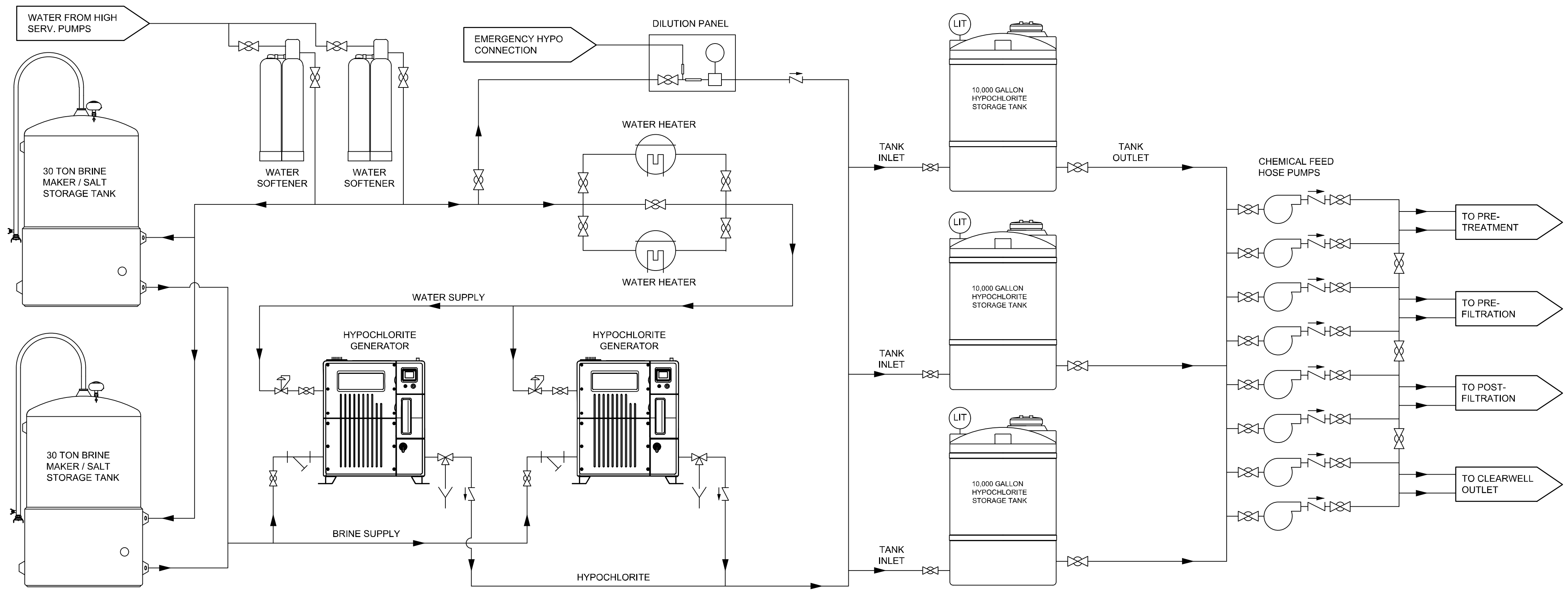
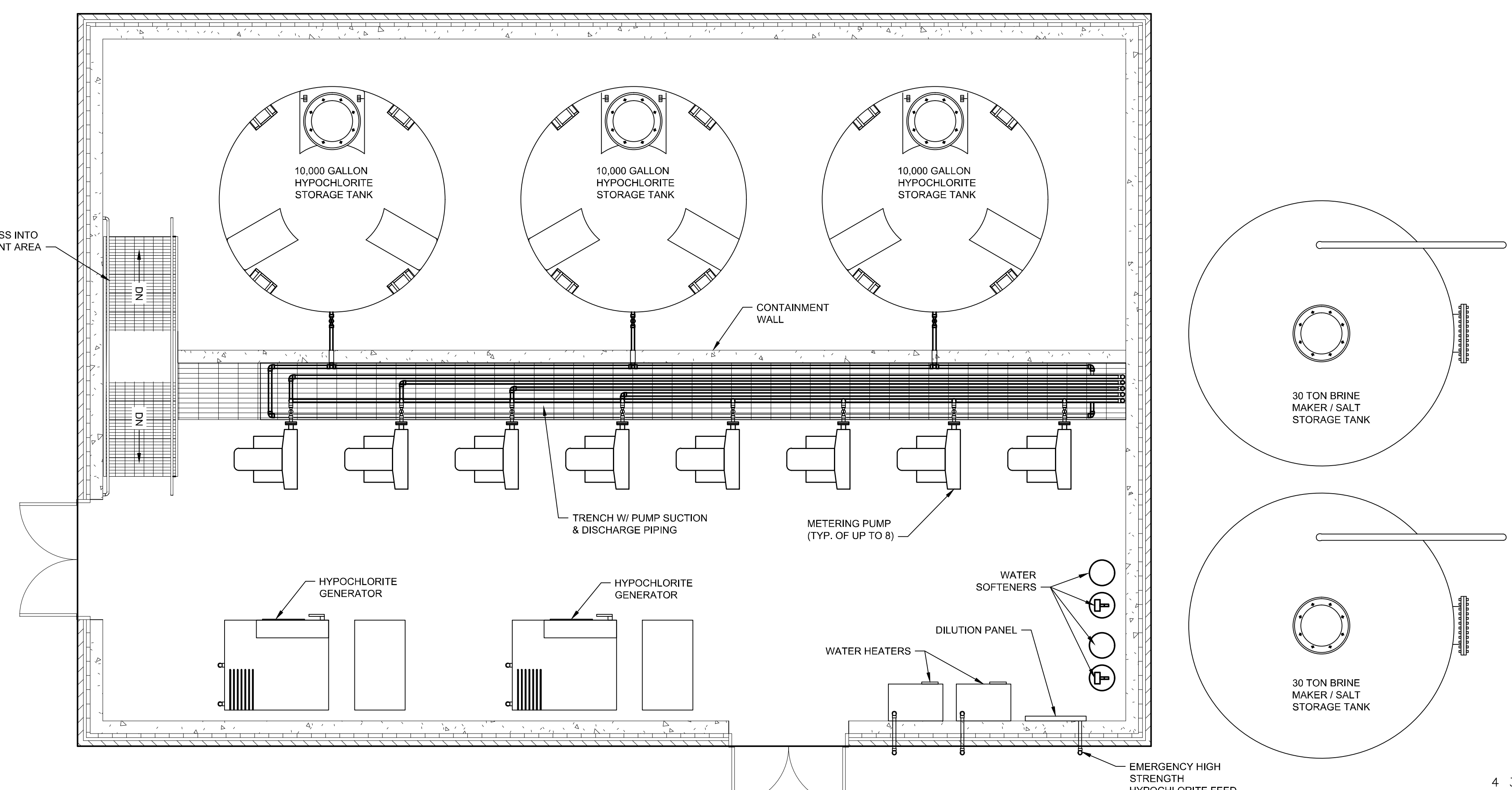
Project Management Initials:



OSNITE GENERATION: FLOW DIAGRAM



OSNITE GENERATION: PLAN

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SCALE: 1/8" = 1'-0" 11x17
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Filename: G:\COLUMBUS\DCS\PROJECTS\WTR\60613867_EVANSVILLE\900-CAD-GIS\910-CAD\20-SHEETS\WATER\CHLORINE - ONSITE GENERATION SYSTEM.DWG
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SHEET TITLE

CHLORINE GAS FLOW DIAGRAM AND CONCEPTUAL PLAN

SHEET NUMBER

FIGURE A4-3

ARCH D 22" x 34"

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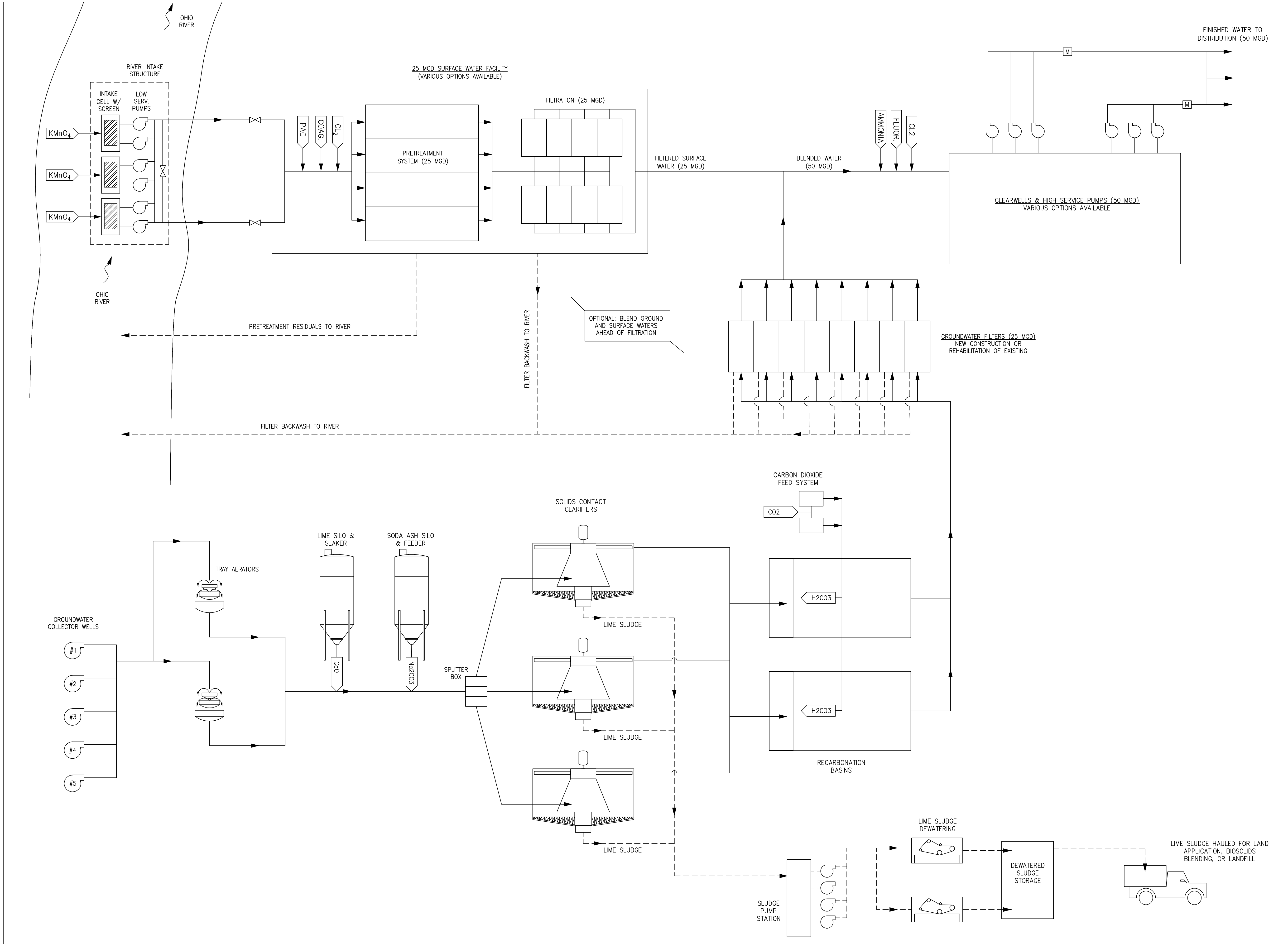

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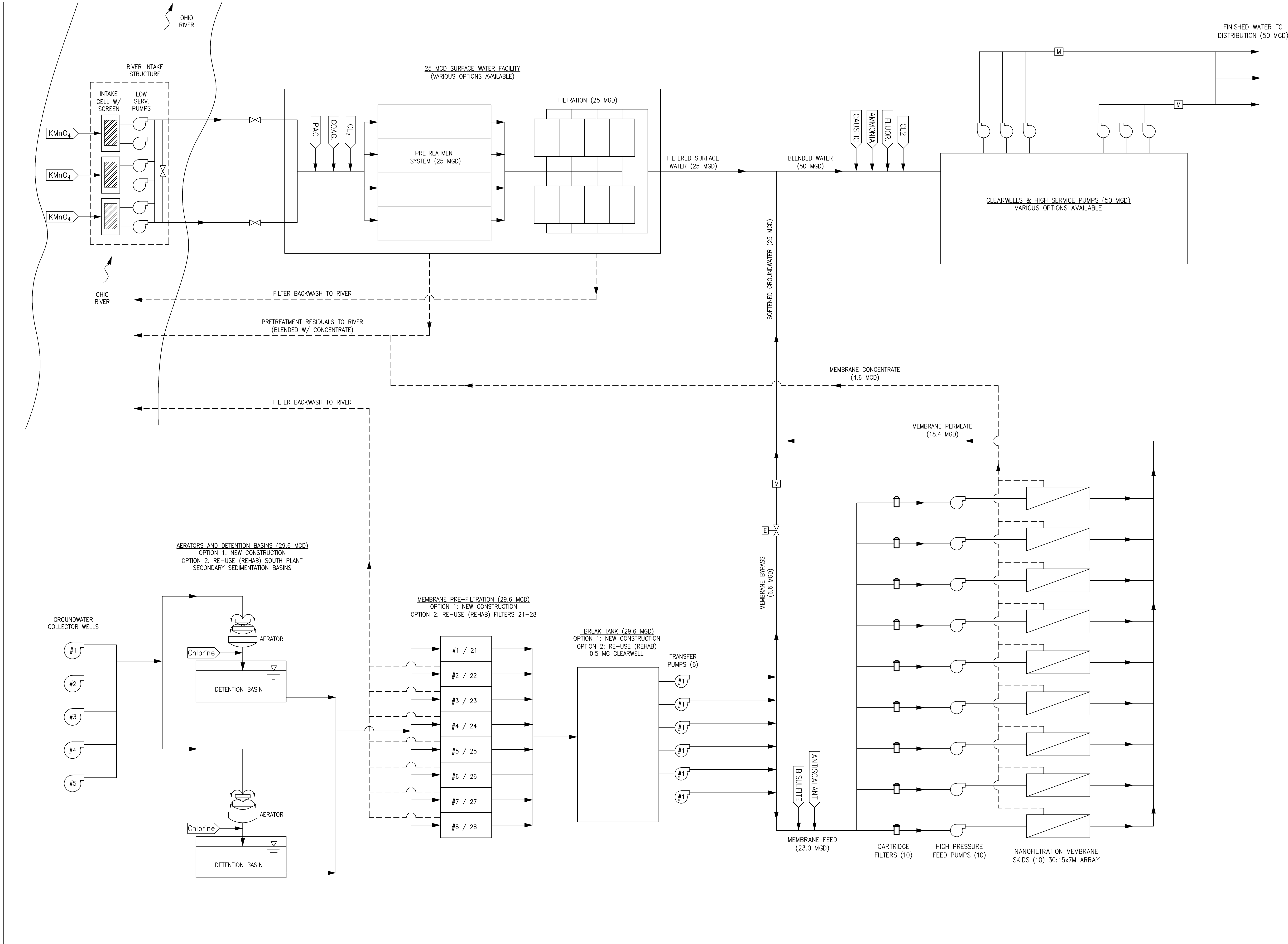
SHEET TITLE

GROUNDWATER SOFTENING ALTERNATIVE 1 FLOW DIAGRAM: LIME SOFTENING

SHEET NUMBER

FIGURE A5-1



ARCH D 22" x 34"

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SHEET TITLE

GROUNDWATER SOFTENING ALTERNATIVE 2 FLOW DIAGRAM: MEMBRANE SOFTENING

SHEET NUMBER

FIGURE A5-2

ARCH D 22" x 34"

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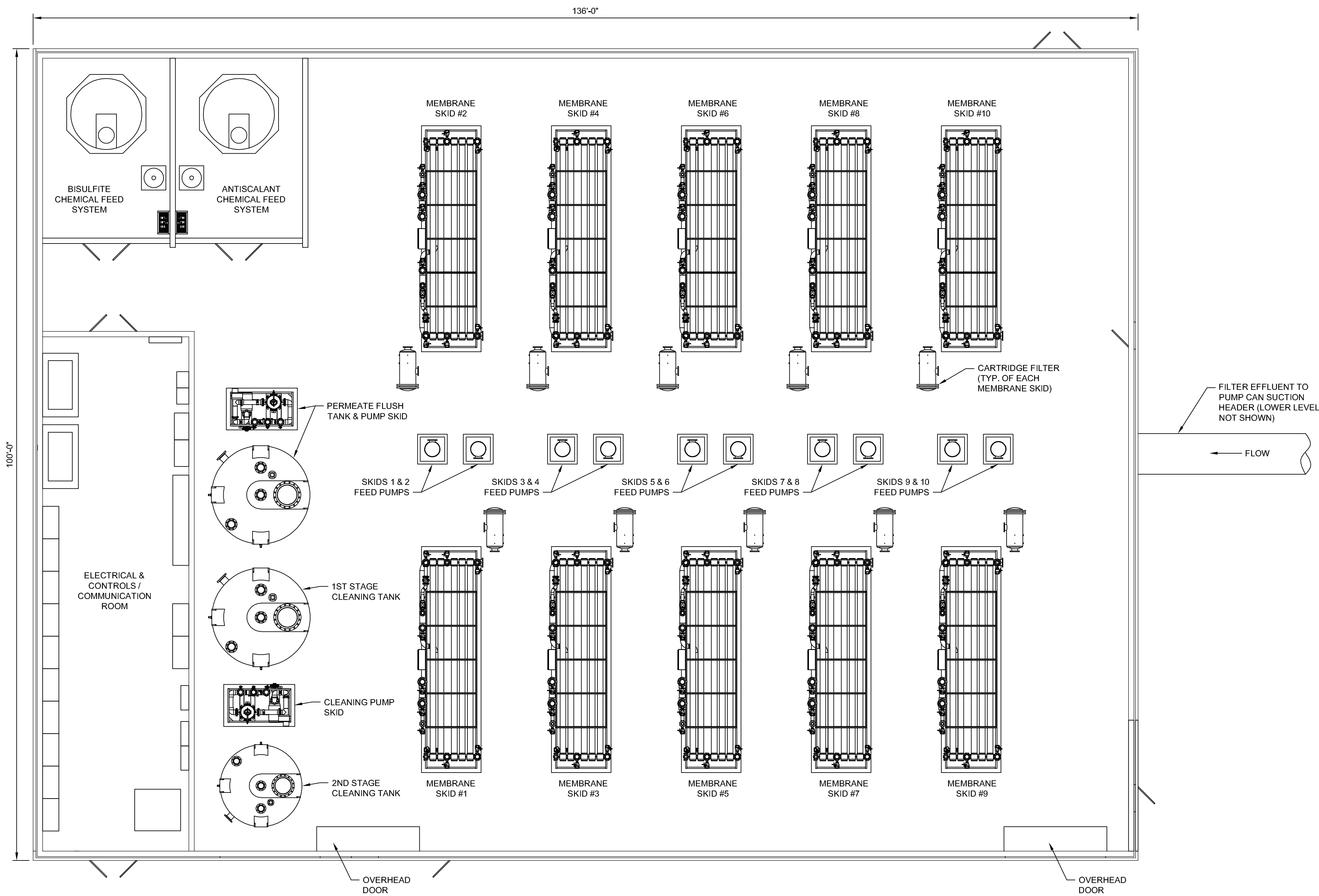

OVERALL PLAN

SCALE: 1/8" = 1'-0"

4 0 4 8 12
SCALE: 1/8" = 1'-0" 22x34
SCALE: 1/16" = 1'-0" 11x17

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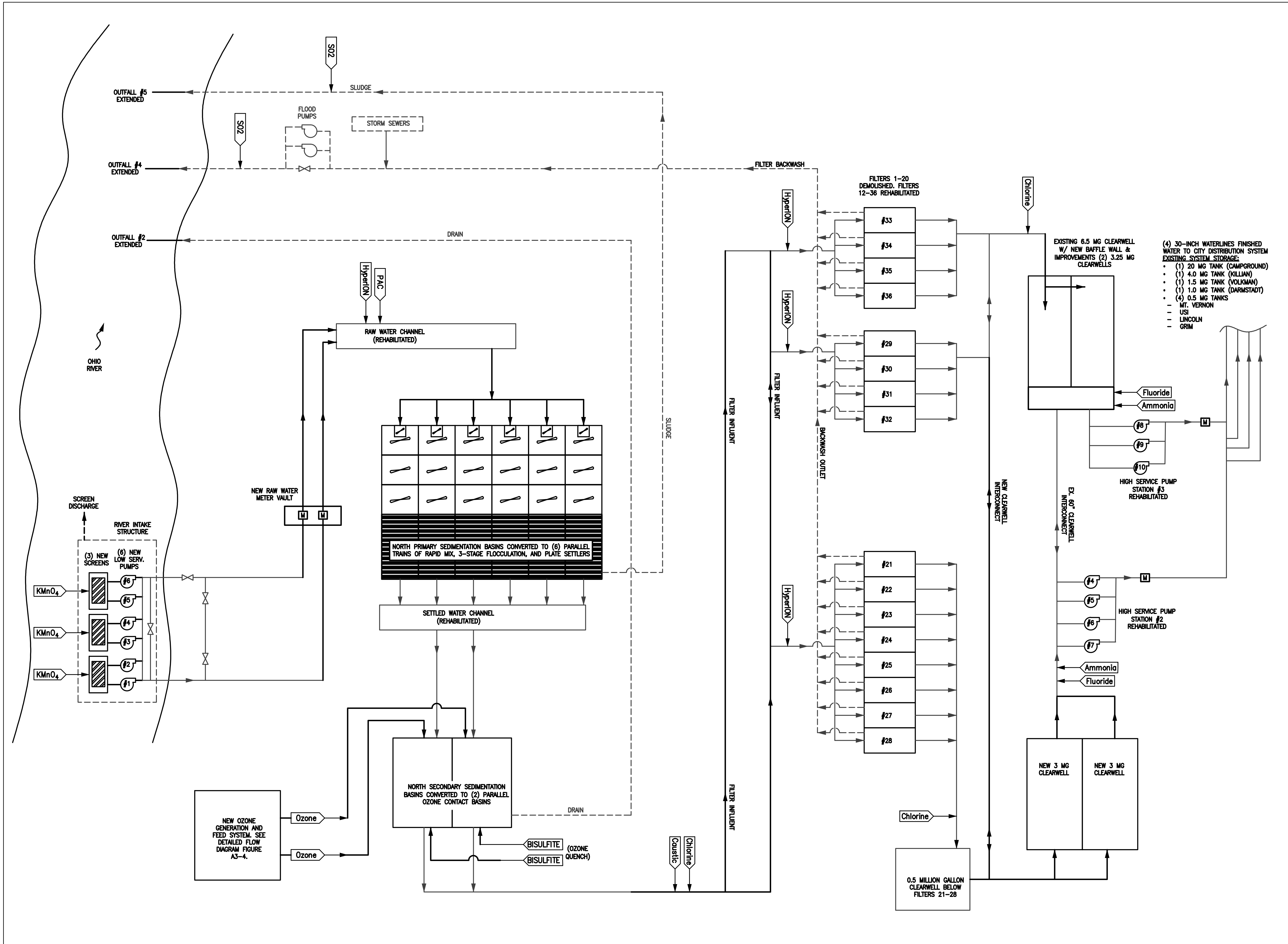
SHEET TITLE

CONCEPTUAL MEMBRANE SOFTENING BUILDING PLAN

SHEET NUMBER

A5-3



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SHEET TITLE

PLANT ALTERNATIVE 1
PROCESS FLOW DIAGRAM

SHEET NUMBER

FIGURE A6-1

ARCH D 22" x 34"
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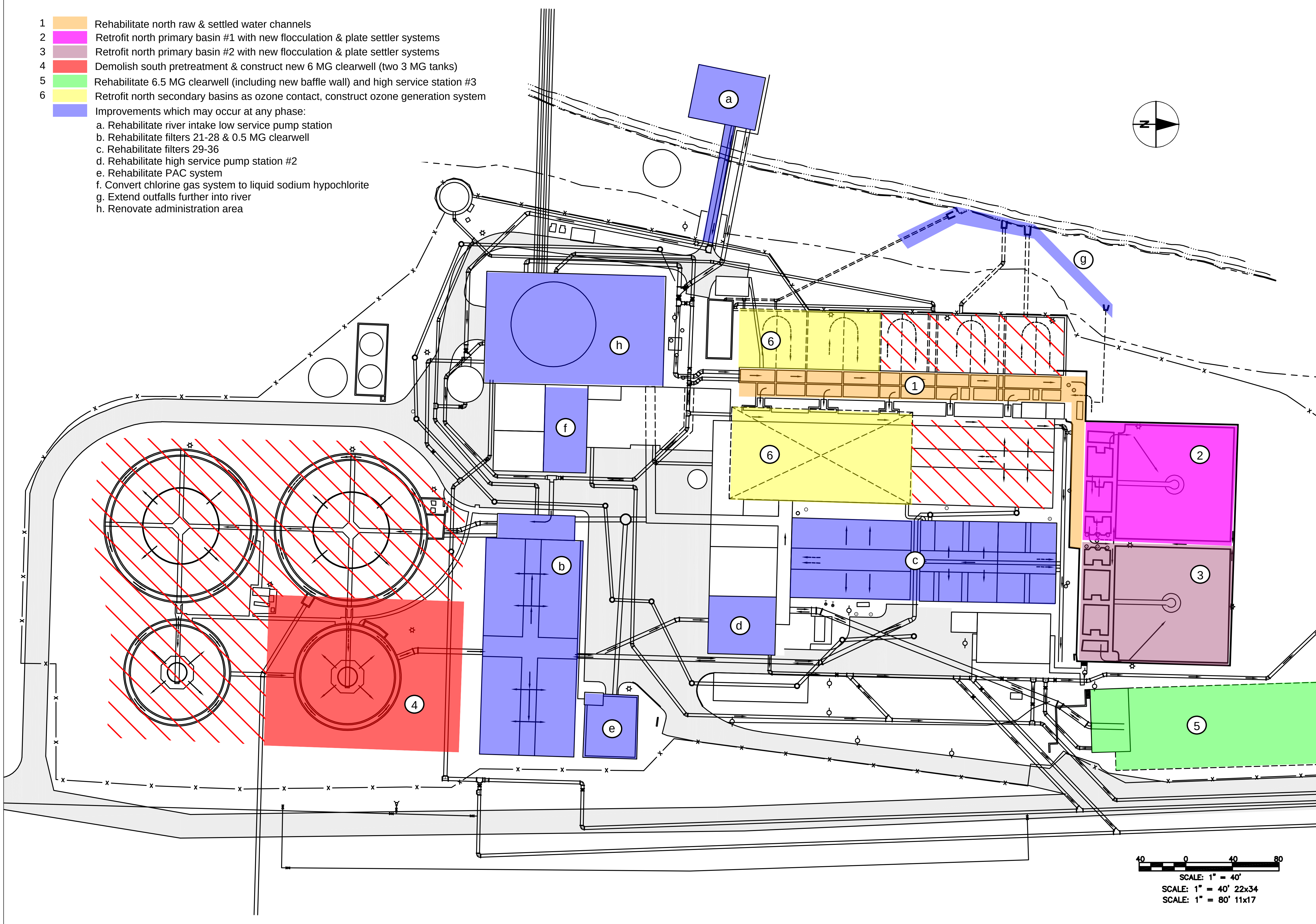
Sequencing of major construction improvements

1. Rehabilitate north raw & settled water channels
2. Retrofit north primary basin #1 with new flocculation & plate settler systems
3. Retrofit north primary basin #2 with new flocculation & plate settler systems
4. Demolish south pretreatment & construct new 6 MG clearwell (two 3 MG tanks)
5. Rehabilitate 6.5 MG clearwell (including new baffle wall) and high service station #3
6. Retrofit north secondary basins as ozone contact, construct ozone generation system

Improvements which may occur at any phase:

a. Rehabilitate river intake low service pump station
b. Rehabilitate filters 21-28 & 0.5 MG clearwell
c. Rehabilitate filters 29-36
d. Rehabilitate high service pump station #2
e. Rehabilitate PAC system
f. Convert chlorine gas system to liquid sodium hypochlorite
g. Extend outfalls further into river
h. Renovate administration area



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Designer: ###
Project Management Initials:
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Evansville: U1032
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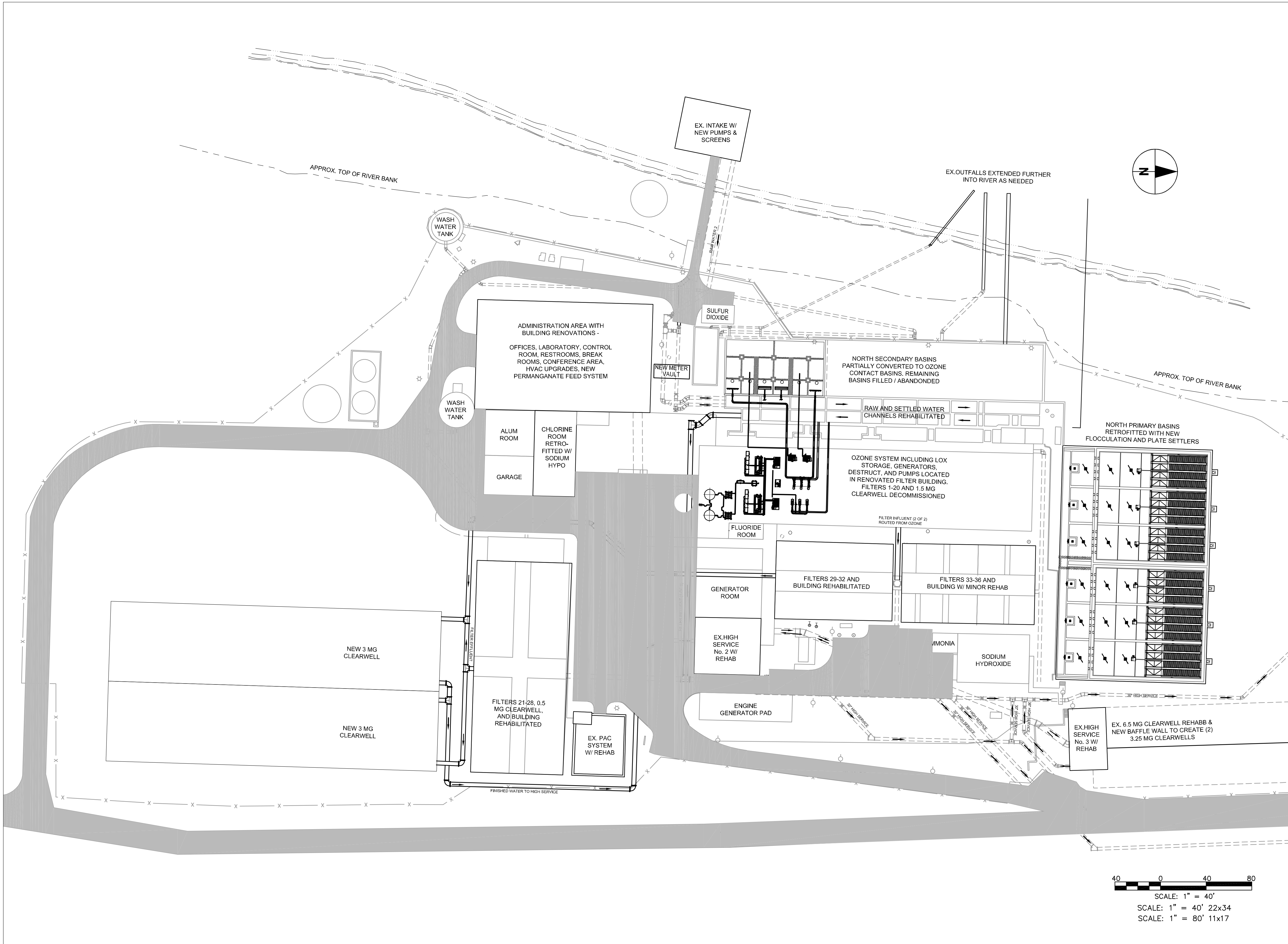
SHEET TITLE

PLANT ALTERNATIVE 1
DEMOLITION AND PHASING PLAN

SHEET NUMBER

FIGURE A6-2



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SHEET TITLE

PLANT ALTERNATIVE 1
PROPOSED SITE PLAN

SHEET NUMBER

FIGURE A6-3

ARCH D 22" x 34"
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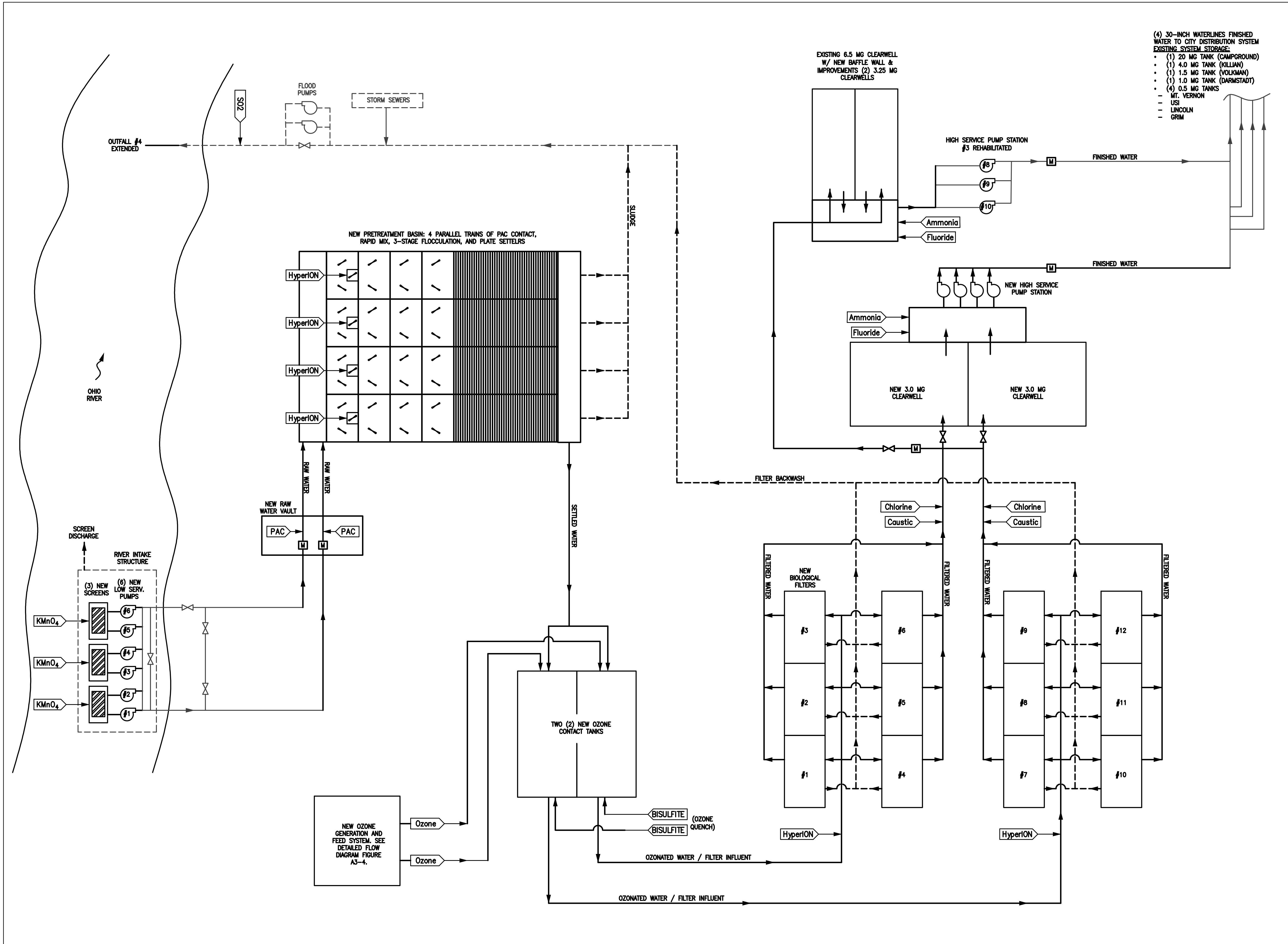

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SHEET TITLE

PLANT ALTERNATIVE 2A PROCESS FLOW DIAGRAM

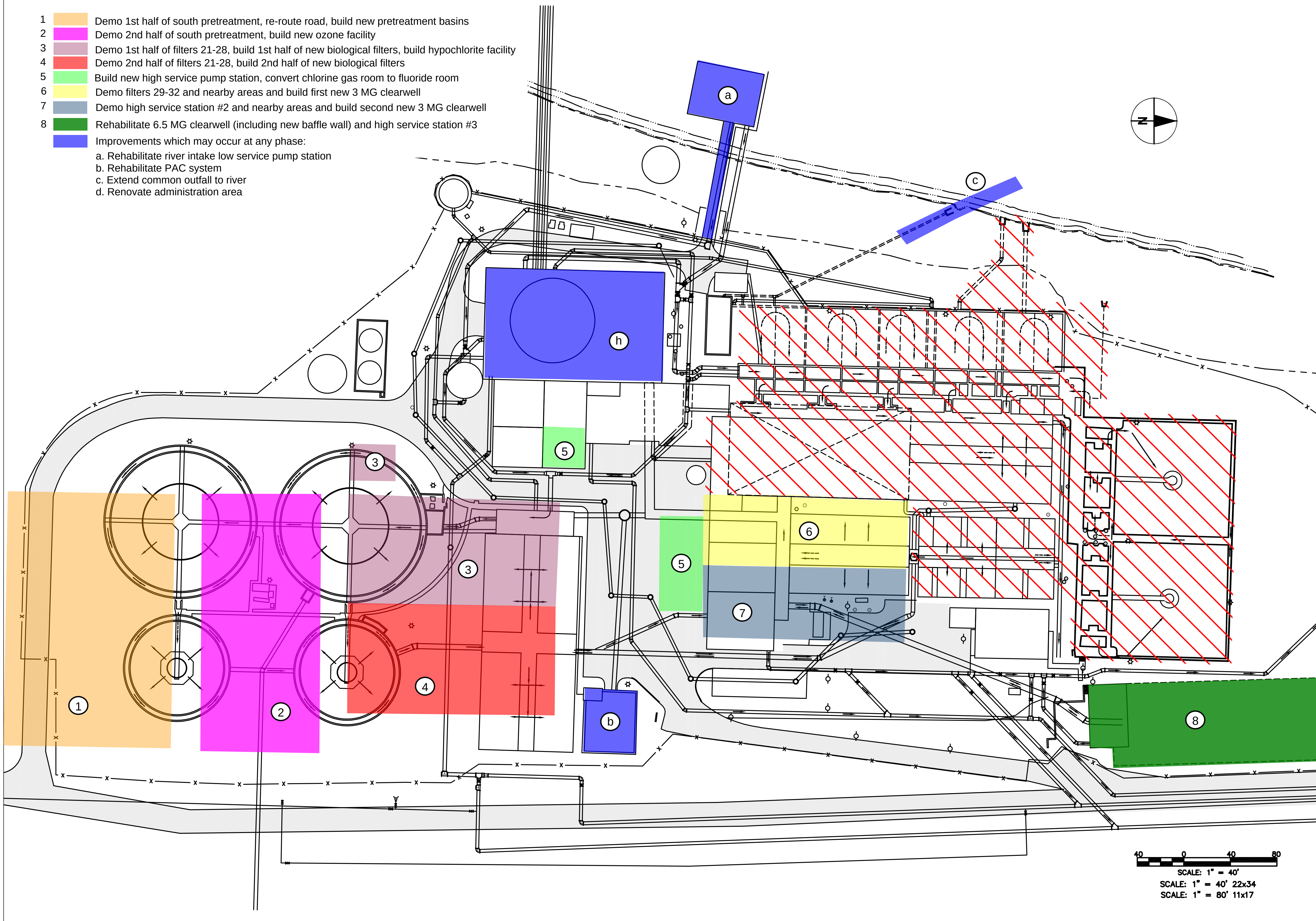
SHEET NUMBER

FIGURE A6-4

Sequencing of major construction improvements

1. Demo 1st half of south pretreatment, re-route road, build new pretreatment basins
2. Demo 2nd half of south pretreatment, build new ozone facility
3. Demo 1st half of filters 21-28, build 1st half of new biological filters, build hypochlorite facility
4. Demo 2nd half of filters 21-28, build 2nd half of new biological filters
5. Build new high service pump station, convert chlorine gas room to fluoride room
6. Demo filters 29-32 and nearby areas and build first new 3 MG clearwell
7. Demo high service station #2 and nearby areas and build second new 3 MG clearwell
8. Rehabilitate 6.5 MG clearwell (including new baffle wall) and high service station #3

Improvements which may occur at any phase:
a. Rehabilitate river intake low service pump station
b. Rehabilitate PAC system
c. Extend common outfall to river
d. Renovate administration area



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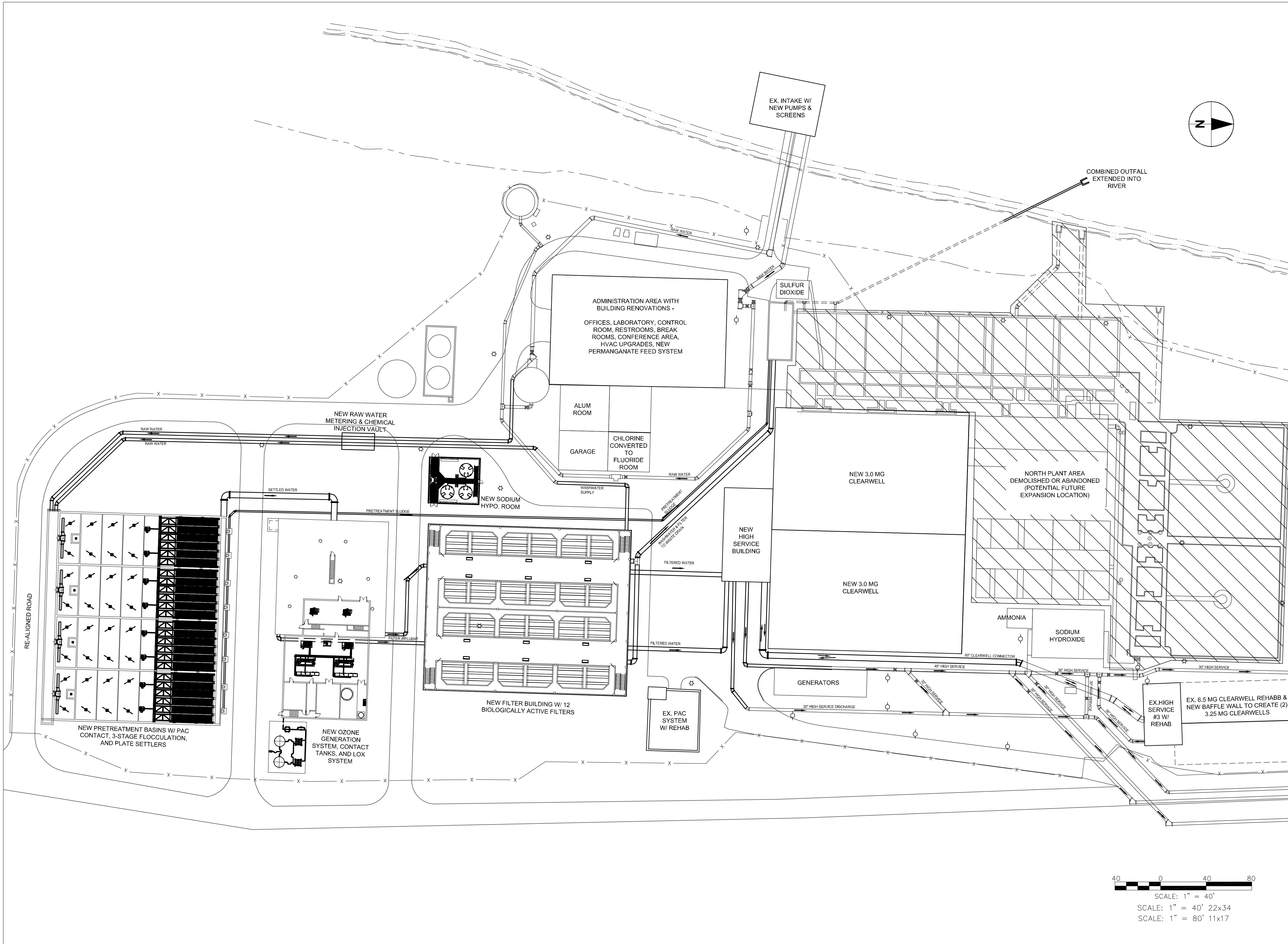
SHEET TITLE

PLANT ALTERNATIVE 2A DEMOLITION AND PHASING PLAN

SHEET NUMBER

FIGURE A6-5



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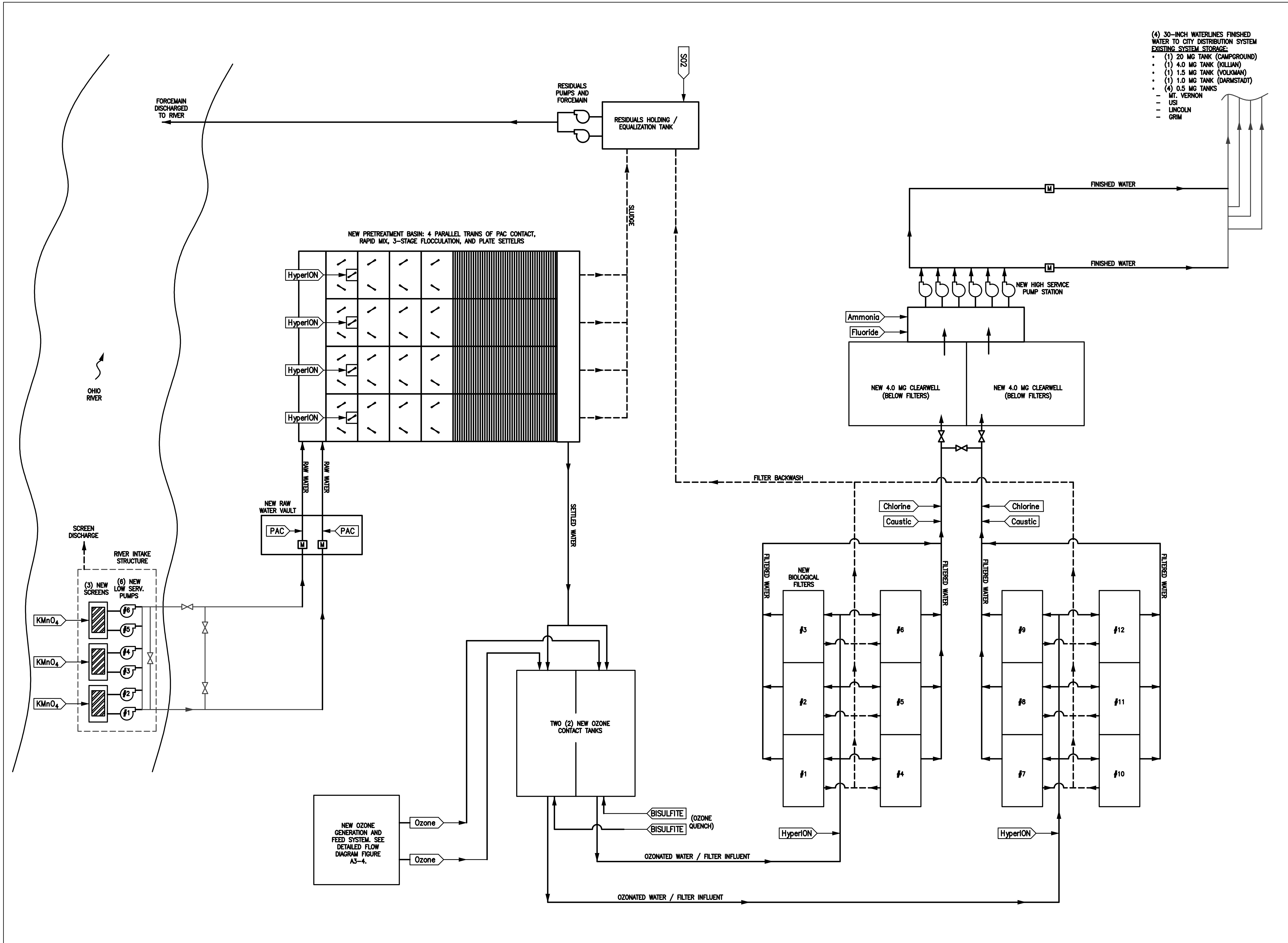
SHEET TITLE

PLANT ALTERNATIVE 2A PROPOSED SITE PLAN

SHEET NUMBER

FIGURE A6-6



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PLANT ALTERNATIVE 2B
PROCESS FLOW DIAGRAM

SHEET NUMBER

FIGURE A6-7