BUREAU OF RECLAMATION

Final Environmental Impact Statement

Eastern North Dakota Alternate Water Supply Project

Volume 3: Appendix B

McClusky Canal, Garrison Diversion Unit, North Dakota

Missouri Basin Region
Dakotas Area Office
Bismarck, North Dakota

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The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

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Appendix B

Biota Water Treatment Plant Appraisal-Level Design Engineering Report

Eastern North Dakota Alternate Water Supply Project
Environmental Impact Statement

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BIOTA WATER TREATMENT PLANT
APPRAISAL-LEVEL DESIGN ENGINEERING REPORT

Eastern North Dakota Alternate Water Supply

B&V PROJECT NO. 403070
B&V FILE NO. 40.7100

PREPARED FOR

BUREAU OF RECLAMATION

U.S. Department of the Interior

15 APRIL 2020

PREPARED BY

BLACK & VEATCH

GARRISON DIVERSION

AE2S

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Acronyms and Abbreviations

AIS	aquatic invasive species
APHA	American Public Health Association (color scale unit)
B&V, BV	Black & Veatch Corporation
BF	baffling factor
BWTP	biota water treatment plant
C	Celsius
$CaCO_3$	calcium carbonate
CAPEX	capital expenditure
CCI	construction cost index
cfs	cubic feet per second
cT	contact time, free chlorine residual, concentration x time, min-mg/L
DBP	disinfection by-products
DCB	disinfection contact basin(s)
DKAO	Bureau of Reclamation, Dakotas Area Office
DOC	dissolved organic carbon
ENDAWS	Eastern North Dakota Alternate Water Supply
ENR	Engineer News Record
EPA	U.S. Environmental Protection Agency
EIS	Environmental Impact Statement
ft	foot
GAC	granular activated carbon
gal	gallon
gfd	gallons per square foot of membrane surface per day
gpm	gallons per minute
GMF	granular media filtration
HAA5	haloacetic acid
HBB	Hudson Bay Basin
hr	hour
IFC	International Fire Code
kW	kilowatt
lb(s)	pound(s)
MF	microfiltration
MG	million gallons
mgd	million gallons per day
mg/L	milligrams per liter (parts per million)
min	minimum
mJ/cm^2	millijoules per square centimeter
MRB	Missouri River Basin
NaOCl	sodium hypochlorite

NDPDES	North Dakota Pollutant Discharge Elimination System
NPV	net present value
NSDWR	National Secondary Drinking Water Regulations
NTU	nephelometric turbidity units
O&M	operation and maintenance
OPCC	opinion of probable construction cost
OPEX	operating expenditure
OSG	on-site generation
pH	potential of hydrogen
ppd	pounds per day
PPE	personal protective equipment
psig	pounds per square inch gauge
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RRVWSP	Red River Valley Water Supply Project
SDWA	Safe Drinking Water Act
TDS	total dissolved solids
TOC	total organic carbon
UF	ultrafiltration
µm	micrometer
USGS	U.S. Geological Survey
UV	ultraviolet
UVT	ultraviolet light transmittance
yr	year

Executive Summary

The U.S. Department of the Interior, Bureau of Reclamation (Reclamation), Dakotas Area Office (DKAO) is preparing an Environmental Impact Statement (EIS) on the Eastern North Dakota Alternate Water Supply (ENDAWS) Project. The ENDAWS Project is a bulk raw water transmission system, taking surface water from the McClusky Canal - which is fed from Lake Audubon and Lake Sakakawea (a reservoir created by the Garrison Dam on the Missouri River) - and delivering it to the main transmission pipeline of the State Red River Valley Water Supply Project (RRVWSP). The State RRVWSP pipeline discharges water into the Sheyenne River which flows into Lake Ashtabula, water stored and released from Lake Ashtabula flows into the Sheyenne River, then the Red River, ultimately flowing into Hudson Bay in Canada. This additional water supply will be for domestic, commercial, and industrial needs of numerous communities and rural water systems in central and eastern North Dakota.

In the fall of 2019, Reclamation requested a design and cost analysis for Biota water treatment options for the ENDAWS Project to support development of an EIS for the proposed project. This analysis provides an appraisal-level design and cost analysis for four types of water treatment systems for biota removal and inactivation at a peak flow of 165 cubic feet per second (cfs) or 107 million gallons per day (mgd). Concerns over the transfer of invasive species from the Missouri River Basin (MRB) to the Hudson Bay Basin (HBB) have led to the development of treatment options to address this issue and evaluate the potential environmental impacts of the various scenarios. There are no regulations in place that govern the removal/inactivation of invasive species. U.S. Environmental Protection Agency (EPA) drinking water standards provide the best reference point for biota removal/inactivation but are not considered the regulatory standard.

Water Treatment – Four treatment options were evaluated for biota removal and/or inactivation for the ENDAWS Project and cost estimates were developed for each. The treatment options build on each other and each option provides more treatment capabilities. The treatment process options evaluated include:

Option 1 – Sand/grit removal and disinfection consisting of chlorination only.

Option 2 – Sand/grit removal and enhanced Disinfection consisting of ultraviolet light (UV) disinfection and chlorination.

Option 3 – Conventional Treatment consisting of coagulation/flocculation, high rate sedimentation, granular media filtration, UV disinfection, and chlorination.

Option 4 – Advanced Treatment consisting of sand/grit removal, coagulation/flocculation, membrane filtration, UV disinfection, and chlorination.

The options incorporate the following processes in addition to those processes identified above:

- Fine screening at the intake for trash and debris removal; additionally, these screens serve as a barrier to the introduction of macro aquatic organisms into the system.
- Off-site reaeration in the State RRVWSP for reoxygenation to increase dissolved oxygen (DO) prior to discharge.
- Off-site dechlorination in the State RRVWSP for removal of any residual chlorine prior to discharge.

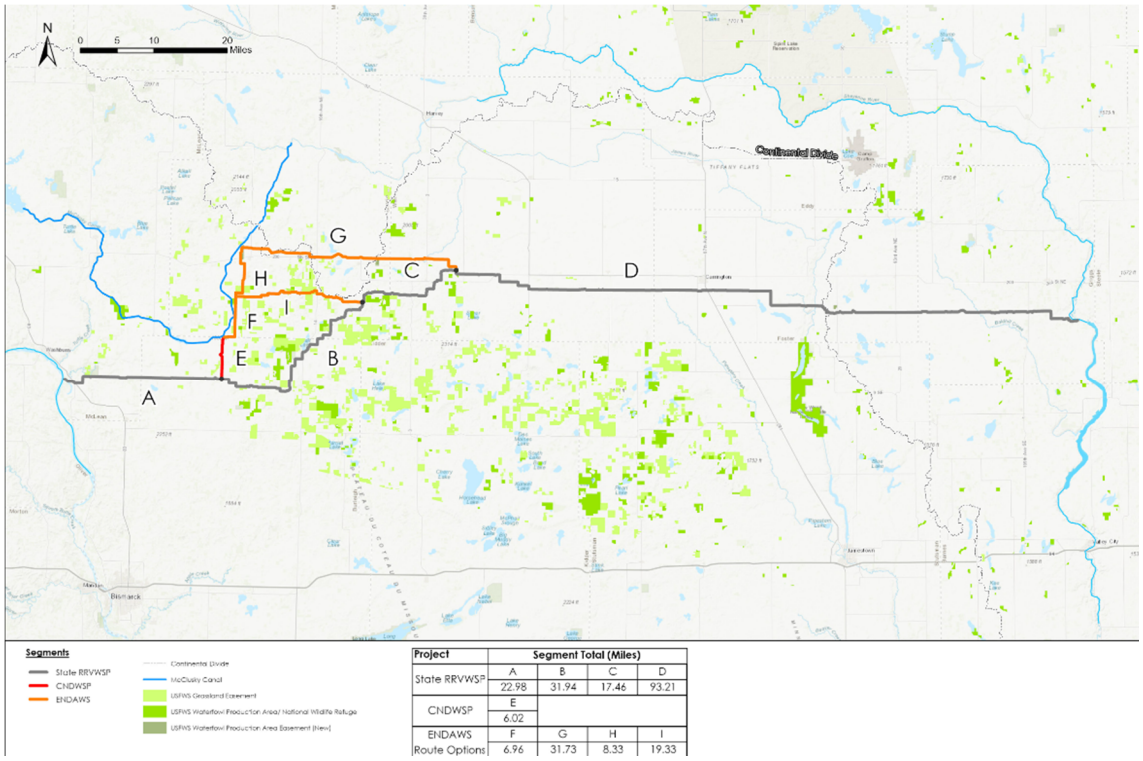
Costs – Details of the cost estimating methods used to determine the 2019 costs for both construction and operation and maintenance (O&M) aspects of each of the four options are presented in Chapter 7. For each option, the estimated costs of construction are:

- Option 1 – $56 million.
- Option 2 – $70 million.
- Option 3 – $220 million.
- Option 4 – $240 million.

An evaluation of treatment effectiveness, operations and maintenance, and costs are included in more detail in Chapter 8 of this analysis.

1.0 Introduction

This Biota Water Treatment Plant Appraisal Level Design Engineering Report (analysis) provides an appraisal-level design and cost analysis for a 165 cfs (107 mgd) Biota Water Treatment Plant (BWTP) as part of the ENDAWS Project in North Dakota. As units in mgd are typically used in water treatment, this analysis will follow that convention from this point forward.



Project	Segment Total (Miles)			
State RRVWSP	A	B	C	D
	22.98	31.94	17.46	93.21
CNDWSP	E			
	6.02			
ENDAWS	F	G	H	I
Route Options	6.96	31.73	8.33	19.33

Figure 1-1 Water Supply Pipeline Overview

The overview map shown above delineates the boundary of the MRB and HBB. It generally shows the proposed ENDAWS pipeline route options. As described in the associated ENDAWS Appraisal Level Design Engineering Report, there are two separate McClusky Canal Intake and BWTP locations being considered, one at the intersection of Segment G and the McClusky Canal and one at the intersection of Segment I and the McClusky Canal A variation in BWTP location will affect the site development costs but not affect the basic water treatment processes described in this analysis.

Reclamation initiated the preparation of an EIS in compliance with the National Environmental Policy Act (NEPA). This analysis considers several treatment options focused on biota removal and inactivation for the inter-basin transfer of water from the MRB to the HBB. Under the ENDAWS project, surface water would be drawn from the McClusky Canal, which obtains its supply from Lake Audubon and Lake Sakakawea on the Missouri River. Water withdrawn from the canal would be pumped over the continental divide and discharged to the State RRVWSP. Flows transferred from the MRB to the HBB via the Red River cross the national boundary between the U.S. and Canada, ultimately discharging into Hudson Bay in Canada.

An appraisal-level design is used to compare relative costs of the options. This level of design uses existing or limited new data and does not go into detailed design or detailed cost analysis. A

feasibility level design, sometimes referred to as a conceptual design, is the subsequent step for development of the favored option's design and to estimate the necessary funding appropriation.

The evaluations presented in this analysis commenced with a meeting at Garrison Diversion Conservancy District's (Garrison Diversion's) headquarters in Carrington on July 24, 2019, with representatives from Reclamation and Garrison Diversion, as well as engineering consultants from Garrison Diversion. At that meeting, Garrison Diversion and its consultants were tasked with performing appraisal-level designs with sub-feasibility details for four water treatment process trains.

The treatment process options evaluated include:

- Option 1 – Disinfection consisting of sand/grit removal and chlorination.
- Option 2 – Enhanced Disinfection consisting of sand/grit removal, UV disinfection, and chlorination.
- Option 3 – Conventional Treatment consisting of coagulation/flocculation, high rate sedimentation, media filtration, UV disinfection, and chlorination.
- Option 4 – Advanced Treatment consisting of sand/grit removal, coagulation/flocculation, membrane filtration, UV disinfection, and chlorination.

This analysis is organized around the following chapters:

Chapter 1 – Introduction

Chapter 2 – Regulatory Considerations

Chapter 3 – Source Water Quality

Chapter 4 – Capacity Requirements

Chapter 5 – Biota Water Treatment Plant Design Overview

Chapter 6 – Detailed Treatment Options Descriptions

Chapter 7 – Cost Evaluation

Chapter 8 – Options Comparison

2.0 Regulatory Considerations

The U.S. government has not developed water treatment standards, rules or regulations specifically for use in reducing the risk of an introduction of an invasive species through interbasin water transfers. However, extensive research has gone into the development of standards, rules and regulation for treating drinking water to reduce risks of transmitting pathogens to humans. The Safe Drinking Water Act (SDWA) sets forth the treatment measures that must be taken to effectively reduce the risk of transmission of human health diseases through drinking water systems. The EPA is responsible for developing regulations designed to comply with the SDWA and ensure that public water supplies used for human consumption provide for adequate treatment to reduce the risks of disease transmission to humans to an acceptable level.

Therefore, the SDWA and the associated research provide the best available information to compare treatment capabilities. The SDWA regulates Giardia, Cryptosporidium, and viruses as human health pathogens for drinking water systems. In the absence of interbasin water transfer treatment standards, the SDWA and the NPDWRs can be used as a basis of comparison to evaluate treatment efficiency. The SDWA and NPDWRs set reduction standards, including the requirements of 3-log (99.9 percent) removal/inactivation of Giardia and 4-log (99.99 percent) removal/inactivation of viruses.

3.0 Source Water Quality

There are two potential water sources for the ENDAWS Project:

- The Missouri River south of Washburn, ND.
- The McClusky Canal west of McClusky, ND.

Irrespective of whether water is withdrawn from the Missouri River or the McClusky Canal, the BWTP will be at one of the two locations described in Chapter 1.

The Missouri River source is located downstream of Lake Sakakawea whereas the McClusky Canal source water would be downstream of both Lake Sakakawea and Lake Audubon. Water quality data from Lake Sakakawea, Lake Audubon near the Snake Creek Pumping, and Lake Audubon at the canal headworks were analyzed for trends and absolute ranges over approximately the past 15 years. Water quality data from the U.S. Geological Survey (USGS) online database were tabulated to form water quality data tables (Appendices A and B).

3.1 MISSOURI RIVER WATER QUALITY

In general, surface water from the Missouri River is anticipated to have a higher quality when compared to that of the McClusky Canal. Due to the stagnant nature of the canal, total dissolved solids (TDS) levels in the river are expected to be significantly lower. On the other hand, heavy sediment loading varies seasonally in the Missouri River while sediment loading in the canal is minimal. During winter, the water temperature is near freezing, which necessitates longer contact time for chemical disinfection than what would be required for a warmer water source. Based on water quality data summarized in **Appendix A**, surface water drawn from the Missouri River is anticipated to have levels of hardness (as calcium carbonate (CaCO3)) as well as TDS above the recommendations established by the EPA as Secondary standards for Drinking Water.

3.2 MCCLUSKY CANAL WATER QUALITY

Water sampled from New Johns Lake is assumed to be representative of the McClusky Canal at the proposed sites for the intake. Based on water quality data summarized in **Appendix A**, surface water drawn from the McClusky Canal is also anticipated to have levels of TDS above the recommendations established by the EPA. In addition, the canal water likely contains elevated levels of iron and manganese based on historic sampling of water upstream at New Johns Lake.

3.3 ANTI-DEGRADATION CONSIDERATIONS

The principle of maintaining the historical uses of natural water bodies that receive discharges of other natural or treated waters is generally termed anti-degradation. The North Dakota Administrative Code, Article 33-16, Control, Prevention, and Abatement of Pollution of Surface Water and its subchapters promulgate water quality standards for discharges to receiving streams. The standards are based on assigned stream classifications of water quality, which are to be maintained in the stream. For example, water quality standards are established for key constituents such as total suspended solids (TSS), sulfates, chlorides, ammonia, E. coli, and minimum dissolved oxygen. . If water to be discharged into a receiving stream is anticipated to not meet constituent limitations for these water quality parameters, some form of treatment is necessary.

3.4 PRIMARY STANDARDS FOR DRINKING WATER

To determine relative quality of the source water, McClusky Canal water is compared to drinking water standards. It is not, however, the objective of this appraisal-level design to meet drinking water treatment standards at the BWTP but Drinking Water Standards are the best available data for determining treatment effectiveness. The available data for Lake Audubon does not show any values that exceed primary standards except for occasional turbidity. Turbidity standards range from 0.3 nephelometric turbidity units (NTU) to 5 NTU depending on the type of treatment. Turbidity averages around 10 in Lake Audubon. Elevated biological contaminants may exist, but data for genus such as *Giardia* are not readily available. If more advanced engineering occurs, it is recommended that data for all regulated contaminants be obtained at that point.

3.5 SECONDARY STANDARDS FOR DRINKING WATER

3.5.1 Total Dissolved Solids

The EPA establishes recommended guidelines for water providers through the National Secondary Drinking Water Regulations (NSDWR). Substances covered by the NSDWR are not harmful to human health, but may cause unpleasant taste, odor and/or color. The available water quality data show the exceedance of some secondary drinking water standards, such as TDS with a secondary standard of 500 milligrams/liter (mg/L) and sulfate with a secondary standard of 250 mg/L.

TDS measurements show an increasing trend from Lake Audubon through the canal to Hoffer Lake as shown in Figure 3-1. The proposed intake locations near the Highway 200 tunnel shows TDS levels roughly 2.5 times higher than the levels entering the canal headworks. With no outlet or irrigation demand, the canal is dead headed, and the TDS continuously increases over time as water evaporates. The canal is replenished by discharge from Lake Audubon as well as surface water runoff. TDS levels during operation of the Project would likely fall over time due to the increased flow of water from Lake Audubon flowing to this section of the canal.

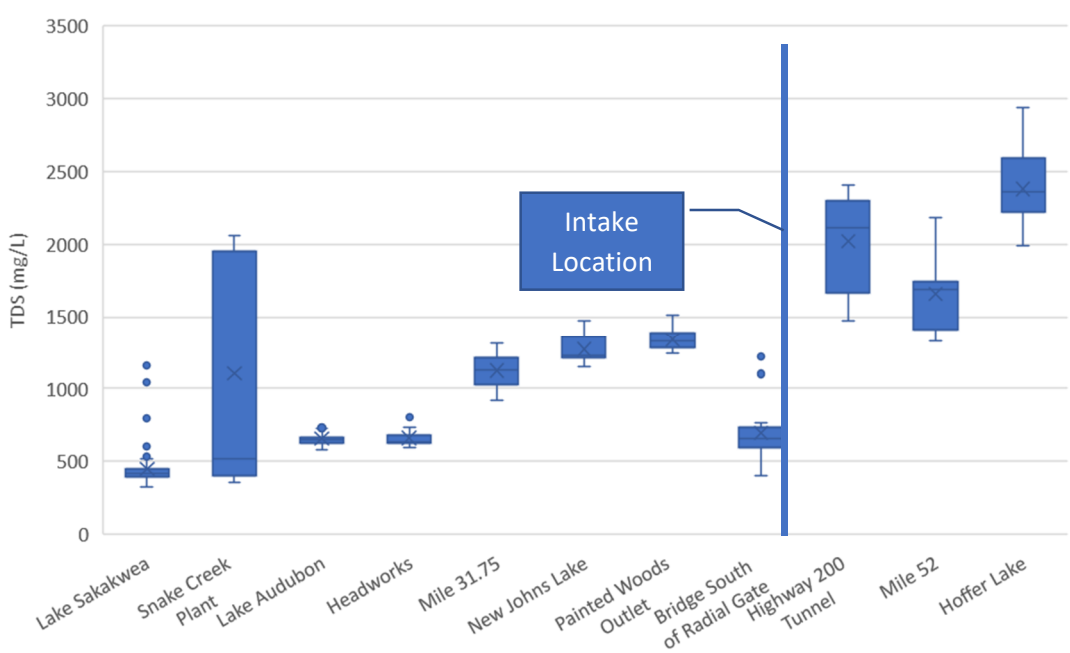


Figure 3-1 Lake and McClusky Canal TDS Data

3.5.2 Turbidity

Turbidity levels are low in the canal with a flat trend from the headworks to Hoffer Lake, as shown in Figure 3-2.

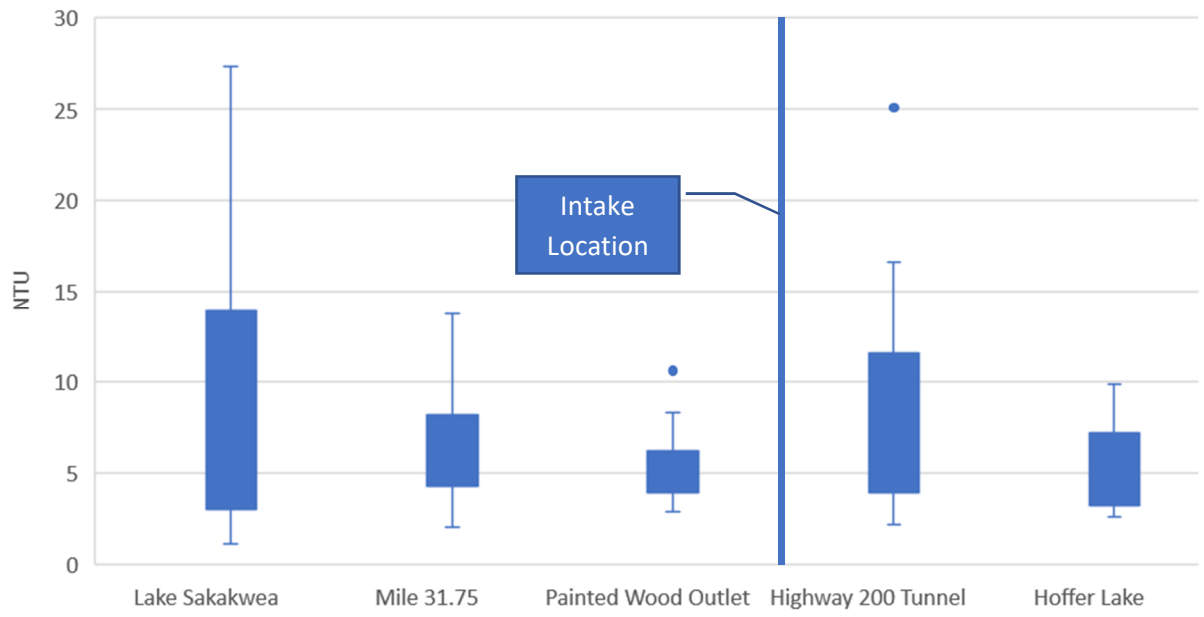


Figure 3-2 Lake Sakakawea and McClusky Canal Turbidity Data

3.5.3 Color

Water color is quantified by APHA (American Public Health Association) color units or "yellowness index." The APHA for Lake Audubon and the canal sampling points are generally low with a spike near the canal headworks (Figure 3-3). The water near the headworks comes from a shallower section of the lake that has more vegetation and algae growth, likely causing the increased color readings. This color is nearly fully removed, as the water moves through the canal to the proposed intake location. The data below is from sampling conducted on September 10, 2019.

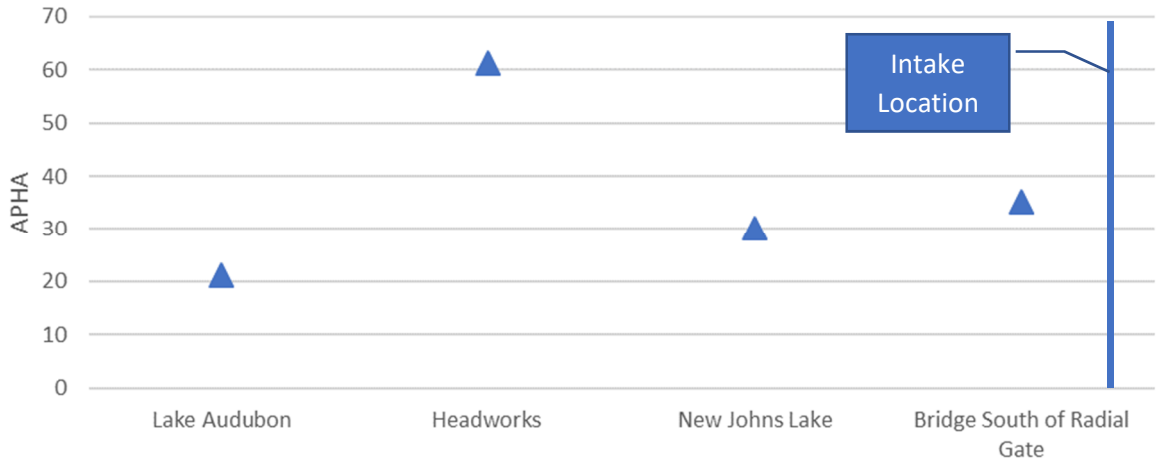


Figure 3-3 Lake Audubon and McClusky Canal Color Data

3.5.4 Total Suspended Solids

TSS measurements show a sharp increase at New Johns Lake and downstream (Figure 3-4). As described previously, the turbidity readings do not show the same sharp increase. This indicates that the TSS are not fines and silt from the canal but are more likely due to algae growth originating in the Chain of Lakes and stagnant water downstream. This hypothesis will be further supported if winter water samples show lower TSS values. The data below is from sampling conducted on September 10, 2019.

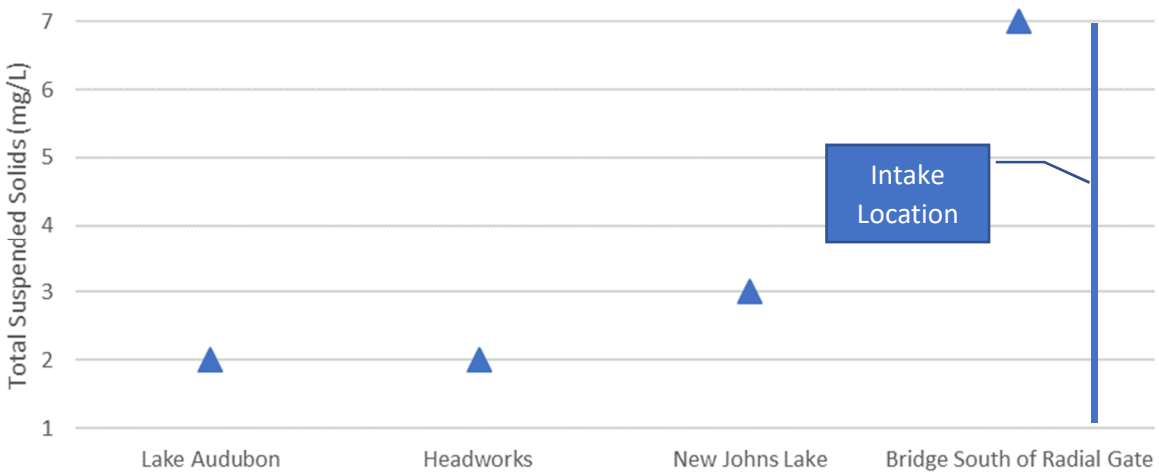


Figure 3-4 Lake Audubon and McClusky Canal TSS Data

3.5.5 Sulfate

The average sulfate concentration at Lake Sakakawea (176 mg/L) was below the secondary standard (250 mg/L), but the sulfate levels measured in Lake Audubon and New Johns Lake (296 and 676 mg/L, respectively) exceed the secondary drinking water standard.

3.5.6 Hardness

The water from all three sources is considered "very hard" with a hardness range from 178 to 664 mg/L. The general hardness rating scale is shown in Table 3-1 below.

Table 3-1 General Hardness Rating Scale (USGS)

DEGREE OF HARDNESS	CONCENTRATION (mg/L as $CaCO_3$)
Soft	0 – 60
Moderately Hard	61 – 120
Hard	121 – 180
Very Hard	180+

3.6 BIOTA REMOVAL AND INACTIVATION

Biota treatment is based on technologies that physically remove microbial contaminates from the process stream and/or render them unable to propagate in the environment (known as inactivation) after treated water is discharged. Microorganisms would be removed and/or inactivated via treatment technologies for surrogate pathogens that share similar life history characteristics with disease-causing microorganisms that may be present in source water. Biota treatment is proposed to be met through a combination of disinfection and/or filtration barriers under a log-removal/inactivation approach. Several solids removal and disinfection barriers at the BWTP are described herein, including sedimentation basins plate-assisted settling basins, granular media filtration, membrane filtration, UV light disinfection, and chlorine disinfection.

4.0 Capacity Requirements

Operational flowrates of the BWTP are anticipated to vary widely, depending on the hydrologic conditions and water supply availability in central and eastern North Dakota. The capacity of the BWTP is based on delivering as much as 107 mgd on a sustained basis during relatively dry periods. Conversely, during relatively wet periods with abundant rain and snowmelt, deliveries from the BWTP may be limited to maintenance flows or roughly 2.6 mgd, which is projected to maintain high enough velocities in the pipeline to maintain water quality and avoid freezing conditions. The facilities evaluated here were based on a range of treatment flows between 2.6 mgd at a minimum and 107 mgd at the maximum as summarized in Table 4-1 below.

Table 4-1 Design Flow Rates

FLOW	MGD	CFS
Minimum	2.6	4
Peak Daily	107	165

5.0 Biota Water Treatment Plant Design Overview

This chapter presents a summary of four BWTP options, the level of treatment achieved, and how residuals would be handled in each option. Treatment processes selected vary from basic sand/grit removal and free chlorine disinfection to conventional and enhanced water treatment designs that include additional physical removal and inactivation of biological pathogens. Table 5-1 provides a summary of the treatment options and their respective purposes. Table 5-2 presents a summary of the treatment processes associated with each option.

Table 5-1 Treatment Capabilities for Various Options

OPTION	PURPOSE	CAPABILITIES OF BIOTA TREATMENT PLANT COMPONENTS	
		Biological Removal	Biological Inactivation
1	Macro-organisms (greater than 100 microns) and Primary Biological Constituents	Sand/Grit Removal (macro)	Chlorine
2	Macro-organisms (greater than 100 microns) and Primary Biological Constituents	Sand/Grit Removal (macro)	UV, Chlorine
3	Macro-organisms, Primary Biological Constituents and Natural Organic Matter	Coagulation/Flocculation, Sedimentation, and Granular Media Filtration	UV, Chlorine
4	Macro-organisms (greater than 100 microns), Primary Biological Constituents, and Natural Organic Matter	Sand/Grit Removal (macro), Coagulation/Flocculation, and Membrane Filtration	UV, Chlorine

Table 5-2 Treatment Processes for Various Options

TREATMENT PROCESS	BIOTA TREATMENT OPTION			
	1	2	3	4
Main Process				
Intake Fine Screening	■	■	■	■
Sand/Grit Removal	■	■		■
High-Rate Sedimentation			■	
Media Filtration			■	
Membrane Filtration				■
UV Disinfection		■	■	■
Chlorine Disinfection	■	■	■	■
Residuals Treatment				

TREATMENT PROCESS	BIOTA TREATMENT OPTION			
	1	2	3	4
Solids Equalization			■	■
High-Rate Sedimentation			■	■
Residuals Lagoon			■	■

Process flow diagrams for the four biota treatment options are shown in **Figure 5-1**; brief descriptions of each option follow in this chapter. Option 1 is the most basic biota treatment option. Options 2, 3, and 4 include UV disinfection as well as additional pretreatment processes to improve the effectiveness of aquatic invasive species (AIS) removal. As the biota treatment options progress, additional levels of treatment capabilities are added. The treatment options are discussed in further detail in the following sections.

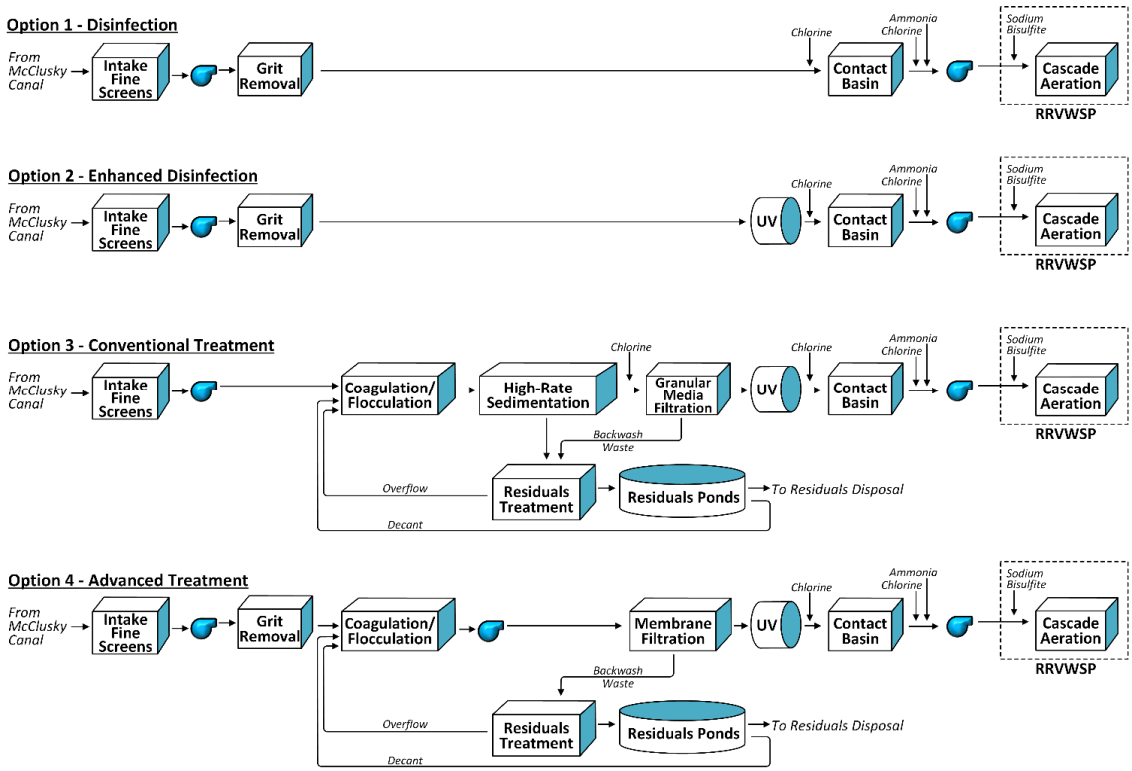


Figure 5-1 Biota Water Treatment Options

5.1 OPTION 1 – DISINFECTION

Option 1 provides water treatment through sand/grit removal and chlorine disinfection for removal of AIS. Sand/grit removal physically separates macro-organisms and fine material from the inflow before continuing to chlorine disinfection. Removing macro-organisms such as mollusks and mud snails reduces the chlorine demand as well as time required to maintain the treatment equipment. The chlorine disinfection process is designed to meet 3-log *Giardia* and 4-log virus inactivation. Chlorine disinfection provides both the log-inactivation credit and disinfectant residual to reduce the opportunity for re-growth of organisms in the pipeline.

5.1.1 Sand/Grit Removal

Sand/grit includes sand, gravel, or other heavy solid materials that have a higher density than water, which enables it to be physically separated from the raw water inflow. Sand/grit removal can be achieved through several means, the most common of which are with hydraulic settling, aerated grit chambers, mechanical-forced vortex units, and gravity-forced vortex units. Due to the ability to achieve higher removals of smaller particles only vortex removal processes were considered for this project. A mechanical-forced vortex unit uses a paddle to create a vortex that separates sand/grit from the raw water. Gravity-forced units have no moving parts; they passively split the sand/grit from inlet flow using a pressure drop applied over a stack of cones providing a high surface area. Both mechanical forced and gravity forced vortex units have been used for sand/grit removal at water production facilities. To enhance the capture and removal of AIS of concern, the sand grit system has been designed to remove 95 percent of all particles with a specific gravity greater than 2.1 and size greater than or equal to 100 microns. This conceptual design has been developed using the gravity-forced vortex units selected as the basis of design to achieve the greatest removal through either settling or adsorption of AIS on to the sand/grit particle for removal. Once removed, the sand/grit is pumped to a classifying unit where it is washed, cleaned, concentrated, and dewatered. Dewatered grit is typically collected in a roll-off dumpster and trucked to a landfill. A landfill in the MRB would be used for this application.

5.1.2 Chlorine Disinfection

Free chlorine disinfection will be the primary disinfectant in this option to meet the targeted inactivation. The chlorine disinfection system proposed for the State RRVWSP relies upon a combination of contact basins and pipeline volume to achieve the targeted chlorine residual contact times. For the ENDAWS options, the target chlorine contact times will be achieved only through contact basins. At the discharge of the contact basins, ammonia will be added to consume the free chlorine and generate chloramines. Chloramines are a more stable chlorine residual, and eliminating free chlorine significantly reduces potential disinfection by-products (DBP) formation.

5.1.3 Residual Chlorine

This option provides basic disinfection with 215 minutes of free chlorine contact time at an expected residual of 3.0 mg/L in a serpentine disinfection contact basin with a baffling factor of 0.8, which calculates to a contact time (cT) of 516 mg-min/L. A cT of 516 mg-min/L is required to achieve greater than 3-log removal/inactivation of *Giardia*, as well as provide greater than 4-log removal/inactivation of viruses. Free chlorine disinfection is followed by ammonia addition to form chloramines.

A chlorine residual will be maintained entering the transmission pipeline for this Option 1 and all subsequent biota treatment options discussed in Chapter 5 (Options 2, 3, and 4). Furthermore, a detectable residual may be present throughout the water delivery pipeline in all options. Therefore, prior to the transferred water entering the receiving natural water source, any remaining disinfection residual will be quenched and removed by the State RRVWSP. This is accomplished using a quenching chemical, sodium bisulfite. Additional chemical feed and storage systems will be required at the discharge location to achieve proper quenching of the disinfectant residual before discharge.

5.2 OPTION 2 – ENHANCED DISINFECTION

Option 2 is an enhanced disinfection process, including sand/grit removal and UV light irradiation and free chlorine disinfection and chloramine formation. UV is an effective disinfection process that provides significant inactivation of *Giardia, Cryptosporidium*, and other chlorine resistant AIS with

minimal DBP formation. It provides system flexibility by decreasing the necessary chlorine contact time due to its efficacy at *Giardia* inactivation compared to the sole use of chlorine (Option 1). Unlike chlorine disinfection, UV disinfection is not as effective against viruses at typical UV dosages and does not provide a disinfection residual in the effluent. Post UV chlorine application is necessary to establish a residual in the transmission pipeline. Virus inactivation is possible using UV disinfection, but at the cost of significantly increasing energy usage by an approximate factor of three. Therefore, the UV system will not be designed for virus inactivation. The UV and chlorine disinfection systems are designed for a peak flow of 107 mgd.

5.2.1 UV Disinfection

The UV system capacity is designed to provide a dose of 40 millijoules per square centimeter (mJ/cm^2) at a peak flow of 107 mgd. UV dose requirements are selected in order to achieve greater than 3-log removal/inactivation of *Giardia* based upon tables provided by the EPA. In addition, the UV system has been designed to achieve 4-log removal/inactivation of *Myxobolus cerebralis* (Hedrick 2007, Hedrick 2008, Hedrick 2012). In order to provide consistent pathogen removal capabilities, the maximum capacity of the UV system designed for Option 2 is also proposed as the UV system for Options 3 and 4.

5.2.2 Chlorine Disinfection

UV disinfection is followed by chlorination in a contact basin, which provides the log-inactivation of viruses that is not achieved in the UV reactors. The additional disinfection/AIS removal provided by UV reduces the *Giardia* log-inactivation potentially required by the chemical chlorine disinfection alone. In accordance with a conservative approach, the same disinfection contact basin (DCB) design for the chlorine disinfection described in Option 1 will be used in Option 2 as well to provide full disinfection redundancy to the UV system. As with Option 1, this treatment design provides a calculated cT of 516 mg-min/L based on 215 minutes of free chlorine contact time in a serpentine disinfection contact basin with a baffling factor of 0.8 at an expected residual of 3.0 mg/L. Following chlorine disinfection, ammonia is fed into the chlorinated water stream to form chloramines before entering the transmission line.

Enhanced disinfection consisting of UV irradiation followed by chlorination is also proposed as the disinfection/AIS inactivation process for Options 3 and 4.

5.3 OPTION 3 – CONVENTIONAL TREATMENT

Option 3 consists of coagulation, flocculation, high-rate sedimentation, and filtration (granular media filtration (GMF) considered as a representative process) followed by advanced disinfection processes (UV irradiation and chlorination) for AIS inactivation.

5.3.1 Coagulation/Flocculation

Removal of total organic carbon (TOC), turbidity, and AIS of concern in the treatment process begins with the addition of a coagulant - such as aluminum salts, ferric chloride and/or polymer - mixed in a rapid mix chamber. Rapid mix is followed by flocculation with vertical shaft equipment. This allows for AIS of concern to be attached to the particles being formed so that removal can be enhanced through sedimentation and filtration.

5.3.2 High-Rate Sedimentation

A large percentage of the flocculated particles are then removed in a sedimentation basin equipped with plate settlers, where the floc meets the plates and sluffs off to the bottom of the basin. The basin is equipped with a solids removal system, such as a hose-less vacuum system, that removes

settled solids accumulated at the bottom of the basin. The pre-treatment process is optimized to remove as much natural organic matter and AIS of concern, particulates, and other solid material as possible. The use of a coagulant results in additional solids generation and disposal. Plate settlers are a type of high-rate sedimentation and an option to conventional gravity sedimentation. Plate settlers are a proven technology with many successful installations in North Dakota drinking water treatment plants.

5.3.3 Media Filtration

Most surface water treatment facilities in the U.S. generally include a filtration process, such as GMF or cloth media filtration (CMF). Filtration has the benefits of removing a significant percentage of algae, sediment, AIS of concern, and other inorganic and organic particles from the surface water source.

GMF is the process of removing suspended solids passing water through a porous granular medium. The removal of particles is performed by several mechanisms: sedimentation, interception, diffusion, and straining. The use of multiple stratified layers of media with increasing density and decreasing size removes larger solids near the bed top and smaller solids further down the filter bed. Filtration is commonly the final polishing step in the conventional water treatment process. It is designed to meet final treated water turbidity limits. GMF meets the requirements of EPA's drinking water regulations for achieving log-removal credits for *Giardia* and viruses, allowing for removal credits ahead of disinfection and a reduction of required inactivation from the disinfection processes.

The GMF process provided for Option 3 is dual media filtration. Dual media filtration is proven to have high particle removal and filtered water quality. Dual media filtration typically uses a combination of sand and carbon media (anthracite or granular activated carbon (GAC)) with support media and underdrains at the base of the filter bed. This form of conventional media filtration is widely used in North Dakota for drinking water treatment and has been a standard drinking water treatment process in the U.S. for decades. Granular media filters provide good removal of particles, AIS of concern, and eliminate the potential shielding issue of particulates and organics associated with undesirable microbes. Properly operated GMF systems can be expected to produce a filtered water turbidity of less than 0.3 NTU. The filtration process results in a gradual accumulation of entrapped solids within the granular media, which require intermittent removal by means of a filter backwash cycle. This cycle typically comprises both air scour and water wash phases to effectively loosen and flush out the retained solids.

CMF utilizes an engineered cloth media made from thick pile fibers. The fibers provide filtration over the surface area and depth of the media. Historically, this process has been used solely in tertiary wastewater treatment processes for the removal of phosphorus and solids in stormwater and wastewater systems. Recently, select manufacturers have begun producing cloth media filtration process units designed for primary wastewater treatment applications. One significant disadvantage of cloth filtration for biota treatment is that no credit is currently given for log-inactivation of the constituents targeted in this treatment unit. CMF vendors indicate that data is available and could be submitted to regulatory agencies to receive the log-removal/inactivation credits. CMF system have shown to have the capability of achieving effluent levels of less than 1 NTU.

Backwash water and solids captured from the sedimentation basin are further concentrated by a side stream plate settler sedimentation basin. The overflow from the sedimentation process will be returned to the head of the plant. The underflow from the sedimentation process will flow by

gravity to a lagoon for decanting. The thickened solids in the lagoon are trucked offsite to the nearest landfill in the MRB. Decanted water from the lagoon is also pumped back to the head of the plant.

5.3.4 UV and Chlorine Disinfection

As with Option 2, enhanced disinfection consists of UV disinfection followed by chlorination in contact basins. UV disinfection supplements the filters upstream by adding to the removal/inactivation of Giardia, and chlorine disinfection provides the log-inactivation of viruses and AIS of concern that are not achieved by the UV reactors.

Given the additional removal/inactivation of *Giardia* provided by filtration, the UV system is not required to provide the same dose required in Option 2. The UV system is being designed to provide the same 40 mJ/cm^2 identified in Option 2 in order to provide the Giardia removal/inactivation necessary in the unlikely event that the entire filtration process needs to be bypassed. Although the UV system is designed for 40 mJ/cm^2, it would operate at 25 mJ/cm^2 if the filtration process remains effective. The system would be designed to increase the UV dose to 40 mJ/cm^2 if water quality monitoring (i.e. turbidity or ultraviolet light transmittance (UVT)) indicates limited filtration functionality.

The additional water treatment and disinfection provided by UV reduces the *Giardia* log-inactivation and AIS removal potentially required by the chemical chlorine disinfection process. The serpentine contact basin included in this option is like that of Option 1, with the main difference being a smaller capacity and lower baffling factor as a lower contact time is necessary in this option due to the *Giardia* removal provided by filtration and the inactivation provided by the UV disinfection process. This option provides basic disinfection with 20.2 minutes of free chlorine contact time in a basin with a baffling factor of 0.66 at an expected residual of 1.0 mg/L in a serpentine disinfection contact basin with a calculated cT of 13.3 mg-min/L. Although the target chlorine residual is only 1.0 mg/L, the same chlorine storage capacity and transfer capacity is being assumed as for Options 1 and 2. Following chlorine disinfection, ammonia is fed into the chlorinated water stream to form chloramines in similar fashion to Option 1.

5.4 OPTION 4 – ADVANCED TREATMENT

Option 4 involves sand/grit removal, coagulation, flocculation, and membrane filtration followed by an enhanced disinfection process as defined in Option 3. The process begins with sand/grit removal to help protect the membranes followed by the addition of coagulant(s) in a rapid mix chamber and flocculation to form pin floc. The coagulant is added with enough time to form pin floc that is not large enough to settle but can be easily removed by the membrane. The pin floc increases organic matter removal by the membranes and can also improve flux through the membrane. As is the case with Option 3, the use of a coagulant and a filtration process that will be backwashed requires solids separation and disposal. The membrane process is also an effective barrier for the removal of AIS of concern.

5.4.1 Membrane Filtration

Membrane treatment technologies may be used for particulate or dissolved constituent removal from drinking water, depending on the membrane pore size and material used. Microfiltration (MF) and ultrafiltration (UF) membrane systems, which have pore sizes in the range of 0.1 µm and 0.01 µm, respectively, are used for particulate removal, but do not remove dissolved constituents such as dissolved organic carbon (DOC), hardness, salts, taste and odor compounds, and organic chemicals without the addition of coagulations ahead of the membranes. Pretreatment of low-pressure

membrane feedwater is required for source waters that commonly have elevated turbidity or TOC levels. Prior to the MF or UF membranes, the pretreatment processes of coagulation and flocculation will create pin floc enhancing the ability of the membrane system to capture larger sized particles. Membrane filtration systems are very effective barriers against microorganisms such as *Giardia* as well as many of the AIS of concern identified in this study. Ultrafiltration membranes typically remove particles, sediment, algae, protozoa, bacteria, AIS of concern, and viruses. Each individual membrane product, dependent on supplier and model, is certified for a specific log-removal/inactivation of both *Giardia* and viruses.

MF and UF systems typically operate at trans-membrane pressures of 8 pounds per square inch gauge (psig) to 30 psig and are thus classified as low-pressure technologies. Typical average flux rates are in the range of 30 to 70 gallons per square foot of membrane surface per day (gfd) for polymer-based membrane systems; however, ceramic membrane systems may have flux rates of 100 gal/ft^2·d or more. Overall recovery from low-pressure membrane systems is typically 90 to 95 percent depending on membrane material and configuration and source water quality. Because low-pressure membrane filtration provides an absolute barrier to particulates based on membrane pore size and integrity, filtered water turbidity of less than 0.1 NTU is readily achieved.

There are two primary types of membrane systems used in water treatment, pressurized and submerged. Submerged configurations use open basins to house racks of membrane modules and drive water through the membranes using the static pressure provided by the water column in the basin and use of a vacuum pump. These submerged membrane systems are best used in waters with high solids loading rates. Their use, however, is limited due to the need to operate at atmospheric pressure. This factor reduces flexibility of the membrane system to adjust pressure for situations such as process upsets, a change in inlet water quality, or other changes in plant operation.

In comparison to submerged systems, pressure membrane systems provide a host of benefits specific to the requirements of this project. Pressure membrane systems are comprised of several tubular membranes arranged in racks or skids. These tubular membranes are an engineered compact product, which provides a high density of filter area within each membrane. This provides a significant capacity in a relatively small footprint without the need for basins. The operating pressure of tubular pressurized membranes builds a safety factor into the design allowing for greater ranges of operating pressure to cope with changes in water quality. Pressurized systems also have the benefit of being impacted less by cold water conditions due to the ability of the pressurized system to accommodate the higher viscosity water – a feature that submerged systems do not have. Regarding operation and maintenance, breaches in membrane integrity or broken fibers can be identified easily and replaced without significant downtime.

At this stage of the appraisal-level design, pressurized UF membranes are being considered based on their ability to provide a high degree of particulate and AIS of concern removal prior to the disinfection processes. The higher level of treatment with UF membranes provides many benefits to the biota treatment goals of this proposed BWTP, including virus removal. The membrane product used in this initial appraisal-level design is certified for 4-log removal/inactivation of Giardia and 1.5-log removal/inactivation of viruses. This is subject to change dependent on the final membrane filter product used in the final design. Additionally, the removal of TOC and other organic constituents with UF membranes pretreated with coagulants may reduce the formation of DBPs during disinfection and improve UV disinfection performance through potential impacts on UVT. In the event Option 4 is the treatment technology selected, further consultation with membrane manufacturers and suppliers will be completed to identify the most effective membrane treatment solution to meet the requirements of the BWTP and removal of AIS of concern.

Membrane filtration backwash water will be further concentrated in a side stream plate settler sedimentation basin. The overflow from the sedimentation process will be returned to head of the plant. The underflow from the sedimentation process flows by gravity to a lagoon for decanting. The thickened solids in the lagoon are trucked offsite to the nearest landfill in the MRB. Decanted water from the lagoon is also pumped back to the front of the plant. Cleaning waste generated during normal monthly maintenance of the UF system is neutralized and disposed. An air scour system is typically used to prevent solids buildup on the membrane surface.

5.5 RESIDUALS TREATMENT

The additional water treatment processes incorporated in Options 3 and 4 result in the generation of additional residual solids. Residual solids include organic solids, metal precipitates, and additive chemicals used to assist in the settling processes (e.g., aluminum salts, ferric chloride, and/or polymer). The expected concentrations and rates of residual production are summarized for each process in Table 5-3.

Table 5-3 Estimated BWTP Residuals Generation

BIOTA TREATMENT OPTION(S)	PROCESS	SOLIDS STREAM
3	High-Rate Sedimentation	0.25 – 3.5 percent solids 890 gpm daily average (all units in service) Generated continuously or periodically at staff discretion
3	Granular Media Filtration	<0.1 percent solids 1.1 – 5.4 MG generated daily(1) One backwash per filter per day 15- to 30-minute backwash cycle
4	Membrane Filtration	0.25 – 3.5 percent solids 400 gpm daily average Generated continuously or periodically at staff discretion

Note:
(1) 1 to 5 percent of plant throughput at 107 mgd.

The residual waste streams contain such a low concentration of solids that sending all underflow directly to a lagoon would require a significant amount of land area for storage. Initially, the underflow and backwash waste streams would flow by gravity to a flow equalization tank. Submersible pumps in the equalization tank would continuously feed residuals to a high-rate settling basin, such as an inclined plate settler.

The combined waste flow would be clarified, and the overflow returned to the head of the plant or otherwise utilized as reuse water. The remaining solids underflow would be concentrated (ranging from 2 to 4 percent solids) and would be pumped to residuals lagoons for gravity settling.

Residuals lagoons are an inexpensive and effective non-mechanized form of solids treatment and residuals management in projects where land is readily available and inexpensive. Residuals lagoons are often built directly into the ground onsite and are simple in construction and operation. Lagoons are equipped with basic controls such as inlet control devices and overflow structures. Residuals streams generated from the sedimentation process underflow and the filter backwashes at the plant are discharged, after clarification and solids concentration, into the lagoons where the solids are separated by gravity sedimentation.

Two pairs of two decant ponds would both be sized to provide seven days of detention time. The decant water from the ponds can either be returned to the head of the biota treatment train or used for irrigation on the plant site or a nearby field. The use of residuals lagoons provides passive gravity thickening and the residual solids would be hauled offsite either for disposal at a landfill or for land application within the MRB.

5.6 BIOTA TREATMENT

The treatment options developed here would address biota treatment using several different unit process combinations and treatment strategies. Biota treatment for *Giardia,* AIS of concern, and viruses was considered as part of the conceptual design of facilities. Cryptosporidium and whirling disease serve as surrogates for other potential AIS that may be present in McClusky Canal source water or the Missouri River water.

Biota treatment options assessed in this analysis rely upon chlorine disinfection for the 4-log inactivation credit of viruses, cryptosporidium, and whirling disease, although Option 4 provides some virus removal through UF and partial credit for 3-log inactivation of *Giardia* (apart from Option 1, which achieves 3-log inactivation of *Giardia* from solely chlorine contact).

The appraisal-level assessment of the estimated log-removal/inactivation credit for each option is based upon established EPA drinking water regulatory criteria as well as a literature review of the removal of AIS of concern identified in this study. Additionally, for this assessment, the cold-water temperature of 0.5°C and high pH of 8.8 from the McClusky Canal were chosen based upon analysis of the available source water quality data. Log-inactivation credit is calculated for disinfectant contact in the UV and DCB only, not including any additional contact in the pipeline at the exit of the BWTP.

Further bench-scale testing of the source water is necessary to better gauge potential water quality interferences with the UV system and chlorine demand of the source water. Bench scale testing will also need to be completed to verify the UV doses for various AIS of concern identified in this study.

The conceptual level estimated log-inactivation of biological contaminants with each option is shown in Table 5-4.

Table 5-4 Biota Treatment Options and Associated Log-Removal/Inactivation of *Giardia*, Viruses, *Cryptosporidium* and *Myxobolus cerebralis*

BIOTA TREATMENT OPTION	PATHOGEN	INTAKE FINE SCREEN REMOVAL	CONVENTIONAL MEDIA FILTRATION REMOVAL(1)	MEMBRANE FILTRATION REMOVAL(2)	UV LIGHT INACTIVATION (3)	CHLORINE DISINFECTION INACTIVATION	TOTAL
1	*Giardia*	0	0	0	0	>3.0	>3.0
	Cumulative	0	0	0	0	>3.0	
	Viruses	0	0	0	0	> 4.0	> 4.0
	Cumulative	0	0	0	0	> 4.0	
	Cryptosporidium	0	0	0	0	0	0
	Cumulative	0	0	0	0	0	
	Myxobolus cerebralis(6)	1.0	0	0	0	>3.0	>4.0
	Cumulative	1.0	1.0	1.0	1.0	>4.0	
2	*Giardia*	0	0	0	>3.0	>3.0	>3.0
	Cumulative(5)	0	0	0	>3.0	>3.0	
	Viruses	0	0	0	0	>4.0	>4.0
	Cumulative	0	0	0	0	>4.0	
	Cryptosporidium	0	0	0	3.0	0	3.0
	Cumulative	0	0	0	3.0	3.0	
	Myxobolus cerebralis(6)	1.0	0	0	>4.0	>3.0	>4.0
	Cumulative(5)	1.0	1.0	1.0	>4.0	>4.0	
3	*Giardia*	0	2.5	0	3.0	0.1	>3.0
	Cumulative(5)	0	2.5	2.5	>3.0	>3.0	
	Viruses	0	2.0	0	0	4.0	>4.0
	Cumulative(5)	0	2.0	2.0	2.0	>4.0	

BIOTA TREATMENT OPTION	PATHOGEN	INTAKE FINE SCREEN REMOVAL	CONVENTIONAL MEDIA FILTRATION REMOVAL(1)	MEMBRANE FILTRATION REMOVAL(2)	UV LIGHT INACTIVATION (3)	CHLORINE DISINFECTION INACTIVATION	TOTAL
	Cryptosporidium	0	2.5	0	3.0	0	>3.0
	Cumulative(5)	0	2.5	2.5	>3.0	>3.0	
	Myxobolus cerebralis	0	2.5	0	4.0	0	>4.0
	Cumulative(5)	0	2.5	2.5	>4.0	>4.0	
4	*Giardia*	0	0	4.0	3.0	0.1	>3.0
	Cumulative(5)	0	0	>3.0	>3.0	>3.0	
	Viruses	0	0	1.5	0	4.0	>4.0
	Cumulative(5)	0	0	1.5	1.5	>4.0	
	Cryptosporidium	0	0	4.0	3.0	0	>3.0
	Cumulative(5)	0	0	>3.0	>3.0	>3.0	
	Myxobolus cerebralis	1.0	0	4.0	4.0	0	>4.0
	Cumulative(5)	1.0	1.0	>4.0	>4.0	>4.0	

Notes:

(1) Includes coagulation, flocculation, and sedimentation processes.

(2) Includes sand/grit removal, coagulation, and flocculation processes and UF membranes.

(3) UV log-inactivation is based on an applied dose of 40 mJ/cm^2 for Option 2 and 25 mJ/ cm^2 for Options 3 and 4.

(4) The log-inactivation/removal credits shown above are based upon 'expected values' for appraisal-level BWTP designs and are subject to change as the design is further refined.

(5) Actual cumulative log-inactivation and/or log-removal values are likely to be higher than the minimum totals shown for each treatment option. Bench- and/or pilot-scale testing would be necessary to confirm higher cumulative values (e.g., *Giardia* removal/inactivation for membrane filtration, UV disinfection, and chlorine disinfection is 4.0-, 3.0-, and 0.1-log, respectively, for Option 4. Total committed cumulative log-removal/inactivation for this approach is >3.0, which is the same as for the single process of UV disinfection in the Enhanced Disinfection approach.).

(6) In Options 1 and 2, the log-inactivation is based on the design cT being in excess of literature values for whirling disease removal.

6.0 Detailed Biota Treatment Options Descriptions

The sections below describe the specific treatment processes proposed for each option. For the appraisal-level design described herein, the intent is to conservatively represent the major unit processes while recognizing that future refinements would occur during preliminary and detailed design. All processes were designed based upon available raw water quality data and a low water temperature of 0.5° C. The drawings presented in Appendixes D, E, and F accompany the written descriptions provided in this chapter. The biota water treatment options build on each other and each option with additional treatment capabilities.

6.1 OPTION 1 – DISINFECTION

Treatment Option 1 is the treatment process that provides the least complex treatment to achieve the degree of log-inactivation for both *Giardia,* cryptosporidium, whirling disease, and viruses. Previous projects with water transfer across the continental divide to the HBB are treating to meet 3-log inactivation of *Giardia* and 4-log inactivation of viruses. These inactivation/removal targets are met using sand/grit removal and a single disinfection treatment process in Option 1 - Disinfection. The treatment process consists of screening for large debris at the raw water intake, passing raw water through a gravity-vortex sand/grit removal system, and disinfection maintaining a free chlorine residual as well as the addition of ammonia for chloramine formation in the pipeline distribution system. All inactivation is achieved in DCBs with a free chlorine disinfectant; chloramines are formed following primary disinfection to provide a chlorine residual entering the distribution pipeline. After the intersection of ENDAWS with the State RRVWSP, a dechlorination system is included to quench any remaining residual chlorine prior to discharge.

6.1.1 Sand/Grit Removal

The sand/grit system considered for Options 1, 2, and 4 would be housed in an independent building designed to process the inlet flow through gravity-forced vortex units upstream of pretreatment and disinfection. The inlet pipe would feed a splitter zone tied to six independent forced sand/grit removal units. Each unit would be sized to handle a peak flow of 33 cfs (21.4 mgd), for an overall treatment capacity of 165 cfs (107 mgd). The conceptual design for this project includes sand/grit removal units consisting of a set of plastic trays, which force water into a vortex pattern physically separating dense grit, large AIS with specific gravity greater than 2.1, and macro-organisms from the raw water. Sand/grit removal will also remove AIS of concern that may have adsorbed to the sand/grit particles. After settling to the bottom, the grit slurry is pumped to a washing and classifying unit followed by a dewatering unit. The dewatered grit would fall from the second story into a dumpster directly below. See the State RRVWSP Preliminary Design Report (April 2018) for the preliminary design of the sand/grit removal system. The sand/grit removal system is designed to remove 95 percent of the sand/grit particles with a specific gravity greater than 2.1 and a size more than 100 microns. It is anticipated that organisms considered AIS above the 100-micron size and a specific gravity greater than 2.1 would be removed with the same removal efficiency as sand/grit.

6.1.2 Free Chlorine Disinfection

The sole method of disinfection in Option 1 is with free chlorine. This occurs in serpentine contact basins, which provide the required contact time with the disinfectant to meet the treatment objectives. Due to several factors including the treated flow, organic content of the water, and chlorine demand required for *Giardia* inactivation, the contact basin size for this option is larger in comparison to Options 3 and 4.

The serpentine DCB proposed to meet log-inactivation targets is, in total, 167 feet wide, 167 feet long, and 22 feet deep. Four basins are included in this design. Each basin is sized for 33 percent design capacity to treat the 107-mgd flow with a total combined volume of 16 MG. The basins are designed with common wall construction and include a total of eight passes with a width of 20 feet (ft) and total hydraulic detention time of 215 minutes in order to achieve a baffling factor of 0.8. A larger baffling factor reduces the chlorine dose and contact basin volume required to achieve the cT. Additionally, the necessary chlorine residual for Option 1 is 3.0 mg/L to meet cT requirements.

The lack of additional pretreatment processes preceding disinfection will impact treatment process efficacy in that chlorine demand causing constituents are not removed. The presence of organic matter, suspended solids, and iron will increase the chlorine demand in the process water flow if they are not removed by pretreatment. This increases the chlorine dose required to achieve the desired level of inactivation and disinfection. Without pretreatment and the associated reduction of chlorine demand, larger basins, higher chemical volumes, and larger chemical feed systems are needed to meet the treatment needs.

Additionally, chlorine disinfectants have shown a substantial decreased effectiveness with inactivation of protozoa such as *Giardia* further increasing the amount of cT required for inactivation. As cT is a function of the chlorine concentration and contact time, an increase in cT is an additional factor in the large basins required for chlorine disinfection in Option 1.

Due to a combination of the organic matter present in the source water and absence of pretreatment in the treatment process to remove those organics, there is a higher risk of DBP formation with Options 1 and 2 than with the other options. The predominant DBPs of concern are total trihalomethanes (TTHMs) and haloacetic acids (HAA5s), which form through the reaction of chlorine with natural organic matter. Removal of DBPs ranges from challenging and expensive (TTHMs) to impractical and problematic (HAA5s). Avoiding formation of DBPs is generally preferred due to the difficulty in removal from produced water and associated negative human health impacts.

While DBP generation within the chlorine contact basin cannot be eliminated, it can be significantly reduced within the transmission pipeline by converting residual chlorine to chloramine. Adding ammonia downstream of the chlorine contact basin would remove residual chlorine and provide a residual disinfectant. An additional benefit gained by using chloramines as the residual disinfectant in the transmission main is its stability when compared to free chlorine. Although it is not nearly as effective as a primary disinfectant it does dissipate less quickly over time. It will be more effective maintaining a residual in the extended travel time in the transmission main and should dissipate closer to, if not at, the State RRVWSP discharge point.

6.1.3 Chlorine Disinfectant Options

There are two forms of chlorine commonly used for water disinfection: chlorine gas and liquid chlorine (sodium hypochlorite). Chlorine gas is typically supplied from 1-ton containers and injected indirectly through carrier water. Sodium hypochlorite is either delivered in concentrated form (12.5 percent) or generated on site. The design parameters along with the advantages and disadvantages of each of these three chlorine options are discussed below.

6.1.3.1 Ton Containers of Chlorine Gas

Chlorine gas has been used for drinking water disinfection since the early 1900s, and it is among the most common forms of chlorine disinfection used in the U.S. The gas is typically transported and stored as liquid chlorine gas in either 150-lb or 1-ton containers.

Chlorine is generated through an electrolytic process that breaks sodium chloride solution into chlorine gas and sodium hydroxide. The chlorine gas can then be used for disinfection. The typical process of a chlorination facility includes: transporting the liquid chlorine from storage vessels, evaporating the liquid chlorine, drawing the chlorine gas into carrier water under vacuum, mixing the chlorinated water with the process flow, and generating contact time in a basin or pipeline. Separate design considerations and potential challenges exist for each element of this process and must be carefully considered.

Chlorine gas has been used in the drinking water industry for over a century because it is a relatively simple and inexpensive process. The process has become more complicated, however, as technology and safety measures are implemented to reduce the inherent risks.

Chlorine gas is highly reactive and can be fatal if inhaled. Due to the health hazards, robust safety measures must be taken at chlorine gas facilities. The significant danger posed to operations staff and the surrounding community in the case of a chlorine gas leak requires additional instrumentation and systems to prevent, detect, and mitigate the impact of spills and exposure. These systems include gas tight storage rooms with both dedicated continuous and intermittent ventilation, covered areas for storage of bulk delivered chemical, leak detection monitors, and non-standard personal protective equipment (PPE). In addition, the International Fire Code (IFC) also requires the containers be equipped with an automatic containment system (ChlorTainer™). An optional emergency exhaust ventilation system and gas treatment system could be employed to neutralize a gas leak in the storage area. These additional safety measures increase both the capital expenditure (CAPEX) and operating expenditure (OPEX) of chlorine gas disinfection.

6.1.3.2 Bulk Delivery of Sodium Hypochlorite

Sodium hypochlorite (NaOCl), also commonly known as bleach, has historically been used for municipal water disinfection due to its relatively low risk and reduced safety considerations when compared to chlorine gas. This disinfectant can either be delivered in bulk as a prepared solution or generated onsite as needed. Both options are discussed in more detail here and in the following section. Sodium hypochlorite suffers from chemical stability issues as it decreases in strength over time. This is due to high reactivity as well as pH, temperature, sunlight exposure, and the presence of certain metals. For this reason, hypochlorite facilities require additional monitoring and control systems to manage solution decay. Sodium hypochlorite is a very aggressive chemical so tanks, pumps, and conveyance piping must be made of compatible materials. It is worth noting that the use of hypochlorite results in the formation of chlorite and chlorate ions through bleach decay. Chlorite is a regulated chemical by the EPA; chlorate may be subject to local regulations but is not currently Federally regulated.

Sodium hypochlorite solution is commercially available as a bulk delivered solution by either rail or tank truck typically in a concentration of 12.5 percent by volume, although higher-strength product is available from certain suppliers. The use of bulk sodium hypochlorite requires large on-site storage. Tank farms providing a minimum of 14 days of storage based on typical usage rates is common. Some frequent issues with on-site storage include a need for climate-controlled storage to control off-gassing and solution strength degradation. There are several safety risks associated with the use of bulk hypochlorite solution although they are less impactful than those of chlorine gas.

6.1.3.3 On-Site Generation of Sodium Hypochlorite

Sodium hypochlorite can be generated through electrolysis of salt water also called brine. Typically, an on-site generation system directs potable water through a softener before introduction into an electrolytic cell or a brine storage tank. Softened water directed to the electrolytic cell is mixed with

a near-saturated brine solution. An electrical current is then passed through the electrolytic cell, producing sodium hypochlorite, chlorine gas, and hydrogen gas.

The sodium hypochlorite is sent to storage, and the hydrogen is diluted and released to the atmosphere. Generator systems are scalable to meet chemical volumes required of the application. The system can be designed to provide dilute sodium hypochlorite (0.8 percent) or high strength sodium hypochlorite (12.5 percent), or chlorine gas. With this type of system, chlorine gas storage is minimized as the chlorine gas is generated at the same rate as the demand. While high strength sodium hypochlorite is less stable, the volume of dilute hypochlorite required daily would require a far greater volume of storage tank capacity. Given the size of the treatment facility and the large facility footprint required, a dilute system would not be economically favorable.

High strength on-site generation systems are available from numerous manufacturers in the U.S. Another benefit of on-site generation (OSG) of sodium hypochlorite is the ability to produce a specific concentration of hypochlorite versus the fixed-concentration solutions indicative of bulk-delivered systems. Total life-cycle costs of OSG systems are typically higher than gaseous chlorine due to increased operation and maintenance of the generation equipment and the cost of the raw materials necessary for generation.

One of the main advantages of on-site generation is salt and water are the only raw materials required. Concentrated sodium hypochlorite degrades over time so producing smaller volumes of disinfectant, produced on an as-needed basis, ensures correct dosing and reduces waste. Two disadvantages of OSG are the upfront capital cost and the complexity of operating and maintaining the system over long periods of use and during times of inactivity. The periodic use of an OSG system can cause issues with critical components. As this plant is intended to be offline for extended periods of time, it is likely the electrochemical system will require parts to be replaced more frequently driving up the operation and maintenance costs. It is difficult to estimate the added cost of frequent OSG startups and shutdowns and has not been accounted for in the 20-year net present value (NPV) calculations.

6.1.3.4 Chlorine Disinfectant Design Criteria

The systems have been designed for an average chlorine dose of 5,336 lbs/day, and a peak dose of 7,115 lbs/day.

The chlorine gas option includes three 4,000 lb/day evaporators, three feeders, and three eductors to feed chlorine directly to two separate injection locations. The gas storage area would include space to connect three cylinders to the evaporators and store an additional 37 cylinders to provide 14 days of storage.

The on-site generator's electrolyzer modules (2) produce 6,000 ppd each, and both units are equipped with ten duty and two standby electrolyzers for redundancy (12 total). This provides a firm capacity of 6,000 ppd.

Finally, the bulk-delivered sodium hypochlorite system would require approximately twelve 5,000-gallon tanks to provide storage capacity for 14 days at the peak flow (107 mgd) and average dose (6.0 mg/L). The day tanks would be 6,000-gallon tanks sized for peak flow and max dose (8.0 mg/L), which equates to 5,700 gallons of 12.5-percent hypochlorite. Three day tanks would provide adequate flexibility and redundancy to ensure disinfection capability under most conditions.

Table 6-1 Chlorine System Design Parameters

DESIGN PARAMETER	CHLORINE GAS	SODIUM HYPOCHLORITE	
		Bulk Delivery	On-Site Generation
Chemical Capacity (lb/d as Cl_2)	8,000	22,486	12,000
Storage Container Type	1-ton containers (37)	12 Bulk Tanks (5,000 gal)	Saturated Brine Tank
Total Storage Volume	800,000 lb	78,600 gal	11,310 gal
Storage Capacity (107 mgd, 6 mg/L)	14 days	14 days	14 days
Equipment Configuration	(3) Evaporators (3) Chlorinators (3) Eductors (1) Emergency Gas Scrubber	(3) Day Tanks (6,000 gal) (12) Bulk Tanks (5,000 gal) (4) Feed Pumps	(2) Day Tanks (6,000 gal) (2) Electrolyzer Modules (4) Generator Units (2) Production Tanks (4) Feed Pumps

6.1.3.5 Chlorine Disinfectant Net Present Value

The capital costs and annual O&M costs were estimated for each of the three chlorine disinfection systems in order to calculate a 20-year NPV. Table 6-2 summarizes the estimated capital cost of each of the systems, and includes modifiers for installation, electrical and instrumentation, and a contingency.

Table 6-2 Chlorine System Options' Estimated Capital Costs

DESIGN PARAMETER	CHLORINE GAS	SODIUM HYPOCHLORITE	
		Bulk Delivery	On-Site Generation
Cost of System	$845,000	$754,000	$2,761,000
Installation (15%)	$127,000	$113,000	$414,000
Electrical & Instrumentation (15%)	$127,000	$113,000	$414,000
Direct Cost Subtotal	**$1,099,000**	**$980,000**	**$3,589,000**
General Conditions (5%)	$55,000	$49,000	$179,000
Contingency (30%)	$346,000	$309,000	$1,130,000
Contractor's Overhead and Profit (12%)	$180,000	$161,000	$588,000
Bonds and Insurance (2.0%)	$30,000	$27,000	$98,000
Total Capital Cost	**$1,710,000**	**$1,526,000**	**$5,584,000**

Table 6-3 Chlorine System Options' Estimated O&M Costs

DESIGN PARAMETER	UNITS	CHLORINE GAS	SODIUM HYPOCHLORITE	
			Bulk Delivery	On-Site Generation
Maintenance Cost(1)	$/yr	$120,000	$107,000	$391,000
Chemical Dose (as Cl_2)	lb/day	5,336	5,336	5,336
Chemical Price	$/lb Cl_2	$0.29	$1.11	$0.20(2)
Chemical Cost	$/yr	$168,000	$643,000	$116,000
Electrical Use	kWh/day	500	300	8,000
Electrical Cost(3)	$/yr	$4,300	$2,600	$66,600
Total Annual O&M(4)	**$/yr**	**$292,000**	**$753,000**	**$573,000**

Notes:

(1) Assumes 7-percent annual maintenance cost based on the initial capital cost of the system.
(2) Manufacturer provided cost for all on-site generation chemicals required.
(3) Chlorine dose is assumed to be the average dose (6.0 mg/L).
(4) Electrical rate is assumed to be $0.08/kWh.
(5) O&M calculations assume the plant operates at 107 mgd for 102 days/year (28%).

Table 6-3 summarizes the estimated annual O&M costs assuming the plant operates at an average flow rate of 107 mgd with an average chlorine dose of 6.0 mg/L for 102 days/year. As the number of days the plant operates increases each year, the O&M cost for OSG does not increase as quickly as the other two options. Figure 6-1 shows the 20-year NPV that was estimated for the three processes based on the percentage of days the plant operates at full capacity (107 mgd). It is assumed the plant operates at 4 cfs (2.6 mgd) all other days.

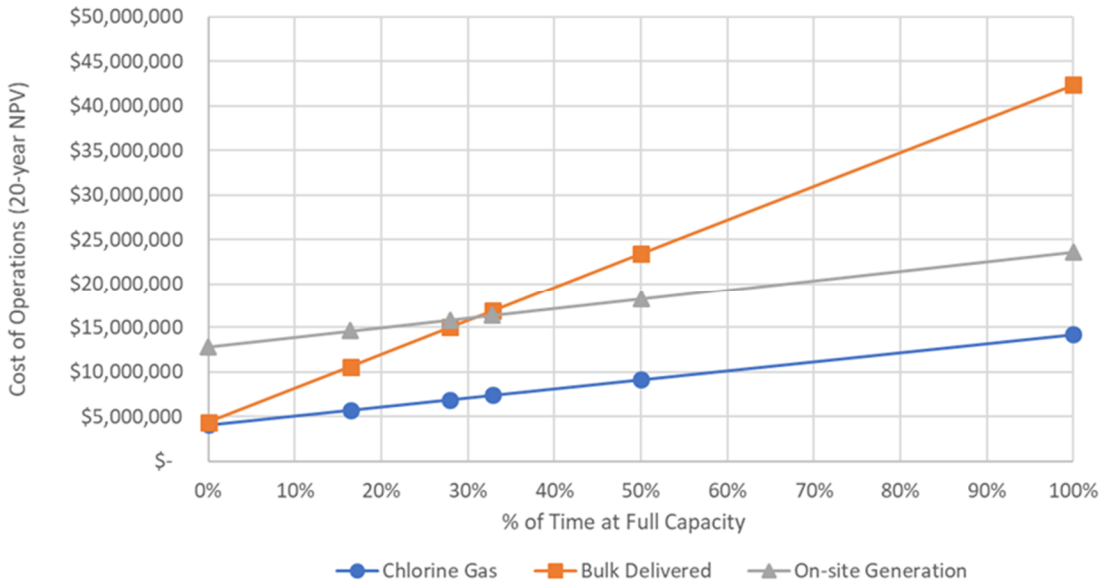


Figure 6-1 Chlorine System Options' Estimated Cost of Operation (20-year NPV)

Based on the cost-of-operation analysis, using chlorine gas for disinfection results in the lowest cost of ownership over a 20-year period no matter if the plant is operating one day or every day of the year. At 120 days of operation per year (33 percent), the least economically viable option switches from OSG to bulk-delivered sodium hypochlorite. When the system is operated more than 120 days per year, bulk-delivered sodium hypochlorite becomes the most expensive option. NPV costs escalate significantly for the bulk-delivered sodium hypochlorite system the more it is operated. The main cost for the OSG system is the upfront capital cost and the recurring maintenance costs. The actual operating costs, which are based on the quantity of water treated, is relatively low. Conversely, the bulk sodium hypochlorite system is relatively inexpensive, but the annual O&M cost is directly proportional to the quantity of water treated.

Table 6-4 summarizes the 20-year NPV for each process based on the percentage of days the plant operates at full capacity (107 mgd), assuming a chlorine dose of 6.0 mg/L.

Table 6-4 Chlorine System Options' Estimated 20-year NPV

% FULL CAPACITY	OPERATING DAYS/YR	CHLORINE GAS	SODIUM HYPOCHLORITE	
			Bulk Delivery	On-Site Generation
16%	60 days	$5,800,000	$10,600,000	$14,600,000
28%	102 days	$6,900,000	$15,000,000	$15,800,000
33%	120 days	$7,400,000	$16,900,000	$16,400,000
50%	183 days	$9,200,000	$23,400,000	$18,200,000
100%	365 days	$14,200,000	$42,300,000	$23,600,000

Notes:
1. Full Capacity assumes a constant flow of 107 mgd.
2. Chlorine dose is assumed to be the average dose (6.0 mg/L).

6.1.3.6 Chlorine Disinfectant Comparison

A review of the chlorine disinfection options available for use in treatment Options 1, 2, 3, and 4 for AIS of concern removal will assist in identifying the most practical and cost-effective process. This review considered several factors including: capital cost, simplicity of operation, footprint, the cost of operations, and overall safety.

Table 6-5 Chlorine System Options' Qualitative Analysis

SELECTION CRITERIA	CHLORINE GAS	SODIUM HYPOCHLORITE	
		Bulk Delivery	On-Site Generation
Capital Cost	Low ($1.7M)	Low ($1.5M)	High ($5.6M)
Complexity	Low	Low	High
Cost of Operations	Low	High	Low
Risk of Hazard	Moderate	Low	Low

The use of chlorine gas for disinfection at new WTPs is becoming less common because of the inherent risks. Both OSG and bulk delivery of sodium hypochlorite are very safe, and the cost viability of both depends on the volume of water treated. As it is anticipated that the plant will run at full capacity for approximately 14 years over the next 50 years, the plant is assumed to operate at 107 mgd or 28 percent of the time and 2.6 mgd for the remainder of time. Given the annual cost of maintaining the on-site generation system and the relatively low volume of water being treated, bulk delivery of high strength sodium hypochlorite is the safest and most economical option. The remainder of this report will be based on the use of bulk hypochlorite, including the cost estimates as well as building layouts.

6.1.4 Chloramine Disinfectant Residual System

Chloramines, or combined chlorine, is a disinfectant chemical that is formed through the reaction of ammonia with free chlorine. Chloramines are a less reactive and a weaker disinfectant compared to free chlorine; however, they are more persistent and have the benefit of reduced DBP formation potential. For these reasons, chloramine is often generated following chlorine disinfection at drinking water treatment plants before the water leaves the plant.

Several forms of chloramines can be formed through the reaction of ammonia with chlorine. Out of these, monochloramines are preferred due to stability. The reaction that dictates chloramine formation is influenced primarily by the ratio of ammonia present in the water to chlorine added, and some water quality parameters like chlorine demand causing constituents and pH. For the purposes of this design estimate, a ratio of 4:1 chlorine to ammonia is used to determine the ammonia dose required for chloramine formation. Given this assumption, and the 3 mg/L chlorine residual of Option 1, the ammonia dose is 0.8 mg/L.

The design of the chloramine system uses the aqueous form of ammonia for chloramine formation, out of the potential options of liquefied ammonia, liquid ammonia sulfate, and dry ammonia sulfate. Considering the design parameters of a design flow of 107 mgd and a 0.8 mg/L ammonia design dose the estimated chemical feed system and usage is presented in Table 6-6.

Table 6-6 Chloramine Feed System Design Parameters

DESIGN PARAMETER	VALUE
Ammonia Usage Rate (lb/h)	33.9
Ammonia Solution Usage Rate (gal/h)	23
Pumps	5
Day Tanks	2
Bulk Tanks (2,500 gal each)	4
Total Process Footprint (ft^2)	1,100
Chemical Delivery (Truck = 5,800 gal)	12 trucks/month

6.1.5 Disinfectant Residual Quenching System

Following the extended travel time along the pipeline from the BWTP to and within the State RRVWSP transmission pipeline, there may still be a chlorine residual in the water at the proposed discharge point. Any remaining chlorine residual must be removed for the State RRVWSP to comply

with stipulations normally included in a North Dakota Pollutant Discharge Elimination System (NDPDES) discharge permit. Removal of a chlorine residual will be achieved by dosing sodium bisulfite immediately before the State RRVWSP Sheyenne River outfall. Sodium bisulfite is commonly used as a disinfection quenching chemical and reductant. A sodium bisulfite dose of 1.0 mg/L has been estimated based on a ratio of 1.5 mg of $NaHSO_3$ per 1.0 mg of Cl_2 or chloramine, a disinfectant residual of 0.3 mg/L, and a 38-percent concentration of sodium bisulfite at a density of 10.9 lb/gal. The system design is shown in Table 6-7.

Table 6-7 Sodium Bisulfite System Design Parameters

DESIGN PARAMETER	VALUE
Sodium Bisulfite Usage Rate (lb/d)	895
Solution Usage Rate (gal/h)	9
Pumps	2
Day Tanks	2
Bulk Tanks (5,000 gal each)	2
Total Process Footprint (ft^2)	215
Chemical Truck Delivery (gal)	4,500

6.2 OPTION 2 – ENHANCED DISINFECTION

For Option 2, enhanced disinfection is provided with a combination of UV irradiation and chlorination. This strategy provides an effective means for the inactivation of surrogate protozoa (*Giardia)* and viruses. As with Option 1, Option 2 uses the sand/grit removal for pretreatment prior to disinfection. The enhanced disinfection process also includes the formation of a chloramine residual and disinfectant residual quenching at the State RRVWSP discharge.

6.2.1 UV Disinfection

UV light disinfection treatment is used in Option 2. The main objective of this treatment process is to provide a minimum of 3-log *Giardia* inactivation. Although the effective dose for *Giardia* 3.0-log inactivation is approximately 25 mJ/cm^2, in order to effectively inactivate other AIS such as *M. cerebralis*, a maximum UV dose of 40 mJ/cm^2 has been selected. An approximate 4-log inactivation of *M. cerebralis* is expected for an LPHO UV system sized to provide a MS2 validated dose of 40 mJ/cm^2 (Trojan Technologies).

The UV system for each option is based on a conceptual design from Wedeco using their K143 low pressure high output (LPHO) reactors. Option 2 includes 10 duty and one standby reactor with 156 lamps per reactor. The 10 duty reactors have a total connected power load of 605 kilowatts (kW).

Table 6-8 UV System Design Parameters

DESIGN PARAMETER	VALUE
UV Reactor Manufacturer and Model	Wedeco K143
UV Lamp Technology	LPHO
Max UV Dose (mJ/cm^2)	40
Giardia Log-Inactivation	>4.0
Duty Reactor Number	10
Standby Reactor Number	1
Number of Lamps per Reactor	156
Total Number of Lamps	1,716
Total Connected Power Load (kW)	605

The UV system outlined for Option 2 has been designed with conservatism, assuming a UVT of 70 percent. Further study of actual water quality conditions and AIS inactivation prior to UV treatment will need to be completed in order to ensure validation of a UV system for this treatment process and project. It will be necessary to further evaluate the ability of the UV system proposed to meet the log-inactivation targets before transitioning into detailed design and construction. This evaluation can be achieved through further sampling of the source water to obtain a broader UVT data set. Several water quality factors, such as turbidity, may negatively degrade water quality and transmittance prior to the UV system and should be studied further to better determine the degree UV transmittance to be expected.

6.2.2 Chlorine Disinfection

The chlorine disinfection system described in paragraph 6.1.2 for Option 1 is used for the treatment scheme of Option 2. Pretreatment (UV Disinfection) is included in this treatment option, which could reduce the log-inactivation proposed for the chemical chlorine disinfection process. However, in accordance with the conservative approach taken herein, the DCB design for chlorine disinfection of Option 2 is the same as that employed in Option 1 so as to provide additional treatment capabilities.

6.2.3 Chloramine Disinfectant Residual System

As with the chlorine disinfection system, the residual system described in paragraph 6.1.4 for Option 1 is used for the treatment scheme of Option 2. While the chlorine system is being designed to provide a finished water chlorine residual of 3.0 mg/L, in order to achieve 4.0-log inactivation of viruses, a final residual of 1.0 mg/L is acceptable while the UV system is active.

For the purposes of this design estimate, a ratio of 4:1 chlorine to ammonia is used to determine the ammonia dose required for chloramine formation. Given this assumption and the 3 mg/L chlorine residual of Option 1, the maximum ammonia dose is 0.8 mg/L.

The design of the chloramine system uses the aqueous form of ammonia for chloramine formation, out of the potential options of liquefied ammonia, liquid ammonia sulfate, and dry ammonia sulfate.

Considering the design parameters of a design flow of 107 mgd and a 0.8 mg/L ammonia design dose the estimated chemical feed system and usage is presented in Table 6-6.

Free chlorine will be converted into chloramine to provide a residual in the transmission pipeline. The maximum and design ammonia doses for Option 2 are 0.75 mg/L and 0.25 mg/L respectively, assuming a 4:1 ratio of chlorine to ammonia. The maximum design dose matches that of Option 1, while the design dose will be used under normal operating conditions. The enhanced disinfection provided by the UV reduces the chlorine residual needed for disinfection. With an aqueous liquid ammonia concentration of 19 percent and a density of 7.77 lb/gal, the associated feed system is described in Table 6-9.

Table 6-9 Chloramine System Design Parameters

DESIGN PARAMETER	MAX DOSE	DESIGN DOSE
Ammonia Usage Rate (lb/h)	33.9	11
Ammonia Solution Usage Rate (gal/h)	23	7.7
Pumps	5	5
Day Tanks	2	2
Bulk Tanks (2,500 gal each)	4	2
Total Process Footprint (ft^2)	1,100	600
Chemical Delivery (trucks/month, truck = 5,800 gal)	12	4

As discussed previously in Section 6.1 for Option 1, any remaining disinfectant residual will be quenched from the treated water with sodium bisulfite at the State RRVWSP outfall. The residual disinfectant is assumed to be the same at the pipeline discharge for each option; reference Table 6-7 for design parameters.

6.3 OPTION 3 – CONVENTIONAL TREATMENT

Option 3 adds coagulation, flocculation, sedimentation, and filtration prior to UV and chlorination disinfection previously described in Option 2.

6.3.1 Coagulation

The coagulation basins are sized for a design flow of 107 mgd processed in four single-stage basins with a straight flow path. The hydraulic detention time (HDT) of each basin is 40 seconds with a Ten States Standards' compliant G value of 750 s^{-1}. The basin water depth is 15 feet with a total basin depth of 17 feet. The basin dimensions are 10.5 feet wide by 10.5 feet long with a basin volume of 14,000 gallons each and gross process volume of 56,000 gallons. Based upon the prior stated design parameters, the resulting basin design is shown in Table 6-10.

Ferric chloride is assumed as the coagulant in the coagulation process due to its general prevalence in water treatment and its high efficiency and effectiveness in clarification. The design dose is 50 mg/L, and the average dose is assumed to be 10 mg/L at a concentration of 38 percent. This coagulant will need to be validated during detailed design.

Liquid polymer is added as a coagulant aid to further improve the formation of a strong floc in the flocculation process. This polymer is added at a design dose of 1.5 mg/L and an average dose of 0.5 mg/L. The ferric chloride coagulant and polymer are introduced to the treatment process by chemical metering pumps and are stored onsite in bulk chemical storage tanks.

Table 6-10 Coagulation Basin Design Parameters

DESIGN PARAMETER	VALUE
Flow Path	Straight
Basin HDT (seconds)	40
Stage 1 G, Avg (s^{-1})	750
Number of Basins	4
Individual Basin Volume (gal)	12,400
Basin Water Depth (ft)	15
Basin Depth (ft)	17
Basin Width (ft)	10.5
Basin Length (ft)	10.5
System Footprint (ft^2)	715

6.3.2 Flocculation Process

Option 3 includes flocculation basins in the treatment process trains, which are designed as straight flow basins with vertical shaft flocculators. The design criteria for the basins are defined by the number of basins, number of stages, water depth, and design flow. The resulting basin design details are shown in Table 6-11.

Table 6-11 Flocculation Basin Design Parameters

DESIGN PARAMETER	VALUE
Flow Path	Straight
Number of Basins	12
Number of Stages	3
Total Basin Volume (MG)	2.26
HDT (minutes)	30
Velocity Gradient	Stage 1: 40 s-1 Stage 2: 18 s-1 Stage 3: 5 s-1
Basin Water Depth (ft)	15
Basin Depth (ft)	17

DESIGN PARAMETER	VALUE
Basin Width (ft)	25
Basin Length (ft)	67
Total System Footprint (ft2)	21,000

A total of 12 basins are used in this conceptual design to treat the design flow of 107 mgd, with three stages per basin, one row per basin, a basin HDT of 30 minutes, and average G values of 40 s^{-1}, 18 s^{-1}, and 5 s^{-1} for each of the three consecutive stages. The design HDT exceeds the required minimum Ten States Standards' flocculation time of 30 minutes per train. The degree of mixing or G-values per stage will need to be verified through jar testing as the design progresses further if this process is selected for adoption. Each of the 12 basins has a volume of 188,000 gallons, width of 25 feet, length of 67 feet, water depth of 15 feet, and basin depth of 17 feet.

6.3.3 High-Rate Sedimentation Process

Sedimentation in Option 3 is achieved by an inclined plate-assisted settling process. The basins are sized for the following design criteria: a design flow of 107 mgd, a solids loading rate of 0.30 gpm/ft^2, and a water depth of 15 feet. The full listing of design criteria is shown in Table 6-12.

From these design factors, the inclined assisted settling system was determined to have a total of 12 active basins using common wall construction, a plate pack design of 10 feet long plates at an angle of 55 degrees with a total of four rows per basin at 250 plates per row. The water depth of each basin is 15 feet, with a total basin depth of 17 feet. This design allows for additional space for maintenance access and a residuals removal system. Each basin has a length of 62 feet and width of 25 feet, allowing for an HDT of 28 minutes per basin.

Table 6-12 Inclined Plate Settler Design Parameters

DESIGN PARAMETER	VALUE
Number of Basins	12
Total Basin Volume (MG)	2.09
Number of Plate Rows	250
Number of Plates	12,000
Basin Water Depth (ft)	15
Basin Depth (ft)	17
Basin Length (ft)	62
Basin Width (ft)	25
Basin Volume (gal)	174,000
HDT (minutes)	14
Overall System Footprint (ft^2)	19,000

6.3.4 Filtration Process

Granular media filtration is used in Option 3 and is sized based on design criteria for a 107 mgd flow, 8 gpm/ft^2 surface loading rate, and 1,000 ft^2 of area per filter. This results in a design of 11 duty filters and one redundant filter for a total of 12 units. Each filter has two cells. The media filter beds consist of 18 inches of anthracite on top of 12 inches of sand. The surface area of each individual filter bed is 1,175 ft^2, 47 feet by 25 feet (length by width), which results in a surface loading rate of 8.0 gpm/ft^2. The basin water depth is 12.5 feet, which provides 9 feet of water depth above the combined height of the media and the underdrain system. Each filter has a total basin depth of 14.5 feet.

Table 6-13 Dual Media Filter Design Parameters

DESIGN PARAMETER	VALUE
Media Bed Configuration	Anthracite: 18 in Sand: 12 in
Number of Cells/Filter	2
Number of Filters	12
Velocity (ft/min)	1.07
Basin Water Depth (ft)	12.5
Basin Depth (ft)	14.5
Basin Length (ft)	47
Cell Width (ft)	10.5
Basin Width (ft)	25
Total Filter Volume (MG)	1.35
Total System Footprint (ft^2)	15,000

6.3.5 Residuals Handling

Liquid and solid residuals are generated through treatment with the processes described in both treatment Options 3 and 4. Liquid residuals are primary generated through backwashing processes in the GMF and membrane filtration processes of Options 3 and 4, respectively. Solids residuals are collected from the sedimentation and filtration processes, and mainly are composed of coagulant, settled particles (floc), and solids from backwash.

6.3.5.1 Liquid Residuals

Liquid residuals are collected in a downgradient circular clarifier from either form of filtration used in Options 3 and 4 during backwashing and typical maintenance cleaning activities. The overflow from the clarifier pumped back to the head of the process prior to coagulation and flocculation for treatment. The use of a clarifier has the additional benefit of providing additional flow to the treatment process, allowing for a more continuous feed of water to the plant in potential low flow conditions.

6.3.5.2 Solid Residuals

Solid residuals are largely generated through the coagulation and flocculation processes and accumulation of solids in the media and membrane filtration systems. The residuals and backwash water containing solids are transferred to a high rate sedimentation basin, where additional settling occurs to separate settleable solids from the water. The high rate settling basin, which in this option is a plate assisted settling basin, provides additional solids removal from the solids residual stream. Clarified water from the plate assisted settling basin is returned to the head of the plant for treatment and the further concentrated solids are transferred to a residuals lagoon for drying and storage.

In this treatment scheme, four residuals lagoons provide operations staff with flexibility in storage and drying of the solids residuals generated during treatment. In this process, two lagoons are kept in continual operation, receiving a flow of solids residuals while the supernatant water on the upper layer of the lagoon is continuously decanted and pumped to the head of the treatment process. This results in the lagoon acting as a residuals thickener. The other two lagoons act as drying beds for the thickened residuals once the lagoons are sufficiently full of residuals and drained of supernatant. The dried residuals are then removed from the lagoons and transferred by front-end loader to dump trucks for removal. The solids can be disposed of by land application or at a landfill in the MRB. It is common for water treatment plants to follow a cycle of filling and drying, with the duration of each dependent upon site climate and seasonal conditions. An optional method of dealing with the reject water would be to increase the size of the residuals treatment process and return the decanted water to the equalization basin.

6.3.6 UV Disinfection

Although the UV design dose for Option 3 will need a lower intensity than in Option 2 due to the inclusion of additional pretreatment, the UV system has been designed to provide the same maximum output of 40 mJ/cm^2. Operational costs assume operation at a UV dose of 25 mJ/cm^2.

Table 6-14 Option 3 UV System Design Parameters

DESIGN PARAMETER	VALUE
UV Reactor Manufacturer and Model	Wedeco K143
UV Lamp Technology	LPHO
Max UV Dose (mJ/cm^2)	40
Giardia (Log-Inactivation)	>4.0
Duty Reactor Number	10
Standby Reactor Number	1
Number of Lamps per Reactor	156
Total Number of Lamps	1,716
Total Connected Power Load (kW)	605

6.3.7 Chlorine Disinfection

Chlorine disinfection provides the primary source of the 4-log virus inactivation target in this treatment process scheme. The design is based in part on maintaining a chlorine residual of 1.0 mg/L at the outlet of the contact basin to meet cT targets. The design chlorine dose, based in part on the available raw water quality data, is 8.0 mg/L, the average dose is 6.0 mg/L, and the minimum dose is 4.0 mg/L. The design dose was estimated based upon demand from the observed level of particulates, dissolved organic content, iron, and ammonia present in the source water. Bench-scale testing will be necessary to refine the chlorine dosage assumptions if this process is selected.

The DCB is designed to provide a cT necessary to achieve a 4-log virus inactivation. Two DCBs with a serpentine flow path in order to provide baffling. Each basin has a volume of 0.80 MG. At the design flow of 107 mgd, each basin provides 20 minutes of contact time with a baffling factor (BF) of 0.66. The BF in Options 3 and 4 are reduced compared to Option 1 based upon several factors, including the reduced demand on chlorine to meet log-inactivation goals in Option 1 and differences in the necessary basin design to meet CT. Each DCB has a water depth of 15 ft, total basin depth of 17 ft, width of 127 ft and length of 56 ft. Both chlorine gas and hypochlorite disinfection were considered for this treatment option. A comparison of the DCB designs for Options 1 and 2 versus Options 3 and 4 is shown in Table 6-15.

Table 6-15 Comparison of Options 1 thru 4 Disinfection Contact Basin Design Parameters

DESIGN PARAMETER	OPTIONS 1 & 2	OPTIONS 3 & 4
Flow Pattern	Serpentine	Serpentine
Number of Basins	4	2
Individual Basin Volume (MG)	4.17	0.80
Hydraulic Detention Time (HDT, minutes)	215	20
Baffling Factor	0.80	0.66
Target Residual (mg/L)	3.0	1.0
cT (mg-min/L)	516	13.3
Water Depth (ft)	20	15
Basin Depth (ft)	22	17
Basin Length (ft)	167	127
Basin Width (ft)	167	56
Total Footprint (ft^2)	123,000	15,600

6.3.8 Chloramine Disinfectant Residual System

Free chlorine will be converted into chloramine to provide a residual in the transmission pipeline. The ammonia design dose for Option 3 is 0.25 mg/L assuming a 4:1 ratio of chlorine to ammonia, which represents one third of the dose of Option 1. The enhanced disinfection provided by UV reduces the chlorine residual required for disinfection. With an aqueous liquid ammonia concentration of 19 percent and a density of 7.77 lb/gal, the associated feed system is described in Table 6-9.

Table 6-16 Chloramine System Design Parameters

DESIGN PARAMETER	VALUE
Ammonia Usage Rate (lb/h)	11
Ammonia Solution Usage Rate (gal/h)	7.7
Pumps	3
Day Tanks	2
Bulk Tanks (2,500 gal, each)	2
Total Process Footprint (ft^2)	600
Chemical Delivery (totes/day, tote = 385 gal)	4

As discussed previously in Section 6.1 for Option 1, any remaining disinfectant residual will be quenched from the treated water with sodium bisulfite at the discharge of the State RRVWSP The residual disinfectant is assumed to be the same at the pipeline discharge for each option; reference Table 6-7 for design parameters.

6.4 OPTION 4 – ADVANCED TREATMENT

All the pretreatment processes for Option 4 are the same as described in Option 3, except there will be sand/grit removal (see Option 1) and the high-rate sedimentation and GMF processes from Option 3 are replaced with membrane filtration. The UV and chlorine disinfection portions of the process would be the same as described above in Option 3.

6.4.1 Membrane Filtration

The membrane filtration design is based on the form of Evoqua Memcor© UF membranes. This enclosed hollow-fiber, polymeric material UF membrane process includes a four-train system comprised of 32 skids with 170 installed membrane modules per skid; this is a total of 5,440 modules. Due to the proprietary nature of membrane technology, membrane filtration system designs rely heavily upon product specifications and design parameters, which would be obtained from vendors if this process is selected and moves forward into preliminary and final design.

6.5 COMPARISON OF BIOTA TREATMENT OPTIONS

The four biota treatment options described in this report encompass differing strategies to meet the treatment targets outlined, each with varying operability factors and treatment results. Outlined in Table 6-17 is a high-level comparison of Options 1 thru 4 based upon defining characteristics such as AIS reduction capability, ease of operability, and degree of water treatment possible with each treatment scheme.

Table 6-17 Comparison of Treatment Options

PARAMETER	OPTION 1	OPTION 2	OPTION 3	OPTION 4
Treatment Process	-Sand/Grit Removal -Chlorine Disinfection	-Sand/Grit Removal -UV Disinfection -Chlorine Disinfection	-Coagulation -Flocculation -High-Rate Sedimentation -Granular Media Filtration -UV Disinfection -Chlorine Disinfection	-Sand/Grit Removal -Coagulation -Flocculation -Membrane Filtration -UV Disinfection -Chlorine Disinfection
AIS Reduction Capability	High	Very High	Very High	Very High
Complexity of Operation	Low	Moderate	High	High
DBP Formation Potential	Moderate	Low	Very Low	Very Low

6.6 ANCILLARY FACILITIES

The BWTP would have support facilities similar for all options. The building layout was designed to allow Options 1 and 2 to have the same support facility layout. The treatment processes identified for Options 3 and 4 are also similar enough in scale to where they both share the same support facility layout as well.

The operations and maintenance building conceptualized for Options 2, 3 and 4 includes all processes excluding chlorine contact basins. As UV is the only additional process in Option 2 compared to Option 1, the BWTP building is a copy of the structure designed for Option 1, with a UV reactor room included. The large area required for the processes in Options 3 and 4 requires a completely different building layout, where the administrative and ancillary rooms are designed around the building perimeter. Combining the process space with the operations area will cut construction costs as well as simplify plant operations.

Additional facilities include: a propane yard to supply fuel to the plant, a substation to provide power to the plant, a septic leach field, a treated water pump station, a surge control building, and for Options 3 and 4, the structures required for handling residual solids.

6.7 PLANT HYDRAULICS

The BWTP was laid out to facilitate flow through the plant, minimize pipe lengths, and maintain gravity flow of the process water. A full hydraulic profile was not developed for this appraisal-level design, but the major impacts to head loss were considered and water surface elevations were set based on general assumptions about the plant layout and the individual processes.

Each process was evaluated in order to develop an estimation of head losses. The following values were selected as appropriate for this appraisal-level design at the maximum plant flow of 107 mgd:

- Sand/Grit Removal – 1.5 feet
- Rapid-Mix Basins – 1 foot
- Sedimentation Basins – 1 foot
- Plate Settling Basins – 1 foot
- Granular Media Filters – 10 feet
- Membrane Filtration System – 6 feet
- UV and In-Plant Piping – 2 feet
- Site Piping and Splitter Box – 1 foot
- Disinfection Splitter Box and Contact Basin– 2 feet (1 foot for Options 3 & 4)

For the purposes of developing facility layouts, representative water surface elevations were selected. Table 6-18 summarizes the assumed water surface elevations with respect to the datum. The elevations shown in Appendix E display the estimated water surface elevations, as well as the top of the tank, platform, or floor elevations.

Once a process option and a site have been selected, a complete hydraulic analysis should be completed. This would verify if gravity flow is possible, or if layout modifications are needed to accommodate gravity flow. Hydraulic analysis could also identify some of the elevation differences that could be reduced in order to save construction costs if head losses are found to be less than assumed in this appraisal-level design.

Table 6-18 Estimated Cumulative Head Losses

PROCESS /FACILITY	OPTION 1	OPTION 2	OPTION 3	OPTION 4
Sand/Grit Removal	1.5	1.5	-	1.5
Rapid Mix Coagulation Basins	-	-	-1	-1
Plate-assisted Settling Basins	-	-	-2	-2
Granular Media Filters	-	-	-12	-
Membrane Filters	-	-	-	-8
UV Disinfection	-	-2	-14	-10
Chlorine Splitter Box	-1	-3	-15	-11
Disinfection Contact Basins	-3	-5	-16	-12
(1) Baseline = operating floor/grade = 0 ft.				

6.8 SITE LAYOUT

The BWTP building and all support facilities were sized to provide 107 mgd of treated water. A layout for all four options was prepared at the McClusky site along the McClusky Canal.

In order to allow for gravity flow through the BWTP for Options 3 and 4, the head of the plant was located at the high point of the site. The main pumping station, residuals lagoons, and septic leach field were all located such that they would be at a lower elevation than the BWTP building in order to facilitate gravity flow. The other support facilities were located close to the BWTP building to allow the best use of the site. There was no concern with providing gravity flow in Options 1 and 2, since only a few feet were needed to account for head loss in the sand/grit removal, UV reactors (Option 2) and the disinfection contact basins.

7.0 Cost Evaluation

As part of this appraisal-level design, opinions of probable construction costs (OPCC) have been documented to compare the four treatment options. CAPEX and OPEX are based on a 107-mgd BWTP.

7.1 METHODOLOGY

Costs are presented in September 2019 dollars. These appraisal-level costs were developed from approximate quantities, existing design data, along with recent quotes from suppliers, previous studies, and recent contractor bids for similar facilities. They are intended for planning and preliminary budgetary purposes. The prices derived from historical data and past estimates were adjusted to September 2019 using the Engineering News Record's (ENR) construction cost index (CCI). The direct costs were summed, and markups for indirect costs such as general conditions, insurance and bonding, and contractor overhead and profit were added. These indirect costs were represented by percentage-based markups.

Based on the conceptual level of the BWTP configuration, a 30-percent contingency was added to the costs developed in the OPCC. This contingency is intended to cover items not captured in the quantities, items that lack a certain level of detail and may be more expensive when fully designed, and items not detailed at this level of concept that would be required for an operational WTP. The costs do not include engineering, construction management, legal, permitting, and administrative costs that would be associated with the project. Based on the conceptual level, and the fact that a specific site has not been selected, any utilities or work outside of the site were not included in the cost. Escalation has not been added but should be added once a time frame for building the BWTP is better defined.

The BWTP building includes quantities based on the concept level drawings provided. The ancillary buildings around the site were estimated based on approximate size and treatment capacity using historical costs from similar sized projects. Equipment, electrical, instrumentation, and other systems were based on historical costs for similar-sized projects or quotes from vendors where available.

7.2 COST ASSUMPTIONS

It is assumed that the contract will be issued under full and open bidding conditions. Costs presented are broken down into the following categories and are computed in the order presented:

- Estimated Direct Costs (Sitework, Building Construction, Equipment, Electrical, Instrumentation, and Installation).
- General Conditions (Mobilization/Demobilization, Contractor Operations Facilities) (5 Percent of Direct).
- Unidentified Costs (Contingency) (30 Percent Total Direct).
- Contractor Overhead and Profit (12 Percent of Total Direct + Unidentified Costs).
- Bonds and Insurance (2 Percent of Total Direct + Unidentified Costs).

Operation, maintenance, and replacement costs/unit costs were obtained from various sources, including chemical costs from a local chemical supplier (Table 7-1).

Table 7-1 O&M Cost Assumptions

ITEM	COST	UNITS
Ferric Chloride (40%)	$1.91	per gal
Polymer	$7.89	per gal
Hypochlorite (12.5% NaOCl)	$1.40	per gal
Liquid Ammonium Sulfate (40%)	$1.33	per gal
UF Cleaning Chemicals	$0.0057	per 1,000 gal
Electricity	$0.08	per kW-hr used

7.3 COST RESULTS

The results of the detailed cost estimates for each option are shown in Table 7-2 and Table 7-3. Appendix G includes the detailed breakdown of the OPCC for all four treatment options. Capital costs include construction and all expected overheads and profits.

Table 7-2 Summary of Estimated Annual Operations Costs for Treatment

OPTION(1,2,3)	MINIMUM COST PER YEAR(4,5)	AVERAGE COST PER YEAR (4,6)	MAXIMUM COST PER YEAR (4,7)
1	$1,100,000	$1,700,000	$3,500,000
2	$1,400,000	$2,100,000	$4,100,000
3	$5,000,000	$6,200,000	$8,400,000
4	$5,600,000	$6,900,000	$9,400,000

Notes:

(1) Option 1 – Sand/Grit Removal, Liquid Chlorination (typical); Option 2 – Sand/Grit Removal, UV, Chlorination; Option 3 – Coagulation, Flocculation, High Rate Sedimentation, Media Filtration, UV, Chlorination; Option 4 – Sand/Grit Removal, Coagulation, Flocculation, Ultrafiltration, UV, Chlorination.

(2) Chlorine disinfection is provided by bulk liquid sodium hypochlorite (aka bleach).

(3) Assumes the UV system operates at 40 mJ/cm2 for Option 2 and 25 mJ/cm2 for Options 3 and 4.

(4) Cost considers the treatment process only.

(5) Assumes plant operates an average of 2.6 mgd.

(6) Annual cost of operations assumes the plant operates at full capacity (107 mgd) for 28 percent of the time and at minimum flow (2.6 mgd) for the remainder of the year.

(7) Assumes plant operates an average of 107 mgd.

Table 7-3 Summary of Estimated Capital Costs and 20-year NPV

OPTION (1,3)	CONSTRUCTION COST	CAPITAL COST PER MG	20-YEAR NPV(2)
1	$56M	$0.53	$100M
2	$70M	$0.66	$120M
3	$220M	$2.06	$370M
4	$240M	$2.26	$410M

Notes:

(1) Option 1 – Grit Removal, Chlorination; Option 2 – Grit Removal, UV, Chlorination; Option 3 – Coagulation, Flocculation, High Rate Sedimentation, Media Filtration, UV, Chlorination; Option 4 – Grit Removal, Coagulation, Flocculation, Ultrafiltration, UV, Chlorination.

(2) 20-Year NPV assumes a discount rate of 3.0 percent, inflation rate of 2.1 percent, and the plant operates at full capacity (107 mgd) for 28 percent of the time and at minimum flow (2.6 mgd) for the remainder of the year. Chemical usage is assumed to be the average dose for all processes.

(3) Chlorine disinfection is provided by bulk liquid sodium hypochlorite (aka bleach).

8.0 Options Comparison

Table 8-1 presents a BWTP options comparison by summarizing the treatment process, complexity of operation, CAPEX, OPEX, and the estimated 20-year net present worth.

Table 8-1 Overall Biota Treatment Plant Option Summary

PARAMETER	OPTION 1	OPTION 2	OPTION 3	OPTION 4
Treatment Process	-Sand/Grit Removal -Chlorine Disinfection	-Sand/Grit Removal -Chlorine Disinfection -UV Disinfection	-Coagulation -Flocculation -High Rate Sedimentation -Media Filtration -Chlorine Disinfection -UV Disinfection	-Sandy/Grit Removal -Coagulation -Flocculation -High Rate Sedimentation -Membrane Filtration -Chlorine Disinfection -UV Disinfection
AIS Reduction Capability	High	Very High	Very High	Very High
Complexity of Operation	Low	Moderate	High	High
CAPEX	$56M	$70M	$220M	$240M
OPEX (/yr) for Average Operations	$1.7M	$2.1M	$6.2M	$6.9M
20-year NPV	$100M	$120M	$370M	$410M

Appendix A Water Quality Table

Table A-1: Water Quality Table

CONSTITUENT	UNITS[1]	MCCLUSKY CANAL (NEW JOHNS LAKE)		LAKE AUDUBON		LAKE SAKAKAWEA	
		RANGE	AVERAGE	RANGE	AVERAGE	RANGE	AVERAGE
Temperature	°C	0.6-22.90	14.1	0.27-25.75	12.9	0.14-21.43	11.4
Turbidity	NTU	n/a	n/a	6.74-22.10	12.6	1.13-27.36	9.4
pH	s.u.	7.8-8.5	8.3	7.4-8.8	8.5	7.1-8.6	8.2
Alkalinity	mg/L as $CaCO_3$	233-323	258	205-304	229	138-303	169
Hardness	mg/L as $CaCO_3$	526-664	584	247-350	277	178-596	224
TDS	mg/L	1150-1470	1274	608-910	680	321-1159	448
Ammonia	mg/L as N	0.01-0.23	0.06	0.01-0.06	0.03	0.01-0.16	0.04
Calcium	mg/L as $CaCO_3$	65.1-90.3	80	38.8-54.5	44	0.04-150.2	53
Magnesium	mg/L as $CaCO_3$	85.4-109	93	35.9-52.1	40	16.6-53.9	21.9
Sodium	mg/L	136-192	164	99.5-162	123	43.9-131.1	62
Potassium	mg/L	16-21.4	18.2	5.8-8.42	6.6	3.43-5.61	4.1
Chloride	mg/L	15.4-21.8	18.4	13.5-19.1	15.2	6.65-12.68	9.2
Sulfate	mg/L as SO_4	582-779	676	267-384	296	128-524	176
Iron, Tot	mg/L	3.6-27.8	7.2	0.003-0.07	0.14	0.003-0.20	0.02
Manganese, Tot	mg/L	1.03-26.6	7.5	0.0002-0.07	0.01	0.0009-1.01	0.04

(1) Abbreviations: $CaCO_3$ – calcium carbonate, NTU – nephelometric turbidity units, s.u. – standard units, Tot – total

Appendix B Historic Water Quality

Table B-1: Lake Sakakawea Water Quality Table

Data Source	Sample Date	Temperature (Deg C)	Turbidity (NTU)	pH	Alkalinity Total (CaC03) (mg/L)	Hardness Total (CaCO3) (mg/L)	Dissolved Solids Total (mg/L)	Ammonia (N) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sodium (Na) (mg/L)	Potassium (K) (mg/L)	Chloride (mg/L)	Sulfate as (SO4) (mg/L)	Iron (Fe) (mg/L)	Manganese (Mn) (mg/L)
GDCD	8/23/2012		1.1	8.3	164	262	503	<0.03	60.4	26.9	78.1	4.4	<15	218.0	0.071	<0.01
GDCD	6/19/2013		2.8	8.4	169	253	479	<0.03	57.4	26.7	67.6	4.1	9.7	211.0	0.124	0.013
GDCD	6/11/2014		3.8	8.4	173	240	500	<0.03	53.9	25.5	79.4	4.4	9.9	222.0	0.076	0.036
GDCD	10/1/2014		3.1	8.4	167	240	483	0.04	54.3	25.3	76.4	4.6	9.8	211.0	0.146	0.014
GDCD	6/1/2015		2.7	8.3	159	229	446	<0.03	52.3	23.9	68.4	4.3	8.9	190.0	0.151	0.016
GDCD	8/26/2015		1.9	8.5	164	224	455	<0.03	51.6	23.1	71.9	5.0	9.8	193.0	0.088	<0.01
GDCD	6/6/2016		4.4	8.4	168	240	467	<0.03	55.5	24.5	73.7	4.4	10.2	197.0	0.198	0.023
GDCD	6/6/2017	20.0	2.9	8.3	164	230	477	<0.03	53.3	23.4	73.8	4.1	10.7	212.0	0.155	0.020
GDCD	8/31/2017	21.0	2.5	8.4	166	230	481	<0.03	52.4	24.0	72.5	3.7	11.1	217.0	0.084	0.010
GDCD	5/17/2018	10.0	1.3	8.3	150	209	398	<0.03	49.9	20.5	58.4	3.6	8.9	165.0	<0.05	<0.01
GDCD	8/28/2018	10.0	2.1	8.4	149	222	409	<0.03	51.8	22.4	62.2	4.0	8.6	169.0	0.079	0.014
USGS	9/2/1997	19.9	1.5	8.1	147	184	394	0.02	0.0	17.9	48.6	3.9	8.2	145.7	0.003	0.003
USGS	9/24/1997	17.2	1.5	8.0	147	196	386	0.02	47.7	18.6	51.0	3.8	7.5	159.0	0.003	0.002
USGS	10/29/1997	8.6	2.9	8.4	145	186	382	0.01	44.0	18.3	50.6	3.8	7.8	148.0	0.004	0.001
USGS	4/29/1998	7.5	7.5	8.6	139	182	342	0.05	45.6	16.6	43.9	3.7	6.7	128.0	0.010	0.006
USGS	5/19/1998	9.8	11.7	8.3	144	179	322	0.05	43.6	16.9	45.5	3.7	6.8	131.5	0.012	0.004
USGS	6/23/1998	13.5	13.4	8.5	149	187	363	0.04	45.3	18.0	46.9	3.6	7.2	134.0	0.010	0.018
USGS	7/7/1998	15.1	10.4	8.2	150	191	364	0.04	45.5	18.7	48.3	3.7	7.3	133.0	0.010	0.004
USGS	8/5/1998	17.6	10.1	8.1	153	196	378	0.04	47.4	18.7	47.3	3.9	7.5	138.5	0.010	0.025
USGS	8/24/1998	19.2	17.1	8.3	156	201	391	0.02	47.9	19.7	48.7	3.9	7.8	145.3	0.010	0.013
USGS	9/24/1998	17.0	12.6	8.0	163	214	393	0.02	49.6	21.8	59.1	3.6	9.1	159.5	0.010	0.003
USGS	10/21/1998	10.4	14.3	8.3	159	207	408	0.02	49.6	20.1	52.5	3.8	8.7	152.5	0.010	0.005
USGS	11/23/1998	3.6	8.7	8.2	158	209	418	0.04	49.9	20.4	54.6	3.4	8.7	153.5	0.010	0.005
USGS	12/4/1998	4.3	20.6	8.4												
USGS	2/9/1999	0.9	4.9	8.2	166	215	430	0.02	51.5	21.0	55.9	4.2	9.1	165.5	0.010	0.006
USGS	3/15/1999	1.1	3.2	8.2	192	264	549		65.0	24.5	69.8	4.2	9.7	220.5	0.010	0.005
USGS	5/12/1999	6.6	16.9	8.4	154	204	402	0.02	49.6	19.6	53.4	3.6	8.9	149.0	0.008	0.003
USGS	6/18/1999	14.1	6.9	8.3	167	202	404	0.02	48.6	19.5	53.0	3.6	8.5	153.0	0.010	0.013
USGS	7/29/1999	21.3	2.2	8.4	153	201	399	0.02	49.0	19.2	52.4	3.5	8.7	156.5	0.009	0.003
USGS	8/17/1999	19.2	5.7	8.4	153	205	400	0.02	48.7	20.1	54.8	4.0	8.3	153.0	0.010	0.003
USGS	9/10/1999	16.5	4.4	8.5	162	207	411	0.02	48.3	20.8	57.5	4.0	9.4	164.5	0.009	0.004
USGS	10/13/1999	11.9	2.6	8.4	160	209	416	0.02	50.2	20.4	56.7	3.7	9.2	164.5	0.010	0.002
USGS	11/8/1999	8.2	3.2	8.3	156	211	414	0.02	50.2	20.6	55.5	3.8	8.9	163.5	0.010	0.002
USGS	12/9/1999	2.9	11.3	8.2	158	208	417	0.02	50.9	19.6	54.5	3.9	8.9	166.0	0.010	0.001

Data Source	Sample Date	Temperature (Deg C)	Turbidity (NTU)	pH	Alkalinity Total (CaC03) (mg/L)	Hardness Total (CaCO3) (mg/L)	Dissolved Solids Total (mg/L)	Ammonia (N) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sodium (Na) (mg/L)	Potassium (K) (mg/L)	Chloride (mg/L)	Sulfate as (SO4) (mg/L)	Iron (Fe) (mg/L)	Manganese (Mn) (mg/L)
USGS	1/28/2000	0.5	2.6	8.0	162	214	429	0.02	51.9	21.1	60.9	3.9	8.2	167.0	0.014	0.002
USGS	5/2/2000	8.0	11.2	7.7	149	195	390	0.02	47.3	18.8	54.6	3.7	7.5	153.5	0.010	0.004
USGS	5/22/2000	10.7	2.7	8.2	150	194	393	0.02	46.3	18.9	54.6	3.5	8.0	153.8	0.010	0.002
USGS	6/7/2000	11.1	9.5	8.1	152	189	399	0.02	45.1	18.4	54.9	3.9	7.4	151.5	0.011	0.010
USGS	6/27/2000	14.3	6.6	8.0	150	190	392	0.02	45.5	18.5	54.1	3.5	7.5	150.0	0.010	0.013
USGS	7/20/2000	17.7	3.2	8.2	151	190	390	0.02	45.7	18.4	52.2	3.6	7.9	147.5	0.018	0.003
USGS	8/29/2000	19.2	5.6	8.0	157	204	398	0.02	48.9	19.8	54.6	3.5	8.2	149.5	0.010	0.004
USGS	9/25/2000	13.5	7.1	8.3	163	207	410	0.02	49.0	20.5	57.6	3.9	8.0	158.0	0.010	0.003
USGS	10/11/2000	11.0	2.1	8.2	162	204	413	0.04	48.5	20.1	57.8	3.8	8.7	160.0	0.010	0.004
USGS	1/18/2001	1.1	8.2	7.9	200	255	540	0.05	61.8	24.4	74.5	4.4	9.6	218.7	0.010	0.077
USGS	2/28/2001	1.4	4.0	8.6	219	265	604	0.10	64.8	25.1	89.7	4.3	9.8	250.0	0.010	0.080
USGS	5/8/2001	8.1	19.9	8.2	154	198	393	0.04	47.4	19.4	52.2	3.7	8.0	140.5	0.010	0.004
USGS	6/20/2001	12.7	7.3	8.1	159	194	392	0.03	46.7	18.8	54.4	3.6	7.7	146.0	0.010	0.008
USGS	7/23/2001	18.9	25.9	8.2	161	201	396	0.03	48.3	19.5	52.9	3.7	8.6	147.3	0.010	0.003
USGS	8/22/2001	20.6	23.7	8.2	166	204	412	0.04	49.1	19.9	55.7	3.7	8.6	153.3	0.011	0.024
USGS	9/7/2001	20.2	1.7	8.3	163	210	413	0.03	50.5	20.4	54.6	3.9	8.8	151.0	0.009	0.003
USGS	9/27/2001	15.1	5.8	8.5	164	209	408	0.04	50.3	20.3	54.5	3.9	8.9	153.5	0.010	0.002
USGS	11/2/2001	6.9	14.4	8.2	178	215	444	0.04	49.7	22.0	61.5	4.1	9.5	165.0	0.008	0.003
USGS	11/20/2001	6.5	2.5	8.2	180	216	412	0.04	51.4	21.2	54.5	4.0	9.1	156.0	0.006	0.003
USGS	2/8/2002	1.1		7.9	212	260	568	0.08	63.2	24.8	82.5	4.2	9.2	231.0	0.010	0.171
USGS	2/28/2002	1.7		8.1	173	210	432	0.04	50.1	20.5	57.1	3.9	9.4	164.0	0.010	0.003
USGS	3/26/2002	2.4	8.5	7.9	225	284	632	0.04	70.1	26.4	92.9	4.4	9.6	257.0	0.010	0.037
USGS	4/26/2002	2.7	8.5	8.1	159	204	405	0.04	48.7	19.8	54.8	3.6	7.5	149.5	0.010	0.003
USGS	5/13/2002	5.9	1.5	8.1	164	205	415	0.04	49.4	19.8	53.9	3.8	8.8	157.5	0.010	0.002
USGS	7/2/2002	18.0		8.1	168	210	429	0.04	49.8	20.7	59.6	4.1	9.2	161.5	0.010	0.001
USGS	7/24/2002	20.5	27.4	8.2	168	218	428	0.06	52.7	20.9	61.4	4.2	9.6	160.5	0.010	0.002
USGS	10/23/2002	6.8		8.1	178	217	460	0.04	50.3	22.3	65.7	4.2	9.0	174.5	0.010	0.008
USGS	1/7/2003	0.9		7.8	171	222	435	0.04	53.1	21.6	63.5	3.8	8.6	166.0	0.010	0.002
USGS	2/20/2003	1.1		7.6	225	315	633	0.07	79.1	28.7	80.8	4.4	9.1	265.0	0.010	0.198
USGS	5/29/2003	11.9	23.3	7.9	171	203	434	0.03	49.3	19.4	57.7	3.6	9.5	165.0	0.006	0.010
USGS	6/24/2003	14.1	9.5	8.2	165	215	402	0.04	52.0	20.6	58.7	3.9	9.5	154.0	0.008	0.001
USGS	7/17/2003	19.1	16.7	8.2	165	207	417	0.04	50.2	19.9	55.8	4.1	9.7	154.0	0.005	0.003
USGS	7/31/2003	20.2	26.4	8.1	174	223	449	0.09	54.4	21.2	64.0	4.1	9.6	164.0	0.008	0.099
USGS	8/15/2003	21.4		8.2	162	207	412	0.04	48.9	20.7	58.7	4.4	9.7	153.5	0.011	0.002
USGS	8/28/2003	20.6	15.9	8.0	171	229	396	0.04	55.8	21.8	58.8	4.5	9.6	158.0	0.005	0.185
USGS	9/9/2003	20.4	9.8	8.6	164	213	417	0.04	52.2	20.1	56.1	4.4	9.5	153.0	0.007	0.004
USGS	10/7/2003	14.0	6.5	8.1	175	227	449	0.04	53.4	22.6	67.8	4.5	9.9	176.0	0.005	0.033
USGS	11/6/2003	1.8	6.7	8.1	187	232	516	0.04	48.1	27.2	81.5	5.3	11.2	203.0	0.004	0.010

Data Source	Sample Date	Temperature (Deg C)	Turbidity (NTU)	pH	Alkalinity Total (CaC03) (mg/L)	Hardness Total (CaCO3) (mg/L)	Dissolved Solids Total (mg/L)	Ammonia (N) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sodium (Na) (mg/L)	Potassium (K) (mg/L)	Chloride (mg/L)	Sulfate as (SO4) (mg/L)	Iron (Fe) (mg/L)	Manganese (Mn) (mg/L)
USGS	2/13/2004	0.5		7.2	166	225	418	0.04	54.9	21.2	59.8	4.5	9.8	156.0	0.006	0.004
USGS	4/16/2004	4.6	16.3	8.1	149	197	374	0.04	47.4	19.2	51.9	4.0	8.7	136.0	0.006	0.004
USGS	5/17/2004	9.0	19.0	7.8	171	227	433	0.04	55.0	21.8	60.1	4.3	9.7	163.5	0.006	0.013
USGS	6/29/2004	16.7	25.2	8.3	166	213	410	0.04	51.8	20.4	58.3	4.1	9.7	150.0	0.005	0.003
USGS	7/19/2004	18.7	21.8	8.1	176	222	448	0.08	54.8	20.8	61.9	4.3	9.4	165.5	0.006	0.072
USGS	8/12/2004	17.0	15.6	8.3	168	222	428	0.04	53.2	21.6	54.0	4.0	9.7	155.0	0.003	0.010
USGS	8/31/2004	17.5	17.8	8.2	175	226	450	0.04	54.0	22.1	61.8	4.2	9.5	170.5	0.006	0.023
USGS	9/9/2004	16.8	11.5	8.2	186	228	495	0.04	54.8	22.1	65.8	4.1	9.6	183.0	0.006	0.041
USGS	10/12/2004	13.4		8.2	202	266	554	0.04	56.0	30.5	91.5	5.2	11.5	228.5	0.006	0.036
USGS	11/8/2004	5.9		8.0	183	240	501	0.03	53.7	25.7	76.6	4.9	10.5	193.5	0.005	0.019
USGS	11/2/2005	7.9		8.0	182	247	540	0.04	51.6	28.8	91.0	5.1	11.4	219.0	0.006	0.026
USGS	1/26/2006	1.6		7.1	248	387	795	0.08	96.1	35.9	109.5	5.2	11.1	338.0	0.005	0.347
USGS	3/8/2007	1.2		7.7	303	596	1159	0.15	150.2	53.9	131.1	5.5	12.7	524.0	0.012	1.010
USGS	5/1/2007	10.1		8.5	154	187	391	0.02	45.7	17.8	55.9	3.7	8.8	142.0	0.006	0.002
USGS	7/26/2007	20.2		8.2	169	203	409	0.08	49.4	19.2	55.5	3.9	9.7	149.5	0.006	0.039
USGS	9/5/2007	19.1		8.1	175	219	449	0.03	53.0	21.0	65.4	4.1	10.1	166.0	0.005	0.019
USGS	10/17/2007	10.0		8.6	193	228	532	0.03	46.1	27.2	83.8	5.0	12.3	213.0	0.008	0.003
USGS	2/26/2008	2.6		7.9	299	532	1041	0.07	132.5	48.9	119.5	5.6	12.2	467.5	0.008	0.412
USGS	5/20/2008	11.8		8.2	168	214	425	0.02	51.1	21.0	58.8	4.2	10.0	159.0	0.008	0.003
USGS	7/22/2008	18.8		8.2	169	213	424	0.03	51.1	20.8	57.1	4.3	10.9	163.0	0.008	0.003
USGS	9/3/2008	18.7		8.2	168	214	424	0.02	51.2	21.0	58.4	4.4	10.8	163.5	0.008	0.001
USGS	11/4/2008	8.7		8.4	166	224	422	0.02	52.9	22.3	62.0	4.5	10.6	167.0	0.004	0.001
USGS	2/24/2009	0.9		7.8	192	274	534	0.07	67.5	25.5	84.0	4.8	11.2	213.0	0.005	0.089
USGS	5/14/2009	6.8		8.1	148	192	367	0.01	46.6	18.2	47.4	3.8	9.1	141.5	0.004	0.003
USGS	7/21/2009	16.9		8.2	155	201	388	0.05	47.1	20.2	50.0	4.4	9.4	144.5	0.005	0.007
USGS	9/1/2009	18.9		8.3	150	199	375	0.02	49.1	18.4	49.9	4.1	9.3	145.0	0.003	0.022
USGS	10/21/2009	8.9		8.3	155	203	383	0.02	49.2	19.4	52.9	4.1	9.3	149.0	0.005	0.003
USGS	2/19/2010	0.2		7.1	159	202	400	0.02	48.5	19.5	53.1	4.3	9.7	153.5	0.005	0.012
USGS	5/19/2010	9.2		8.5	153	194	382	0.02	46.4	18.9	51.2	3.7	9.0	143.0	0.005	0.001
USGS	7/21/2010	18.4		8.3	161	198	376	0.16	48.4	18.7	48.4	3.7	9.5	143.0	0.005	0.275
USGS	9/7/2010	17.7		8.3	155	191	394	0.01	46.8	18.0	50.7	3.8	9.2	146.5	0.005	0.003
USGS	10/13/2010	14.4		8.2	159	195	396	0.01	47.5	18.5	51.7	3.8	9.3	148.0	0.003	0.007
USGS	2/16/2011	0.1		8.0	165	208	416	0.02	50.8	19.5	59.4	4.1	9.7	162.0	0.005	0.003

Table B-2: Lake Audobon Water Quality Table

Location	Data Source	Sample Date	Temperature (Deg C)	Turbidity (NTU)	pH	Alkalinity Total (CaC03) (mg/L)	Hardness Total (CaCO3) (mg/L)	Dissolved Solids Total (mg/L)	Ammonia (N) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sodium (Na) (mg/L)	Potassium (K) (mg/L)	Chloride (mg/L)	Sulfate as (SO4) (mg/L)	Iron (Fe) (mg/L)	Manganese (Mn) (mg/L)
unknown	GDCD	8/23/2012		11.9	8.4	207	279	637	<0.03	45.4	40.2	124.0	6.7	17.9	277.0	0.242	0.023
unknown	GDCD	10/1/2014		8.0	8.6	219	283	645	0.04	45.2	41.2	120.0	6.5	<15	284.0	0.348	0.029
unknown	GDCD	6/1/2015		14.1	8.5	221	293	655	<0.03	47.7	42.3	120.0	6.4	13.7	291.0	0.670	0.036
unknown	GDCD	8/26/2015		5.1	8.6	219	270	657	<0.03	41.3	40.6	120.0	7.4	15.0	299.0	0.209	0.011
unknown	GDCD	6/6/2016		11.0	8.6	222	298	673	<0.03	49.0	42.7	124.0	6.5	14.0	302.0	0.399	0.026
unknown	GDCD	6/6/2017	20.0	13.0	8.5	217	290	689	<0.03	46.2	42.4	124.0	6.6	15.8	323.0	0.624	0.041
unknown	GDCD	8/31/2017	21.0	8.6	8.6	217	280	701	<0.03	43.4	41.6	128.0	6.0	15.7	334.0	0.377	0.025
unknown	GDCD	5/17/2018	10.0	8.8	8.5	207	278	643	<0.03	43.9	41.0	123.0	6.2	14.1	289.0	0.352	0.042
unknown	GDCD	8/28/2018	10.0	8.3	8.6	214	295	688	<0.03	44.4	44.6	134.0	7.0	17.0	311.0	0.295	0.021
Near Snake Creek Pump	USGS	2/5/1997		1.4	8.1	238	280	676	0.11	46.0	39.0	117.0	6.6	14.0	280.0	0.010	0.170
Near Snake Creek Pump	USGS	8/5/1997	22.9	2.3	8.3	197	234	568	0.03	42.7	30.9	96.9	5.6	12.0	233.0	0.003	0.001
Near Snake Creek Pump	USGS	9/2/1997	20.5	2.4	8.3	203	233	684	0.03	41.1	31.5	96.7	5.9	12.8	239.5	0.003	0.003
Near Snake Creek Pump	USGS	9/24/1997	15.6	3.0	8.3	210	244	596	0.02	42.9	33.1	102.0	5.9	13.8	252.5	0.005	0.001
Near Snake Creek Pump	USGS	10/28/1997	5.5	1.3	8.4	214	240	613	0.04	41.3	33.1	102.0	6.0	13.4	259.5	0.003	0.003
Near Snake Creek Pump	USGS	1/15/1998	2.1	0.6	8.2	232	258	646	0.03	42.0	37.2	115.0	6.6	14.3	275.0	0.010	0.034
Near Snake Creek Pump	USGS	2/5/1998	2.8	1.0	7.9	235	278	669	0.08	46.4	39.3	117.0	6.7	13.9	278.0	0.010	0.089
Near Snake Creek Pump	USGS	3/11/1998	2.8	2.7	8.0	235	271	666	0.02	44.6	38.8	119.0	6.6	14.8	278.5	0.010	0.041
Near Snake Creek Pump	USGS	4/29/1998	7.6	6.9	8.5	193	233	533	0.05	44.3	29.8	88.9	5.5	11.5	217.5	0.010	0.005
Near Snake Creek Pump	USGS	5/19/1998	12.4	9.7	8.4	201	233	557	0.07	41.8	31.3	92.4	5.7	11.8	229.5	0.010	0.006
Near Snake Creek Pump	USGS	6/24/1998	16.8	13.6	8.6	205	238	573	0.04	42.1	32.3	95.3	5.6	12.4	232.5	0.010	0.005
Near Snake Creek Pump	USGS	7/7/1998	19.1	8.0	8.3	205	243	573	0.05	41.3	33.9	100.4	6.0	12.1	232.5	0.010	0.006
Near Snake Creek Pump	USGS	8/5/1998	21.5	12.8	8.3	205	238	582	0.03	41.2	32.7	97.0	6.2	12.2	235.0	0.010	0.004
Near Snake Creek Pump	USGS	8/24/1998	21.6	17.0	8.5	206	243	587	0.03	41.1	34.0	100.0	6.8	11.8	240.0	0.010	0.004
Near Snake Creek Pump	USGS	9/24/1998	17.1	12.6	8.3	209	247	604	0.02	41.6	34.8	104.8	5.7	13.3	248.0	0.010	0.004
Near Snake Creek Pump	USGS	10/21/1998	8.2	12.5	8.5	212	245	614	0.03	41.1	34.5	99.5	6.6	13.1	248.0	0.008	0.004

Location	Data Source	Sample Date	Temperature (Deg C)	Turbidity (NTU)	pH	Alkalinity Total (CaC03) (mg/L)	Hardness Total (CaCO3) (mg/L)	Dissolved Solids Total (mg/L)	Ammonia (N) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sodium (Na) (mg/L)	Potassium (K) (mg/L)	Chloride (mg/L)	Sulfate as (SO4) (mg/L)	Iron (Fe) (mg/L)	Manganese (Mn) (mg/L)
Near Snake Creek Pump	USGS	12/4/1998	1.2	10.7	8.2	212	241	617	0.03	41.4	33.4	101.0	6.0	13.0	252.0	0.010	0.004
Near Snake Creek Pump	USGS	2/9/1999	2.4	7.9	8.3	231	259	667	0.06	42.5	37.1	116.0	6.8	13.7	275.5	0.010	0.018
Near Snake Creek Pump	USGS	3/15/1999	2.6	10.1	8.3	235	267	672		44.5	37.7	114.0	6.8	14.1	276.0	0.010	0.007
Near Snake Creek Pump	USGS	5/12/1999	8.9	9.3	8.5	203	243	582	0.02	42.7	33.2	100.5	5.8	12.3	234.0	0.010	0.002
Near Snake Creek Pump	USGS	6/18/1999	17.9	5.8	8.5	186	238	589	0.02	41.1	32.9	98.7	5.8	12.1	240.0	0.010	0.003
Near Snake Creek Pump	USGS	7/29/1999	22.2	7.3	8.5	202	237	578	0.06	41.2	32.7	99.5	5.7	13.0	240.5	0.011	0.003
Near Snake Creek Pump	USGS	8/17/1999	20.5	7.5	8.6	152	242	572	0.02	40.6	34.1	101.5	6.1	12.4	242.0	0.007	0.003
Near Snake Creek Pump	USGS	9/10/1999	16.6	8.4	8.7	208	230	573	0.02	37.7	32.9	100.5	6.2	12.9	245.5	0.010	0.003
Near Snake Creek Pump	USGS	10/13/1999	9.5	1.1	8.7	212	246	594	0.03	40.9	35.0	105.5	6.0	13.2	248.0	0.010	0.002
Near Snake Creek Pump	USGS	11/8/1999	5.3	1.4	8.5	215	251	600	0.03	41.1	36.0	104.5	5.8	12.8	251.5	0.010	0.002
Near Snake Creek Pump	USGS	12/9/1999	1.1	5.4	8.2	216	247	643	0.02	41.6	34.9	103.5	6.5	12.9	257.0	0.010	0.002
Near Snake Creek Pump	USGS	1/28/2000	1.6	0.5	8.2	231	269	651	0.04	43.9	38.9	119.0	6.5	13.1	268.5	0.008	0.004
Near Snake Creek Pump	USGS	4/24/2000	6.3	1.3	8.3	203	230	570	0.02	40.1	31.4	98.1	6.1	12.7	228.0	0.010	0.002
Near Snake Creek Pump	USGS	5/22/2000	12.1	5.7	8.4	205	240	576		41.2	33.2	101.0	5.5	11.9	236.5	0.010	0.002
Near Snake Creek Pump	USGS	6/7/2000	15.1	3.2	8.4	205	236	577	0.02	40.8	32.7	101.0	5.8	11.6	242.0	0.008	0.002
Near Snake Creek Pump	USGS	6/27/2000	17.0	4.1	8.3	206	238	580	0.02	40.2	33.3	103.0	5.6	11.6	243.0	0.008	0.002
Near Snake Creek Pump	USGS	7/20/2000	20.1	13.5	8.2	206	237	586	0.03	39.8	33.3	102.5	6.1	12.0	243.3	0.018	0.003
Near Snake Creek Pump	USGS	8/29/2000	20.7	5.2	8.3	206	241	589	0.02	39.6	34.6	106.5	5.9	11.9	244.0	0.010	0.003
Near Snake Creek Pump	USGS	9/25/2000	13.1	1.7	8.5	210	239	582	0.02	39.5	34.2	104.5	6.3	11.5	246.0	0.010	0.002
Near Snake Creek Pump	USGS	10/11/2000	9.6	1.4	8.3	212	240	597	0.04	40.0	34.0	109.0	4.6	12.2	253.5	0.007	0.003
Near Snake Creek Pump	USGS	12/27/2000	2.3	22.0	7.5	237	269	648	0.12	44.4	38.2	112.5	6.6	13.3	274.5	0.010	0.161
Near Snake Creek Pump	USGS	1/18/2001	2.6	9.6	8.3	241	266	664	0.05	42.5	38.8	115.0	7.0	13.6	277.0	0.010	0.049

Location	Data Source	Sample Date	Temperature (Deg C)	Turbidity (NTU)	pH	Alkalinity Total (CaC03) (mg/L)	Hardness Total (CaCO3) (mg/L)	Dissolved Solids Total (mg/L)	Ammonia (N) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sodium (Na) (mg/L)	Potassium (K) (mg/L)	Chloride (mg/L)	Sulfate as (SO4) (mg/L)	Iron (Fe) (mg/L)	Manganese (Mn) (mg/L)
Near Snake Creek Pump	USGS	2/28/2001	2.8	16.6	8.7	250	270	672	0.04	43.3	39.2	118.0	6.9	13.9	285.0	0.010	0.008
Near Snake Creek Pump	USGS	3/20/2001	3.7	1.7	8.0	216	237	594	0.07	38.5	34.1	102.8	6.1	11.6	242.0	0.005	0.037
Near Snake Creek Pump	USGS	5/8/2001	9.1	6.4	8.3	210	243	580	0.04	42.0	33.6	101.5	5.6	11.4	231.0	0.014	0.005
Near Snake Creek Pump	USGS	6/20/2001	16.1	2.0	8.3	209	238	577	0.04	40.3	33.4	104.0	5.7	11.1	238.5	0.010	0.003
Near Snake Creek Pump	USGS	7/23/2001	23.1	11.1	8.3	207	241	581	0.04	40.5	33.7	99.3	5.9	12.4	241.0	0.010	0.004
Near Snake Creek Pump	USGS	8/22/2001	22.4	9.3	8.5	212	240	594	0.05	39.6	34.3	103.0	5.9	11.9	246.5	0.010	0.007
Near Snake Creek Pump	USGS	9/7/2001	20.4	1.8	8.5	213	248	606	0.04	41.4	35.2	106.5	6.6	12.2	251.0	0.010	0.003
Near Snake Creek Pump	USGS	9/27/2001	14.6	1.7	8.6	218	247	613	0.04	40.2	35.5	108.0	6.0	12.7	253.5	0.010	0.003
Near Snake Creek Pump	USGS	11/2/2001	4.9	8.5	8.3	237	256	644	0.04	41.2	37.2	113.0	6.4	13.7	261.0	0.010	0.001
Near Snake Creek Pump	USGS	11/20/2001	4.2	8.5	8.4	243	247	640	0.03	39.3	36.1	108.5	6.2	13.0	263.0	0.010	0.002
Near Snake Creek Pump	USGS	1/9/2002	1.6	1.5	8.0	237	262	667	0.03	41.2	38.5	114.0	6.4	14.1	290.0	0.010	0.003
Near Snake Creek Pump	USGS	2/23/2006	3.9		7.5	248	291	713	0.05	44.7	43.6	132.5	7.1	15.1	303.5	0.005	0.039
Near Snake Creek Pump	USGS	5/11/2006	10.0	27.4	8.5	202	258	621	0.04	43.1	36.5	111.0	5.9	12.9	256.0	0.006	0.003
Near Snake Creek Pump	USGS	6/15/2006	17.4		8.5	208	245	600	0.02	42.9	33.6	103.1	5.7	12.4	246.0	0.006	0.002
Near Snake Creek Pump	USGS	7/12/2006	21.1		8.5	212	244	611	0.05	41.7	33.8	102.2	6.0	12.7	251.5	0.006	0.001
Near Snake Creek Pump	USGS	8/23/2006	21.8		8.6	216	256	643	0.01	41.6	36.8	112.0	6.4	13.4	265.5	0.017	0.001
Near Snake Creek Pump	USGS	9/6/2006	20.0	23.3	8.5	219	250	650	0.02	40.1	36.2	112.0	6.1	13.8	274.0	0.011	0.002
Near Snake Creek Pump	USGS	10/25/2006	5.4	9.5	8.5	226	271	656	0.02	43.6	39.4	118.5	6.3	13.9	281.5	0.006	0.001
Near Snake Creek Pump	USGS	3/8/2007	2.8	16.7	8.2	258	301	762	0.04	46.4	45.1	138.0	7.4	15.9	323.5	0.006	0.014
Near Snake Creek Pump	USGS	5/1/2007	9.1	26.4	8.6	211	247	619	0.02	43.8	33.4	111.5	5.7	12.8	249.5	0.006	0.001
Near Snake Creek Pump	USGS	7/26/2007	23.9		8.5	211	241	600	0.02	41.6	33.3	107.5	5.8	13.4	254.5	0.005	0.003
Near Snake Creek Pump	USGS	9/5/2007	20.7	15.9	8.6	215	259	635	0.01	42.9	36.9	117.0	6.3	14.0	264.0	0.005	0.001

Location	Data Source	Sample Date	Temperature (Deg C)	Turbidity (NTU)	pH	Alkalinity Total (CaC03) (mg/L)	Hardness Total (CaCO3) (mg/L)	Dissolved Solids Total (mg/L)	Ammonia (N) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sodium (Na) (mg/L)	Potassium (K) (mg/L)	Chloride (mg/L)	Sulfate as (SO4) (mg/L)	Iron (Fe) (mg/L)	Manganese (Mn) (mg/L)
Near Snake Creek Pump	USGS	10/17/2007	10.0	9.8	8.7	222	252	653	0.02	41.4	36.1	112.5	6.2	14.3	276.0	0.008	0.001
Near Snake Creek Pump	USGS	2/26/2008	2.9	6.5	8.5	254	299	742	0.02	47.8	43.5	133.5	7.2	15.9	303.0	0.008	0.004
Near Snake Creek Pump	USGS	5/20/2008	11.3	6.7	8.4	211	257	607	0.02	45.1	35.1	105.5	6.0	13.6	252.5	0.008	0.006
Near Snake Creek Pump	USGS	7/22/2008	21.5		8.4	214	247	628	0.02	42.4	34.4	108.0	6.2	14.2	265.0	0.008	0.001
Near Snake Creek Pump	USGS	9/3/2008	18.8	16.3	8.4	219	252	628	0.02	42.9	35.0	112.0	6.3	14.2	263.5	0.008	0.001
Near Snake Creek Pump	USGS	11/4/2008	6.2	19.0	8.6	225	266	647	0.02	44.3	37.6	118.5	6.6	14.7	276.5	0.004	0.001
Near Snake Creek Pump	USGS	2/24/2009	2.4	25.2	8.2	253	294	730	0.03	48.3	42.1	138.5	7.0	16.1	308.0	0.004	0.038
Near Snake Creek Pump	USGS	5/14/2009	8.4	21.8	8.4	212	249	603	0.02	42.9	34.4	103.0	5.6	13.9	259.5	0.004	0.002
Near Snake Creek Pump	USGS	7/21/2009	19.3	15.6	8.5	216	259	631	0.02	41.4	37.8	110.0	6.6	14.3	271.5	0.004	0.000
Near Snake Creek Pump	USGS	9/1/2009	19.4	17.8	8.6	212	256	615	0.02	43.4	35.9	112.0	6.4	14.6	275.0	0.003	0.001
Near Snake Creek Pump	USGS	10/20/2009	6.1	11.5	8.7	219	266	627	0.02	44.5	37.5	116.0	6.4	14.8	279.0	0.008	0.001
Near Snake Creek Pump	USGS	2/19/2010	1.3		6.9	246	293	705	0.06	47.5	42.5	126.5	6.9	16.4	294.5	0.006	0.092
Near Snake Creek Pump	USGS	5/20/2010	11.2		8.6	207	254	581	0.02	45.9	33.7	102.5	5.7	13.6	248.0	0.006	0.003
Near Snake Creek Pump	USGS	7/21/2010	21.5		8.6	211	251	597	0.06	42.8	34.9	99.9	5.7	14.2	255.5	0.005	0.034
Near Snake Creek Pump	USGS	9/7/2010	17.5		8.6	208	241	597	0.02	39.6	34.6	106.0	6.0	14.2	263.0	0.005	0.001
Near Snake Creek Pump	USGS	10/13/2010	13.1		8.5	213	234	617	0.02	38.1	33.7	108.5	5.9	14.2	262.0	0.004	0.007
Near Snake Creek Pump	USGS	2/16/2011	2.2		7.7	233	268	662	0.06	44.2	38.4	122.5	6.5	15.0	289.5	0.006	0.061
Bouy 17	USGS	2/23/2006	4.1		8.2	252	304	725	0.04	47.1	45.3	138.5	7.5	15.7	309.5	0.006	0.001
Bouy 17	USGS	5/11/2006	10.7		8.5	212	265	659	0.04	41.1	39.5	118.5	6.3	13.7	276.5	0.006	0.002
Bouy 17	USGS	6/15/2006	17.5		8.5	222	261	645	0.02	41.3	38.2	117.0	6.3	13.5	274.5	0.006	0.001
Bouy 17	USGS	7/12/2006	22.9		8.7	223	254	665	0.01	40.0	37.4	114.0	6.5	13.7	277.0	0.006	0.001
Bouy 17	USGS	8/23/2006	21.8		8.6	224	259	667	0.01	40.2	38.6	118.0	6.6	14.0	280.5	0.006	0.001
Bouy 17	USGS	9/6/2006	20.1		8.6	224	258	671	0.02	40.1	38.3	117.5	6.5	14.2	283.5	0.006	0.001
Bouy 17	USGS	10/25/2006	3.5		8.5	229	270	664	0.02	43.4	39.2	121.0	6.3	14.0	284.5	0.006	0.001
Bouy 17	USGS	3/8/2007	2.1		8.3	259	294	770	0.04	46.0	43.6	139.0	7.3	15.8	325.5	0.006	0.002
Bouy 17	USGS	5/1/2007	12.0		8.6	223	255	659	0.02	41.2	37.0	123.0	6.1	13.9	276.5	0.006	0.001

Location	Data Source	Sample Date	Temperature (Deg C)	Turbidity (NTU)	pH	Alkalinity Total (CaC03) (mg/L)	Hardness Total (CaCO3) (mg/L)	Dissolved Solids Total (mg/L)	Ammonia (N) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sodium (Na) (mg/L)	Potassium (K) (mg/L)	Chloride (mg/L)	Sulfate as (SO4) (mg/L)	Iron (Fe) (mg/L)	Manganese (Mn) (mg/L)
Bouy 17	USGS	7/26/2007	24.9		8.5	216	245	625	0.01	41.0	34.6	110.5	6.1	13.8	265.0	0.006	0.002
Bouy 17	USGS	9/5/2007	20.3		8.5	219	258	643	0.02	41.7	37.2	120.0	6.4	14.1	269.5	0.006	0.001
Bouy 17	USGS	10/17/2007	9.2		8.7	224	265	661	0.02	43.0	38.3	122.5	6.7	14.2	275.5	0.008	0.001
Bouy 17	USGS	2/26/2008	3.4		8.5	262	306	771	0.02	48.7	44.9	136.5	7.4	16.4	314.0	0.006	0.003
Bouy 17	USGS	5/20/2008	12.4		8.4	224	267	662	0.02	43.0	38.8	116.5	6.3	14.6	279.0	0.008	0.004
Bouy 17	USGS	7/22/2008	22.1		8.5	221	254	657	0.02	41.7	36.4	114.0	6.4	14.6	279.5	0.008	0.001
Bouy 17	USGS	9/3/2008	17.9		8.5	228	265	646	0.01	43.1	38.3	119.0	6.9	14.6	277.5	0.008	0.001
Bouy 17	USGS	11/4/2008	5.4		8.6	227	272	663	0.01	45.0	38.7	122.5	6.7	14.8	278.5	0.004	0.001
Bouy 17	USGS	2/24/2009	1.6		8.2	252	297	740	0.04	48.7	42.5	150.0	7.2	16.5	305.5	0.004	0.001
Bouy 17	USGS	5/19/2009	10.5		8.4	217	270	625	0.02	45.2	38.2	110.0	6.0	14.4	272.5	0.004	0.001
Bouy 17	USGS	7/21/2009	19.9		8.6	218	261	636	0.02	40.7	38.8	111.5	6.8	14.5	275.5	0.005	0.001
Bouy 17	USGS	9/1/2009	19.6		8.7	216	262	617	0.02	43.5	37.2	116.5	6.7	15.1	283.0	0.004	0.002
Bouy 17	USGS	10/20/2009	4.7		8.7	225	265	634	0.02	44.0	37.7	115.5	6.4	14.9	282.5	0.005	0.001
Bouy 17	USGS	2/18/2010	0.7		6.6	255	303	745	0.02	48.4	44.1	134.0	7.6	17.2	312.0	0.005	0.004
Bouy 17	USGS	5/20/2010	13.4		8.6	218	254	633	0.02	41.2	36.4	110.5	5.9	14.6	270.0	0.006	0.004
Bouy 17	USGS	7/21/2010	22.3		8.7	215	258	613	0.02	42.7	36.8	108.5	6.0	14.8	275.5	0.005	0.001
Bouy 17	USGS	9/7/2010	16.8		8.7	216	248	625	0.02	40.4	35.6	114.5	6.2	14.4	268.5	0.009	0.002
Bouy 17	USGS	10/13/2010	13.1		8.5	216	243	613	0.01	39.7	35.1	113.5	6.0	14.3	267.5	0.008	0.001
Bouy 17	USGS	2/15/2011	1.9		7.9	239	272	688	0.04	44.6	39.0	124.5	6.3	15.6	295.0	0.003	0.006
Game Management Area	USGS	3/8/2007	2.6		8.2	260	302	769	0.04	47.0	44.7	139.0	7.4	16.1	326.0	0.006	0.003
Game Management Area	USGS	5/1/2007	11.4		8.6	224	258	711	0.02	41.7	37.3	122.5	6.2	13.9	278.0	0.006	0.001
Game Management Area	USGS	7/26/2007	25.1		8.5	214	243	617	0.02	40.7	34.3	110.0	5.9	13.4	261.0	0.006	0.001
Game Management Area	USGS	9/5/2007	20.1		8.6	218	258	644	0.01	42.1	37.0	118.5	6.3	14.0	267.0	0.006	0.001
Game Management Area	USGS	10/17/2007	9.6		8.7	225	258	662	0.01	41.9	37.1	116.0	6.3	14.3	280.0	0.008	0.001
Game Management Area	USGS	2/26/2008	2.9		8.5	258	303	753	0.02	48.4	44.2	136.0	7.4	16.0	308.0	0.006	0.002
Game Management Area	USGS	5/20/2008	11.9		8.4	223	267	657	0.02	43.7	38.2	115.5	6.3	14.4	275.0	0.008	0.004

Location	Data Source	Sample Date	Temperature (Deg C)	Turbidity (NTU)	pH	Alkalinity Total (CaC03) (mg/L)	Hardness Total (CaCO3) (mg/L)	Dissolved Solids Total (mg/L)	Ammonia (N) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sodium (Na) (mg/L)	Potassium (K) (mg/L)	Chloride (mg/L)	Sulfate as (SO4) (mg/L)	Iron (Fe) (mg/L)	Manganese (Mn) (mg/L)
Game Management Area	USGS	7/22/2008	22.8		8.5	218	256	657	0.02	41.9	36.7	114.5	6.5	14.5	277.5	0.008	0.001
Game Management Area	USGS	9/3/2008	18.3		8.5	226	266	647	0.01	42.7	38.7	119.0	7.0	14.7	276.5	0.008	0.001
Game Management Area	USGS	11/4/2008	5.8		8.6	230	276	654	0.01	44.6	40.0	125.0	7.0	14.7	285.5	0.004	0.001
Game Management Area	USGS	2/24/2009	1.6		8.2	247	293	711	0.05	48.1	42.0	148.5	7.2	16.2	300.5	0.004	0.001
Game Management Area	USGS	5/14/2009	9.7		8.4	223	265	639	0.01	42.7	38.3	116.0	6.2	14.8	284.5	0.004	0.001
Game Management Area	USGS	7/21/2009	19.9		8.5	217	259	635	0.02	39.9	38.7	111.0	6.7	14.6	274.5	0.004	0.002
Game Management Area	USGS	9/1/2009	19.7		8.6	215	261	626	0.02	43.5	37.0	116.0	6.6	15.0	281.5	0.003	0.001
Game Management Area	USGS	10/20/2009	5.5		8.7	225	267	631	0.02	43.8	38.3	118.5	6.5	14.9	286.5	0.004	0.002
Game Management Area	USGS	2/18/2010	0.8		7.0	250	303	743	0.02	48.5	44.1	131.5	7.3	16.7	304.5	0.006	0.004
Game Management Area	USGS	5/20/2010	13.3		8.6	218	255	633	0.02	41.7	36.5	110.5	5.9	14.5	269.0	0.005	0.001
Game Management Area	USGS	7/21/2010	22.6		8.8	213	250	609	0.02	40.8	35.9	105.0	6.0	14.6	269.0	0.005	0.001
Game Management Area	USGS	9/7/2010	17.1		8.6	211	244	612	0.02	39.4	35.2	110.5	6.0	14.3	267.0	0.004	0.001
Game Management Area	USGS	10/13/2010	13.4		8.6	214	249	615	0.01	39.7	36.4	112.0	6.2	14.2	266.5	0.015	0.002
Game Management Area	USGS	2/15/2011	1.1		8.2	238	267	690	0.03	42.8	38.9	123.5	6.4	15.3	298.0	0.009	0.002

Table B-3: New Johns Lake Water Quality Table

Data Source	Sample Date	Temperature (Deg C)	Turbidity (NTU)	pH	Alkalinity Total (CaC03) (mg/L)	Hardness Total (CaCO3) (mg/L)	Dissolved Solids Total (mg/L)	Ammonia (N) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sodium (Na) (mg/L)	Potassium (K) (mg/L)	Chloride (mg/L)	Sulfate as (SO4) (mg/L)	Iron (Fe) (mg/L)	Manganese (Mn) (mg/L)
USGS	5/23/2007	15.5	n/a	8.5	261	619	1350	0.09	81.3	101.0	176.0	19.0	18.4	687.0	5.200	9.980
USGS	8/29/2007	18.4	n/a	8.5	249	622	1370	0.02	80.3	102.0	185.0	20.5	19.0	717.0	5.000	1.030
USGS	5/29/2008	13.4	n/a	8.5	262	664	1470	0.05	85.6	109.0	192.0	21.4	20.5	799.0	8.000	7.320
USGS	9/2/2008	18.6	n/a	8.3	270	548	1380	0.09	65.1	93.7	192.0	18.7	21.5	745.0	8.000	3.350
USGS	5/20/2009	13.0	n/a	7.8	246	543	1210	0.04	69.8	89.5	161.0	16.4	19.1	652.0	4.200	5.910
USGS	9/2/2009	19.5	n/a	8.5	254	538	1230	0.02	69.6	88.5	166.0	17.6	19.1	657.0	3.600	1.800
USGS	2/10/2010	0.6	n/a	8.0	323	526	1180	0.12	69.9	85.4	165.0	16.0	21.8	582.0	27.800	19.500
USGS	5/19/2010	14.2	n/a	8.3												
USGS	5/19/2010	14.2	n/a	8.5												
USGS	5/19/2010	14.1	n/a	8.5												
USGS	5/19/2010	14.1	n/a	8.5												
USGS	5/19/2010	14.1	n/a	8.5	259	592	1250	0.02	85.0	92.1	159.0	17.1	17.2	659.0	6.000	10.100
USGS	5/19/2010	13.9	n/a	8.5												
USGS	5/19/2010	13.8	n/a	8.5												
USGS	7/19/2010	22.9	n/a	8.3	248	586	1220	0.04	84.2	91.2	149.0	17.3	17.2	664.0	5.400	3.120
USGS	8/31/2010	19.2	n/a	8.4	239	579	1250	0.06	80.3	92.0	164.0	18.5	18.4	683.0	4.000	4.960
USGS	10/19/2010	10.8	n/a	8.3	247	543	1230	0.06	72.4	88.0	160.0	17.6	17.9	662.0	4.800	6.940
USGS	2/17/2011	1.5	n/a	8.3	290	612	1360	0.23	86.3	96.3	173.0	19.9	19.7	728.0	8.600	26.600
USGS	5/11/2011	9.5	n/a	8.1	248	600	1230	0.02	89.8	91.2	148.0	17.4	16.0	638.0	6.100	7.800
USGS	7/12/2011	22.8	n/a	8.1	244	576	1150	0.06	82.8	89.7	138.0	17.3	15.5	614.0	6.200	2.320
USGS	9/26/2011	13.1	n/a	8.1	233	605	1230	0.01	90.3	92.1	136.0	17.7	15.4	651.0	4.500	1.500

Appendix C Water Treatment Standards

Table C-1: Option 1 – Disinfection

Unit Process	Units	ENDAWS Design Parameter Used	10-States Standards Requirement	Other Reputable Source Recommendation
Chlorine Disinfection				
Number of Chlorine Feeders (including 1 redundant unit)	units	3	minimum 2	
Log Removal Giardia	log	>3.0		
Log Removal Viruses	log	>4.0		
Log Removal Cryptosporidium	log	0		
Log Removal Myxobolus cerebralis	log	>3.0		
Design Chlorine Dosage at Peak Flow	mg/L	8		
Average Chlorine Dosage at Peak Flow	mg/L	4.5	minimum 2.0	
Supply of Chlorine	days	30	minimum 30	
Number of Contact Basins	tanks	4	minimum 2	
HDT	minutes	215		
Velocity	ft/min	22.2		
Baffling Factor	ratio	0.8		
Chloramine Generation				
Number of Ammonia Feeders (including 1 redundant unit)	units	5	minimum 2	
Max Ammonia Dosage at Peak Flow	mg/L	1.0		0.2 to 1.5
% of Ammonia to Chlorine	NH_3/Cl_2	0.25		25 to 30% of Cl
Storage Volume for Ammonia (storage volume/tanker truck volume)	ratio	1.5	minimum 1.5	

Table C- 2: Option 2 – Enhanced Disinfection

Unit Process	Units	ENDAWS Design Parameter Used	10-States Standards Requirement	Other Reputable Source Recommendation
UV Disinfection				
Number of UV Reactor Units (including 1 redundant unit)	units	11		
Design UVT	%	70		
UV Dosage per Reactor	mJ/cm^2	40		
Log Removal Giardia	log	>3.0		
Log Removal Viruses	log	>3.0		
Log Removal Cryptosporidium	log	0		
Log Removal Myxobolus cerebralis	log	3.0		
Chlorine Disinfection				
Number of Chlorine Feeders (including 1 redundant unit)	units	3	minimum 2	
Log Removal Giardia	log	>3.0		
Log Removal Viruses	log	>4.0		
Log Removal Cryptosporidium	log	0		
Log Removal Myxobolus cerebralis	log	>3.0		
Design Chlorine Dosage at Peak Flow	mg/L	8		
Average Chlorine Dosage at Peak Flow	mg/L	4.5	minimum 2.0	
Supply of Chlorine	days	30	minimum 30	
Number of Contact Basins	tanks	4		
HDT	minutes	215		
Velocity	ft/min	22.2		
Baffling Factor	ratio	0.8		
Chloramine Generation				
Number of Ammonia Feeders (including 1 redundant unit)	units	5	minimum 2	
Max Ammonia Dosage at Peak Flow	mg/L	1.0		0.2 to 1.5
% of Ammonia to Chlorine	NH_3/Cl_2	0.25		25 to 30% of Cl
Storage Volume for Ammonia (storage volume/tanker truck volume)	ratio	1.5	minimum 1.5	

Table C-3: Option 3 – Conventional Treatment

Unit Process	Units	ENDAWS Design Parameter Used	10-States Standards Requirement	Other Reputable Source Recommendation
Rapid Mix				
Number of Rapid Mix Tanks (including 1 redundant unit)	tanks	6	minimum 2	
Number of Chemical Feeders (including 1 redundant unit)	units	6	minimum 2	
Ferric Chloride Design Dosage	mg/L	50		
Ferric Chloride Average Dosage	mg/L	15		
Storage Volume for Coagulant (storage volume/tanker truck volume)	ratio	1.5	minimum 1.5	
Flocculation				
Number of Flocculation Tanks	tanks	12	minimum 2	
Detention time per train - 11 Basins Running	minutes	30	minimum 30	
Cross Sectional Flow Velocity - 5 Basins Running	ft/min	2.5	0.5 < V < 1.5	
Detention time per train - 12 Basins Running	minutes	32.7	minimum 30	
Cross Sectional Flow Velocity - 12 Basins Running	ft/min	2.42	0.5 < V < 1.5	
Velocity Gradient - Stage 1		40		
Velocity Gradient - Stage 2		20		
Velocity Gradient - Stage 3		10		
D/T Ratio (impeller diameter/tank diameter)	ratio	0.45		0.3 to 0.6 (AWWA,MWH)
Sedimentation (Inclined Plate Settlers)				
Number of Settling Tanks	tanks	12	minimum 2	
Loading Rate per Settling Tank - 11 Basins Running	gpm/ft^2	0.3	maximum 0.5	
Loading Rate per Settling Tank - 12 Basins Running	gpm/ft^3	0.275	maximum 0.5	
Media Filtration				
Number of Media Filter Beds (including 1 redundant unit)	tanks	12		
Loading Rate per Media Filter - 11 Basins Running	gpm/ft^2	8		4 to 10
Loading Rate per Media Filter - 12 Basins Running	gpm/ft^2	7.33		4 to 10
Sand Bed Depth	in	12		
Anthracite Bed Depth	in	18		
L:W Ratio	ft	1.75		
UV Disinfection				
Number of UV Reactor Units (including 1 redundant unit)	units	11		
Design UVT	%	70		
UV Design Dosage per Reactor	mJ/cm^2	40		
UV Operating Dosage per Reactor	mJ/cm^2	25		
Log Removal Giardia	log	3.0		
Log Removal Viruses	log	0		
Log Removal Cryptosporidium	log	3.0		

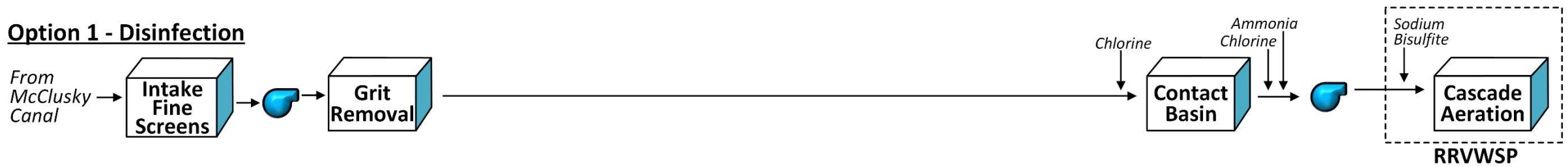
Unit Process	Units	ENDAWS Design Parameter Used	10-States Standards Requirement	Other Reputable Source Recommendation
Log Removal Myxobolus cerebralis	log	4.0		
Chlorine Disinfection				
Number of Chlorine Feeders (including 1 redundant unit)	units	3	minimum 2	
Log Removal Giardia	log	0.1		
Log Removal Viruses	log	4.0		
Log Removal Cryptosporidium	log	0		
Log Removal Myxobolus cerebralis	log	0		
Design Chlorine Dosage at Peak Flow	mg/L	8		
Average Chlorine Dosage at Peak Flow	mg/L	4.5	minimum 2.0	
Supply of Chlorine	days	30	minimum 30	
Number of Contact Basins	tanks	2		
HDT	minutes	20.2		
Velocity	ft/min	22.2		
Baffling Factor	ratio	0.66		
Chloramine Generation				
Number of Ammonia Feeders (including 1 redundant unit)	units	3	minimum 2	
Max Ammonia Dosage at Peak Flow	mg/L	1.0		0.2 to 1.5
% of Ammonia to Chlorine	NH_3/Cl_2	0.25		25 to 30% of Cl
Storage Volume for Ammonia (storage volume/tanker truck volume)	ratio	1.5	minimum 1.5	

Table C-4: Option 4 - Advanced Treatment

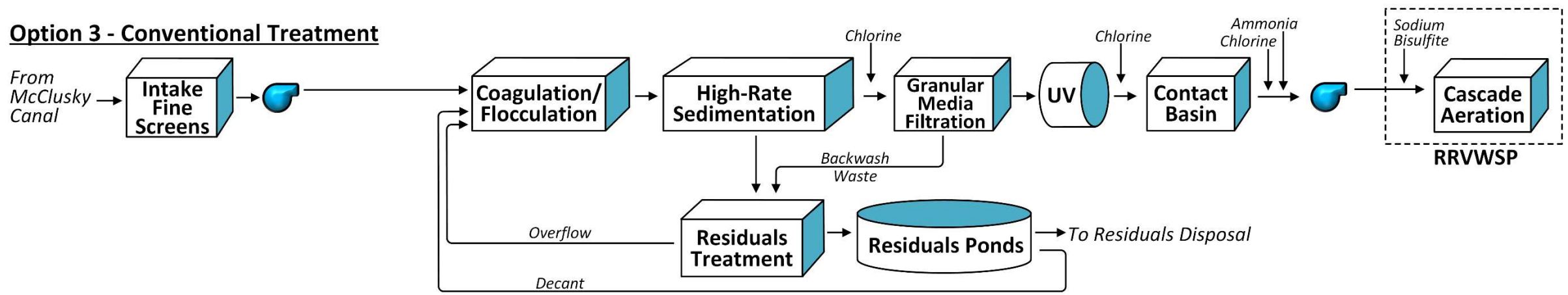
Unit Process	Units	ENDAWS Design Parameter Used	10-States Standards Requirement	Other Reputable Source Recommendation
Rapid Mix				
Number of Rapid Mix Tanks (including 1 redundant unit)	tanks	6	minimum 2	
Number of Chemical Feeders (including 1 redundant unit)	units	6	minimum 2	
Ferric Chloride Design Dosage	mg/L	50		
Ferric Chloride Average Dosage	mg/L	15		
Storage Volume for Coagulant (storage volume/tanker truck volume)	ratio	1.5	minimum 1.5	
Flocculation				
Number of Flocculation Tanks	tanks	12	minimum 2	
Detention time per train - 11 Basins Running	minutes	30	minimum 30	
Cross Sectional Flow Velocity - 5 Basins Running	ft/min	2.5	0.5 < V < 1.5	
Detention time per train - 12 Basins Running	minutes	32.7	minimum 30	
Cross Sectional Flow Velocity - 12 Basins Running	ft/min	2.42	0.5 < V < 1.5	
Velocity Gradient - Stage 1		40		
Velocity Gradient - Stage 2		20		
Velocity Gradient - Stage 3		10		
D/T Ratio (impeller diameter/tank diameter)	ratio	0.45		0.3 to 0.6 (AWWA,MWH)
Sedimentation (Inclined Plate Settlers)				
Number of Settling Tanks	tanks	12	minimum 2	
Loading Rate per Settling Tank - 11 Basins Running	gpm/ft^2	0.3	maximum 0.5	
Loading Rate per Settling Tank - 12 Basins Running	gpm/ft^3	0.275	maximum 0.5	
Membrane Filtration				
Number of Skids	#	87		
Area per Module	ft^2	375		4 to 10
Flux	gpm/ft^2	30		4 to 10
Recovery	%	95		
UV Disinfection				
Number of UV Reactor Units (including 1 redundant unit)	units	11		
Design UVT	%	70		
UV Design Dosage per Reactor	mJ/cm^2	40		
UV Operating Dose per Reactor	mJ/cm^2	25		
Log Removal Giardia	log	3.0		
Log Removal Viruses	log	0		
Log Removal Cryptosporidium	log	3.0		
Log Removal Myxobolus cerebralis	log	4.0		

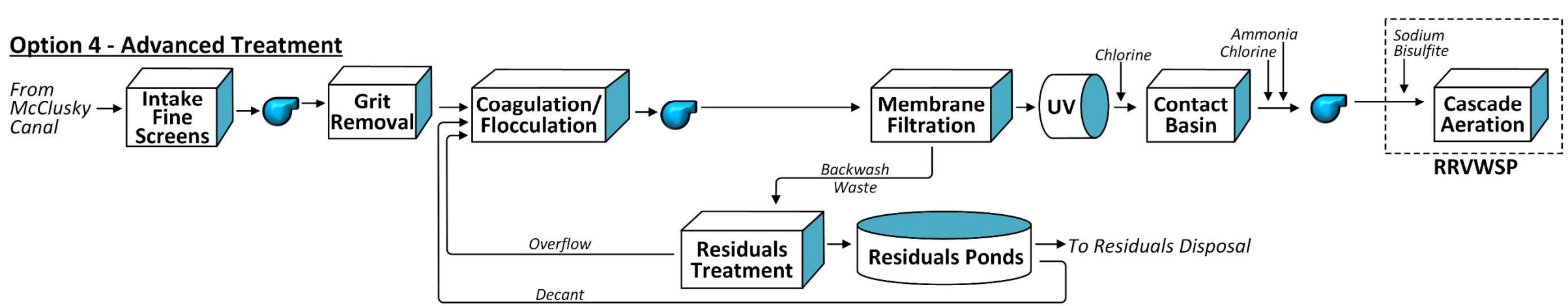
Unit Process	Units	ENDAWS Design Parameter Used	10-States Standards Requirement	Other Reputable Source Recommendation
Chlorine Disinfection				
Number of Chlorine Feeders (including 1 redundant unit)	units	3	minimum 2	
Log Removal Giardia	log	0.1		
Log Removal Viruses	log	4.0		
Log Removal Cryptosporidium	log	0		
Log Removal Myxobolus cerebralis	log	0		
Design Chlorine Dosage at Peak Flow	mg/L	8		
Average Chlorine Dosage at Peak Flow	mg/L	4.5	minimum 2.0	
Supply of Chlorine	days	30	minimum 30	
Number of Contact Basins	tanks	2		
HDT	minutes	20.2		
Velocity	ft/min	22.2		
Baffling Factor	ratio	0.66		
Chloramine Generation				
Number of Ammonia Feeders (including 1 redundant unit)	units	3	minimum 2	
Max Ammonia Dosage at Peak Flow	mg/L	1		0.2 to 1.5
% of Ammonia to Chlorine	NH_3/Cl_2	0.25		25 to 30% of Cl
Storage Volume for Ammonia (storage volume/tanker truck volume)	ratio	1.5	minimum 1.5	

Appendix D Process Flow Diagrams

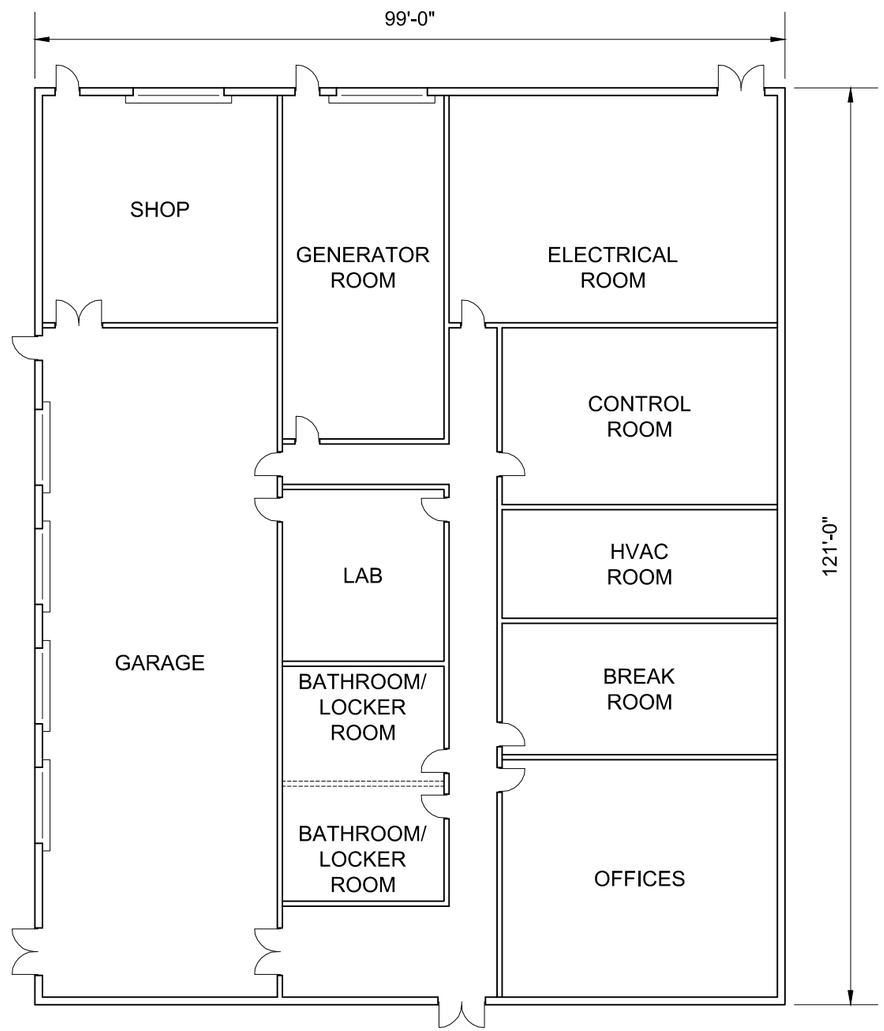

Option 1 - Disinfection
From McClusky Canal
Intake Fine Screens
Grit Removal
Chlorine
Contact Basin
Ammonia Chlorine
Sodium Bisulfite
Cascade Aeration
RRVWSP

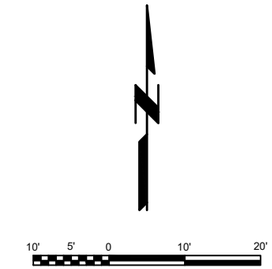
Option 2 - Enhanced Disinfection
From McClusky Canal
Intake Fine Screens
Grit Removal
UV
Chlorine
Contact Basin
Ammonia Chlorine
Sodium Bisulfite
Cascade Aeration
RRVWSP


Option 3 - Conventional Treatment
From McClusky Canal
Intake Fine Screens
Coagulation/ Flocculation
High-Rate Sedimentation
Chlorine
Granular Media Filtration
UV
Chlorine
Contact Basin
Ammonia Chlorine
Sodium Bisulfite
Cascade Aeration
RRVWSP
Backwash Waste
Overflow
Residuals Treatment
Residuals Ponds
To Residuals Disposal
Decant


Option 4 - Advanced Treatment
From McClusky Canal
Intake Fine Screens
Grit Removal
Coagulation/ Flocculation
Membrane Filtration
UV
Chlorine
Contact Basin
Ammonia Chlorine
Sodium Bisulfite
Cascade Aeration
RRVWSP
Backwash Waste
Overflow
Residuals Treatment
Residuals Ponds
To Residuals Disposal
Decant

Appendix E Water Treatment Plant Conceptual Layouts



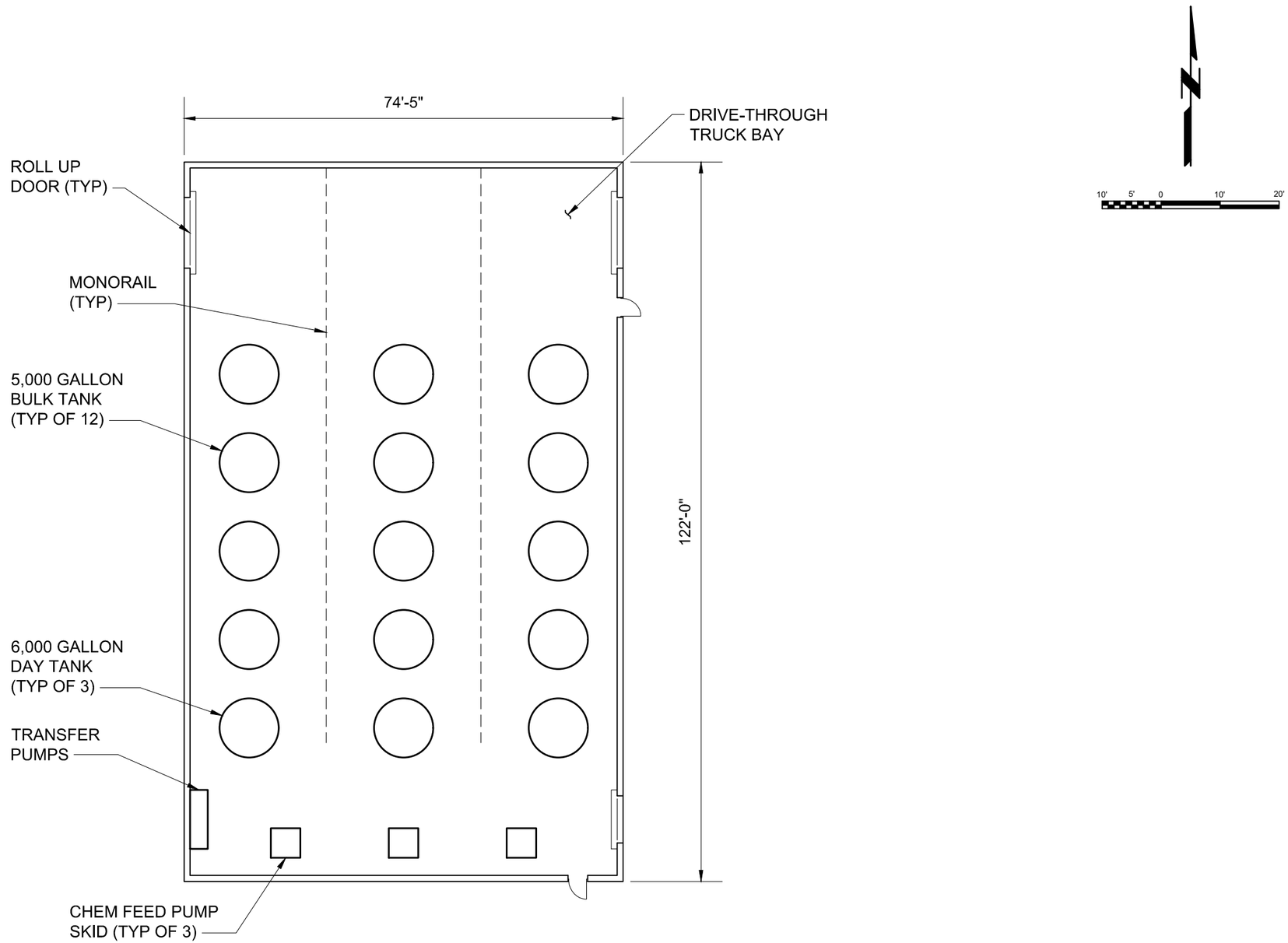


EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BIOTA WTP

OPTION 1 - DISINFECTION
OPERATIONS AND MAINTENANCE BUILDING

E-1

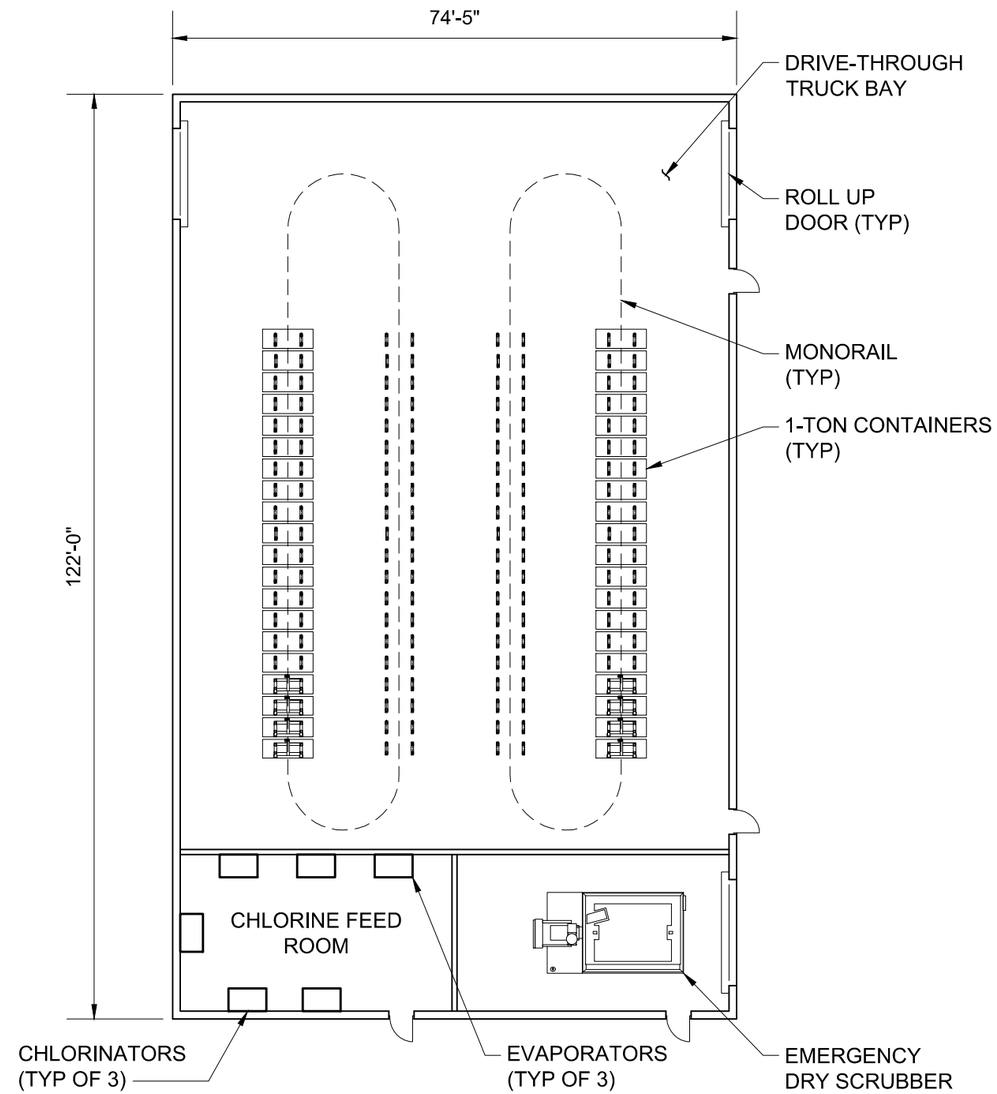


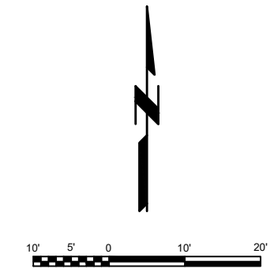
EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BIOTA WTP

OPTION 1 - DISINFECTION
BULK SODIUM HYPOCHLORITE

E-2



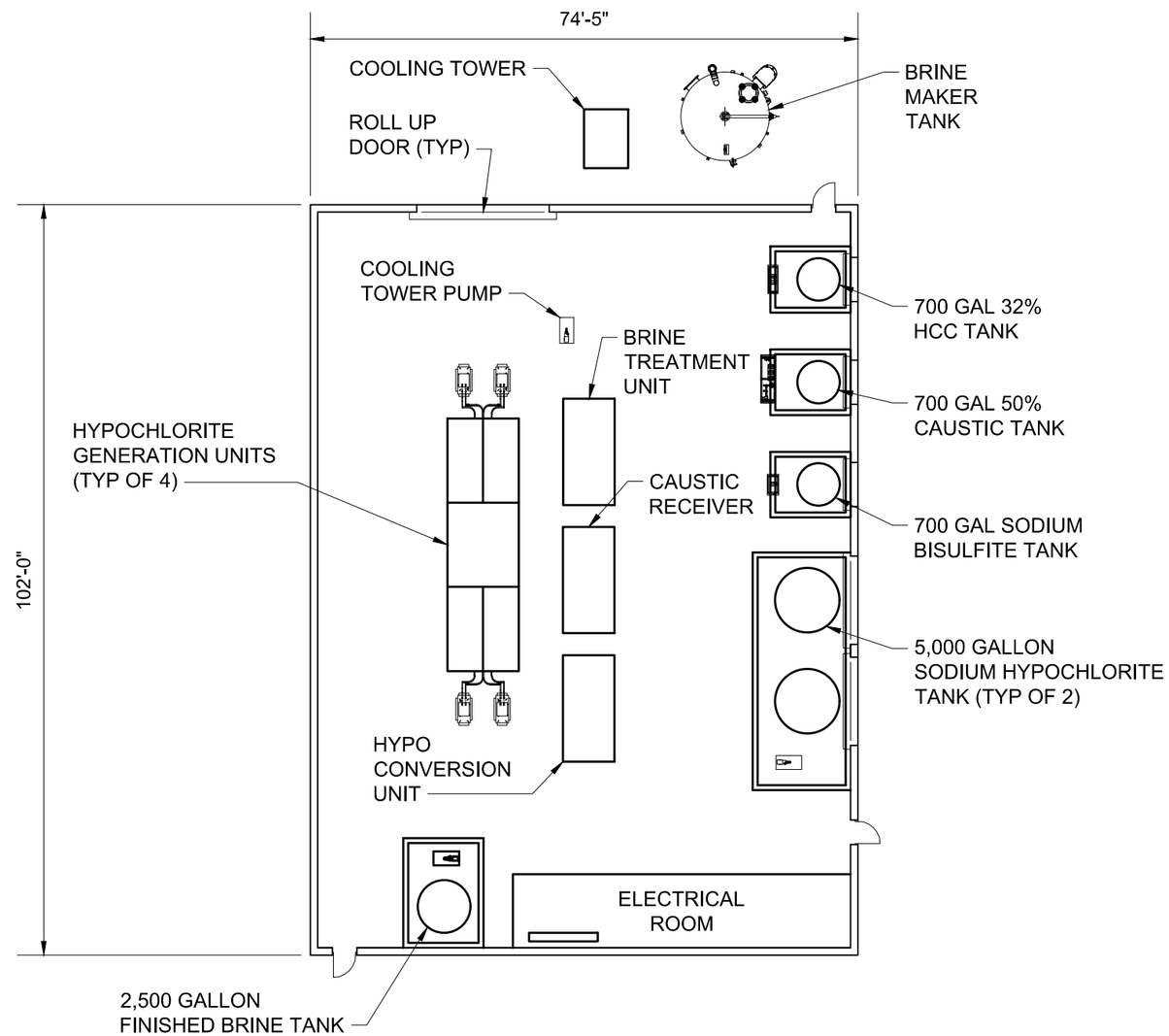


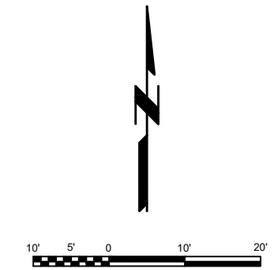
EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BIOTA WTP

OPTION 1 - DISINFECTION
CHLORINE 1-TON CONTAINERS

E-3





GARRISON DIVERSION

EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BUREAU OF RECLAMATION

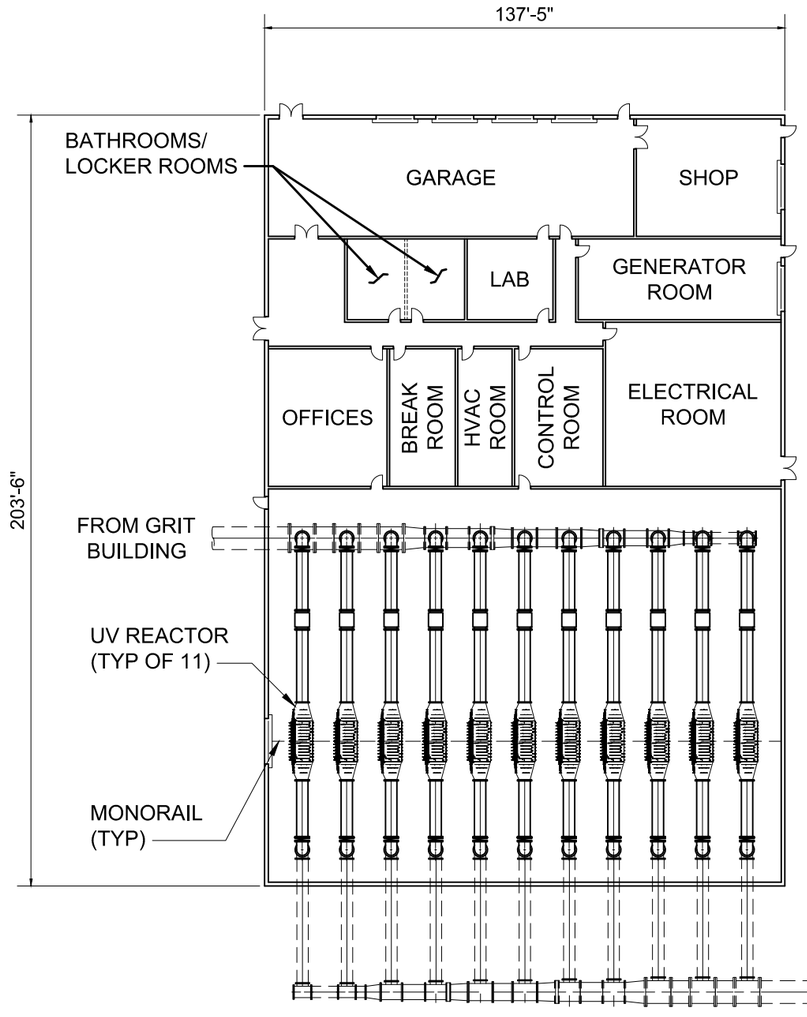
BLACK & VEATCH

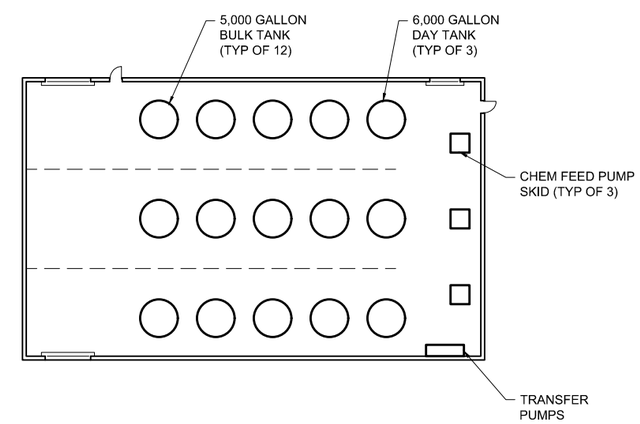
AE2S

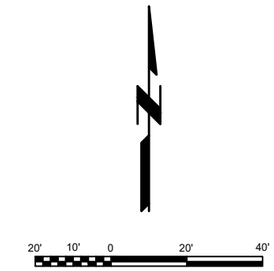
BIOTA WTP

OPTION 1 - DISINFECTION
ON-SITE HYPO GENERATION

E-4





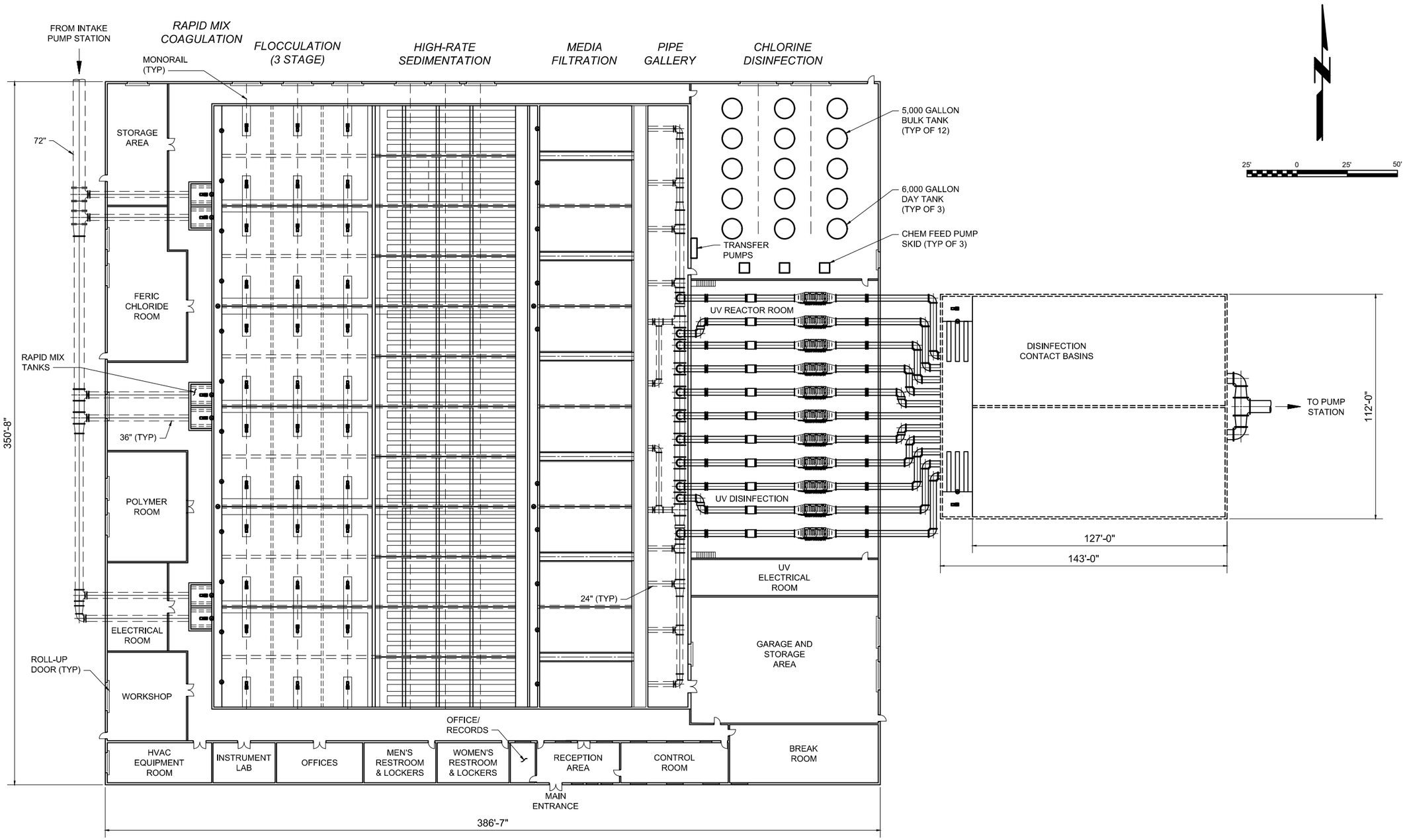


EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BIOTA WTP

OPTION 2 - ENHANCED DISINFECTION
PLAN LAYOUT

E-5

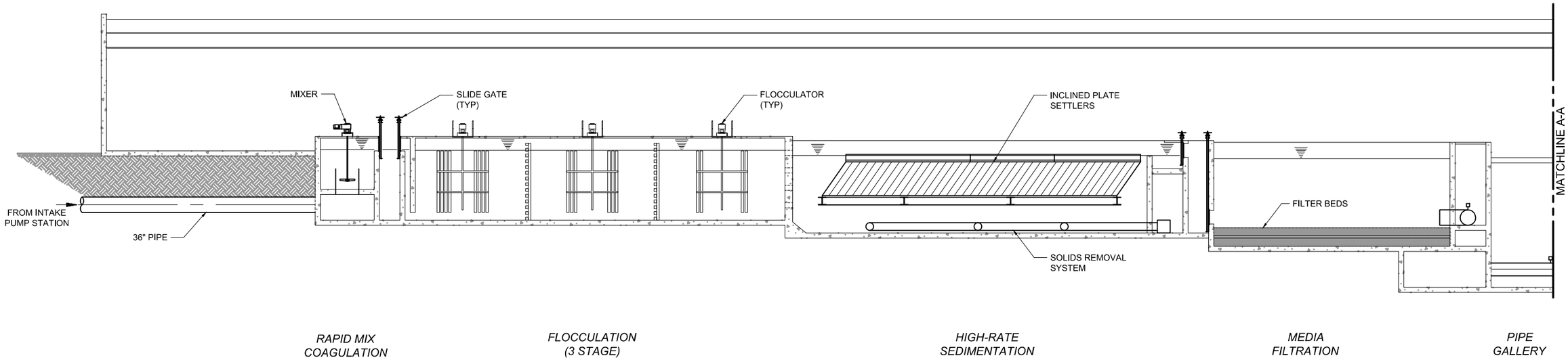


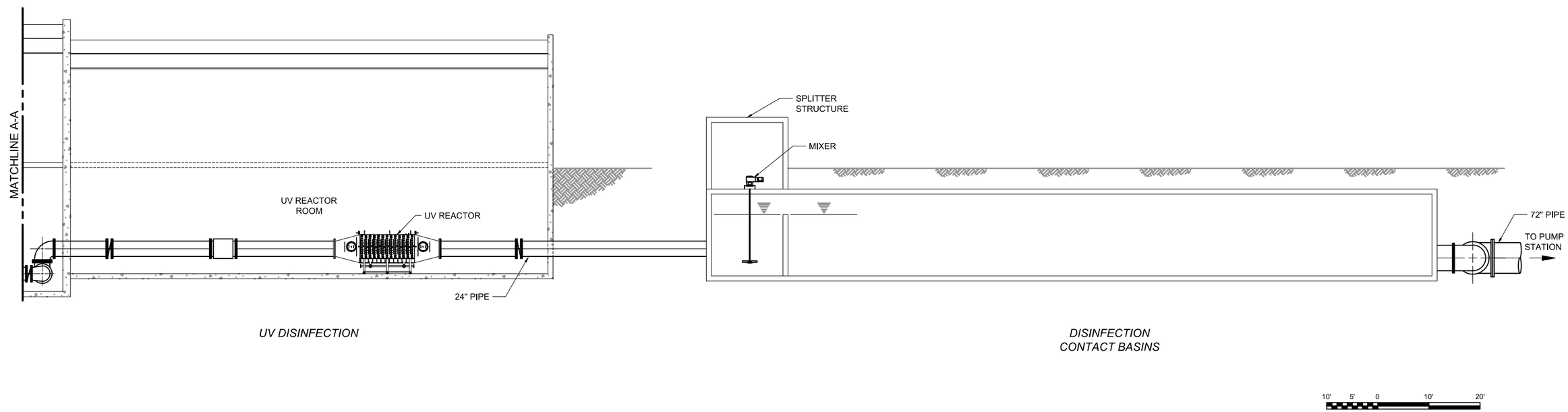
EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BIOTA WTP

OPTION 3 - CONVENTIONAL TREATMENT
PLAN VIEW

E-6



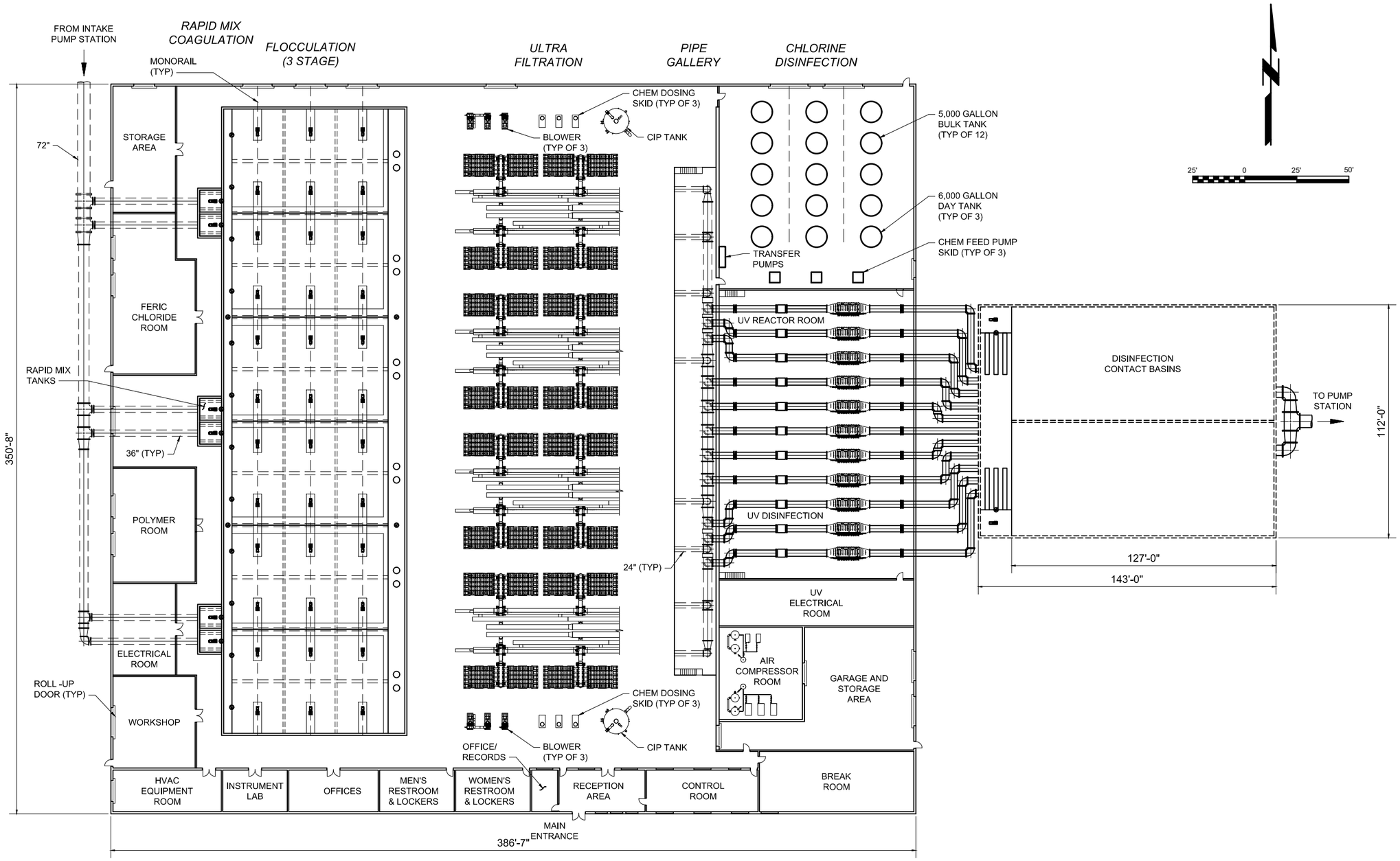


EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BIOTA WTP

OPTION 3 - CONVENTIONAL TREATMENT
SECTION VIEW

E-7

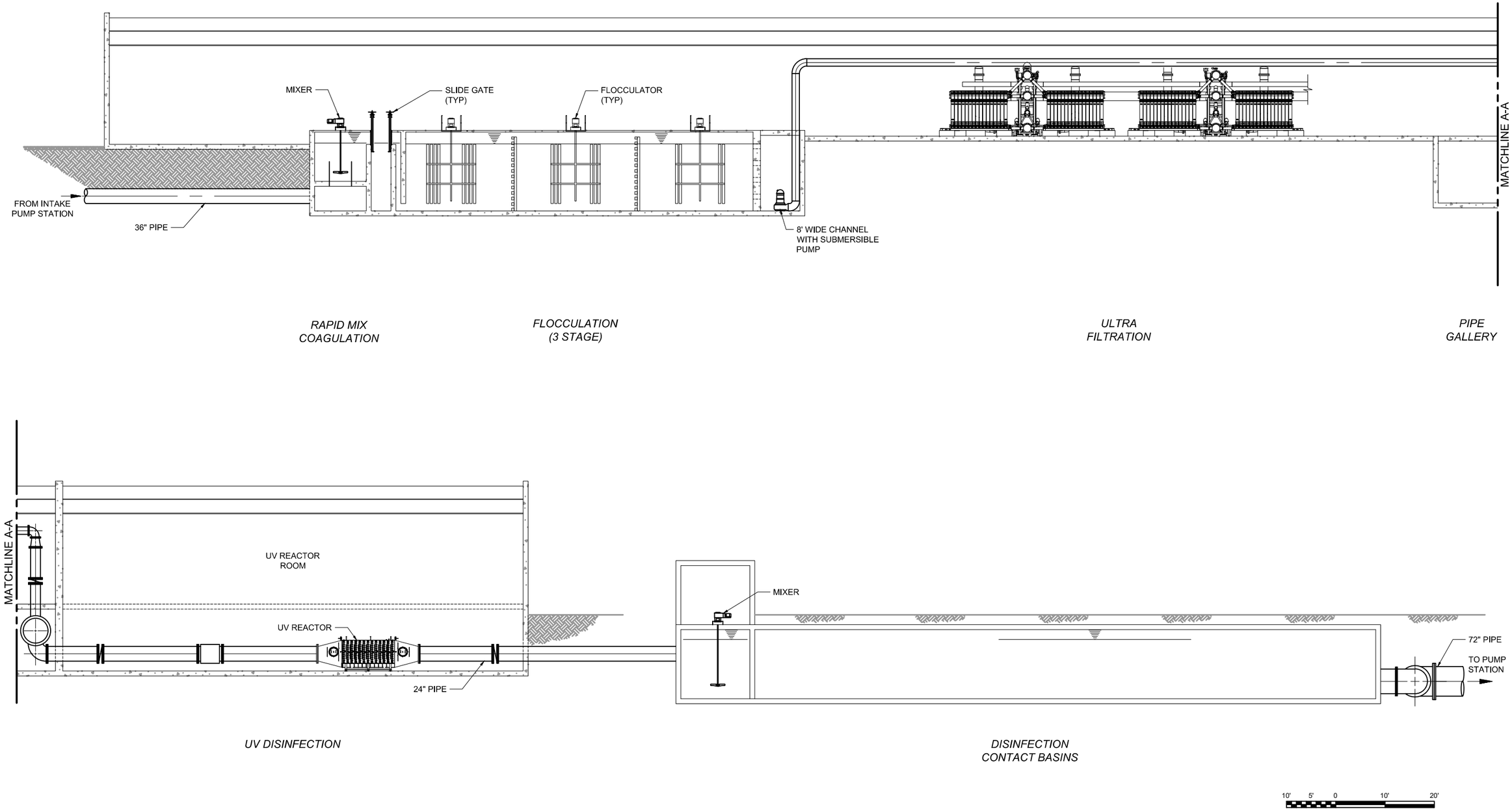


EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BIOTA WTP

OPTION 4 - ADVANCED TREATMENT
PLAN VIEW

E-8



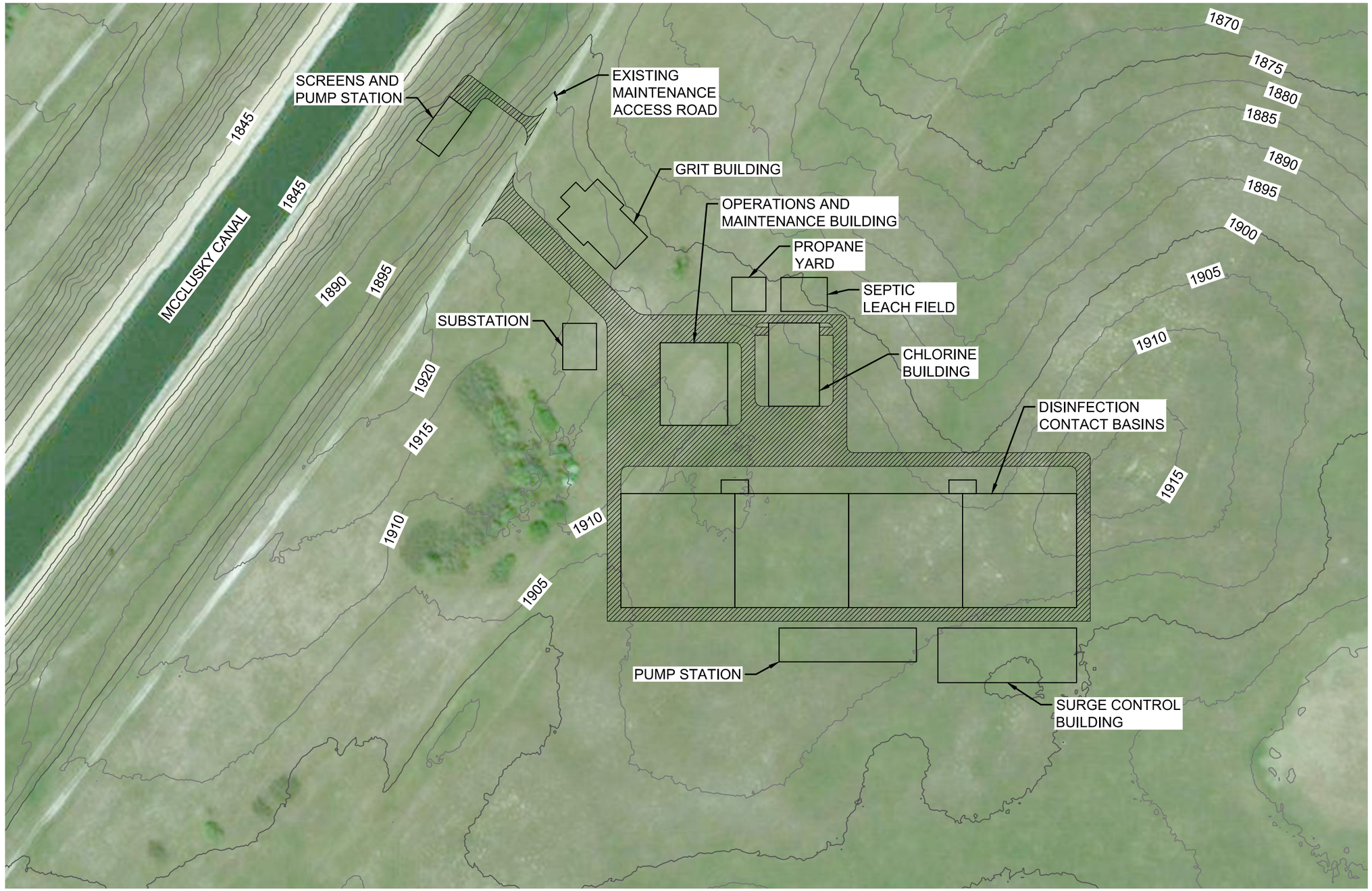
EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BIOTA WTP

OPTION 4 - ADVANCED TREATMENT
SECTION VIEW

E-9

Appendix F Water Treatment Plant Conceptual Site Plans

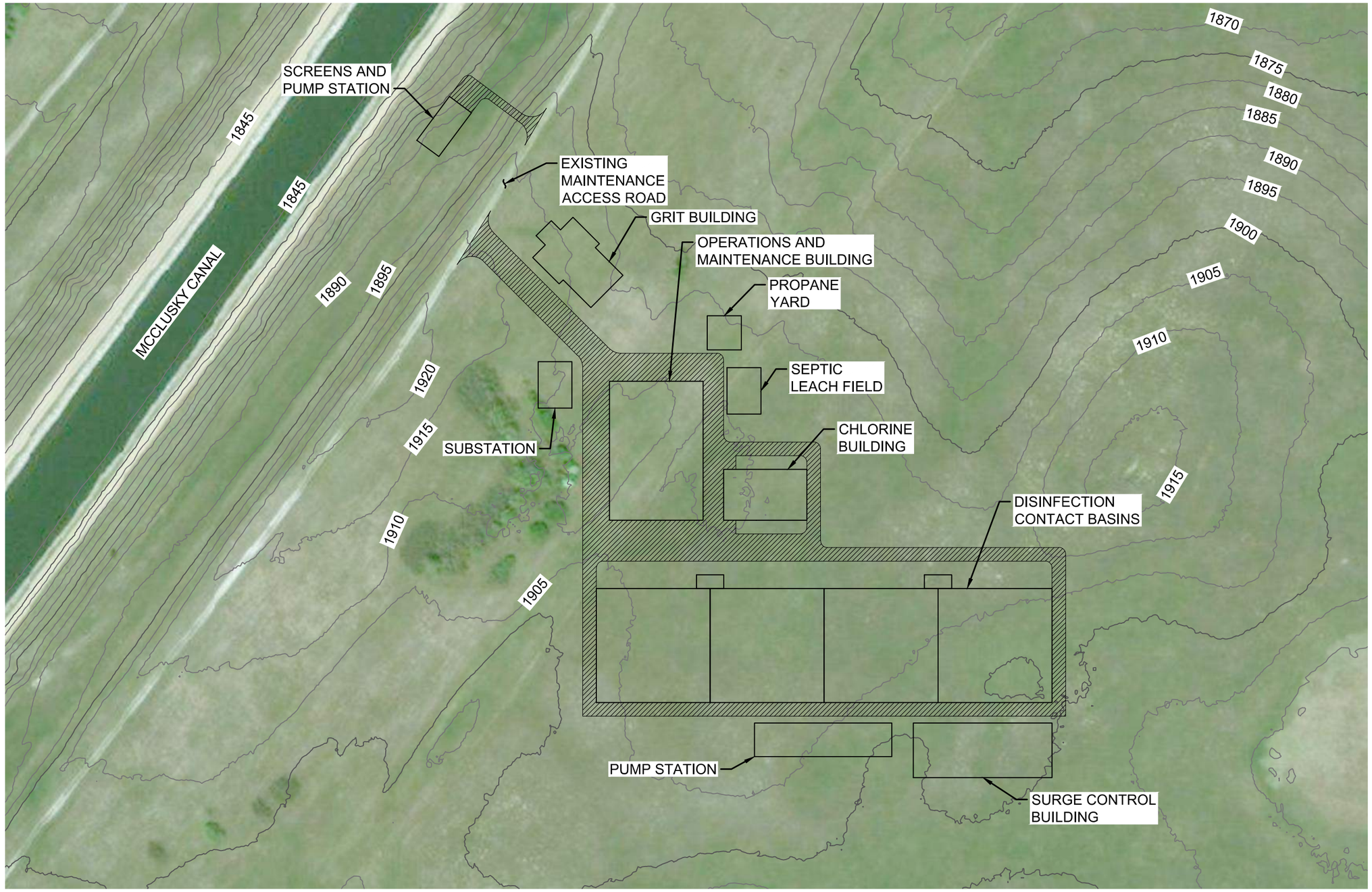


EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BIOTA WTP

OPTION 1 - DISINFECTION
SITE PLAN

F-1

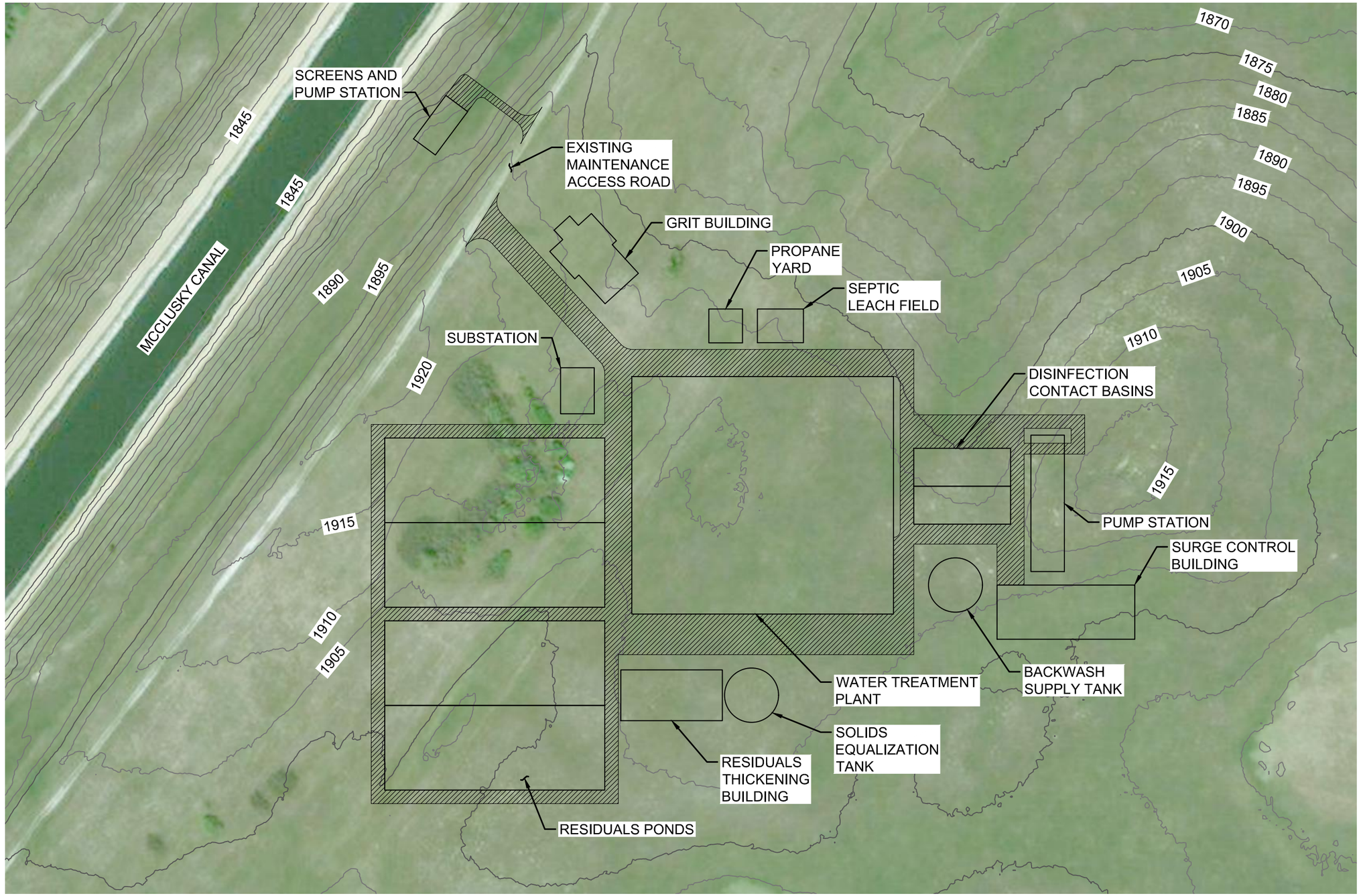


EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BIOTA WTP

OPTION 2 - ENHANCED DISINFECTION
SITE PLAN

F-2



EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

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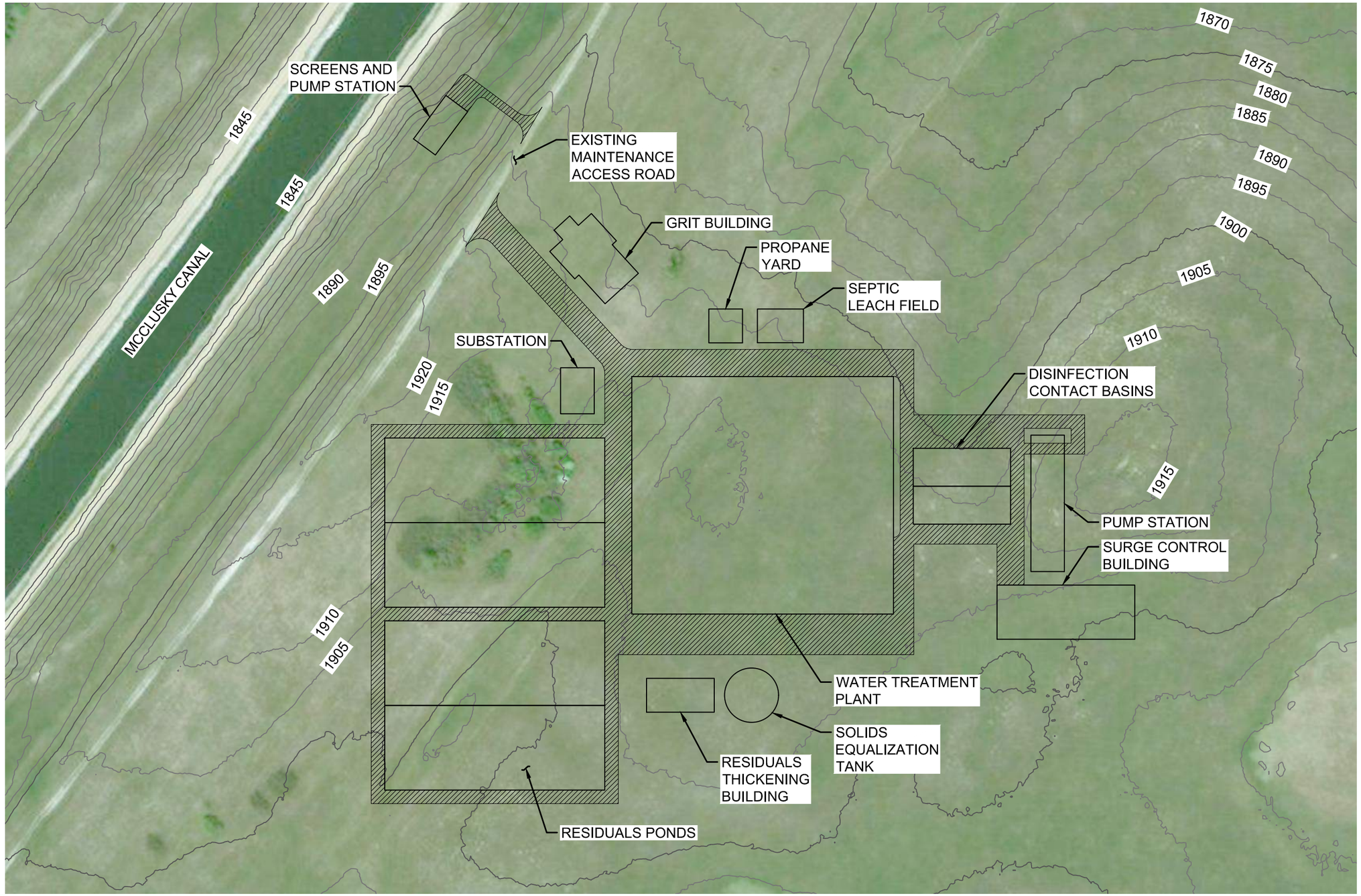
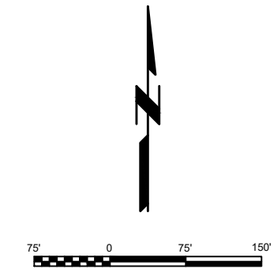
BIOTA WTP

OPTION 3 - CONVENTIONAL TREATMENT SITE PLAN

F-3





EASTERN NORTH DAKOTA
ALTERNATE WATER SUPPLY PROJECT

BIOTA WTP

OPTION 4 - ADVANCED TREATMENT
SITE PLAN

F-4

Appendix G Opinion of Probable Construction Cost Detailed Breakdown

ENDAWS

Opinion of Probable Construction Cost
Biota Water Treatment Plant Estimate
Option 1 - Disinfection
April 15, 2020

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Sitework						
Division 2 Site Construction						
General						
Property Cost	1	EA	$ 1,000,000	$ 1,000,000	$ 1,556,073	$ 1,556,073
Utility Extensions	1	LS	$ 2,500,000	$ 2,500,000	$ 3,890,183	$ 3,890,183
Comissioning Costs	1	LS	$ 287,000	$ 287,000	$ 446,593	$ 446,593
Earthwork						
Site excavation	13,556	CY	$ 14	$ 196,391	$ 23	$ 305,598
Embankment & fill	2,711	CY	$ 26	$ 71,407	$ 41	$ 111,114
Wasting - haul off	10,844	CY	$ 4	$ 41,295	$ 6	$ 64,259
Load wasting - haul off	10,844	CY	$ 3	$ 27,412	$ 4	$ 42,655
Finish grading	13,431	SY	$ 1	$ 18,371	$ 2	$ 28,587
Clear & grub	40	AC	$ 1,717	$ 68,667	$ 2,671	$ 106,851
Restoration	1	LS	$ 10,942	$ 10,942	$ 17,027	$ 17,027
Septic Leach Field	1	LS	$ 136,781	$ 136,781	$ 212,841	$ 212,841
Yard Piping						
72" Steel - McClusky Canal to Pump Station	175	LF	$ 587	$ 102,640	$ 913	$ 159,716
72" Steel - Pump Station to Chlorine Contact Basins	800	LF	$ 587	$ 469,213	$ 913	$ 730,131
72" Steel - Contact Basins to PS	50	LF	$ 587	$ 29,326	$ 913	$ 45,633
72" Tee	3	EA	$ 105,704	$ 317,113	$ 164,484	$ 493,451
72" 45 deg elbow	1	EA	$ 62,919	$ 62,919	$ 97,907	$ 97,907
Misc. fittings	1	LS	$ 30,639	$ 30,639	$ 47,676	$ 47,676
72" Butterfly valve	3	EA	$ 49,241	$ 147,723	$ 76,623	$ 229,869
60" Steel pipe	500	LF	$ 514	$ 257,148	$ 800	$ 400,142
60" 90 deg elbow	4	EA	$ 56,627	$ 226,509	$ 88,116	$ 352,465
60" Butterfly valve	4	EA	$ 44,591	$ 178,362	$ 69,386	$ 277,545
Surfacings						
Asphalt pavement	33,240	SF	$ 4	$ 133,488	$ 6	$ 207,717
Prime coat	3,693	SY	$ 3	$ 9,901	$ 4	$ 15,407
Concrete curb & gutter	5,140	LF	$ 16	$ 84,535	$ 26	$ 131,543
Marking & signage	1	LS	$ 16,414	$ 16,414	$ 25,541	$ 25,541
Landscaping	1	LS	$ 54,712	$ 54,712	$ 85,136	$ 85,136
Fencing						
Chain link	3,100	LF	$ 31	$ 97,287	$ 49	$ 151,386
Gate	1	EA	$ 5,465	$ 5,465	$ 8,504	$ 8,504
Storm Drainage						
Storm drainage	1	LS	$ 109,425	$ 109,425	$ 170,273	$ 170,273
Electrical Yard Accessories						
Yard Accessories	1	LS	$ 547,124	$ 547,124	$ 851,365	$ 851,365
Division 2 Site Construction				***$ 7,238,213***		***$ 11,263,190***
Sitework Subtotal				**$ 7,238,000**		**$ 11,263,000**
Propane Yard						
Division 2 Site Construction						
Structural excavation	711	CY	$ 14	$ 10,302	$ 23	$ 16,031
Compact fill	237	CY	$ 26	$ 6,243	$ 41	$ 9,715
Structural backfil	237	CY	$ 45	$ 10,645	$ 70	$ 16,564
Wasting - haul off	474	CY	$ 4	$ 1,805	$ 6	$ 2,809
Load wasting - haul off	474	CY	$ 3	$ 1,198	$ 4	$ 1,865
Division 2 Site Construction				***$ 30,194***		***$ 46,984***
Division 3 Concrete						
Slab on grade/footings	356	CY	$ 633	$ 225,164	$ 985	$ 350,372
Walls	190	CY	$ 1,036	$ 196,436	$ 1,612	$ 305,668
Division 3 Concrete				***$ 421,600***		***$ 656,040***

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Division 26 Electrical						
Electrical	1	LS	$ 43,770	$ 43,770	$ 68,109	$ 68,109
Division 26 Electrical				***$ 43,770***		***$ 68,109***
Division 40 Process Interconnections						
Gas piping	1	LS	$ 13,678	$ 13,678	$ 21,284	$ 21,284
Division 40 Process Interconnections				***$ 13,678***		***$ 21,284***
Division 43 Process Handling and Storage Equipment						
Propane tank	2	EA	$ 78,169	$ 156,339	$ 121,637	$ 243,275
Division 43 Process Handling and Storage Equipment				***$ 156,339***		***$ 243,275***
Propane Yard Subtotal				**$ 666,000**		**$ 1,036,000**
Grit Basin Building						
Division 2 Site Construction						
Structural excavation	7,881	CY	$ 14	$ 113,735	$ 22	$ 176,981
Compacted Fill	4,465	CY	$ 26	$ 117,145	$ 41	$ 182,286
Drying Bed	6,693	CY	$ 25	$ 166,772	$ 39	$ 259,510
Division 2 Site Construction				***$ 397,653***		***$ 618,777***
Division 3 Concrete						
Slab on grade/footings	615	CY	$ 631	$ 387,952	$ 982	$ 603,681
Walls	890	CY	$ 1,032	$ 918,374	$ 1,606	$ 1,429,058
Floors	161	CY	$ 1,225	$ 197,302	$ 1,907	$ 307,016
Division 3 Concrete				***$ 1,503,628***		***$ 2,339,755***
Division 4 Masonry						
16" CMU	5,715	SF	$ 22	$ 126,830	$ 35	$ 197,356
Division 4 Masonry				***$ 126,830***		***$ 197,356***
Division 5 Metals						
Miscellaneous steel members	1	TON	$ 4,218	$ 4,218	$ 6,564	$ 6,564
Metal decking	7,459	SF	$ 10	$ 78,051	$ 16	$ 121,453
Standing seam roof	7,459	SF	$ 11	$ 85,775	$ 18	$ 133,472
Division 5 Metals				***$ 168,044***		***$ 261,489***
Division 7 Thermal and Moisture Protection						
Roof insulation	7,459	SF	$ 3	$ 19,350	$ 4	$ 30,110
Wall insulation	5,715	SF	$ 2	$ 11,587	$ 3	$ 18,030
Division 7 Thermal and Moisture Protection				***$ 30,937***		***$ 48,140***
Division 8 Openings						
Hollow metal (with security hardware)	49	SF	$ 109	$ 5,341	$ 170	$ 8,311
Roll-up door with motor	2	EA	$ 3,931	$ 7,863	$ 6,118	$ 12,235
Covers for slab openings	32	SF	$ 55	$ 1,744	$ 85	$ 2,714
Division 8 Openings				***$ 14,948***		***$ 23,260***
Division 10 Specialties						
Miscellaneous specialties	1	LS	$ 5,450	$ 5,450	$ 8,481	$ 8,481
Division 10 Specialties				***$ 5,450***		***$ 8,481***
Division 22 Plumbing						
Plumbing	1	LS	$ 330,270	$ 330,270	$ 513,924	$ 513,924
Division 22 Plumbing				***$ 330,270***		***$ 513,924***
Division 23 HVAC						
HVAC	1	LS	$ 462,160	$ 462,160	$ 719,155	$ 719,155
Division 23 HVAC				***$ 462,160***		***$ 719,155***
Division 26 Electrical						
Electrical	1	LS	$ 719,400	$ 719,400	$ 1,119,439	$ 1,119,439
Division 26 Electrical				***$ 719,400***		***$ 1,119,439***
Division 40 Process Interconnections						
Process Piping						
Pipe support	8	EA	$ 1,635	$ 13,080	$ 2,544	$ 20,353
4" Grit pipe	576	LF	$ 32	$ 18,207	$ 49	$ 28,332
6" Grit pipe	30	LF	$ 51	$ 1,537	$ 80	$ 2,392
4" Strainer	6	EA	$ 3,270	$ 19,620	$ 5,088	$ 30,530
Instrumentation						
Instrumentation	1	LS	$ 335,720	$ 335,720	$ 522,405	$ 522,405
Division 40 Process Interconnections				***$ 388,164***		***$ 604,012***
Division 43 Process Handling and Storage Equipment						
Headcell, Teacup, and Snail	6	EA	$ 434,471	$ 2,606,824	$ 676,068	$ 4,056,410
Grit Pump	6	EA	$ 32,700	$ 196,200	$ 50,884	$ 305,302
3'x5' slide gates	6	EA	$ 10,791	$ 64,746	$ 16,792	$ 100,750

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
6'x5' slide gates	2	EA	$ 17,658	$ 35,316	$ 27,477	$ 54,954
Dumpster	3	EA	$ 2,180	$ 6,540	$ 3,392	$ 10,177
Division 43 Process Handling and Storage Equipment				***$ 2,909,626***		***$ 4,527,592***
Grit Building Subtotal				**$ 7,057,000**		**$ 10,981,000**
Disinfection Contact Basins						
Division 2 Site Construction						
Structural excavation	80,667	CY	$ 14	$ 1,168,686	$ 23	$ 1,818,561
Compact fill	8,067	CY	$ 26	$ 212,464	$ 41	$ 330,610
Structural backfil	4,033	CY	$ 45	$ 181,129	$ 70	$ 281,849
Finish grading	12,100	SY	$ 1	$ 16,550	$ 2	$ 25,754
Wasting - haul off	68,567	CY	$ 4	$ 261,101	$ 6	$ 406,292
Load wasting - haul off	68,567	CY	$ 3	$ 173,317	$ 4	$ 269,694
Division 2 Site Construction				***$ 2,013,247***		***$ 3,132,760***
Division 3 Concrete						
Slab footings	550	CY	$ 633	$ 348,301	$ 985	$ 541,981
Slab on grade	8,067	CY	$ 633	$ 5,108,411	$ 985	$ 7,949,062
Walls	2,640	CY	$ 1,036	$ 2,734,754	$ 1,612	$ 4,255,478
Elevated Slab	4,033	CY	$ 1,230	$ 4,962,016	$ 1,914	$ 7,721,261
Splitter box Equipment (inlc. Mixers, slide gates)	1	LS	$ 250,000	$ 250,000	$ 389,018	$ 389,018
Division 3 Concrete				***$ 13,403,481***		***$ 20,856,800***
Division 26 Electrical						
Electrical	2	LS	$ 27,356	$ 54,712	$ 42,568	$ 85,136
Division 26 Electrical				***$ 54,712***		***$ 85,136***
Division 40 Process Interconnections						
Instruments	2	LS	$ 10,942	$ 21,885	$ 17,027	$ 34,055
Division 40 Process Interconnections				***$ 21,885***		***$ 34,055***
Disinfection Contact Basins Subtotal				**$ 15,493,000**		**$ 24,109,000**
Chlorine Building						
Division 2 Site Construction						
Structural excavation	519	CY	$ 14	$ 7,512	$ 23	$ 11,690
Compact fill	200	CY	$ 26	$ 5,268	$ 41	$ 8,197
Structural backfil	135	CY	$ 45	$ 6,063	$ 70	$ 9,434
Finish grading	778	SY	$ 1	$ 1,064	$ 2	$ 1,655
Wasting - haul off	184	CY	$ 4	$ 699	$ 6	$ 1,087
Load wasting - haul off	184	CY	$ 3	$ 464	$ 4	$ 722
Division 2 Site Construction				***$ 21,069***		***$ 32,785***
Division 3 Concrete						
Cast-In-Place Concrete						
Slab on grade	389	CY	$ 633	$ 246,273	$ 985	$ 383,219
Slab footings	113	CY	$ 633	$ 71,771	$ 985	$ 111,681
Precast Concrete						
Precast suspended slab roof	7,000	SF	$ 15	$ 105,475	$ 23	$ 164,126
Division 3 Concrete				***$ 177,246***		***$ 659,026***
Division 4 Masonry						
8" CMU	5,100	SF	$ 10	$ 50,840	$ 16	$ 79,111
Division 4 Masonry				***$ 50,840***		***$ 79,111***
Division 7 Thermal and Moisture Protection						
Roof insulation	7,000	SF	$ 3	$ 18,230	$ 4	$ 28,367
Wall insulation	5,100	SF	$ 2	$ 10,380	$ 3	$ 16,152
Division 7 Thermal and Moisture Protection				***$ 28,610***		***$ 44,520***
Division 8 Openings						
Hollow metal doors (with security hardware)	5	EA	$ 2,688	$ 13,442	$ 4,183	$ 20,917
Interior doors (with hardware)	15	EA	$ 1,494	$ 22,414	$ 2,325	$ 34,877
Roll-up door with motor	4	EA	$ 3,947	$ 15,787	$ 6,141	$ 24,566
Division 8 Openings				***$ 51,643***		***$ 80,360***
Division 9 Finishes						
Painting	1	LS	$ 25,000	$ 25,000	$ 38,902	$ 38,902
Division 9 Finishes				***$ 25,000***		***$ 38,902***
Division 15 Mechanical						
Misc. Piping	1	LS	$ 200,000	$ 200,000	$ 311,215	$ 311,215
Misc. fittings	1	LS	$ 100,000	$ 100,000	$ 155,607	$ 155,607
Division 15 Mechanical				***$ 300,000***		***$ 466,822***

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Division 22 Plumbing						
Plumbing	1	LS	$ 50,000	$ 50,000	$ 77,804	$ 77,804
Division 22 Plumbing				***$ 50,000***		***$ 77,804***
Division 23 HVAC						
HVAC	1	LS	$ 200,000	$ 200,000	$ 311,215	$ 311,215
Division 23 HVAC				***$ 200,000***		***$ 311,215***
Division 26 Electrical						
Electrical	1	LS	$ 150,000	$ 150,000	$ 233,411	$ 233,411
Division 26 Electrical				***$ 150,000***		***$ 233,411***
Division 40 Process Interconnections						
Instruments	1	LS	$ 75,000	$ 75,000	$ 116,706	$ 116,706
Division 40 Process Interconnections				***$ 75,000***		***$ 116,706***
Division 43 Process Handling and Storage Equipment						
5,000 gal FRP Bulk Tank	12	LS	$ 17,500	$ 210,000	$ 27,231	$ 326,775
6,000 gal FRP Day Tank	3	LS	$ 20,000	$ 60,000	$ 31,121	$ 93,364
Transfer Pump Skid	3	LS	$ 35,799	$ 107,396	$ 55,705	$ 167,115
Feed Pump Skid	3	LS	$ 35,799	$ 107,396	$ 55,705	$ 167,115
Tank Pads & Floor grating	1	LS	$ 30,000	$ 30,000	$ 46,682	$ 46,682
Monorail & Hoist System	5	LS	$ 20,000	$ 100,000	$ 31,121	$ 155,607
Misc Valves & Piping	1	LS	$ 138,838	$ 138,838	$ 216,043	$ 216,043
Division 43 Process Handling and Storage Equipment				***$ 753,629***		***$ 1,172,703***
Chlorine Building Subtotal				**$ 2,129,000**		**$ 3,313,000**
Office Building						
Division 2 Site Construction						
Structural excavation	2,662	CY	$ 14	$ 38,567	$ 23	$ 60,013
Compact fill	666	CY	$ 26	$ 17,528	$ 41	$ 27,275
Structural backfil	444	CY	$ 45	$ 19,924	$ 70	$ 31,003
Finish grading	1,331	SY	$ 1	$ 1,821	$ 2	$ 2,833
Wasting - haul off	1,553	CY	$ 4	$ 5,913	$ 6	$ 9,201
Load wasting - haul off	1,553	CY	$ 3	$ 3,925	$ 4	$ 6,108
Division 2 Site Construction				***$ 87,678***		***$ 136,433***
Division 3 Concrete						
Cast-In-Place Concrete						
Slab on grade/footings	666	CY	$ 633	$ 421,444	$ 985	$ 655,798
Perimeter footing	180	CY	$ 633	$ 113,778	$ 985	$ 177,047
Column Footings	80	CY	$ 1,419	$ 113,511	$ 2,208	$ 176,632
Column Roof	160	CY	$ 1,419	$ 227,022	$ 2,208	$ 353,263
Precast Concrete						
Precast suspended slab roof	11,979	SF	$ 33	$ 393,240	$ 51	$ 611,910
Division 3 Concrete				***$ 1,268,995***		***$ 1,974,650***
Division 4 Masonry						
Face Brick	7,920	SF	$ 13	$ 104,777	$ 21	$ 163,041
12" CMU	7,920	SF	$ 13	$ 102,784	$ 20	$ 159,939
Bond beam	968	LF	$ 4	$ 4,195	$ 7	$ 6,527
Division 4 Masonry				***$ 211,756***		***$ 329,508***
Division 5 Metals						
Structural Steel	17	TON	$ 4,235	$ 71,993	$ 6,590	$ 112,027
Stairs	1	LS	$ 32,827	$ 32,827	$ 51,082	$ 51,082
Division 5 Metals				***$ 104,821***		***$ 163,109***
Division 7 Thermal and Moisture Protection						
Roof insulation	11,979	SF	$ 3	$ 31,197	$ 4	$ 48,545
Wall insulation	7,920	SF	$ 2	$ 16,120	$ 3	$ 25,083
Division 7 Thermal and Moisture Protection				***$ 47,317***		***$ 73,628***
Division 8 Openings						
Hollow metal doors (with security hardware)	9	EA	$ 1,313	$ 11,818	$ 2,043	$ 18,389
Roll-up door with motor	5	EA	$ 3,947	$ 19,734	$ 6,141	$ 30,707
Division 8 Openings				***$ 31,551***		***$ 49,096***
Division 9 Finishes						
Painting	11,979	SF	$ 8	$ 95,832	$ 12	$ 149,122
Division 9 Finishes				***$ 95,832***		***$ 149,122***
Division 10 Specialties						
Hallway/Entrance	1,000	SF	$ 50	$ 50,000	$ 78	$ 77,804

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Offices	1,080	SF	$ 75	$ 81,000	$ 117	$ 126,042
Break Room	666	SF	$ 100	$ 66,600	$ 156	$ 103,634
Control Room	800	SF	$ 150	$ 120,000	$ 233	$ 186,729
Storage	500	SF	$ 75	$ 37,500	$ 117	$ 58,353
Shop/Garage	3,720	SF	$ 100	$ 372,000	$ 156	$ 578,859
Electrical Room	640	SF	$ 150	$ 96,000	$ 233	$ 149,383
Generator Room	900	SF	$ 150	$ 135,000	$ 233	$ 210,070
Lab	500	SF	$ 200	$ 100,000	$ 311	$ 155,607
Bathrooms/Locker Room	600	SF	$ 75	$ 45,000	$ 117	$ 70,023
Lab Equipment	1	LS	$ 20,000	$ 20,000	$ 31,121	$ 31,121
Furniture	1	LS	$ 35,000	$ 35,000	$ 54,463	$ 54,463
Division 10 Specialties				***$ 1,158,100***		***$ 1,802,089***
Division 22 Plumbing						
Plumbing	1	LS	$ 100,000	$ 100,000	$ 155,607	$ 155,607
Fire sprinkler system	1	LS	$ 50,000	$ 50,000	$ 77,804	$ 77,804
Division 22 Plumbing				***$ 150,000***		***$ 233,411***
Division 23 HVAC						
HVAC	11,979	SF	$ 20	$ 239,580	$ 31	$ 372,804
Division 23 HVAC				***$ 239,580***		***$ 372,804***
Division 26 Electrical						
Generator (500 kW)	1	LS	$ 110,519	$ 110,519	$ 171,976	$ 171,976
Electrical	1	LS	$ 100,000	$ 100,000	$ 155,607	$ 155,607
Division 26 Electrical				***$ 210,519***		***$ 327,583***
Division 40 Process Interconnections						
Instruments	1	LS	$ 75,000	$ 75,000	$ 116,706	$ 116,706
Division 40 Process Interconnections				***$ 75,000***		***$ 116,706***
Office Building Subtotal				**$ 3,681,000**		**$ 5,728,000**
Totals				**$ 36,265,000**		**$ 56,431,000**

Mark-Ups

Item	Rate	Construction Subtotal	Percent of Total
Construction Subtotal		$ 36,265,000	64.3%
Subcontractor Markups		included in construction subtotal	
Design Allowance		-	0.0%
Direct Cost Subtotal		**$ 36,265,000**	**64.3%**
General Conditions	5.0%	$ 1,813,000	3.2%
Contingency	30.0%	$ 11,423,000	20.2%
Contractor's Overhead and Profit	12.0%	$ 5,940,000	10.5%
Bonds and Insurance	2.0%	$ 990,000	1.8%
Grand Total		**$ 56,431,000**	100.0%

Item	Construction Subtotal	Grand Total ($)
Sitework Subtotal	**$ 7,238,000**	**$ 11,263,000**
Propane Yard Subtotal	**$ 666,000**	**$ 1,036,000**
Grit Building Subtotal	**$ 7,057,000**	**$ 10,981,000**
Disinfection Contact Basins Subtotal	**$ 15,493,000**	**$ 24,109,000**
Chlorine Building Subtotal	**$ 2,129,000**	**$ 3,313,000**
Office Building Subtotal	**$ 3,681,000**	**$ 5,728,000**
Totals	**$ 36,265,000**	**$ 56,431,000**

ENDAWS

Opinion of Probable Construction Cost
Biota Water Treatment Plant Estimate
Option 2 - Enhanced Disinfection
April 15, 2020

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Sitework						
Division 2 Site Construction						
General						
Property Cost	1	EA	$ 1,000,000	$ 1,000,000	$ 1,556,136	$ 1,556,136
Utility Extensions	1	LS	$ 2,500,000	$ 2,500,000	$ 3,890,339	$ 3,890,339
Comissioning Costs	1	LS	$ 233,000	$ 233,000	$ 362,580	$ 362,580
Earthwork						
Site excavation	10,889	CY	$ 14	$ 157,756	$ 23	$ 245,490
Embankment & fill	2,178	CY	$ 26	$ 57,359	$ 41	$ 89,259
Wasting - haul off	8,711	CY	$ 4	$ 33,172	$ 6	$ 51,620
Load wasting - haul off	8,711	CY	$ 3	$ 22,019	$ 4	$ 34,265
Finish grading	3,570	SY	$ 1	$ 4,883	$ 2	$ 7,598
Clear & grub	40	AC	$ 1,717	$ 68,667	$ 2,671	$ 106,855
Restoration	1	LS	$ 10,942	$ 10,942	$ 17,028	$ 17,028
Septic Leach Field	1	LS	$ 150,000	$ 150,000	$ 233,420	$ 233,420
Yard Piping						
72" Steel - McClusky Canal to Pump Station	130	LF	$ 587	$ 76,247	$ 913	$ 118,651
72" Steel - Pump Station to Operations and Maintenance Building	850	LF	$ 587	$ 498,539	$ 913	$ 775,795
72" Tee	1	EA	$ 105,704	$ 105,704	$ 164,490	$ 164,490
72" 45 deg elbow	2	LF	$ 62,919	$ 125,839	$ 97,911	$ 195,822
Misc. fittings	1	EA	$ 30,639	$ 30,639	$ 47,678	$ 47,678
72" Butterfly valve	3	EA	$ 49,241	$ 147,723	$ 76,626	$ 229,878
36" Steel pipe	245	LS	$ 305	$ 74,831	$ 475	$ 116,447
Surfacings						
Asphalt pavement	50,900	SF	$ 4	$ 204,409	$ 6	$ 318,088
Prime coat	6,000	SF	$ 3	$ 16,085	$ 4	$ 25,031
Concrete curb & gutter	3,170	LF	$ 16	$ 52,136	$ 26	$ 81,130
Marking & signage	1	LS	$ 16,414	$ 16,414	$ 25,542	$ 25,542
Landscaping	1	LS	$ 54,712	$ 54,712	$ 85,140	$ 85,140
Fencing						
Chain link	2,600	LF	$ 31	$ 81,596	$ 49	$ 126,974
Gate	1	EA	$ 5,465	$ 5,465	$ 8,505	$ 8,505
Storm Drainage						
Storm drainage	1	LS	$ 300,000	$ 300,000	$ 466,841	$ 466,841
Electrical Yard Accessories						
Yard Accessories	1	LS	$ 1,000,000	$ 1,000,000	$ 1,556,136	$ 1,556,136
Division 2 Site Construction				***$ 7,028,139***		***$ 10,936,737***
Sitework Subtotal				**$ 7,028,000**		**$ 10,937,000**
Propane Yard						
Division 2 Site Construction						
Structural excavation	1,111	CY	$ 14	$ 16,098	$ 23	$ 25,050
Compact fill	370	CY	$ 26	$ 9,755	$ 41	$ 15,180
Structural backfil	370	CY	$ 45	$ 16,633	$ 70	$ 25,883
Wasting - haul off	741	CY	$ 4	$ 2,821	$ 6	$ 4,389
Load wasting - haul off	741	CY	$ 3	$ 1,872	$ 4	$ 2,914
Division 2 Site Construction				***$ 47,178***		***$ 73,416***
Division 3 Concrete						
Slab on grade/footings	556	CY	$ 633	$ 351,819	$ 985	$ 547,478
Walls	237	CY	$ 1,036	$ 245,545	$ 1,612	$ 382,101
Division 3 Concrete				***$ 597,364***		***$ 929,579***
Division 26 Electrical						
Electrical	1	LS	$ 43,770	$ 43,770	$ 68,112	$ 68,112

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Division 26 Electrical				***$ 43,770***		***$ 68,112***
Division 40 Process Interconnections						
Gas piping	1	LS	$ 13,678	$ 13,678	$ 21,285	$ 21,285
Division 40 Process Interconnections				***$ 13,678***		***$ 21,285***
Division 43 Process Handling and Storage Equipment						
Propane tank	3	EA	$ 78,169	$ 234,508	$ 121,642	$ 364,927
Division 43 Process Handling and Storage Equipment				***$ 234,508***		***$ 364,927***
Propane Yard Subtotal				**$ 936,000**		**$ 1,457,000**
Grit Basin Building						
Division 2 Site Construction						
Structural excavation	7,881	CY	$ 14	$ 113,735	$ 22	$ 176,988
Compacted Fill	4,465	CY	$ 26	$ 117,145	$ 41	$ 182,294
Drying Bed	6,693	CY	$ 25	$ 166,772	$ 39	$ 259,520
Division 2 Site Construction				***$ 397,653***		***$ 618,801***
Division 3 Concrete						
Slab on grade/footings	615	CY	$ 631	$ 387,952	$ 982	$ 603,705
Walls	890	CY	$ 1,032	$ 918,374	$ 1,606	$ 1,429,115
Floors	161	CY	$ 1,225	$ 197,302	$ 1,907	$ 307,028
Division 3 Concrete				***$ 1,503,628***		***$ 2,339,848***
Division 4 Masonry						
16" CMU	5,715	SF	$ 22	$ 126,830	$ 35	$ 197,364
Division 4 Masonry				***$ 126,830***		***$ 197,364***
Division 5 Metals						
Miscellaneous steel members	1	TON	$ 4,218	$ 4,218	$ 6,565	$ 6,565
Metal decking	7,459	SF	$ 10	$ 78,051	$ 16	$ 121,458
Standing seam roof	7,459	SF	$ 11	$ 85,775	$ 18	$ 133,477
Division 5 Metals				***$ 168,044***		***$ 261,500***
Division 7 Thermal and Moisture Protection						
Roof insulation	7,459	SF	$ 3	$ 19,350	$ 4	$ 30,111
Wall insulation	5,715	SF	$ 2	$ 11,587	$ 3	$ 18,030
Division 7 Thermal and Moisture Protection				***$ 30,937***		***$ 48,142***
Division 8 Openings						
Hollow metal (with security hardware)	49	SF	$ 109	$ 5,341	$ 170	$ 8,311
Roll-up door with motor	2	EA	$ 3,931	$ 7,863	$ 6,118	$ 12,236
Covers for slab openings	32	SF	$ 55	$ 1,744	$ 85	$ 2,714
Division 8 Openings				***$ 14,948***		***$ 23,261***
Division 10 Specialties						
Miscellaneous specialties	1	LS	$ 5,450	$ 5,450	$ 8,481	$ 8,481
Division 10 Specialties				***$ 5,450***		***$ 8,481***
Division 22 Plumbing						
Plumbing	1	LS	$ 330,270	$ 330,270	$ 513,945	$ 513,945
Division 22 Plumbing				***$ 330,270***		***$ 513,945***
Division 23 HVAC						
HVAC	1	LS	$ 462,160	$ 462,160	$ 719,184	$ 719,184
Division 23 HVAC				***$ 462,160***		***$ 719,184***
Division 26 Electrical						
Electrical	1	LS	$ 719,400	$ 719,400	$ 1,119,484	$ 1,119,484
Division 26 Electrical				***$ 719,400***		***$ 1,119,484***
Division 40 Process Interconnections						
Process Piping						
Pipe support	8	EA	$ 1,635	$ 13,080	$ 2,544	$ 20,354
4" Grit pipe	576	LF	$ 32	$ 18,207	$ 49	$ 28,333
6" Grit pipe	30	LF	$ 51	$ 1,537	$ 80	$ 2,392
4" Strainer	6	EA	$ 3,270	$ 19,620	$ 5,089	$ 30,531
Instrumentation						
Instrumentation	1	LS	$ 335,720	$ 335,720	$ 522,426	$ 522,426
Division 40 Process Interconnections				***$ 388,164***		***$ 604,036***
Division 43 Process Handling and Storage Equipment						
Headcell, Teacup, and Snail	6	EA	$ 434,471	$ 2,606,824	$ 676,095	$ 4,056,572
Grit Pump	6	EA	$ 32,700	$ 196,200	$ 50,886	$ 305,314
3'x5' slide gates	6	EA	$ 10,791	$ 64,746	$ 16,792	$ 100,754
6'x5' slide gates	2	EA	$ 17,658	$ 35,316	$ 27,478	$ 54,956
Dumpster	3	EA	$ 2,180	$ 6,540	$ 3,392	$ 10,177

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Division 43 Process Handling and Storage Equipment				***$ 2,909,626***		***$ 4,527,773***
Grit Building Subtotal				**$ 7,057,000**		**$ 10,982,000**
Disinfection Contact Basins						
Division 2 Site Construction						
Structural excavation	80,667	CY	$ 14	$ 1,168,686	$ 23	$ 1,818,634
Compact fill	8,067	CY	$ 26	$ 212,464	$ 41	$ 330,623
Structural backfil	4,033	CY	$ 45	$ 181,129	$ 70	$ 281,861
Finish grading	12,100	SY	$ 1	$ 16,550	$ 2	$ 25,755
Wasting - haul off	68,567	CY	$ 4	$ 261,101	$ 6	$ 406,308
Load wasting - haul off	68,567	CY	$ 3	$ 173,317	$ 4	$ 269,704
Division 2 Site Construction				***$ 2,013,247***		***$ 3,132,885***
Division 3 Concrete						
Slab footings	550	CY	$ 633	$ 348,301	$ 985	$ 542,003
Slab on grade	8,067	CY	$ 633	$ 5,108,411	$ 985	$ 7,949,380
Walls	2,640	CY	$ 1,036	$ 2,734,754	$ 1,612	$ 4,255,648
Elevated Slab	4,033	CY	$ 1,230	$ 4,962,016	$ 1,914	$ 7,721,570
Splitter box Equipment (inlc. Mixers, slide gates)	1	LS	$ 250,000	$ 250,000	$ 389,034	$ 389,034
Division 3 Concrete				***$ 13,403,481***		***$ 20,857,634***
Division 26 Electrical						
Electrical	2	LS	$ 27,356	$ 54,712	$ 42,570	$ 85,140
Division 26 Electrical				***$ 54,712***		***$ 85,140***
Division 40 Process Interconnections						
Instruments	2	LS	$ 10,942	$ 21,885	$ 17,028	$ 34,056
Division 40 Process Interconnections				***$ 21,885***		***$ 34,056***
Disinfection Contact Basins Subtotal				**$ 15,493,000**		**$ 24,110,000**
Chlorine Building						
Division 2 Site Construction						
Structural excavation	519	CY	$ 14	$ 7,512	$ 23	$ 11,690
Compact fill	200	CY	$ 26	$ 5,268	$ 41	$ 8,197
Structural backfil	135	CY	$ 45	$ 6,063	$ 70	$ 9,434
Finish grading	778	SY	$ 1	$ 1,064	$ 2	$ 1,655
Wasting - haul off	184	CY	$ 4	$ 699	$ 6	$ 1,087
Load wasting - haul off	184	CY	$ 3	$ 464	$ 4	$ 722
Division 2 Site Construction				***$ 21,069***		***$ 32,786***
Division 3 Concrete						
Cast-In-Place Concrete						
Slab on grade	389	CY	$ 633	$ 246,273	$ 985	$ 383,235
Slab footings	113	CY	$ 633	$ 71,771	$ 985	$ 111,686
Precast Concrete						
Precast suspended slab roof	7,000	SF	$ 15	$ 105,475	$ 23	$ 164,133
Division 3 Concrete				***$ 105,475***		***$ 659,053***
Division 4 Masonry						
8" CMU	5,100	SF	$ 10	$ 50,840	$ 16	$ 79,114
Division 4 Masonry				***$ 50,840***		***$ 79,114***
Division 7 Thermal and Moisture Protection						
Roof insulation	7,000	SF	$ 3	$ 18,230	$ 4	$ 28,369
Wall insulation	5,100	SF	$ 2	$ 10,380	$ 3	$ 16,153
Division 7 Thermal and Moisture Protection				***$ 28,610***		***$ 44,521***
Division 8 Openings						
Hollow metal doors (with security hardware)	5	EA	$ 2,688	$ 13,442	$ 4,184	$ 20,918
Interior doors (with hardware)	15	EA	$ 1,494	$ 22,414	$ 2,325	$ 34,879
Roll-up door with motor	4	EA	$ 3,947	$ 15,787	$ 6,142	$ 24,567
Division 8 Openings				***$ 51,643***		***$ 80,364***
Division 9 Finishes						
Painting	1	LS	$ 25,000	$ 25,000	$ 38,903	$ 38,903
Division 9 Finishes				***$ 25,000***		***$ 38,903***
Division 15 Mechanical						
Misc. Piping	1	LS	$ 200,000	$ 200,000	$ 311,227	$ 311,227
Misc. fittings	1	LS	$ 100,000	$ 100,000	$ 155,614	$ 155,614
Division 15 Mechanical				***$ 300,000***		***$ 466,841***
Division 22 Plumbing						
Plumbing	1	LS	$ 50,000	$ 50,000	$ 77,807	$ 77,807

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Division 22 Plumbing				***$ 50,000***		***$ 77,807***
Division 23 HVAC						
HVAC	1	LS	$ 200,000	$ 200,000	$ 311,227	$ 311,227
Division 23 HVAC				***$ 200,000***		***$ 311,227***
Division 26 Electrical						
Electrical	1	LS	$ 150,000	$ 150,000	$ 233,420	$ 233,420
Division 26 Electrical				***$ 150,000***		***$ 233,420***
Division 40 Process Interconnections						
Instruments	1	LS	$ 75,000	$ 75,000	$ 116,710	$ 116,710
Division 40 Process Interconnections				***$ 75,000***		***$ 116,710***
Division 43 Process Handling and Storage Equipment						
5,000 gal FRP Bulk Tank	12	LS	$ 17,500	$ 210,000	$ 27,232	$ 326,788
6,000 gal FRP Day Tank	3	LS	$ 20,000	$ 60,000	$ 31,123	$ 93,368
Transfer Pump Skid	3	LS	$ 35,799	$ 107,396	$ 55,707	$ 167,122
Feed Pump Skid	3	LS	$ 35,799	$ 107,396	$ 55,707	$ 167,122
Tank Pads & Floor grating	1	LS	$ 30,000	$ 30,000	$ 46,684	$ 46,684
Monorail & Hoist System	5	LS	$ 20,000	$ 100,000	$ 31,123	$ 155,614
Misc Valves & Piping	1	LS	$ 138,838	$ 138,838	$ 216,051	$ 216,051
Division 43 Process Handling and Storage Equipment				***$ 753,629***		***$ 1,172,750***
Chlorine Building Subtotal				**$ 2,129,000**		**$ 3,313,000**
Office Building						
Division 2 Site Construction						
Structural excavation	4,587	CY	$ 14	$ 66,451	$ 23	$ 103,407
Compact fill	1,147	CY	$ 26	$ 30,202	$ 41	$ 46,998
Structural backfil	764	CY	$ 45	$ 34,330	$ 70	$ 53,422
Finish grading	2,293	SY	$ 1	$ 3,137	$ 2	$ 4,881
Wasting - haul off	2,676	CY	$ 4	$ 10,188	$ 6	$ 15,855
Load wasting - haul off	2,676	CY	$ 3	$ 6,763	$ 4	$ 10,524
Division 2 Site Construction				***$ 151,070***		***$ 235,086***
Division 3 Concrete						
Cast-In-Place Concrete						
Slab on grade/footings	1,529	CY	$ 633	$ 968,206	$ 985	$ 1,506,659
Perimeter footing	195	CY	$ 633	$ 123,277	$ 985	$ 191,836
Column Footings	160	CY	$ 1,419	$ 227,022	$ 2,208	$ 353,277
Column Roof	320	CY	$ 1,419	$ 454,045	$ 2,208	$ 706,555
Precast Concrete						
Precast suspended slab roof	20,640	SF	$ 33	$ 677,558	$ 51	$ 1,054,373
Division 3 Concrete				***$ 2,450,108***		***$ 3,812,701***
Division 4 Masonry						
Face Brick	10,512	SF	$ 13	$ 139,068	$ 21	$ 216,409
12" CMU	10,512	SF	$ 13	$ 136,422	$ 20	$ 212,292
Bond beam	1,376	LF	$ 4	$ 5,963	$ 7	$ 9,278
Division 4 Masonry				***$ 281,453***		***$ 437,979***
Division 5 Metals						
Structural Steel	30	TON	$ 4,235	$ 127,047	$ 6,590	$ 197,703
Stairs	2	LS	$ 32,827	$ 65,655	$ 51,084	$ 102,168
Handrail		LF	$ 63	$ -	$ 98	$ -
Grating		SF	$ 37	$ -	$ 57	$ -
Division 5 Metals				***$ 192,702***		***$ 299,870***
Division 7 Thermal and Moisture Protection						
Roof insulation	20,640	SF	$ 3	$ 53,753	$ 4	$ 83,647
Wall insulation	10,512	SF	$ 2	$ 21,395	$ 3	$ 33,294
Division 7 Thermal and Moisture Protection				***$ 75,148***		***$ 116,941***
Division 8 Openings						
Hollow metal doors (with security hardware)	13	EA	$ 1,313	$ 17,070	$ 2,043	$ 26,564
Roll-up door with motor	6	EA	$ 3,947	$ 23,680	$ 6,142	$ 36,850
Division 8 Openings				***$ 40,751***		***$ 63,413***
Division 9 Finishes						
Painting	20,640	SF	$ 8	$ 165,120	$ 12	$ 256,949
Division 9 Finishes				***$ 165,120***		***$ 256,949***
Division 10 Specialties						
Hallway/Entrance	1,000	SF	$ 50	$ 50,000	$ 78	$ 77,807

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Offices	1,080	SF	$ 75	$ 81,000	$ 117	$ 126,047
Break Room	666	SF	$ 100	$ 66,600	$ 156	$ 103,639
Control Room	800	SF	$ 150	$ 120,000	$ 233	$ 186,736
Storage	500	SF	$ 75	$ 37,500	$ 117	$ 58,355
Shop/Garage	3,720	SF	$ 100	$ 372,000	$ 156	$ 578,882
Electrical Room	640	SF	$ 150	$ 96,000	$ 233	$ 149,389
Generator Room	900	SF	$ 150	$ 135,000	$ 233	$ 210,078
Lab	500	SF	$ 200	$ 100,000	$ 311	$ 155,614
Bathrooms/Locker Room	600	SF	$ 75	$ 45,000	$ 117	$ 70,026
Lab Equipment	1	LS	$ 20,000	$ 20,000	$ 31,123	$ 31,123
Furniture	1	LS	$ 35,000	$ 35,000	$ 54,465	$ 54,465
UV Electrical Room	1,403	SF	$ 100	$ 140,250	$ 156	$ 218,248
UV Room Finishes	9,818	SF	$ 40	$ 392,700	$ 62	$ 611,094
Division 10 Specialties				***$ 1,691,050***		***$ 2,631,503***
Division 15 Mechanical						
72" Steel pipe	100	LF	$ 587	$ 58,652	$ 913	$ 91,270
72" x 36" Tee	7	EA	$ 35,000	$ 245,000	$ 54,465	$ 381,253
72" Reducer	1	LF	$ 30,000	$ 30,000	$ 46,684	$ 46,684
Misc. fittings	1	EA	$ 30,639	$ 30,639	$ 47,678	$ 47,678
36" Butterfly valve	14	EA	$ 15,000	$ 210,000	$ 23,342	$ 326,788
36" 90 deg elbow	21	LF	$ 10,000	$ 210,000	$ 15,561	$ 326,788
36" Steel pipe	350	LS	$ 305	$ 106,901	$ 475	$ 166,352
Division 15 Mechanical				***$ 891,191***		***$ 1,386,815***
Division 22 Plumbing						
Plumbing	2	LS	$ 100,000	$ 200,000	$ 155,614	$ 311,227
Fire sprinkler system	2	LS	$ 50,000	$ 100,000	$ 77,807	$ 155,614
Division 22 Plumbing				***$ 300,000***		***$ 466,841***
Division 23 HVAC						
HVAC	20,640	SF	$ 15	$ 309,600	$ 23	$ 481,780
Division 23 HVAC				***$ 309,600***		***$ 481,780***
Division 26 Electrical						
Generator (750 KW)	1	LS	$ 140,000	$ 140,000	$ 217,859	$ 217,859
Electrical	1	LS	$ 100,000	$ 100,000	$ 155,614	$ 155,614
Division 26 Electrical				***$ 240,000***		***$ 373,473***
Division 40 Process Interconnections						
Instruments	2	LS	$ 50,000	$ 75,000	$ 77,807	$ 116,710
Division 40 Process Interconnections				***$ 75,000***		***$ 116,710***
Division 43 Process Handling and Storage Equipment						
UV Disinfection	1	LS	$ 5,125,000	$ 5,125,000	$ 7,975,195	$ 7,975,195
Division 43 Process Handling and Storage Equipment				***$ 5,125,000***		***$ 7,975,195***
Office Building Subtotal				**$ 11,988,000**		**$ 18,655,000**
Totals				**$ 44,633,000**		**$ 69,454,000**

Mark-Ups

Item	Rate	Construction Subtotal	Percent of Total
Construction Subtotal		$ 44,633,000	64.3%
Subcontractor Markups		included in construction subtotal	
Design Allowance		-	0.0%
Direct Cost Subtotal		**$ 44,633,000**	**64.3%**
General Conditions	5.0%	$ 2,232,000	3.2%
Contingency	30.0%	$ 14,060,000	20.2%
Contractor's Overhead and Profit	12.0%	$ 7,311,000	10.5%
Bonds and Insurance	2.0%	$ 1,219,000	1.8%
Grand Total		**$ 69,455,000**	100.0%

Item	Construction Subtotal	Grand Total ($)
Sitework Subtotal	**$ 7,028,000**	**$ 10,937,000**
Propane Yard Subtotal	**$ 936,000**	**$ 1,457,000**
Grit Building Subtotal	**$ 7,057,000**	**$ 10,982,000**
Disinfection Contact Basins Subtotal	**$ 15,493,000**	**$ 24,110,000**
Chlorine Building Subtotal	**$ 2,129,000**	**$ 3,313,000**

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Office Building Subtotal				**$ 11,988,000**		**$ 18,655,000**
Totals				**$ 44,633,000**		**$ 69,454,000**

ENDAWS

Opinion of Probable Construction Cost
Biota Water Treatment Plant Estimate
Option 3 - Conventional Treatment
April 15, 2020

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Sitework						
Division 2 Site Construction						
General						
Property Cost	1	EA	$ 1,000,000	$ 1,000,000	$ 1,556,094	$ 1,556,094
Utility Extensions	1	LS	$ 2,500,000	$ 2,500,000	$ 3,890,234	$ 3,890,234
Comissioning Costs	1	LS	$ 1,267,000	$ 1,267,000	$ 1,971,571	$ 1,971,571
Earthwork						
Site excavation	40,267	CY	$ 14	$ 583,377	$ 23	$ 907,789
Embankment & fill	8,053	CY	$ 26	$ 212,113	$ 41	$ 330,068
Wasting - haul off	32,213	CY	$ 4	$ 122,668	$ 6	$ 190,883
Load wasting - haul off	32,213	CY	$ 3	$ 81,426	$ 4	$ 126,707
Finish grading	2,239	SY	$ 1	$ 3,062	$ 2	$ 4,765
Clear & grub	40	AC	$ 1,717	$ 68,667	$ 2,671	$ 106,852
Restoration	1	LS	$ 10,942	$ 10,942	$ 17,028	$ 17,028
Septic Leach Field	1	LS	$ 350,000	$ 350,000	$ 544,633	$ 544,633
Yard Piping						
72" Steel - McClusky Canal to Pump Station	130	LF	$ 587	$ 76,247	$ 913	$ 118,648
72" Steel - Pump Station to Water Treatment Plant	770	LF	$ 587	$ 451,618	$ 913	$ 702,760
72" Tee	5	EA	$ 105,704	$ 528,522	$ 164,486	$ 822,429
72" 45 deg elbow	1	LF	$ 62,919	$ 62,919	$ 97,908	$ 97,908
Misc. fittings	1	EA	$ 30,639	$ 30,639	$ 47,677	$ 47,677
72" Butterfly valve	3	EA	$ 49,241	$ 147,723	$ 76,624	$ 229,872
36" Steel pipe	630	LS	$ 305	$ 192,422	$ 475	$ 299,426
12" DIP	1,000	LS	$ 140	$ 140,000	$ 218	$ 217,853
10" DIP	1,200	LS	$ 125	$ 150,000	$ 195	$ 233,414
6" DIP	800	LS	$ 90	$ 72,000	$ 140	$ 112,039
Surfacings						
Asphalt pavement	82,200	SF	$ 4	$ 330,106	$ 6	$ 513,676
Prime coat	9,133	SF	$ 3	$ 24,486	$ 4	$ 38,102
Concrete curb & gutter	6,910	LF	$ 16	$ 113,646	$ 26	$ 176,843
Marking & signage	1	LS	$ 16,414	$ 16,414	$ 25,541	$ 25,541
Landscaping	1	LS	$ 54,712	$ 54,712	$ 85,138	$ 85,138
Fencing						
Chain link	4,400	LF	$ 31	$ 138,085	$ 49	$ 214,874
Gate	1	EA	$ 5,465	$ 5,465	$ 8,504	$ 8,504
Storm Drainage						
Storm drainage	1	LS	$ 1,250,000	$ 1,250,000	$ 1,945,117	$ 1,945,117
Electrical Yard Accessories						
Yard Accessories	1	LS	$ 3,000,000	$ 3,000,000	$ 4,668,281	$ 4,668,281
Division 2 Site Construction				***$ 12,984,260***		***$ 20,204,727***
Sitework Subtotal				**$ 12,984,000**		**$ 20,205,000**
Propane Yard						
Division 2 Site Construction						
Structural excavation	1,556	CY	$ 14	$ 22,537	$ 23	$ 35,069
Compact fill	519	CY	$ 26	$ 13,657	$ 41	$ 21,252
Structural backfil	519	CY	$ 45	$ 23,286	$ 70	$ 36,235
Wasting - haul off	1,037	CY	$ 4	$ 3,949	$ 6	$ 6,145
Load wasting - haul off	1,037	CY	$ 3	$ 2,621	$ 4	$ 4,079
Division 2 Site Construction				***$ 66,050***		***$ 102,779***
Division 3 Concrete						
Slab on grade/footings	778	CY	$ 633	$ 492,546	$ 985	$ 766,449
Walls	284	CY	$ 1,036	$ 294,654	$ 1,612	$ 458,509
Division 3 Concrete				***$ 787,200***		***$ 1,224,957***

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Division 26 Electrical						
Electrical	1	LS	$ 75,000	$ 75,000	$ 116,707	$ 116,707
Division 26 Electrical				***$ 75,000***		***$ 116,707***
Division 40 Process Interconnections						
Gas piping	1	LS	$ 50,000	$ 50,000	$ 77,805	$ 77,805
Division 40 Process Interconnections				***$ 50,000***		***$ 77,805***
Division 43 Process Handling and Storage Equipment						
Propane tank	5	EA	$ 78,169	$ 390,847	$ 121,639	$ 608,195
Division 43 Process Handling and Storage Equipment				***$ 390,847***		***$ 608,195***
Propane Yard Subtotal				**$ 1,369,000**		**$ 2,130,000**
Disinfection Contact Basins						
Division 2 Site Construction						
Structural excavation	12,630	CY	$ 14	$ 182,976	$ 23	$ 284,728
Compact fill	1,263	CY	$ 26	$ 33,265	$ 41	$ 51,763
Structural backfil	631	CY	$ 45	$ 28,359	$ 70	$ 44,129
Finish grading	1,894	SY	$ 1	$ 2,591	$ 2	$ 4,032
Wasting - haul off	10,735	CY	$ 4	$ 40,879	$ 6	$ 63,612
Load wasting - haul off	10,735	CY	$ 3	$ 27,135	$ 4	$ 42,225
Division 2 Site Construction				***$ 315,205***		***$ 490,489***
Division 3 Concrete						
Slab footings	177	CY	$ 633	$ 111,878	$ 985	$ 174,093
Slab on grade	1,263	CY	$ 633	$ 799,802	$ 985	$ 1,244,566
Walls	1,291	CY	$ 1,036	$ 1,337,451	$ 1,612	$ 2,081,199
Elevated Slab	947	CY	$ 1,230	$ 1,165,322	$ 1,914	$ 1,813,350
Splitter box Equipment (inlc. Mixers, slide gates)	1	LS	$ 125,000	$ 125,000	$ 194,512	$ 194,512
Division 3 Concrete				***$ 3,539,453***		***$ 5,507,721***
Division 26 Electrical						
Electrical	1	LS	$ 50,000	$ 50,000	$ 77,805	$ 77,805
Division 26 Electrical				***$ 50,000***		***$ 77,805***
Division 40 Process Interconnections						
Instruments	1	LS	$ 25,000	$ 25,000	$ 38,902	$ 38,902
Division 40 Process Interconnections				***$ 25,000***		***$ 38,902***
Disinfection Contact Basins Subtotal				**$ 3,930,000**		**$ 6,115,000**
Water Treatment Plant						
Division 2 Site Construction						
Structural excavation	47,315	CY	$ 14	$ 685,490	$ 23	$ 1,066,686
Compact fill	23,657	CY	$ 26	$ 623,102	$ 41	$ 969,605
Structural backfil	7,097	CY	$ 45	$ 318,722	$ 70	$ 495,961
Finish grading	14,194	SY	$ 1	$ 19,415	$ 2	$ 30,212
Wasting - haul off	16,560	CY	$ 4	$ 63,061	$ 6	$ 98,129
Load wasting - haul off	16,560	CY	$ 3	$ 41,859	$ 4	$ 65,137
Division 2 Site Construction				***$ 1,751,648***		***$ 2,725,729***
Division 3 Concrete						
Cast-In-Place Concrete						
Slab on grade/footings	10,031	CY	$ 633	$ 6,352,208	$ 985	$ 9,884,631
Walls	2,181	CY	$ 633	$ 1,381,007	$ 985	$ 2,148,976
Perimeter footing	818	CY	$ 633	$ 517,877	$ 985	$ 805,866
Column Footings	351	CY	$ 1,419	$ 498,138	$ 2,208	$ 775,149
Column - roof	1,755	CY	$ 1,419	$ 2,490,689	$ 2,208	$ 3,875,746
Process Walls - Rapid Mix Tanks	375	CY	$ 633	$ 237,161	$ 985	$ 369,045
Process Walls - Flocculation Basins	1,334	CY	$ 633	$ 844,647	$ 985	$ 1,314,350
Process Walls - Sedimentation Basins	1,324	CY	$ 633	$ 838,209	$ 985	$ 1,304,331
Process Walls - Filter Beds	1,003	CY	$ 633	$ 635,332	$ 985	$ 988,636
Process Walls - pipe Gallery	1,193	CY	$ 633	$ 755,543	$ 985	$ 1,175,696
Precast Concrete						
Precast suspended slab roof	135,415	SF	$ 33	$ 4,445,327	$ 51	$ 6,917,346
Division 3 Concrete				***$ 18,996,138***		***$ 29,559,772***
Division 4 Masonry						
Face Brick	29,440	SF	$ 13	$ 389,475	$ 21	$ 606,060
12" CMU	29,440	SF	$ 13	$ 382,066	$ 20	$ 594,530
Bond beam	2,920	LF	$ 4	$ 12,653	$ 7	$ 19,689
8" CMU - Polymer	2,900	SF	$ 10	$ 28,909	$ 16	$ 44,985

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
8" CMU - Ferric	3,070	SF	$ 10	$ 30,604	$ 16	$ 47,622
8" CMU - Chlorine Feed	3,285	SF	$ 10	$ 32,747	$ 16	$ 50,957
Firewall	2,920	SF	$ 10	$ 29,108	$ 16	$ 45,295
Division 4 Masonry				***$ 905,562***		***$ 1,409,139***
Division 5 Metals						
Structural Steel	140	TON	$ 4,235	$ 592,886	$ 6,590	$ 922,587
Stairs	1	LS	$ 32,827	$ 32,827	$ 51,083	$ 51,083
Handrail	2,500	LF	$ 63	$ 157,599	$ 98	$ 245,239
Grating	10,800	SF	$ 37	$ 396,490	$ 57	$ 616,975
Division 5 Metals				***$ 1,179,803***		***$ 1,835,884***
Division 7 Thermal and Moisture Protection						
Roof insulation	135,415	SF	$ 3	$ 352,663	$ 4	$ 548,776
Wall insulation	26,496	SF	$ 2	$ 53,927	$ 3	$ 83,916
Division 7 Thermal and Moisture Protection				***$ 406,590***		***$ 632,692***
Division 8 Openings						
Hollow metal doors (with security hardware)	30	EA	$ 1,313	$ 39,393	$ 2,043	$ 61,299
Roll-up door with motor	20	EA	$ 3,947	$ 78,934	$ 6,141	$ 122,829
Division 8 Openings				***$ 118,327***		***$ 184,128***
Division 9 Finishes						
Painting	135,415	SF	$ 8	$ 1,083,320	$ 12	$ 1,685,748
Division 9 Finishes				***$ 1,083,320***		***$ 1,685,748***
Division 10 Specialties						
Hallway/Entrance	1,500	SF	$ 50	$ 75,000	$ 78	$ 116,707
Offices	2,100	SF	$ 75	$ 157,500	$ 117	$ 245,085
Break Room	1,600	SF	$ 100	$ 160,000	$ 156	$ 248,975
Control Room	1,500	SF	$ 150	$ 225,000	$ 233	$ 350,121
Storage	1,500	SF	$ 75	$ 112,500	$ 117	$ 175,061
Shop/Garage	7,013	SF	$ 100	$ 701,300	$ 156	$ 1,091,289
Electrical Room	1,000	SF	$ 150	$ 150,000	$ 233	$ 233,414
Generator Room	1,300	SF	$ 150	$ 195,000	$ 233	$ 303,438
Lab	900	SF	$ 200	$ 180,000	$ 311	$ 280,097
Bathrooms/Locker Room	1,200	SF	$ 75	$ 90,000	$ 117	$ 140,048
Lab Equipment	2	LS	$ 30,000	$ 60,000	$ 46,683	$ 93,366
Furniture	4	LS	$ 100,000	$ 400,000	$ 155,609	$ 622,438
Conference Room	900	SF	$ 100	$ 90,000	$ 156	$ 140,048
UV Electrical Room	2,057	SF	$ 100	$ 205,700	$ 156	$ 320,088
UV Room Finishes	11,220	SF	$ 40	$ 448,800	$ 62	$ 698,375
Process Area Finishes	89,430	SF	$ 25	$ 2,235,750	$ 39	$ 3,479,037
Division 10 Specialties				***$ 5,486,550***		***$ 8,537,586***
Division 11 Equipment						
Monorail & Hoist	7	LS	$ 60,000	$ 420,000	$ 93,366	$ 653,559
Division 11 Equipment				***$ 420,000***		***$ 653,559***
Division 15 Mechanical						
60" Steel pipe - UV piping	180	LF	$ 475	$ 85,500	$ 739	$ 133,046
60" Steel pipe - Filter Effluent Header	40	LF	$ 475	$ 19,000	$ 739	$ 29,566
48" Steel pipe	100	LF	$ 350	$ 35,000	$ 545	$ 54,463
36" Steel pipe	350	LF	$ 305	$ 106,901	$ 475	$ 166,348
60" Tee	3	EA	$ 85,000	$ 255,000	$ 132,268	$ 396,804
48" Tee	4	EA	$ 25,000	$ 100,000	$ 38,902	$ 155,609
36" Tee	4	EA	$ 18,500	$ 74,000	$ 28,788	$ 115,151
60" Butterfly valve	6	EA	$ 38,000	$ 228,000	$ 59,132	$ 354,789
36" Butterfly valve	12	EA	$ 15,000	$ 180,000	$ 23,341	$ 280,097
Misc. Piping	1	LS	$ 6,500,000	$ 6,500,000	$ 10,114,610	$ 10,114,610
Misc. Fittings	1	LS	$ 2,000,000	$ 2,000,000	$ 3,112,188	$ 3,112,188
Division 15 Mechanical				***$ 9,583,401***		***$ 14,912,671***
Division 22 Plumbing						
Plumbing	1	LS	$ 2,445,644	$ 2,445,644	$ 3,805,651	$ 3,805,651
Fire sprinkler system	1	LS	$ 547,124	$ 547,124	$ 851,376	$ 851,376
Division 22 Plumbing				***$ 2,992,768***		***$ 4,657,028***
Division 23 HVAC						
HVAC	1	LS	$ 3,720,443	$ 3,720,443	$ 5,789,358	$ 5,789,358
Division 23 HVAC				***$ 3,720,443***		***$ 5,789,358***

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Division 26 Electrical						
Generator (1250 KW)	1	LS	$ 250,000	$ 250,000	$ 389,023	$ 389,023
Electrical	1	LS	$ 14,881,771	$ 14,881,771	$ 23,157,431	$ 23,157,431
Division 26 Electrical				***$ 15,131,771***		***$ 23,546,455***
Division 40 Process Interconnections						
Instruments	1	LS	$ 8,753,983	$ 8,753,983	$ 13,622,018	$ 13,622,018
Division 40 Process Interconnections				***$ 8,753,983***		***$ 13,622,018***
Division 43 Process Handling and Storage Equipment						
UV Disinfection	1	LS	$ 5,125,000	$ 5,125,000	$ 7,974,981	$ 7,974,981
Mix Reactor	1	LS	$ 483,000	$ 483,000	$ 751,593	$ 751,593
Flocculation	1	LS	$ 1,980,300	$ 1,980,300	$ 3,081,533	$ 3,081,533
Plate Settlers	12	EA	$ 565,000	$ 6,780,000	$ 879,193	$ 10,550,316
Media Filtration	1	LS	$ 16,430,131	$ 16,430,131	$ 25,566,826	$ 25,566,826
Air Scour Blower	2	EA	$ 234,716	$ 469,432	$ 365,240	$ 730,481
5,000 gal FRP Bulk Tank	12	LS	$ 17,500	$ 210,000	$ 27,232	$ 326,780
6,000 gal FRP Day Tank	3	LS	$ 20,000	$ 60,000	$ 31,122	$ 93,366
Transfer Pump Skid	3	LS	$ 35,799	$ 107,396	$ 55,706	$ 167,118
Feed Pump Skid	3	LS	$ 35,799	$ 107,396	$ 55,706	$ 167,118
Tank Pads & Floor grating	1	LS	$ 30,000	$ 30,000	$ 46,683	$ 46,683
Monorail & Hoist System	5	LS	$ 20,000	$ 100,000	$ 31,122	$ 155,609
Misc Valves & Piping	1	LS	$ 138,838	$ 138,838	$ 216,045	$ 216,045
Basin Underflow Pump	6	EA	$ 39,119	$ 234,716	$ 60,873	$ 365,240
LAS Storage	1	LS	$ 690,000	$ 690,000	$ 1,073,705	$ 1,073,705
Polymer System	1	LS	$ 690,000	$ 690,000	$ 1,073,705	$ 1,073,705
Ferric System	1	LS	$ 690,000	$ 690,000	$ 1,073,705	$ 1,073,705
Packaged Plate Settlers	2	EA	$ 1,408,296	$ 2,816,592	$ 2,191,441	$ 4,382,881
Division 43 Process Handling and Storage Equipment				***$ 37,142,801***		***$ 57,797,683***
Water Treatment Plant Subtotal				**$ 107,673,000**		**$ 167,549,000**
Residuals Thickening						
Division 2 Site Construction						
Structural excavation	1,126	CY	$ 14	$ 16,313	$ 23	$ 25,385
Compact fill	196	CY	$ 26	$ 5,162	$ 41	$ 8,033
Structural backfil	93	CY	$ 45	$ 4,176	$ 70	$ 6,499
Wasting - haul off	930	CY	$ 4	$ 3,541	$ 6	$ 5,511
Load wasting - haul off	930	CY	$ 3	$ 2,351	$ 4	$ 3,658
Division 2 Site Construction				***$ 31,544***		***$ 49,086***
Division 3 Concrete						
Cast-In-Place Concrete						
Slab on grade/footings	205	CY	$ 633	$ 129,821	$ 985	$ 202,014
Roof	200	CY	$ 1,230	$ 246,050	$ 1,914	$ 382,877
Precast Concrete						
80' dia. concrete tank	1	EA	$ 1,200,000	$ 1,200,000	$ 1,867,313	$ 1,867,313
Division 3 Concrete				***$ 1,575,872***		***$ 2,452,204***
Division 5 Metals						
Ladder	20	VLF	$ 127	$ 2,547	$ 198	$ 3,964
Division 5 Metals				***$ 2,547***		***$ 3,964***
Division 15 Mechanical						
Misc. Piping	1	LS	$ 350,000	$ 350,000	$ 544,633	$ 544,633
Misc. fittings	1	LS	$ 150,000	$ 150,000	$ 233,414	$ 233,414
Division 15 Mechanical				***$ 500,000***		***$ 778,047***
Division 26 Electrical						
Electrical	1	LS	$ 400,000	$ 400,000	$ 622,438	$ 622,438
Division 26 Electrical				***$ 400,000***		***$ 622,438***
Division 40 Process Interconnections						
Process Piping						
12" DIP	100	LF	$ 119	$ 11,902	$ 185	$ 18,521
Valves						
12" Check valve	2	EA	$ 7,046	$ 14,092	$ 10,964	$ 21,929
12" Plug valve	2	EA	$ 6,763	$ 13,526	$ 10,524	$ 21,047
I&C						
Instruments	1	LS	$ 200,000	$ 200,000	$ 311,219	$ 311,219
Division 40 Process Interconnections				***$ 239,520***		***$ 372,716***

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Division 43 Process Handling and Storage Equipment						
Packaged Inclined Plate Settler System (1.5 MGD)	5	EA	$ 1,800,000	$ 9,000,000	$ 2,800,969	$ 14,004,844
Submersible pump	4	EA	$ 50,000	$ 200,000	$ 77,805	$ 311,219
Division 43 Process Handling and Storage Equipment				***$ 9,200,000***		***$ 14,316,063***
Residuals Thickening Subtotal				**$ 11,949,000**		**$ 18,595,000**
Backwash Supply Tank						
Division 2 Site Construction						
Structural excavation	1,026	CY	$ 14	$ 14,865	$ 23	$ 23,131
Compact fill	200	CY	$ 26	$ 5,268	$ 41	$ 8,197
Structural backfil	186	CY	$ 45	$ 8,353	$ 70	$ 12,998
Wasting - haul off	826	CY	$ 4	$ 3,145	$ 6	$ 4,895
Load wasting - haul off	826	CY	$ 3	$ 2,088	$ 4	$ 3,249
Division 2 Site Construction				***$ 33,718***		***$ 52,469***
Division 3 Concrete						
Cast-In-Place Concrete						
Slab on grade/footings	47	CY	$ 633	$ 29,764	$ 985	$ 46,315
Roof	200	CY	$ 1,230	$ 246,050	$ 1,914	$ 382,877
Precast Concrete						
80' dia. concrete tank	1	EA	$ 1,200,000	$ 1,200,000	$ 1,867,313	$ 1,867,313
Division 3 Concrete				***$ 1,475,814***		***$ 2,296,505***
Division 5 Metals						
Ladder	20	VLF	$ 127	$ 2,547	$ 198	$ 3,964
Division 5 Metals				***$ 2,547***		***$ 3,964***
Division 26 Electrical						
Electrical	1	LS	$ 75,000	$ 75,000	$ 116,707	$ 116,707
Division 26 Electrical				***$ 75,000***		***$ 116,707***
Division 40 Process Interconnections						
Instruments	1	LS	$ 30,000	$ 30,000	$ 46,683	$ 46,683
Division 40 Process Interconnections				***$ 30,000***		***$ 46,683***
Division 43 Process Handling and Storage Equipment						
Backwash Supply Pump	2	EA	$ 100,000	$ 200,000	$ 155,609	$ 311,219
Division 43 Process Handling and Storage Equipment				***$ 200,000***		***$ 311,219***
Backwash Supply Tank Subtotal				**$ 1,817,000**		**$ 2,828,000**
Residuals Ponds						
Division 2 Site Construction						
Structural excavation	36,111	CY	$ 14	$ 523,172	$ 23	$ 814,105
Compact fill	6,019	CY	$ 26	$ 158,519	$ 41	$ 246,670
Structural backfil	9,028	CY	$ 45	$ 405,419	$ 70	$ 630,870
Wasting - haul off	30,093	CY	$ 4	$ 114,592	$ 6	$ 178,316
Load wasting - haul off	30,093	CY	$ 3	$ 76,065	$ 4	$ 118,365
Division 2 Site Construction				***$ 1,277,767***		***$ 1,988,326***
Division 10 Specialties						
HDPE Liner	162,500	SF	$ 3	$ 444,538	$ 4	$ 691,743
Division 10 Specialties				***$ 444,538***		***$ 691,743***
Division 15 Mechanical						
Misc. Piping	1	LS	$ 500,000	$ 500,000	$ 778,047	$ 778,047
Misc. fittings	1	LS	$ 200,000	$ 200,000	$ 311,219	$ 311,219
Division 15 Mechanical				***$ 700,000***		***$ 1,089,266***
Division 26 Electrical						
Electrical	1	LS	$ 100,000	$ 100,000	$ 155,609	$ 155,609
Division 26 Electrical				***$ 100,000***		***$ 155,609***
Division 43 Process Handling and Storage Equipment						
Return Pumps	8	EA	$ 50,000	$ 400,000	$ 77,805	$ 622,438
Division 43 Process Handling and Storage Equipment				***$ 400,000***		***$ 622,438***
Residuals Ponds Subtotal				**$ 2,922,000**		**$ 4,547,000**
Totals				**$ 142,645,000**		**$ 221,969,000**

Item	Rate	Construction Subtotal	Percent of Total
Construction Subtotal		$ 142,645,000	64.3%
Subcontractor Markups		included in construction subtotal	
Design Allowance		-	0.0%
Direct Cost Subtotal		**$ 142,645,000**	**64.3%**

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
General Conditions			5.0%	$ 7,132,000	3.2%	
Contingency			30.0%	$ 44,933,000	20.2%	
Contractor's Overhead and Profit			12.0%	$ 23,365,000	10.5%	
Bonds and Insurance			2.0%	$ 3,894,000	1.8%	
Grand Total				**$ 221,969,000**	100.0%	

Item	Construction Subtotal	Grand Total ($)
Sitework Subtotal	**$ 12,984,000**	**$ 20,205,000**
Propane Yard Subtotal	**$ 1,369,000**	**$ 2,130,000**
Disinfection Contact Basins Subtotal	**$ 3,930,000**	**$ 6,115,000**
Water Treatment Plant Subtotal	**$ 107,673,000**	**$ 167,549,000**
Solids Equalization Basin Subtotal	**$ 1,817,000**	**$ 2,828,000**
Residuals Thickening Subtotal	**$ 11,949,000**	**$ 18,595,000**
Residuals Ponds Subtotal	**$ 2,922,000**	**$ 4,547,000**
Totals	**$ 142,645,000**	**$ 221,969,000**

ENDAWS

Opinion of Probable Construction Cost
Biota Water Treatment Plant Estimate
Option 4 - Advanced Treatment
April 15, 2020

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Sitework						
Division 2 Site Construction						
General						
Property Cost	1	EA	$ 1,000,000	$ 1,000,000	$ 1,556,104	$ 1,556,104
Utility Extensions	1	LS	$ 2,500,000	$ 2,500,000	$ 3,890,259	$ 3,890,259
Comissioning Costs	1	LS	$ 1,367,000	$ 1,367,000	$ 2,127,194	$ 2,127,194
Earthwork						
Site excavation	40,267	CY	$ 14	$ 583,377	$ 23	$ 907,795
Embankment & fill	8,053	CY	$ 26	$ 212,113	$ 41	$ 330,070
Wasting - haul off	32,213	CY	$ 4	$ 122,668	$ 6	$ 190,884
Load wasting - haul off	32,213	CY	$ 3	$ 81,426	$ 4	$ 126,707
Finish grading	2,239	SY	$ 1	$ 3,062	$ 2	$ 4,765
Clear & grub	40	AC	$ 1,717	$ 68,667	$ 2,671	$ 106,853
Restoration	1	LS	$ 10,942	$ 10,942	$ 17,028	$ 17,028
Septic Leach Field	1	LS	$ 350,000	$ 350,000	$ 544,636	$ 544,636
Yard Piping						
72" Steel - McClusky Canal to Pump Station	130	LF	$ 587	$ 76,247	$ 913	$ 118,649
72" Steel - Pump Station to Water Treatment Plant	770	LF	$ 587	$ 451,618	$ 913	$ 702,764
72" Tee	5	EA	$ 105,704	$ 528,522	$ 164,487	$ 822,435
72" 45 deg elbow	1	LF	$ 62,919	$ 62,919	$ 97,909	$ 97,909
Misc. fittings	1	EA	$ 30,639	$ 30,639	$ 47,677	$ 47,677
72" Butterfly valve	3	EA	$ 49,241	$ 147,723	$ 76,624	$ 229,873
36" Steel pipe	630	LS	$ 305	$ 192,422	$ 475	$ 299,428
12" DIP	1,000	LS	$ 140	$ 140,000	$ 218	$ 217,855
10" DIP	1,200	LS	$ 125	$ 150,000	$ 195	$ 233,416
6" DIP	800	LS	$ 90	$ 72,000	$ 140	$ 112,039
Surfacings						
Asphalt pavement	82,200	SF	$ 4	$ 330,106	$ 6	$ 513,679
Prime coat	9,133	SF	$ 3	$ 24,486	$ 4	$ 38,102
Concrete curb & gutter	6,910	LF	$ 16	$ 113,646	$ 26	$ 176,844
Marking & signage	1	LS	$ 16,414	$ 16,414	$ 25,541	$ 25,541
Landscaping	1	LS	$ 54,712	$ 54,712	$ 85,138	$ 85,138
Fencing						
Chain link	4,400	LF	$ 31	$ 138,085	$ 49	$ 214,875
Gate	1	EA	$ 5,465	$ 5,465	$ 8,504	$ 8,504
Storm Drainage						
Storm drainage	1	LS	$ 1,250,000	$ 1,250,000	$ 1,945,130	$ 1,945,130
Electrical Yard Accessories						
Yard Accessories	1	LS	$ 4,000,000	$ 4,000,000	$ 6,224,415	$ 6,224,415
Division 2 Site Construction				***$ 14,084,260***		***$ 21,916,570***
Sitework Subtotal				**$ 14,084,000**		**$ 21,917,000**
Propane Yard						
Division 2 Site Construction						
Structural excavation	1,556	CY	$ 14	$ 22,537	$ 23	$ 35,069
Compact fill	519	CY	$ 26	$ 13,657	$ 41	$ 21,252
Structural backfil	519	CY	$ 45	$ 23,286	$ 70	$ 36,235
Wasting - haul off	1,037	CY	$ 4	$ 3,949	$ 6	$ 6,145
Load wasting - haul off	1,037	CY	$ 3	$ 2,621	$ 4	$ 4,079
Division 2 Site Construction				***$ 66,050***		***$ 102,780***
Division 3 Concrete						
Slab on grade/footings	778	CY	$ 633	$ 492,546	$ 985	$ 766,453
Walls	284	CY	$ 1,036	$ 294,654	$ 1,612	$ 458,512
Division 3 Concrete				***$ 787,200***		***$ 1,224,965***

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Division 26 Electrical						
Electrical	1	LS	$ 75,000	$ 75,000	$ 116,708	$ 116,708
Division 26 Electrical				***$ 75,000***		***$ 116,708***
Division 40 Process Interconnections						
Gas piping	1	LS	$ 50,000	$ 50,000	$ 77,805	$ 77,805
Division 40 Process Interconnections				***$ 50,000***		***$ 77,805***
Division 43 Process Handling and Storage Equipment						
Propane tank	5	EA	$ 78,169	$ 390,847	$ 121,640	$ 608,199
Division 43 Process Handling and Storage Equipment				***$ 390,847***		***$ 608,199***
Propane Yard Subtotal				**$ 1,369,000**		**$ 2,130,000**
Grit Basin Building						
Division 2 Site Construction						
Structural excavation	7,881	CY	$ 14	$ 113,735	$ 22	$ 176,984
Compacted Fill	4,465	CY	$ 26	$ 117,145	$ 41	$ 182,290
Drying Bed	6,693	CY	$ 25	$ 166,772	$ 39	$ 259,515
Division 2 Site Construction				***$ 397,653***		***$ 618,789***
Division 3 Concrete						
Slab on grade/footings	615	CY	$ 631	$ 387,952	$ 982	$ 603,693
Walls	890	CY	$ 1,032	$ 918,374	$ 1,606	$ 1,429,086
Floors	161	CY	$ 1,225	$ 197,302	$ 1,907	$ 307,022
Division 3 Concrete				***$ 1,503,628***		***$ 2,339,801***
Division 4 Masonry						
16" CMU	5,715	SF	$ 22	$ 126,830	$ 35	$ 197,360
Division 4 Masonry				***$ 126,830***		***$ 197,360***
Division 5 Metals						
Miscellaneous steel members	1	TON	$ 4,218	$ 4,218	$ 6,564	$ 6,564
Metal decking	7,459	SF	$ 10	$ 78,051	$ 16	$ 121,455
Standing seam roof	7,459	SF	$ 11	$ 85,775	$ 18	$ 133,474
Division 5 Metals				***$ 168,044***		***$ 261,494***
Division 7 Thermal and Moisture Protection						
Roof insulation	7,459	SF	$ 3	$ 19,350	$ 4	$ 30,111
Wall insulation	5,715	SF	$ 2	$ 11,587	$ 3	$ 18,030
Division 7 Thermal and Moisture Protection				***$ 30,937***		***$ 48,141***
Division 8 Openings						
Hollow metal (with security hardware)	49	SF	$ 109	$ 5,341	$ 170	$ 8,311
Roll-up door with motor	2	EA	$ 3,931	$ 7,863	$ 6,118	$ 12,235
Covers for slab openings	32	SF	$ 55	$ 1,744	$ 85	$ 2,714
Division 8 Openings				***$ 14,948***		***$ 23,260***
Division 10 Specialties						
Miscellaneous specialties	1	LS	$ 5,450	$ 5,450	$ 8,481	$ 8,481
Division 10 Specialties				***$ 5,450***		***$ 8,481***
Division 22 Plumbing						
Plumbing	1	LS	$ 330,270	$ 330,270	$ 513,934	$ 513,934
Division 22 Plumbing				***$ 330,270***		***$ 513,934***
Division 23 HVAC						
HVAC	1	LS	$ 462,160	$ 462,160	$ 719,169	$ 719,169
Division 23 HVAC				***$ 462,160***		***$ 719,169***
Division 26 Electrical						
Electrical	1	LS	$ 719,400	$ 719,400	$ 1,119,461	$ 1,119,461
Division 26 Electrical				***$ 719,400***		***$ 1,119,461***
Division 40 Process Interconnections						
Process Piping						
Pipe support	8	EA	$ 1,635	$ 13,080	$ 2,544	$ 20,354
4" Grit pipe	576	LF	$ 32	$ 18,207	$ 49	$ 28,333
6" Grit pipe	30	LF	$ 51	$ 1,537	$ 80	$ 2,392
4" Strainer	6	EA	$ 3,270	$ 19,620	$ 5,088	$ 30,531
Instrumentation						
Instrumentation	1	LS	$ 335,720	$ 335,720	$ 522,415	$ 522,415
Division 40 Process Interconnections				***$ 388,164***		***$ 604,024***
Division 43 Process Handling and Storage Equipment						
Headcell, Teacup, and Snail	6	EA	$ 434,471	$ 2,606,824	$ 676,082	$ 4,056,489
Grit Pump	6	EA	$ 32,700	$ 196,200	$ 50,885	$ 305,308
3'x5' slide gates	6	EA	$ 10,791	$ 64,746	$ 16,792	$ 100,751

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
6'x5' slide gates	2	EA	$ 17,658	$ 35,316	$ 27,478	$ 54,955
Dumpster	3	EA	$ 2,180	$ 6,540	$ 3,392	$ 10,177
Division 43 Process Handling and Storage Equipment				***$ 2,909,626***		***$ 4,527,681***
Grit Building Subtotal				**$ 7,057,000**		**$ 10,982,000**
Disinfection Contact Basins						
Division 2 Site Construction						
Structural excavation	12,630	CY	$ 14	$ 182,976	$ 23	$ 284,730
Compact fill	1,263	CY	$ 26	$ 33,265	$ 41	$ 51,763
Structural backfil	631	CY	$ 45	$ 28,359	$ 70	$ 44,129
Finish grading	1,894	SY	$ 1	$ 2,591	$ 2	$ 4,032
Wasting - haul off	10,735	CY	$ 4	$ 40,879	$ 6	$ 63,613
Load wasting - haul off	10,735	CY	$ 3	$ 27,135	$ 4	$ 42,226
Division 2 Site Construction				***$ 315,205***		***$ 490,492***
Division 3 Concrete						
Slab footings	177	CY	$ 633	$ 111,878	$ 985	$ 174,094
Slab on grade	1,263	CY	$ 633	$ 799,802	$ 985	$ 1,244,574
Walls	1,291	CY	$ 1,036	$ 1,337,451	$ 1,612	$ 2,081,213
Elevated Slab	947	CY	$ 1,230	$ 1,165,322	$ 1,914	$ 1,813,362
Splitter box Equipment (inlc. Mixers, slide gates)	1	LS	$ 125,000	$ 125,000	$ 194,513	$ 194,513
Division 3 Concrete				***$ 3,539,453***		***$ 5,507,757***
Division 26 Electrical						
Electrical	1	LS	$ 50,000	$ 50,000	$ 77,805	$ 77,805
Division 26 Electrical				***$ 50,000***		***$ 77,805***
Division 40 Process Interconnections						
Instruments	1	LS	$ 25,000	$ 25,000	$ 38,903	$ 38,903
Division 40 Process Interconnections				***$ 25,000***		***$ 38,903***
Disinfection Contact Basins Subtotal				**$ 3,930,000**		**$ 6,115,000**
Water Treatment Plant						
Division 2 Site Construction						
Structural excavation	10,031	CY	$ 14	$ 145,324	$ 23	$ 226,139
Compact fill	200	CY	$ 26	$ 5,268	$ 41	$ 8,197
Structural backfil	135	CY	$ 45	$ 6,063	$ 70	$ 9,434
Finish grading	15,046	SY	$ 1	$ 20,580	$ 2	$ 32,025
Wasting - haul off	9,696	CY	$ 4	$ 36,921	$ 6	$ 57,453
Load wasting - haul off	9,696	CY	$ 3	$ 24,508	$ 4	$ 38,137
Division 2 Site Construction				***$ 238,664***		***$ 371,385***
Division 3 Concrete						
Cast-In-Place Concrete						
Slab on grade/footings	10,031	CY	$ 633	$ 6,352,208	$ 985	$ 9,884,695
Walls	2,181	CY	$ 633	$ 1,381,007	$ 985	$ 2,148,989
Perimeter footing	818	CY	$ 633	$ 517,877	$ 985	$ 805,871
Column Footings	351	CY	$ 1,419	$ 498,138	$ 2,208	$ 775,154
Column - roof	1,755	CY	$ 1,419	$ 2,490,689	$ 2,208	$ 3,875,771
Process Walls - Rapid Mix Tanks	375	CY	$ 633	$ 237,161	$ 985	$ 369,047
Process Walls - Flocculation Basins	1,334	CY	$ 633	$ 844,647	$ 985	$ 1,314,358
Process Walls - Pump Channel	457	CY	$ 633	$ 289,336	$ 985	$ 450,237
Process Walls - pipe Gallery	818	CY	$ 633	$ 518,300	$ 985	$ 806,528
Precast Concrete						
Precast suspended slab roof	135,415	SF	$ 33	$ 4,445,327	$ 51	$ 6,917,390
Division 3 Concrete				***$ 17,574,690***		***$ 27,348,041***
Division 4 Masonry						
Face Brick	29,440	SF	$ 13	$ 389,475	$ 21	$ 606,064
12" CMU	29,440	SF	$ 13	$ 382,066	$ 20	$ 594,534
Bond beam	2,920	LF	$ 4	$ 12,653	$ 7	$ 19,689
8" CMU - Polymer	2,900	SF	$ 10	$ 28,909	$ 16	$ 44,985
8" CMU - Ferric	3,070	SF	$ 10	$ 30,604	$ 16	$ 47,622
8" CMU - Chlorine Feed	3,285	SF	$ 10	$ 32,747	$ 16	$ 50,957
Firewall	2,920	SF	$ 10	$ 29,108	$ 16	$ 45,296
Division 4 Masonry				***$ 905,562***		***$ 1,409,148***
Division 5 Metals						
Structural Steel	140	TON	$ 4,235	$ 592,886	$ 6,590	$ 922,593
Stairs	1	LS	$ 32,827	$ 32,827	$ 51,083	$ 51,083

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Handrail	2,500	LF	$ 63	$ 157,599	$ 98	$ 245,240
Grating	10,800	SF	$ 37	$ 396,490	$ 57	$ 616,979
Division 5 Metals				***$ 1,179,803***		***$ 1,835,895***
Division 7 Thermal and Moisture Protection						
Roof insulation	135,415	SF	$ 3	$ 352,663	$ 4	$ 548,780
Wall insulation	26,496	SF	$ 2	$ 53,927	$ 3	$ 83,917
Division 7 Thermal and Moisture Protection				***$ 406,590***		***$ 632,696***
Division 8 Openings						
Hollow metal doors (with security hardware)	30	EA	$ 1,313	$ 39,393	$ 2,043	$ 61,299
Roll-up door with motor	20	EA	$ 3,947	$ 78,934	$ 6,142	$ 122,830
Division 8 Openings				***$ 118,327***		***$ 184,130***
Division 9 Finishes						
Painting	135,415	SF	$ 8	$ 1,083,320	$ 12	$ 1,685,758
Division 9 Finishes				***$ 1,083,320***		***$ 1,685,758***
Division 10 Specialties						
Hallway/Entrance	1,500	SF	$ 50	$ 75,000	$ 78	$ 116,708
Offices	2,100	SF	$ 75	$ 157,500	$ 117	$ 245,086
Break Room	1,600	SF	$ 100	$ 160,000	$ 156	$ 248,977
Control Room	1,500	SF	$ 150	$ 225,000	$ 233	$ 350,123
Storage	1,500	SF	$ 75	$ 112,500	$ 117	$ 175,062
Shop/Garage	7,013	SF	$ 100	$ 701,300	$ 156	$ 1,091,296
Electrical Room	1,000	SF	$ 150	$ 150,000	$ 233	$ 233,416
Generator Room	1,300	SF	$ 150	$ 195,000	$ 233	$ 303,440
Lab	900	SF	$ 200	$ 180,000	$ 311	$ 280,099
Bathrooms/Locker Room	1,200	SF	$ 75	$ 90,000	$ 117	$ 140,049
Lab Equipment	2	LS	$ 30,000	$ 60,000	$ 46,683	$ 93,366
Furniture	4	LS	$ 100,000	$ 400,000	$ 155,610	$ 622,442
Conference Room	900	SF	$ 100	$ 90,000	$ 156	$ 140,049
UV Electrical Room	2,057	SF	$ 100	$ 205,700	$ 156	$ 320,091
UV Room Finishes	11,220	SF	$ 40	$ 448,800	$ 62	$ 698,379
Process Area Finishes	89,430	SF	$ 25	$ 2,235,750	$ 39	$ 3,479,059
Division 10 Specialties				***$ 5,486,550***		***$ 8,537,641***
Division 11 Equipment						
Monorail & Hoist	7	LS	$ 60,000	$ 420,000	$ 93,366	$ 653,564
Division 11 Equipment				***$ 420,000***		***$ 653,564***
Division 15 Mechanical						
60" Steel pipe - UV piping	180	LF	$ 475	$ 85,500	$ 739	$ 133,047
60" Steel pipe - Filter Effluent Header	40	LF	$ 475	$ 19,000	$ 739	$ 29,566
48" Steel pipe	100	LF	$ 350	$ 35,000	$ 545	$ 54,464
36" Steel pipe	350	LF	$ 305	$ 106,901	$ 475	$ 166,349
60" Tee	3	EA	$ 85,000	$ 255,000	$ 132,269	$ 396,806
48" Tee	4	EA	$ 25,000	$ 100,000	$ 38,903	$ 155,610
36" Tee	4	EA	$ 18,500	$ 74,000	$ 28,788	$ 115,152
60" Butterfly valve	6	EA	$ 38,000	$ 228,000	$ 59,132	$ 354,792
36" Butterfly valve	12	EA	$ 15,000	$ 180,000	$ 23,342	$ 280,099
Misc. Piping	1	LS	$ 7,500,000	$ 7,500,000	$ 11,670,778	$ 11,670,778
Misc. fittings	1	LS	$ 2,500,000	$ 2,500,000	$ 3,890,259	$ 3,890,259
Division 15 Mechanical				***$ 11,083,401***		***$ 17,246,922***
Division 22 Plumbing						
Plumbing	1	LS	$ 2,445,644	$ 2,445,644	$ 3,805,676	$ 3,805,676
Fire sprinkler system	1	LS	$ 547,124	$ 547,124	$ 851,382	$ 851,382
Division 22 Plumbing				***$ 2,992,768***		***$ 4,657,057***
Division 23 HVAC						
HVAC	1	SF	$ 3,720,443	$ 3,720,443	$ 5,789,395	$ 5,789,395
Division 23 HVAC				***$ 3,720,443***		***$ 5,789,395***
Division 26 Electrical						
Generator (1250 KW)	1	LS	$ 250,000	$ 250,000	$ 389,026	$ 389,026
Electrical	1	LS	$ 14,881,771	$ 14,881,771	$ 23,157,580	$ 23,157,580
Division 26 Electrical				***$ 15,131,771***		***$ 23,546,606***
Division 40 Process Interconnections						
Instruments	1	LS	$ 8,753,983	$ 8,753,983	$ 13,622,106	$ 13,622,106
Division 40 Process Interconnections				***$ 8,753,983***		***$ 13,622,106***

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Division 43 Process Handling and Storage Equipment						
UV Disinfection	1	LS	$ 5,125,000	$ 5,125,000	$ 7,975,032	$ 7,975,032
Mix Reactor	1	LS	$ 483,000	$ 483,000	$ 751,598	$ 751,598
Flocculation	1	LS	$ 1,980,300	$ 1,980,300	$ 3,081,552	$ 3,081,552
Ultra Filtration Membrane Units (w/ CIP Controls)	1	LS	$ 30,000,000	$ 30,000,000	$ 46,683,113	$ 46,683,113
Membrane Feed Pumps	12	LS	$ 96,000	$ 1,152,000	$ 149,386	$ 1,792,632
5,000 gal FRP Bulk Tank	12	LS	$ 17,500	$ 210,000	$ 27,232	$ 326,782
6,000 gal FRP Day Tank	3	LS	$ 20,000	$ 60,000	$ 31,122	$ 93,366
Transfer Pump Skid	3	LS	$ 35,799	$ 107,396	$ 55,706	$ 167,119
Feed Pump Skid	3	LS	$ 35,799	$ 107,396	$ 55,706	$ 167,119
Tank Pads & Floor grating	1	LS	$ 30,000	$ 30,000	$ 46,683	$ 46,683
Monorail & Hoist System	5	LS	$ 20,000	$ 100,000	$ 31,122	$ 155,610
Misc Valves & Piping	1	LS	$ 138,838	$ 138,838	$ 216,047	$ 216,047
Blower System	1	LS	$ 2,400,000	$ 2,400,000	$ 3,734,649	$ 3,734,649
Compressed Air System	1	LS	$ 1,800,000	$ 1,800,000	$ 2,800,987	$ 2,800,987
CIP Tanks	1	LS	$ 840,000	$ 840,000	$ 1,307,127	$ 1,307,127
LAS Storage	1	LS	$ 690,000	$ 690,000	$ 1,073,712	$ 1,073,712
Polymer System	1	LS	$ 690,000	$ 690,000	$ 1,073,712	$ 1,073,712
Ferric System	1	LS	$ 690,000	$ 690,000	$ 1,073,712	$ 1,073,712
Packaged Plate Settlers	2	EA	$ 1,408,296	$ 2,816,592	$ 2,191,455	$ 4,382,909
Division 43 Process Handling and Storage Equipment				***$ 49,420,521***		***$ 76,903,460***
Water Treatment Plant Subtotal				**$ 118,516,000**		**$ 184,424,000**
Solids Equalization Basin						
Division 2 Site Construction						
Structural excavation	1,126	CY	$ 14	$ 16,313	$ 23	$ 25,385
Compact fill	196	CY	$ 26	$ 5,162	$ 41	$ 8,033
Structural backfil	93	CY	$ 45	$ 4,176	$ 70	$ 6,499
Wasting - haul off	930	CY	$ 4	$ 3,541	$ 6	$ 5,511
Load wasting - haul off	930	CY	$ 3	$ 2,351	$ 4	$ 3,658
Division 2 Site Construction				***$ 31,544***		***$ 49,086***
Division 3 Concrete						
Cast-In-Place Concrete						
Slab on grade/footings	205	CY	$ 633	$ 129,821	$ 985	$ 202,015
Roof	200	CY	$ 1,230	$ 246,050	$ 1,914	$ 382,880
Precast Concrete						
80' dia. concrete tank	1	EA	$ 1,200,000	$ 1,200,000	$ 1,867,325	$ 1,867,325
Division 3 Concrete				***$ 1,575,872***		***$ 2,452,220***
Division 5 Metals						
Ladder	20	VLF	$ 127	$ 2,547	$ 198	$ 3,964
Division 5 Metals				***$ 2,547***		***$ 3,964***
Division 15 Mechanical						
Misc. Piping	1	LS	$ 350,000	$ 350,000	$ 544,636	$ 544,636
Misc. fittings	1	LS	$ 150,000	$ 150,000	$ 233,416	$ 233,416
Division 15 Mechanical				***$ 500,000***		***$ 778,052***
Division 26 Electrical						
Electrical	1	LS	$ 250,000	$ 250,000	$ 389,026	$ 389,026
Division 26 Electrical				***$ 250,000***		***$ 389,026***
Division 40 Process Interconnections						
Process Piping						
12" DIP	100	LF	$ 119	$ 11,902	$ 185	$ 18,521
Valves						
12" Check valve	2	EA	$ 7,046	$ 14,092	$ 10,965	$ 21,929
12" Plug valve	2	EA	$ 6,763	$ 13,526	$ 10,524	$ 21,047
I&C						
Instruments	1	LS	$ 150,000	$ 150,000	$ 233,416	$ 233,416
Division 40 Process Interconnections				***$ 189,520***		***$ 294,913***
Division 43 Process Handling and Storage Equipment						
Packaged Inclined Plate Settler System (0.8 MGD)	4	EA	$ 1,300,000	$ 5,200,000	$ 2,022,935	$ 8,091,740
Submersible pump	2	EA	$ 50,000	$ 100,000	$ 77,805	$ 155,610
Division 43 Process Handling and Storage Equipment				***$ 5,300,000***		***$ 8,247,350***
Solids Equalization Basin Subtotal				**$ 7,849,000**		**$ 12,215,000**
Residuals Ponds						

Item	Quantity	Unit	Raw Unit Price ($)	Construction Subtotal	Markup Unit Price ($)	Grand Total ($)
Division 2 Site Construction						
Structural excavation	36,111	CY	$ 14	$ 523,172	$ 23	$ 814,110
Compact fill	6,019	CY	$ 26	$ 158,519	$ 41	$ 246,672
Structural backfil	9,028	CY	$ 45	$ 405,419	$ 70	$ 630,874
Wasting - haul off	30,093	CY	$ 4	$ 114,592	$ 6	$ 178,317
Load wasting - haul off	30,093	CY	$ 3	$ 76,065	$ 4	$ 118,366
Division 2 Site Construction				***$ 1,277,767***		***$ 1,988,339***
Division 10 Specialties						
HDPE Liner	162,500	SF	$ 3	$ 444,538	$ 4	$ 691,748
Division 10 Specialties				***$ 444,538***		***$ 691,748***
Division 15 Mechanical						
Misc. Piping	1	LS	$ 300,000	$ 300,000	$ 466,831	$ 466,831
Misc. fittings	1	LS	$ 125,000	$ 125,000	$ 194,513	$ 194,513
Division 15 Mechanical				***$ 425,000***		***$ 661,344***
Division 26 Electrical						
Electrical	1	LS	$ 100,000	$ 100,000	$ 155,610	$ 155,610
Division 26 Electrical				***$ 100,000***		***$ 155,610***
Division 43 Process Handling and Storage Equipment						
Return Pump	8	EA	$ 50,000	$ 400,000	$ 77,805	$ 622,442
Division 43 Process Handling and Storage Equipment				***$ 400,000***		***$ 622,442***
Residuals Ponds Subtotal				**$ 2,647,000**		**$ 4,119,000**
Totals				**$ 155,453,000**		**$ 241,901,000**

Item	Rate	Construction Subtotal	Percent of Total
Construction Subtotal		$ 155,453,000	64.3%
Subcontractor Markups		included in construction subtotal	
Design Allowance		-	0.0%
Direct Cost Subtotal		**$ 155,453,000**	**64.3%**
General Conditions	5.0%	$ 7,773,000	3.2%
Contingency	30.0%	$ 48,968,000	20.2%
Contractor's Overhead and Profit	12.0%	$ 25,463,000	10.5%
Bonds and Insurance	2.0%	$ 4,244,000	1.8%
Grand Total		**$ 241,901,000**	**100.0%**

Item	Construction Subtotal	Grand Total ($)
Sitework Subtotal	**$ 14,084,000**	**$ 21,917,000**
Propane Yard Subtotal	**$ 1,369,000**	**$ 2,130,000**
Grit Building Subtotal	**$ 7,057,000**	**$ 10,982,000**
Disinfection Contact Basins Subtotal	**$ 3,930,000**	**$ 6,115,000**
Water Treatment Plant Subtotal	**$ 118,516,000**	**$ 184,424,000**
Residuals Thickening Subtotal	**$ 7,849,000**	**$ 12,215,000**
Residuals Ponds Subtotal	**$ 2,647,000**	**$ 4,119,000**
Totals	**$ 155,453,000**	**$ 241,901,000**

Appendix H Design Parameter Tables for Treatment Options

OPTION 1 – DISINFECTION

Table H-1: Option 1 - Chlorine Disinfection Design Parameters

Process: Chlorine Disinfection	
Design Parameter	**Value**
Technology	Serpentine Basin
Disinfectant	Sodium Hypochlorite
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mg/L)	8.0
Average Dose (mg/L)	6.0
Minimum Dose (mg/L)	4.0
Target Residual (mg/L)	3.0
Quantity	4 Basins
Individual Basin Volume (MG)	4.6
Design Flow HDT (min)	215
Velocity (ft/s)	0.4
Baffling Factor	0.8
cT (mg-min/L)	516

Table H-2: Option 1 - Dechlorination Design Parameters

Process: Dechlorination	
Design Parameter	**Value**
Reductant	Sodium Bisulfite
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mg/L)	5.2
Average Dose (mg/L)	3.5
Minimum Dose (mg/L)	1.8

*Dechlorination is performed at the effluent location of the pipeline prior to entrance into the Sheyenne River

OPTION 2 – ENHANCED DISINFECTION

Table H-3: Option 2 - UV Disinfection Design Parameters

Process: UV Disinfection	
Design Parameter	**Value**
Technology	Low Pressure High Output (LPHO) Reactors
Design UVT (%)	70
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mJ/cm^2)	40
Duty Reactor Number	10
Standby Reactor Number	1
Total Reactor Number	11
Total Installed Power (kW)	605

Table H-4: Option 2 - Chlorine Disinfection Design Parameters

Process: Chlorine Disinfection	
Design Parameter	**Value**
Technology	Serpentine Basin
Disinfectant	Sodium Hypochlorite
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mg/L)	8.0
Average Dose (mg/L)	6.0
Minimum Dose (mg/L)	4.0
Target Residual (mg/L)	3.0
Quantity	4 Basins
Individual Basin Volume (MG)	4.6
Design Flow HDT (min)	215
Velocity (ft/s)	0.4
Baffling Factor	0.8
cT (mg-min/L)	516

Figure H-5: Option 2 - Dechlorination Process Design Parameters

Process: Dechlorination	
Design Parameter	**Value**
Reductant	Sodium Bisulfite
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mg/L)	5.2
Average Dose (mg/L)	3.5
Minimum Dose (mg/L)	1.8

*Dechlorination is performed at the effluent location of the pipeline prior to entrance into the Sheyenne River

OPTION 3 – CONVENTIONAL TREATMENT

Figure H-6: Option 3 - Coagulation Process Design Parameters

Process: Coagulation	
Design Parameter	**Value**
Technology	Back Mix Reactor (Single Stage)
Coagulant	Ferric Chloride
Flow Path	Straight
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mg/L)	50
Average Dose (mg/L)	15
HDT (sec)	40
Trains	4
Stages	2
Depth, wtr (ft)	15
G, Avg (s^{-1})	750
L:W Ratio	1

Figure H-7: Option 3 - Flocculation Process Design Parameters

Process: Flocculation	
Design Parameter	**Value**
Technology	Horizontal Shaft Mixer
Polymer	Liquid
Flow Path	Serpentine
Number of Stages	3
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Polymer Dose (mg/L)	1.5
Average Polymer Dose (mg/L)	0.5
HDT, Basin (min)	30
Stage 1 - G,Avg	40
Stage 2 - G,Avg	20
Stage 3 - G,Avg	10

Figure H-8: Option 3 - High Rate Sedimentation Process Design Parameters

Process: High Rate Sedimentation	
Design Parameter	**Value**
Technology	Plate Assisted Sedimentation
Design Flow (mgd)	107
Design Flow (cfs)	165
Shape	Rectangular
Basins	12
SLR (gpm/ft2)	0.3
Depth, wtr (ft)	15
Plate Length (ft)	10
Channel Width (in)	2
Rows/Basin	6

Figure H-9: Option 3 - Media Filtration Process Design Parameters

Process: Media Filtration	
Design Parameter	**Value**
Technology	Dual Media
Design Flow (mgd)	107
Design Flow (cfs)	165
Solids Loading Rate (gpm/ft2)	8
Redundancy	n+1
Basin Number	12
Filter Area (ft^2)	1175
Anthracite Depth (in)	18
Sand Depth (in)	12
Cells/filter	2
L:W Ratio (ft)	1.9

Figure H-10: Option 3 - UV Disinfection Process Design Parameters

Process: UV Disinfection	
Design Parameter	**Value**
Technology	Low Pressure High Output (LPHO) Reactors
Design UVT (%)	70
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mJ/cm^2)	40
Average Dose (mJ/cm^2)	25
Duty Reactor Number	10
Standby Reactor Number	1
Total Reactor Number	11
Total Installed Power (kW)	605

Figure H-11: Option 3 - Chlorine Disinfection Design Parameters

Process: Chlorine Disinfection	
Design Parameter	**Value**
Technology	Serpentine Basin
Disinfectant	Sodium Hypochlorite
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mg/L)	8.0
Average Dose (mg/L)	6.0
Minimum Dose (mg/L)	4.0
Target Residual (mg/L)	1.0
Quantity	4 Basins
Individual Basin Volume (MG)	1.5
Design Flow HDT (min)	20.2
Velocity (ft/s)	0.1
Baffling Factor	0.66
cT (mg-min/L)	13.3

Figure H-12: Option 3 - Dechlorination Design Parameters

Process: Dechlorination	
Design Parameter	**Value**
Reductant	Sodium Bisulfite
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mg/L)	5.2
Average Dose (mg/L)	3.5
Minimum Dose (mg/L)	1.8

*Dechlorination is performed at the effluent location of the pipeline prior to entrance into the Sheyenne River

OPTION 4 – ADVANCED TREATMENT

Figure H-13: Option 4 – Coagulation Process Design Parameters

Process: Coagulation	
Design Parameter	**Value**
Technology	Back Mix Reactor (Single Stage)
Coagulant	Ferric Chloride
Flow Path	Straight
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mg/L)	50
Average Dose (mg/L)	15
HDT (sec)	40
Trains	4
Stages	2
Depth, wtr (ft)	15
G, Avg (s^{-1})	750
L:W Ratio	1

Figure H-14: Option 4 – Flocculation Process Design Parameters

Process: Flocculation	
Design Parameter	**Value**
Technology	Horizontal Shaft Mixer
Coagulant	Liquid
Flow Path	Serpentine
Number of Stages	3
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Polymer Dose (mg/L)	1.5
Average Polymer Dose (mg/L)	0.5
HDT, Basin (min)	30

Figure H-15: Option 4 – Membrane Filtration Process Design Parameters

Process: Membrane Filtration	
Design Parameter	**Value**
Technology	Low Pressure MF/UF (Encased System)
Design Flow (mgd)	107
Design Flow (cfs)	165
Redundancy	n+3
Skids	32 skids, 4 trains
Number of Membrane Modules	5,440
Recovery (%)	95

Figure H-16: Option 4 – UV Disinfection Process Design Parameters

Process: UV Disinfection	
Design Parameter	**Value**
Technology	Low Pressure High Output (LPHO) Reactors
Design UVT (%)	70
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mJ/cm^2)	40
Duty Reactor Number	10
Standby Reactor Number	1
Total Reactor Number	11
Total Installed Power (kW)	605

Figure H-17: Option 4 – Chlorine Disinfection Process Design Parameters

Process: Chlorine Disinfection	
Design Parameter	**Value**
Technology	Serpentine Basin
Disinfectant	Sodium Hypochlorite
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mg/L)	8.0
Average Dose (mg/L)	6.0
Minimum Dose (mg/L)	4.0
Target Residual (mg/L)	1.0
Quantity	4 Basins
Individual Basin Volume (MG)	1.5
Design Flow HDT (min)	20.2
Velocity (ft/s)	0.1
Baffling Factor	0.66
cT (mg-min/L)	13.3

Figure H-18: Option 4 – Dechlorination Process Design Parameters

Process: Dechlorination	
Design Parameter	**Value**
Reductant	Sodium Bisulfite
Design Flow (mgd)	107
Design Flow (cfs)	165
Design Dose (mg/L)	5.2
Average Dose (mg/L)	3.5
Minimum Dose (mg/L)	1.8

*Dechlorination is performed at the effluent location of the pipeline prior to entrance into the Sheyenne River