Big Sky County Water and Sewer District No. 363

WRRF CONCEPTUAL DESIGN AND EFFLUENT REUSE AND DISCHARGE STUDY

WRRF Conceptual Design Executive Summary (DRAFT)

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Executive Summary

The Big Sky County Water and Sewer District, No. 363 (District) is pursuing a project to upgrade and expand its Wastewater Treatment Facility (WWTF), while diversifying and expanding its effluent reuse and disposal options. Note that from here forward, the existing treatment facility will be referred to as the WWTF, but the post expansion and upgrade will be named the Water Resource Recovery Facility (WRRF), per industry guidelines and to differentiate the future plant from the current facility.

The District is generating flows and loads that are encroaching upon the existing WWTF's rated treatment capacity. To date, the District has not discharged effluent, it reclaims all effluent. Additional irrigation disposal capacity is being developed so that the District can continue this "zero-liquid discharge" approach, but the District is heavily reliant on third-party agreements and single points of failure under its current reuse regime. Diversification of the District's effluent reuse "portfolio" is needed to provide reliable, redundant and secure reuse capacity. Direct discharge to the mainstem of the Gallatin River is needed by the District to provide, at minimum, a backup means of discharging effluent, so that effluent can be discharged in the event of a failure of the District's primary reuse pipelines; and so that the District and its reuse partners can periodically drain, inspect and repair-as-needed any of the large effluent storage reservoirs.

Conclusions and Recommendation

Based on the finding in this Conceptual Design and Effluent Reuse and Discharge Study, it is recommended that the District move forward with Phase I of what will ultimately be a multi-phased upgrade and expansion of its wastewater treatment, conveyance and reuse and disposal facilities.

Phase I WRRF Expansion and Upgrade

Phase I should include upgrading the existing WWTF using membrane bioreactor (MBR) technology, which will require upgrades to the existing Headworks Building to provide more robust screening. Phase I should also include the effluent piping distribution upgrades described in TM No. 5, to optimize the flexibility of use of the new and improved effluent, including provisions to allow immediate distribution of the effluent as opposed to storage and potential reduction in quality.

The estimated cost for the Phase I WRRF Expansion and Upgrade is $21.7M[i]. The benefit of the project is expanded treatment capacity, higher quality effluent, new state of the art equipment and SCADA systems, and increased reuse flexibility. Phase I alone should reduce the total output of nitrogen and phosphorus by at least 70 and 90%, respectively.

The key results and findings contained herein will be reviewed with the Board in October and November, and once the DRAFT is approved, a funding plan will be formulated.

Final design services can proceed at the District's prerogative. Design will require approximately nine to twelve months, with MBR equipment pre-procurement, and District and DEQ reviews included. Construction will likely require one full construction season, placing startup in 2020.

Subsequent Phases

There are other projects that the District will eventually want to complete beyond the work recommended for Phase I. These are described in this Report and include the following:

- **Biosolids Improvements** – the improvements needed for the biosolids portion of the WRRF are described in TM No. 8, and are estimated, across two phases, at $6.8M and $2.0M, respectively. The first phase does not need to be included in the $21.7M Phase I WRRF Expansion and Upgrade, it can be initiated as the District sees the labor burden of composting increase to a point where additional biosolids destruction is desired.
- **Effluent Reuse and/or Discharge Projects** – once the District has had an opportunity to review the DRAFT Effluent Reuse and Discharge Study, an order of implementation can be formulated to begin phasing in the permitting and design of reuse and disposal projects according to their relative cost-benefit.
    - Expansion of reuse capacity at the Yellowstone Club, which is on-going and tentatively scheduled over the next two years, improves the timeline for the District to plan its long-term reuse and discharge strategy.
    - The projects evaluated in the Study range from $279,000 to $4.0M for infrastructure, and from $65,000 to $440,000 for water quality, environmental and construction permits, with direct discharge to the mainstem Gallatin River having

[i] The construction cost estimates presented are based on 2018 dollars. The engineer's opinion of probable project costs (EOPCC) was developed based on other, similar projects, budgetary cost proposals from suppliers, engineering judgement and RS Means cost estimating manuals. The EOPCC cost opinions in this report represent a Class 4 Estimate based on the definitions of the Association for Advancement of Cost Engineering (AACE) International. This level of cost opinion is appropriate for planning level evaluations made with incomplete information. The cost opinion at this level of engineering is considered to have an accuracy range of +50/-30 percent.

Engineering design and bidding are estimated at 12 percent of construction costs. Construction administration is estimated at 10 percent of construction costs. Construction contingency is assumed to be 25 percent of construction costs.

the highest cost for both permitting and infrastructure. See TM 10 for additional information.

- The cost for the direct discharge infrastructure do not include potentially necessary additional measures to address dissolved oxygen or temperature mitigation. The need for these will be assess over the coming years, with additional data collection. See TM 9 for additional background.

- **Advanced Treatment** – the estimated cost for an ozone/BAC treatment system for full build-out flows is $5.8M. The effluent quality that will result from this project is not needed at this time, as all current reuse is irrigation. The treatment equipment in the existing Filter Building can be demolished and removed after MBR commissioning and startup in the Phase I Expansion and Upgrade, and the District can evaluate potential piloting and/or phasing in Advanced Treatment in that building.

Introduction

In 2017 the District solicited engineering proposals to evaluate effluent disposal alternatives and develop treatment plant expansion and upgrade alternatives appropriate for the disposal alternatives. AE2S was contracted to provide engineering services for the project in early 2018. The resulting report is organized as follows:

TM 1: Summary of Previous Work, Project Data, and Existing Conditions
TM 2: WRRF Expansion and Upgrade Design Criteria
TM 3: Preliminary Treatment Upgrades
TM 4: Secondary – Tertiary Treatment Process Selection
TM 5: Tertiary Effluent, Reservoir Storage, and Reuse Piping
TM 6: Advanced Treatment
TM 7: Dissolved Oxygen and Temperature Mitigation
TM 8: Biosolids Treatment, Dewatering, and Composting
TM 9: Odor Control Evaluation
TM 10: Effluent Reuse and Discharge Study Executive Summary
TM 11: Snowmaking with Reclaimed Water
TM 12: Indirect Subsurface Discharge
TM 13: Reclaimed Water Irrigation
TM 14: Direct Discharge of Reclaimed Water
TM 15: Effluent Pipeline for Direct Discharge

This Executive Summary (ES) provides an overview of the contents of TMs 1 through 9, which form the WRRF Conceptual Design Report. TM 10 provides a summary of the Effluent Disposal Study (TMs 10 through 15). Note that many individual TMs also have an Executive Summary, where it was deemed warranted due to length and/or complexity.

The District intends for this report to be a living document, as significant portions of the work outlined herein will be ongoing and further developed. As an example, the effluent reuse flow balance is not static, it changes yearly due to variability of influent flows to the treatment facility (driven by occupancy patterns and I/I), irrigation rates being impacted by precipitation and climate fluctuations, and ever-evolving reuse capacity by the District and its reuse partners.

TM No. 1: Summary of Previous Work, Project Data, and Existing Conditions

This TM provides a convenient location to access information about the facilities and District planning prior to the initiation of the current work. It includes information about the existing wastewater treatment facility (WWTF) that was constructed in 2004, summarizes recent relevant work and data regarding treatment and disposal, and describes the existing conditions at the WWTF and with the effluent water balance. The primary takeaways in TM No. 1 are:

- The existing treatment facility will be referred to as the WWTF, but after expansion and upgrade it will be named the Water Resource Recovery Facility (WRRF), in convention with Water Environment Federation and Water Environment Research Foundation guidance.
- The District is obligated to serve 10,678 single-family equivalents (SFEs) at Ultimate Build-Out (UBO) of its service area, including the Lone Moose Meadows and Spanish Peaks obligations converted to SFEs. This is in comparison to the 5,655 SFEs that were on the records as of the end of 2017.
- The existing WWTF is not designed to routinely accomplish nutrient removal to low nutrient (nitrogen and phosphorus) effluent concentrations. The historical 2013-2018 effluent average total nitrogen is 17.5 mg/L, and average total phosphorus is 4.5 mg/L, with higher concentrations of total phosphorus since May of 2015 (trending towards 8.0 mg/L).
- An effluent disposal flow balance was developed based on approximations for the 2017-18 water year. The balance approximates one year in time, and should be updated annually to keep pace with changing conditions, including:
    - Varying levels of precipitation and duration of irrigation season from year to year
    - Difficulties in separating fresh effluent volumes versus holdover storage from previous years
    - On-going changes with effluent disposal:
        - 2018 was the first year that Spanish Peaks has utilized effluent to irrigate the Spanish Peaks Golf Course
        - The Yellowstone Club continues to develop additional disposal capacity at a rapid pace, towards the ultimate disposal capacity agreed upon of 160 million gallons (MG)
        - the District rehabilitated the dilapidated irrigation network in Parcel B (aka the “horse pasture”) and irrigated it in 2018 at quantities not realized in several years
- At full build-out of SFEs, it is estimated that the District will need to reuse or dispose of approximately 320 MG annually. With the Yellowstone Club rapidly developing its full commitment of 160 MG of disposal and the potential additional disposal and reuse

methodologies included in the Effluent Reuse and Discharge Study, the current estimate for future disposal as surface water discharge is "up to" 70 MG. This is simply the amount of water remaining after taking the minimum estimated ultimate disposal capacity of all other disposal methods that have been evaluated to date, and it is strongly dependent upon a very preliminary estimate of potential disposal capacity for snow-making.

- 70 MG is not necessarily the disposal capacity that the District might ultimately seek for surface water discharge.
  - The flow balance shows that over 60% of the District's build-out disposal capacity would not be under their direct control. This heavy weight on third-party agreements presents risk, so the District must have its own capability to reuse or dispose of effluent.
  - There may also be situations in the future where significant effluent disposal capacity would not be available for extended periods, such as a break in the 7-mile Yellowstone Club effluent forcemain (or a pump or valve failure, or a wildfire that could take the irrigation distribution system out of operation). Any future application for surface water discharge must take these reliability and redundancy issues into consideration.
- In the coming years the District will assess the potential cost-benefit of aquifer recharge for the Meadow Village aquifer, as a possible approach to indirect potable reuse (IPR). The treatment needs, public perception and permitting requirements will be gauged before any firm plans are made for IPR.

TM No. 2: WRRF Expansion and Upgrade Design Criteria

Influent Design Criteria

TM No. 2 processes historical influent data provided by the District and integrates SFE data to characterize the District's current flows and loads, and then project the characteristics out to ultimate build-out (10,678 SFEs). Loads are the key water quality parameters for raw wastewater (biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP). The resulting flow and load design criteria for the WRRF Expansion and Upgrade are provided in Table ES 1.

Table ES 1 Influent Design Criteria for the WRRF Expansion and Upgrade

Parameter	Units	Average Annual	ADMMF		PDF	
Flow (MGD)	MGD	0.91	1.4		1.8	
BOD_5	lb/day	2,667	1.4	3,734	2.3	6,134
COD		5,782	1.4	8,095	2.3	13,299
TSS		2,808	1.4	3,931	2.5	7,020
TN		270	1.9	513	2.4	648
TP		90	1.8	162	2.1	189

Effluent Design Criteria

Design criteria for the effluent quality is two-fold. First, to take advantage of all reuse alternatives that are feasible in Big Sky, the District should target Class A-1 reclaimed water. Class A-1 reclaimed wastewater must always be oxidized, coagulated, filtered and disinfected (DEQ Circular 2). Numerical quality should comply with the following:

- Less than 10 mg/L biochemical oxygen demand (BOD_5) and total suspended solids (TSS)
- Total Coliform
  - Less than 2.2 colony forming units per 100 milliliters (CFU/100 mL), 7 sample running average
  - Less than 23 CFU/100 mL in any sample
- Complies with nondegradation requirements, allowing application to land at rates that exceed agronomic uptake rate
- Total Nitrogen less than 5.0 mg/L in any sample.

Beyond these effluent quality criteria for reuse, there are effluent reuse and disposal methods under consideration that have specific water quality drivers that may warrant additional, advanced treatment of the effluent:

1. **Snow-making** – while treatment beyond Class A-1 reuse criteria may not be necessary to comply with a Montana DEQ discharge permit for snow-making, advanced treatment may be pursued for snow-making for the following reasons:
   a. Areas under consideration for snow-making drain to the Middle Fork of the West Fork, which is impaired for nitrate/nitrite.
   b. Advanced treatment would include technologies able to remove color, an important factor in snow-making.
   c. Public acceptance of the use of effluent for snow-making would be made easier with advanced treatment.
2. ***De facto* Indirect Potable Reuse** – groundwater infiltration is one effluent disposal method being considered by the District. Current irrigation areas overlay the District's primary drinking water source aquifer. This provides additional motivation to utilized Advanced Treatment to target compounds of emerging concern (CECs). In the future, the District will evaluate and could elect to practice intentional Indirect Potable Reuse via aquifer recharge.

3. **Surface water discharge –** discharge of effluent to the Gallatin River (Class B-1 surface water, ARM 17.30.623) is being considered by the District. Preliminary evaluations indicate a high probability that a Class A-1 reuse water, with the inclusion of phosphorus treatment, could provide an effluent of sufficient quality to obtain a direct discharge permit to the mainstem of the Gallatin River, with the exception of phosphorus.
    a. Treating for phosphorus will be necessary to obtain a direct discharge permit for discharge to the mainstem Gallatin River. The numerical limit for phosphorus has not yet been established, but a planning value of 0.1 mg/L has been utilized in the surface water discharge evaluation.
    b. CECs that could potentially affect aquatic organisms in the Gallatin River are discussed in TM No. 6, Advanced Treatment. Treatment for CECs is not required by MPDES regulations, but inclusion of CEC treatment measures demonstrates good stewardship of the watershed, addresses concerns of some members of the public, and further protects the aquatic health of the Gallatin River.

These motivators for advanced treatment, beyond Class A-1 standards, do not yet incur numerical limits for the WRRF Expansion and Upgrade. The permitting efforts for the above reuse and disposal strategies will be on-going, but it is highly probable that the advanced treatment technologies being considered for a subsequent phase of the project will meet the future numerical criteria for these reuse and disposal strategies.

TM No. 3: Preliminary Treatment Upgrades

This TM covers review of the existing preliminary treatment system (screening and grit removal) and assesses the need for and options for upgrade and/or expansion of the screening and grit removal system. The existing screens are approaching the end of their useful life, and will not be appropriate for the downstream treatment MBR alternative. The existing grit chamber was not incorporated into the original building, a structure was retrofitted around it after construction. District staff would like this to be rectified with the Upgrade and Expansion project, so that operators can adequately access the grit chamber.

The preliminary treatment process designs are dependent on the downstream secondary-tertiary treatment process that is ultimately selected (MBR or AquaNereda/UF). Technical Memorandum No. 4, Secondary-Tertiary Treatment Process Selection, provides an evaluation of the secondary-tertiary treatment alternatives, but the impacts on preliminary treatment are incorporated into TM No. 3.

Essentially, MBR treatment requires finer screening (2 mm openings as opposed to 6 mm openings). This requires larger screen sizes to maintain the hydraulic gradeline (not incur additional head loss), which requires increasing the width of the channels in the District’s Headworks. The cost impact of this is approximately $370,000. This differential is incorporated into the secondary-tertiary treatment process selection in TM No. 4 so that the additional cost impact is applied to the MBR alternative.

TM 4: Secondary – Tertiary Treatment Process Selection

TM No. 4 evaluates secondary-tertiary treatment upgrade alternatives for improving the treatment performance and increasing the treatment capacity of the District's existing WWTF.

Two secondary-tertiary treatment alternatives were considered: Membrane Bioreactor (MBR) technology, and Aerobic Granular Sludge [AGS, also known by the trade-name AquaNereda from Aqua Aerobics Systems, Inc. (AASI, who also is the supplier of the District's existing sequencing batch-reactor system)]. The AGS alternative would be followed by tertiary ultrafiltration, to comply with reuse regulations and to provide approximately equivalent treatment performance to MBR. The ultrafiltration equipment downstream of AGS could be either polymeric or ceramic membrane filters. A third subset of the AGS based alternative was evaluated whereby an algae-based nutrient removal process known as CLEARAS would follow the AGS treatment. CLEARAS incorporates a microfiltration membrane for algae separation. To summarize the four alternatives evaluated herein:

- Alternative 1: Membrane Bioreactor (MBR) System
- Alternative 2: Aerobic Granular Sludge with Ultrafiltration (AGS/UF) Alternatives
    - 2A: AGS with Polymeric Membrane Ultrafiltration
    - 2B: AGS with Ceramic Membrane Ultrafiltration
    - 2C: AGS with CLEARAS Algae-Based "Advanced Biological Nutrient Recovery" (ABNR) treatment system.

These secondary-tertiary treatment alternatives were evaluated for their ability to treat the projected flows and loads of the Big Sky Water and Sewer District at build-out of the currently identified and obligated single-family equivalents (SFEs, 10,678), while also meeting the estimated effluent water quality requirements for future effluent disposal and reuse alternatives.

Alternative 1: MBR

Implementation of MBR technology (Alternative 1) would consist of retrofitting the existing SBR tanks into a nutrient removal configuration (anaerobic/anoxic/aerobic) and constructing a membrane bioreactor (MBR) facility downstream with a second, post-anoxic zone. Effluent from the aerobic zone would be conveyed through new underground pipes to the post-anoxic zone and then to the aerated (aerobic) membrane tank.

MBR advanced wastewater treatment has been utilized to an increasing degree in the wastewater treatment industry over the last 20 years. MBR technology provides the following benefits to the District:

- Compact size – the existing treatment footprint is limited, so maximizing footprint efficiency is important for long-term planning.
- The membrane separation process enables operators to utilize a longer solids retention time (SRT), which is critical for reliable nitrification in cold wastewater like the District's.

- Consistent, reliable effluent quality – the reuse and disposal options under consideration by the District in some cases require, and in all cases would benefit, from a more consist, and consistently high-quality, effluent.
- Disinfection capabilities – MBRs have proven capable of removing pathogenic organisms smaller than the membrane actual rated pore size. This is thought to be due to the reduction of the membrane effective pore size due to pore blocking from biomass, biofilm growth, gels and scales, as well as adsorption of pathogenic microbes by activated sludge impinged on the membrane surface (Hirani, 2018) and enhanced biological predation (Erdal, 2017). Just as an example, the disinfection performance of the Butte, MT MBR has been so good that the City was able to turn off its UV Disinfection system.
- Contaminants of Emerging Concern (CEC) removal performance – research has indicated that MBRs provide improved removal of trace organics (including some classes of CECs). (Kent et al 2011; Grandclement et al, 2017). Optimization of CEC removal is an added benefit for the District, since CEC removal is also being evaluated in a future downstream advanced treatment process.

The District's existing SBRs would be partitioned into anaerobic, anoxic, and aerobic tanks are to provide the environments necessary to trigger bacterial populations to provide nutrient removal ahead of the membrane separation process. Envirosim's Biowin wastewater treatment process simulation software was used to assess how these existing tanks could be best partitioned to optimize treatment performance. The details of this evaluation can be found in TM No. 4.

Zones retrofitted into the existing SBR Tanks:

- Anaerobic zone: this zone is used to select for phosphorus accumulating organisms (PAOs). Anaerobic refers to a lack of dissolved oxygen and/or nitrate in the zone.
- Pre-Anoxic zone: This zone will also be void of dissolved oxygen, as the intent is to force bacteria to reduce nitrate that will be recycled from the aerobic zones to this zone, once nitrification of ammonia is accomplished in the aerobic zones.
- Aerobic zone: Blowers and diffusers will distribute air throughout an aerobic zone to provide dissolved oxygen for microbes to degrade BOD and convert ammonia to nitrate (nitrification).

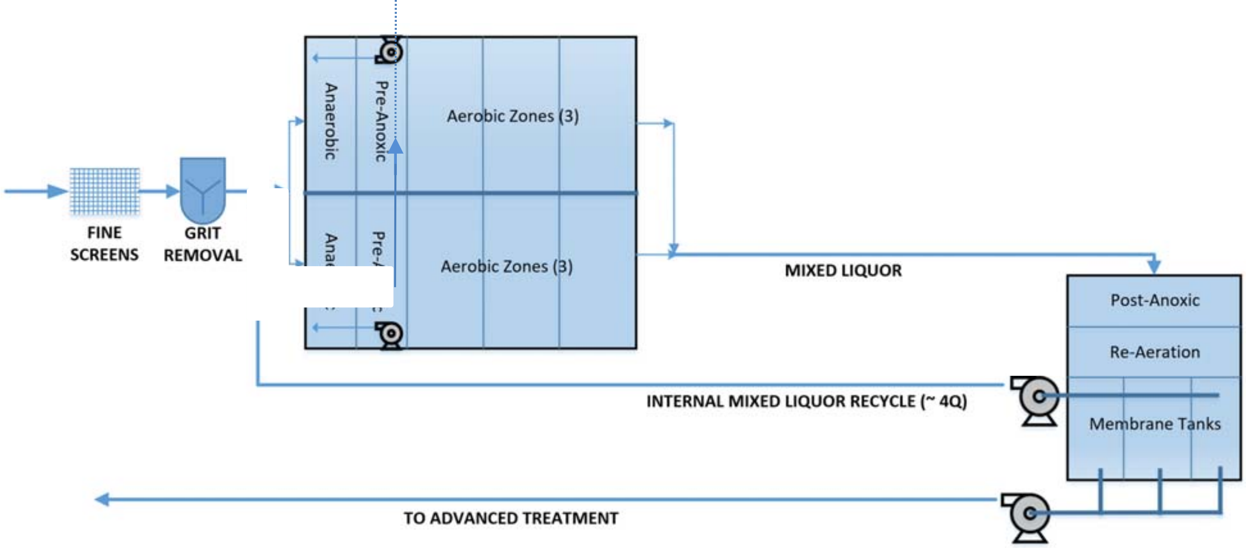
New Tank within the Membrane Facility structure:

The biological process engineering revealed that while the existing SBR volumes provide sufficient capacity for anaerobic, pre-anoxic and aerobic zones, an additional post-anoxic zone will need to be constructed to provide good nutrient removal performance at the future peak month flows and loads derived in TM No. 2.

- Post-Anoxic zone: This second, "post-" anoxic zone will be located with the membrane facility to the east of the District's existing parking lot. It will provide a second opportunity to reduce remaining nitrate to nitrogen gas. Supplemental carbon will be added to this zone as needed to achieve low total nitrogen in the membrane permeate.

Two biological treatment trains would be utilized, similar to the existing SBR configuration, to provide redundancy and operational flexibility. Influent wastewater will be screened through 2 mm openings, and de-gritted, and then flow by gravity through the biological treatment process and then to the MBR facility. The preliminary process flow diagram is shown in Figure ES 1.

Figure ES 1 Alternative 1 (MBR) Preliminary Process Flow Diagram



The new MBR Building would include the post-anoxic tank, a small re-aeration tank, the membrane tanks and associated equipment (cleaning equipment, air scour, blowers, etc.) as well as supplemental carbon and aluminum-based coagulant storage and feed systems. The aluminum-based coagulant will be provided to coagulate phosphorus that remains after optimization of biological phosphorus removal, ahead of the membrane.

Alternative 2: AGS/UF Alternatives

Alternative 2 consists of upgrading the existing Aqua-Aerobics SBR treatment process to the AASI's Aerobic Granular Sludge (AGS) Technology process and integrating an ultrafiltration (UF) membrane system downstream of the AGS system to further improve effluent water quality. Alternative 2A would utilize polymeric membranes, 2B would utilize ceramic membranes.

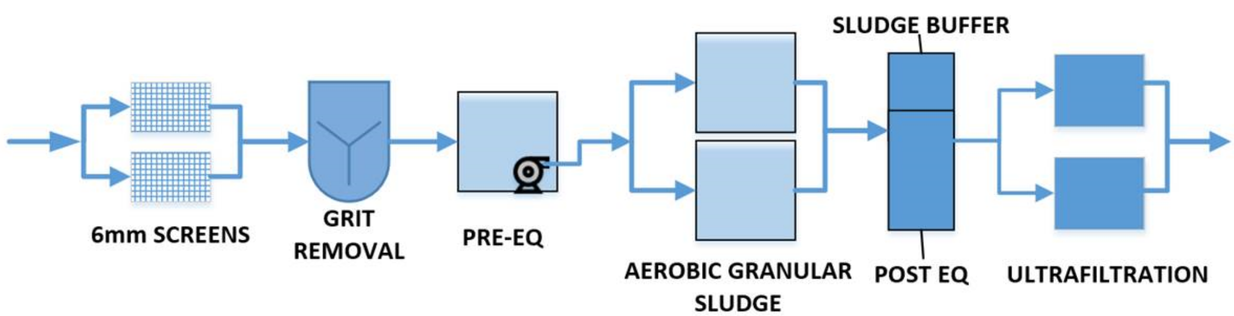
The AGS AquaNereda® wastewater treatment system was developed in 2006 and as the first full-scale application of the aerobic granular sludge technology. Granular sludge offers several benefits including simultaneous nitrification/denitrification and phosphorus removal, high settling velocities which allow for increased hydraulic loads, high biomass retention and reduced energy demand. Aerobic, anoxic, and anaerobic reactions can occur on and within granules within a single basin, so these systems do not utilize the sequential anaerobic/anoxic/aerobic processes utilized for nutrient removal in the conventional activated sludge process.

AquaNereda® is in the early-stage of implementation in the U.S. The District's existing SBRs provide good geometry (length/width/depth) for AquaNereda® implementation, but questions remain regarding the technology's long-term treatment performance for applications where enhanced nutrient removal performance is targeted. Achieving simultaneous nutrient removal in a single reactor is very efficient, but whether the process can obtain the same results as enhanced biological nutrient removal in compartmentalized reactors remains to be seen.

Ultrafiltration (UF) membrane treatment downstream of the AGS process would be used to improve treatment performance, including providing a location for chemical coagulation of phosphorus. The District's existing filter technology is not robust enough to achieve the level of effluent quality that is targeted for the project. UF membrane filtration (using either polymeric or ceramic membranes) will improve the quality and consistency of the filtration process, with a barrier to the passage of particles larger than the pore size of approximately 0.01 µm.

The preliminary process flow diagram for Alternative 2 is shown in Figure ES 2**Error! Reference source not found.**. The AGS system requires a pre-equalization tank prior to the biological treatment system to act as a buffer to store influent between feed cycles to the SBR basins. The existing SBR basins would be retrofitted with the new AGS equipment.

Figure ES 2 Alternative 2 Preliminary Process Flow Diagram



Using the existing Filter Building to house the new UF system was evaluated for its potential to avoid construction of new membrane building at the existing SBR site. After much evaluation, it was determined that the existing floorspace would be insufficient to contain all the necessary process equipment and allow sufficient access for operation and maintenance of the UF system.

Ceramic ultrafiltration (UF) membrane systems were evaluated for Alternative 2B, to determine if the potential additional benefits compared to polymeric membrane systems justify the higher capital cost of these systems. The benefits claimed by ceramic system suppliers include elimination of fiber breakage, higher flux rates, chemical resistance for better CIP performance, and significantly longer equipment life.

Alternative 2C consists of upgrading the existing Aqua-Aerobics SBR treatment process to the AGS Aerobic Granular Sludge (AGS) process and integrating the CLEARAS Advanced

Biological Nutrient Recovery (ABNR) system downstream of the AGS system to further improve effluent water quality. The CLEARAS system incorporates a polymeric ultrafiltration membrane in its algal-based treatment process, so a separate, standalone ultrafiltration membrane system would not be necessary with this AGS/CLEARAS approach.

The CLEARAS system uses algal growth to remove nitrogen and phosphorus to lower concentrations than those achievable in enhanced nutrient removal activated sludge systems. A photobioreactor is used to grow algae, using a supplemental carbon source and the nutrients in the wastewater. A budgetary cost proposal was requested from CLEARAS for the purposes of this evaluation. Initial review indicated that this technology does not yet have a proven track record to justify installation at the Big Sky WRRF. It appears that the process performance would dependent on a very consistent feed quality and the nitrogen predominantly in ammonia form. It also had a significantly greater capital cost than Alternatives 1 and 2A and 2B. The high-risk, high-cost factors led to its removal from additional consideration.

CLEARAS does offer a “polishing” approach where high quality effluent is fed to the ABNR process, to take nutrients from already relatively low concentrations to extremely low concentrations. This alternative is discussed in TM No. 6, advanced treatment.

A summary of probable construction and capital costs for the secondary-tertiary treatment alternatives ultimately considered in TM No. 4 is presented in Table ES 2. The MBR alternative has the lowest capital cost alternative. The AGS with ultrafiltration alternatives are the second (polymeric membranes) and third (ceramic membranes) capital cost alternatives, respectively. The complete Engineer's Opinion of Probable Construction Costs (EOPCC) – Secondary/Tertiary Alternatives worksheet is included in Appendix 4B.

Table ES 2 Engineer's Opinion of Probable Construction Costs (EOPCC) – Secondary/Tertiary Alternatives

Engineer's Opinion of Probable Construction Costs (EOPCC)			
Description	Membrane Bioreactor	Aerobic Granular Sludge-Polymeric UF	Aerobic Granular Sludge-Ceramic UF
Mobilization, Bonds, Insurance	$1,064,000	$1,141,000	$1,157,000
Pretreatment[1]	$872,000	$505,000	$505,000
Biological Process Equipment	$2,335,000	$5,456,000	$5,456,000
Membrane Equipment and Facilities	$7,182,000	$5,197,000	$5,350,000
SCADA System (Master PLC, Programming/Integration)	$250,000	$250,000	$250,000
Subtotal Construction Costs	**$11,703,000**	**$12,549,000**	**$12,718,000**
Contractor Overhead and Profit	**$1,405,000**	**$1,506,000**	**$1,527,000**
Construction Cost (w/o Contingency)	**$13,108,000**	**$14,055,000**	**$14,245,000**
Undeveloped Design Details (10%)	$1,311,000	$1,406,000	$1,425,000
Construction Contingency (15%)	$1,967,000	$2,109,000	$2,137,000
Engineering, Legal, Administration	$1,967,000	$2,109,000	$2,137,000
Construction Administration	$1,639,000	$1,757,000	$1,781,000
Total Project Cost	**$20,000,000**	**$21,500,000**	**$21,800,000**
NOTE: 1. Pretreatment costs impact total project costs and were included in secondary-tertiary EOPCC			

Note that the cost differential between the alternatives are relatively minor (less than 10-percent difference) compared to the overall accuracy of the cost opinions at this conceptual design stage. This places more impetus on other factors for selection.

OM&R costs for the secondary-tertiary treatment alternatives are presented in Table ES 3. The complete Engineer's Opinion of Probable OM&R Costs worksheet is included in Appendix 4B. Alternative 3, AGS-ceramic UF has the lowest OM&R costs and MBR has the highest, but the differentials are again relatively minor, and essentially negate the minor differences in the total project cost estimates.

Table ES 3 EOPCC OM&R Costs – Secondary/Tertiary Alternatives

Engineer's Opinion of Probable OM&R Costs			
Description	MBR	AGS/Polymeric UF	AGS/Ceramic UF
Annual Power Cost	$215,200	$149,400	$165,800
Annual Chemical Cost	$224,600	$269,800	$266,000
Annual Labor Cost	$400,000	$400,000	$400,000
Annual Membrane and Diffuser Replacement Cost	$142,700	$102,000	$28,200
Annual Total	**$982,500**	**$921,200**	**$860,000**
20-year NPW of OM&R	**$19,650,000**	**$18,424,000**	**$17,200,000**

Given that capital and OM&R cost estimation differences are negligible when the accuracy range for estimates at this level of engineering are considered, the decision between the three secondary-tertiary treatment alternatives should be based on non-cost considerations. To assist in this evaluation and provide a more transparent decision-making process, a Kepner-Tregoe analysis was conducted.

The KT results reflect that all alternatives evaluated are feasible and generally high-performing, the MBR alternative is the best selection for the District for the WRRF Expansion and Upgrade.

The primary differentiators found between the MBR alternative and the AGS based alternatives, and captured in the KT analysis, are performance-based:

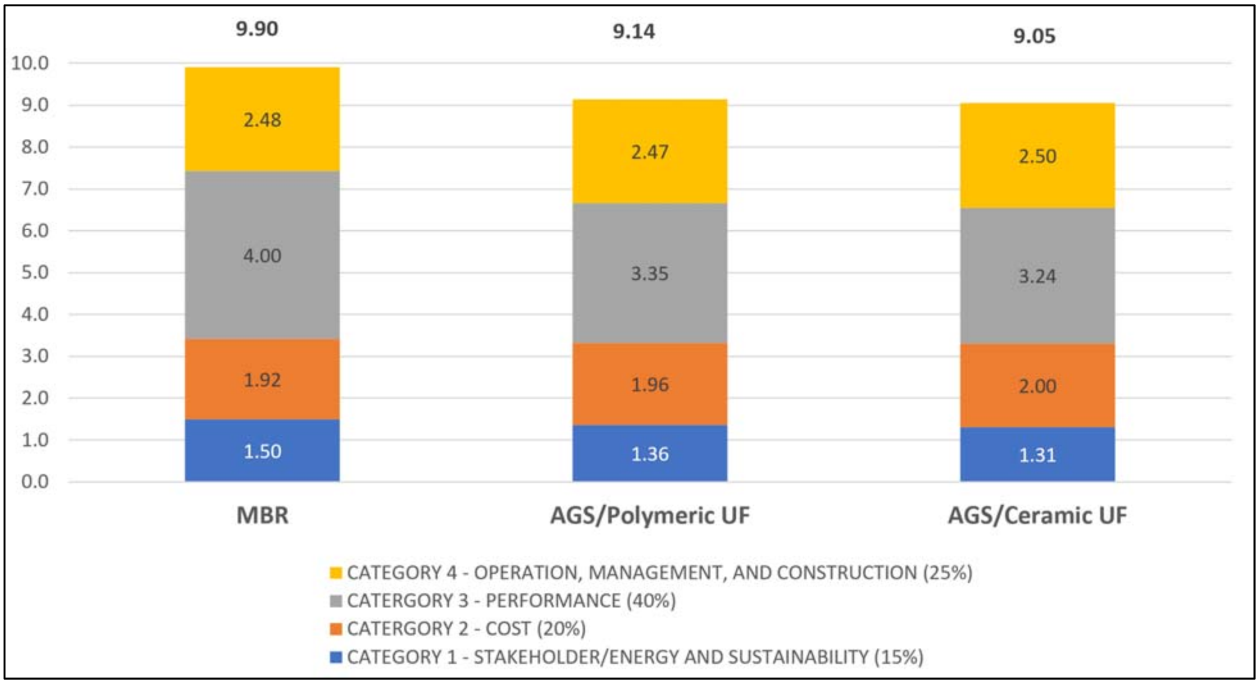
1. MBR has a relatively long track record for wastewater treatment where stringent discharge limits are in place.
2. The post-anoxic zone upstream of the membrane tanks provides a second opportunity to achieve full denitrification of the effluent. This capability does not existing with the AGS process.
3. Generally, multiple-stage plug flow reactor configurations with segregated anaerobic/anoxic/aerobic environments are believed to provide better nutrient removal potential than configurations where nutrient removal processes are all occurring in a single reactor.
4. MBR treatment has shown synergistic treatment performance for pathogens and dissolved organics, including many CECs. This is believed to be because of increased contact between microbial populations and contaminants near the membrane interface, with increased opportunities for adsorption, dissolution, particle exclusion and predation.
5. Based on the lack of provided data, the AGS process has yet to be proven capable of achieving very low total nitrogen and total phosphorus concentrations, especially in very cold environments such as Big Sky.

These key differentiators, and the KT analysis in its entirety, was discussed with District operations and management. The full KT analysis is explained in TM No. 4. A summary of the Kepner-Tregoe analysis is shown in Table ES 4 and Figure ES 3**Error! Reference source not found.**.

Table ES 4 Kepner-Tregoe Analysis

TOTAL WEIGHTED VALUES	MBR	Granular Sludge/Polymeric UF	Granular Sludge/Ceramic UF
Weighted Value	9.90	9.14	9.05

Figure ES 3 Kepner-Tregoe Analysis – Secondary/Tertiary Treatment Alternatives



Based on approximately equivalent costs, but a more favorable performance projection, track record, and Kepner-Tregoe result, the District should move forward with MBR technology for the WRRF Upgrade and Expansion.

It is recommended that the District proceed with an MBR equipment pre-procurement document in the fall of 2018, and design the other ancillary upgrades necessary for a complete facility upgrade and expansion, which will consist of the following:

- 2 mm screening upgrade and Headworks Building expansion
- Biological nutrient removal process upstream of the membrane tanks
- Installation design for selected equipment
- Yard piping configuration modifications
- Site access improvements

The Phase 1 improvements to the secondary-tertiary treatment process will improve the quality of the District's effluent quality substantially (70 to 75% for nitrogen, and 90 to 95% reduction for phosphorus).

TM 5: Tertiary Effluent, Reservoir Storage, and Reuse Piping

Upgrades and expansion of the Big Sky County Water and Sewer District (District) WRRF will affect existing effluent storage and distribution, future advanced treatment piping, and reuse operations. Providing maximum flexibility in use of the effluent, including giving the District and its third-party effluent reusers the ability to utilize effluent when it is still fresh from treatment and undegraded by storage, will require significant modifications to the pipelines at the existing Filter Building, storage reservoirs and irrigation pump stations (both the District's and the Yellowstone Club Booster Station No. 1).

Currently, treated wastewater from the existing Sequencing Batch Reactor (SBR) process is pumped to the 8.2 MG SBR Effluent Storage Pond, and then pumped from this Pond No. 2 to the Filter Building using the "Recirculation Pump Station" for coagulation/flocculation/filtration and disinfection. Final effluent from the Filter Building flows into the District's 19.6 MG reservoir (Pond No. 3). The District's Irrigation Pump Station pumps reuse water from Pond No. 3 to the Meadow Village Golf Course. Pond 3 also feeds the 60 MG reservoir (Pond No. 1) that supplies the YC Booster Station. A flow diagram and site layout are provided in TM No. 5 for visualization of this system.

The Phase 1 improvements to the secondary-tertiary treatment process will improve effluent quality substantially, as discussed in TM No. 4. However, the quality of the effluent from the upgraded treatment facilities will only deteriorate with storage, so the District will implement conveyance improvements around the Filter Building and Pond Complex to enable effluent to be utilized immediately. Connections to chlorine contact and the storage ponds will be retained, because some storage will always be necessary, the timing of the reuse water demand will never fully match with effluent production.

TM No. 5 provides a review of the existing Sequencing Batch Reactor (SBR) effluent conveyance and effluent piping configuration, and outlines preliminary considerations for modifications to the effluent conveyance and piping configurations to accommodate flexibility in use of the secondary-tertiary effluent (storage, future advanced treatment, or immediate reuse). The following design criteria were used for evaluation of effluent conveyance needs:

- Maximization of future effluent reuse and disposal flexibility, including the following routing:
  - Chlorination in the contact chamber under the existing Filter Building
  - Immediate (no storage) reuse via the YC Booster Station No. 1. This station pumps reclaimed water to Spanish Peaks and the Yellowstone Club reservoirs. In the future it may also supply reclaimed water to the Firelight Meadows Subdivision (landscape irrigation and subsurface disposal).
  - Immediate reuse via the District's Irrigation Pump Station. The District irrigates the Meadow Village Golf Course, Community Park and Chapel landscapes.
  - Immediate conveyance to the future Advanced Treatment process train that will be installed in the existing Filter Building

- Storage in any of the existing three reservoirs (Ponds 1, 2 or 3).

- Pumping and piping systems are sized to convey projected peak flow rates with firm pumping capacity when one unit is out-of-service
- Optimize operational control and flexibility

A summary of probable construction costs for the effluent conveyance and piping modifications is presented in Table ES 5**Error! Reference source not found.**. This work should be included in the Phase I WRRF Expansion and Upgrade project

Table ES 5 EOPCC for Effluent Pipelines and Pond Modifications

Engineer's Opinion of Probable Construction Costs (EOPCC)	
Description	**Piping Modifications**
Mobilization, Bonds, Insurance	$87,700
Process Equipment and Valves	$143,000
Sitework, Yard Piping and Fittings	$376,000
Structural	$253,000
Electrical and Architectural	$60,000
Process I&C	$45,000
Subtotal Construction Costs	**$964,700**
Contractor Overhead and Profit	**$120,000**
Construction Cost (w/o Contingency)	**$1,084,700**
Undeveloped Design Details (10%)	$110,000
Construction Contingency (15%)	$170,000
Engineering, Legal, Administration	$170,000
Construction Administration	$140,000
Total Construction Cost	**$1,675,000**

TM 6: Advanced Treatment

Previous technical memorandums covered preliminary (screening and grit removal) and secondary-tertiary (BOD, TSS, nutrient removal and membrane filtration) treatment. Tertiary treatment (with disinfection) that will be used in the Expansion and Upgrade will likely be sufficient to remove the pathogens that are regulated for typical discharges. However, additional “advanced” treatment alternatives are being considered for a future phase of the Big Sky WRRF Expansion and Upgrade:

1. Treatment for “Contaminants of Emerging Concern” (CECs). CECs are, generally, trace organic contaminants (TOrC) that are documented in wastewater effluents and are at least somewhat recalcitrant to typical wastewater treatment. Research has shown that CECs can have environmental or public health impacts when present in sufficient concentrations, or if present with a suite of other CECs (synergistic impacts).

2. Further reduction in nutrients to minimize the WRRF's potential to contribute to algal growth. The Big Sky WWTF is but one of many known sources of nutrients in the region, but the other sources are all non-point (e.g., septic systems, fertilizers, livestock). Algal blooms in the watershed are occurring in 2018 (including some upstream or in other tributaries than those in the West Fork basin). The South and Middle Forks of the West Fork, and the West Fork are all currently listed as impaired for nutrients (all three for nitrate/nitrite nitrogen, and phosphorus for the South Fork and West Fork).

Additional, advanced treatment will also help overcome public perceptions by providing a very high-quality effluent for consumer-sensitive reuse alternatives. For example, snow-making will be easier to implement with advanced treatment, and it will also reduce the potential for the snow to have any trace of color. Also, the District is evaluating potential implementation of rapid infiltration to groundwater, and/or potential future aquifer recharge, which both represent "de facto" indirect potable reuse, so advanced treatment to protect the aquifer is warranted.

The advanced treatment alternatives considered in TM No. 6 are presented as two general categories: 1) CEC treatment and 2) enhanced nutrient removal.

CEC Treatment

1. Advanced Oxidation Processes (AOP, which is the generation of hydroxyl radicals OH· to oxidize and fragment recalcitrant organic compounds) followed by activated carbon-based treatment (granular activated carbon (GAC), biologically activated carbon (BAC), or hybrid GAC/BAC) was proposed to provide some additional removal of CECs beyond that achieved in the upstream secondary-tertiary treatment process.
2. The evaluation of AOP and activated-carbon based processes focused on identification of the most appropriate AOP for the District's application, the potential performance, operations challenges, design considerations for AOP and activated carbon, and the capital (construction) and OM&R costs.
    a. Two approaches were evaluated for oxidation and fragmentation of trace organics upstream of BAC: ozone and UV/hydrogen peroxide (H_2O_2). Both approaches have a proven track record for oxidation and fragmentation (for subsequent biodegradation) of a wide suite of CECs.
    b. The evaluation of GAC/BAC focused primarily on the efficacy of BAC treatment for CECs, the appropriate design criteria, construction costs, and the long-term replacement costs for the carbon. BAC is preferable over GAC, as GAC would require frequent offsite regeneration of the carbon, whereas BAC relies on continuous regeneration from microbial degradation. If adsorption only (GAC) proves necessary in the longer-term, the initial setup for BAC could be easily converted to GAC or a GAC/BAC hybrid process by more frequent replacement and regeneration of the carbon.

Enhanced Nutrient Removal

1. Several secondary-tertiary and biosolids handling enhancements are available to achieve enhanced nutrient removal, and these are covered elsewhere in the engineering report:
    a. The secondary-tertiary treatment selection process evaluated MBR and AGS/UF, as well as optimization of nutrient removal in both systems (supplemental carbon for the post-anoxic zone for full denitrification, and aluminum-based coagulation of phosphorus ahead of membranes).
        i. These treatment approaches are discussed in TM No. 4, Secondary-Tertiary Treatment since they would be implemented in that portion of the WRRF. Both processes were simulated using Envirosim's Biowin wastewater treatment process simulation software.
        ii. The primary purpose of coagulation will be to reduce total phosphorus concentration, but some additional removal of trace organics via coagulation will likely occur as well.
    b. Sidestream treatment for high nutrient return/recycle streams from biosolids treatment and/or dewatering processes is discussed in TM No. 8, Biosolids Handling.
2. For Advanced Treatment, the enhanced nutrient removal consideration focuses on two approaches:
    a. The potential for additional nitrogen removal across the AOP/BAC process. The evaluation herein is intended to determine if additional nutrient removal can be expected across this advanced treatment that is primarily intended to achieve additional CEC removal. Neither oxidation of ammonia, or oxidation/fragmentation of organic nitrogen and phosphorus by ozone or other AOPs is well-studied. If these reactions do take place, then the resulting nitrate and more bioassimilable nitrogen and phosphorus could be utilized by bacteria that colonize BAC.
    b. CLEARAS, an algae-based treatment system that can be utilized to remove nutrients, especially phosphorus, to extremely low concentrations (less than 0.05 mg/L). CLEARAS is relatively expensive, has a large footprint and high energy demands for LED lighting.

Capital and OM&R Costs

Advanced Oxidation

Budgetary cost proposals were solicited from ozone generation, feed and destruction equipment package suppliers, a liquid oxygen system supplier for the ozone generation in Bozeman, MT; as well as UV/H2O2 equipment package suppliers. Based on the submittals and estimates for retrofitting the equipment into the existing Filter Building, the total project cost for an Ozone system is estimated at $3.9M, and the cost to retrofit UV/H_2O_2 into the Filter Building is estimated at $3.0M.

The operation, maintenance and replacement (OM&R) costs were estimated for both systems as well, based on an estimated 20-year average throughput of 0.75 mgd. OM&R for ozone is estimated to cost $79,300 annually. UV/$H_2O_2$ is estimated to cost $134,200 annually. The difference is substantial and is due to the 1) additional labor and materials replacement costs for UV lamp inspection and replacement, 2) the significantly higher power consumption for UV light production, and 3) the need for H_2O_2 and an H_2O_2 quenching chemical ahead of BAC.

The OM&R costs were multiplied by the 20-year timespan for the NPV analysis (assuming the discount rate and the inflation rate for construction are approximately equal), and added to the EOPCC, with the results shown below in Table ES 6 Ozone costs more to implement, but costs much less to operate and maintain. The 20-year NPV results are similar, with UV/H_2O_2 slightly higher. It was expected that UV/H_2O_2 would have a higher NPV result based on the literature review, and the gap here is actually less than the literature reviews indicate.

Table ES 6 EOPCC, OM&R and NPV Estimates for Ozone and UV/H2O2

Description	Ozone	UV/H_2O_2
Engineer's Opinion of Probable Project Cost	$3,900,000	$3,000,000
Estimated OM&R Cost (20 yr)	$1,586,000	$2,684,000
Total Present Value Cost (20 yr)	**$5,486,000**	**$5,684,000**

Activated Carbon

A budgetary estimate was obtained from Calgon Carbon for supply of the vessels, for $660,000, which includes the initial load of granular activated carbon and shipping. This cost was incorporated into an EOPCC for a complete BAC installation project, with allowances for piping, valving, equipment pads and miscellaneous plumbing and instrumentation and controls work.

Table ES 7 ES1 EOPCC for GAC/BAC Treatment

Description	GAC/BAC
Mobilization, Bonds, Insurance	$98,000
Process	$845,250
Sitework	$0
Building Modifications	$50,000
Architectural	$0
Mechanical	$50,000
Electrical	$0
Instrumentation and Controls	$25,000
Subtotal Construction Costs	**$1,068,250**
Contractor Overhead and Profit	**$129,000**
Construction Cost (w/o Contingency)	**$1,197,250**
Undeveloped Design Details (10%)	$120,000
Construction Contingency (15%)	$180,000
Engineering, Legal, Administration	$180,000
Construction Administration	$150,000
Total Project Cost	**$1,900,000**

Current pricing for activated carbon is $1.35/lb, including delivery and installation. At 80,000 lbs the current cost to completely replace the carbon is $108,000. At a 5-year estimated carbon life cycle (the lead vessel carbon may need replacement more frequently, the lag might last longer, so 5 years is used as a midpoint), the 20-year NPV for carbon replacement is $432,000.

Conclusion and Recommendations

It is recommended that the District plan for an ozone and BAC approach for advanced treatment. Ozone is recommended over other AOP processes for the following reasons:

1. Ozone/BAC is a well-proven process, demonstrating excellent reduction (90 to 99%) across a broad range of trace organic compounds.
2. One of the most significant concerns for chronic toxicity effects on salmonids near effluent outfalls is feminization due to high exposure to estrogen and estrogen mimicking compounds. The combination of ozonation and biofiltration has proven to reduce estrogenicity by more than 95%.
3. Ozone/BAC is simpler to operate than UV/H_2O_2/BAC. UV/H_2O_2 has two chemical storage and feed systems (H_2O_2 plus an H_2O_2 quenching agent, typically sodium metabisulfite or sodium thiosulfite). This is because the UV/H_2O_2 process is inefficient from an H_2O_2 conversion to the hydroxyl radical (HO•). Only about 10% of the H_2O_2 is successfully converted to hydroxyl radicals, and the remaining 90% of the feed dose has too great of an impact on the BAC, so it must be quenched prior to entering the BAC vessels.

4. Ozone/BAC is flexible and adaptable. If necessary, the granular activated carbon can be replaced more frequently to provide the hybrid BAC/GAC treatment (improving adsorption capacity). In addition, if more powerful advanced oxidation is warranted in the future, UV or H_2O_2 can be added at that time to enhance treatment.
5. The treatment train of MBR/Ozone/BAC has gained increasing use as a treatment approach for indirect potable reuse systems where RO treatment is not feasible due to the brine disposal, and there is little or no concern for bromate or NDMA formation. Additional disinfection may be necessary downstream of this train if the District chooses to pursue indirect potable reuse, but the base treatment of MBR/ozone/BAC is being promoted for its combined ability to provide water that is equal or near-equal to RO permeate, and ozone is an excellent disinfectant that could be fed downstream of the BAC if/when additional disinfection is needed. Potentially the UV Disinfection system that is in place on the Meadow Village wells would eliminate the need for additional disinfection. This will be the subject of further study by the District, but the key takeaway is that MBR/Ozone/BAC provides an excellent base for developing IPR.
6. Ozone/BAC may help reduce total nitrogen and total phosphorus concentrations. There is little research in the fate of nutrients across ozone/BAC, but ozone has proven capable of oxidizing ammonia to nitrate. Nitrate may be utilized by bacteria in the downstream BAC process if the dissolved oxygen concentration within the BAC falls below approximately 0.3 mg/L. Ozone has also shown the potential to break dissolved organic nitrogen (DON) and organic phosphorus into bio-assimilable forms of nitrogen and phosphorus that could be utilized by bacterial populations in the BAC.

The primary disadvantage of using ozone for AOP is the potential to generate bromate (from bromide) and/or N-nitrosodimethylamine (NDMA). However, these are not expected to pose a problem for the District because:

- Bromide presence in concentrations greater than 50 g/L may result in bromate formation at levels greater than the maximum contaminant level (MCL) of 10 g/L. This level of bromide is not anticipated in the District's wastewater. The usual reason that bromide is present in groundwater is that the groundwater is near the ocean. However, the District will begin testing for bromide to ensure that the background concentration is not sufficient to cause bromate issues.
- NDMA formation would be a concern if the District were to engage in potable reuse. The logical recourse would be to either add H_2O_2 upstream of ozone, which has demonstrated the ability to limit NDMA (as well as bromate) concentrations in treated water.

Phasing and Implementation

- It is recommended that for full build-out the District plan for the installation of the following:
- Two 75 lb/day Ozone generation equipment packages (complete with controls, mixing and contact equipment, ozone destruction equipment, etc.)

- Liquid Oxygen (LOX) storage and feed system for Ozone generation. The LOX system could be provided and maintained by General Distributing Co., who provides the same service for the Big Sky Medical Center.
- Four 20,000 lb GAC/BAC vessels, arranged in two skids of two vessels with piping and valving enabling lead-lag operation. 80,000 lbs of GAC is necessary to provide redundancy at full build-out maximum month flow, providing a minimum empty bed contact time (EBCT) of 15 minutes at 1.4 MGD.

Advanced Treatment alternatives may be constructed with the preliminary and secondary-tertiary upgrade, but the work could be moved to a subsequent Phase 2 project, for the following reasons:

- Advanced treatment is not necessary to comply with the discharge requirements for the District's currently permitted effluent disposal method (irrigation). The secondary-tertiary treatment approach outlined in TM No. 4, that would be implemented in Phase 1, will produce a Class A-1 reclaimed wastewater that will be suitable for reuse for irrigation.
- The EOPCC for the total Advanced Treatment project (Ozone plus BAC) is $5.8M, and the total project cost for constructing preliminary (screening improvements), secondary-tertiary, biosolids, Advanced Treatment and effluent disposal and reuse distribution pipelines are well beyond what the budget the District has planned for the near future. Dividing these projects into phases will allow the District to conduct a rate study and adequately budget for subsequent phases. In addition, the current bidding environment for large construction is very unfavorable, with materials and equipment cost instability as well as construction labor shortages. Moving projects that are not immediately necessary to later years may result in a more favorable bidding environment.
- The existing Filter Building will be taken offline and emptied as part of the Phase 1 Expansion and Upgrade. Having this building available after Phase I, with the tertiary effluent pipeline connected to the building, will provide the District with the ability to relatively easily pilot the ozone/BAC process between the Phase 1 and 2 Improvements, to prove its efficacy and ensure that bromate and NDMA are not valid concerns with usage of this treatment train at full-scale. Alternatively, the District could proceed with installing one 75-lb/day ozone system and one set of two 20,000 lb carbon vessels. This would enable treatment of up to 0.7 MGD at the target 15-minute EBCT and would essentially be a full-scale pilot that could be utilized long-term.

TM 7 Dissolved Oxygen and Temperature Mitigation

During the scoping phase of the Conceptual Design Report it was presumed that dissolved oxygen and temperature of the District's effluent would need to be addressed to obtain and comply with a direct discharge permit. No direct discharge permit application is pending currently, and the Phase I Upgrade and Expansion will result in a new quality of effluent. Therefore, the only recommendation at this time is to monitor the new effluent dissolved oxygen and temperature, and use the new information, along with additional data gathered on the mainstem of the Gallatin River in the late fall, winter and early spring (conceptual timeframe for future direct discharge), to assess whether dissolved oxygen and/or temperature mitigation is needed for discharging to the Gallatin.

TM 8 Biosolids Treatment, Dewatering, and Composting

The Big Sky Water Resource Recovery Facility (WRRF) currently utilizes aerobic digestion followed by composting for the treatment and disposal of biosolids generated at WRRF. The existing biosolids treatment system is currently operating within its design parameters and meets the operational needs for biosolids treatment. As flows and loads to the facility increase biosolids generation rates will correspondingly increase. The increased biosolids production will stress both the capacity of the aerobic digestion system and the downstream composting system.

TM 8 identifies alternatives that will improve biosolids treatment performance and increase treatment capacity.

Four biosolids treatment alternatives were screened to identify reasonable alternatives for addressing the future biosolids treatment needs for the WRRF. Key factors for the screening process were the ability to meet Class A biosolids requirements, compatibility with existing treatment components, conformance of the alternative with the physical site constraints and economic impact factors for capital and operations/maintenance costs. The four treatment alternatives include the following:

Alternative 1: No action (current Class A biosolids with existing equipment/capacity);

Alternative 2: Convert the facility from aerobic digestion to anaerobic digestion. Maintain the existing composting system;

Alternative 3: Convert the facility from aerobic digestion to autothermal thermophilic aerobic digestion. Maintain the existing composting system; and,

Alternative 4: Upgrade the existing aerobic digestion system to include thickening of waste activated sludge (WAS) prior to aerobic digestion, incorporate jet mixing/aeration into the existing digesters and phase improvements to match capacity needs. Maintain the existing composting system.

Based on the recommended liquid train alternatives and existing facility operations, solids treatment train flows and loads were determined to form a biosolids basis of design. All solids treatment equipment alternatives and processes were sized to accommodate the peak month flows/loads presented.

Screening of alternatives was conducted to determine reasonable alternatives that warrant further evaluation. Alternative 4: Upgrade the existing aerobic digestion system was deemed the most promising alternative and further evaluated. Un-thickened waste activated sludge would be stored, aerated and mixed in one of the two existing aerobic digesters. Jet mixing and aeration would be provided in both existing digester tanks. A thickening unit would be provided near the existing belt filter press and would be used to thicken WAS. Thickened WAS would be sent to the other aerobic digester for storage and volatile solids reduction. The thickened digested WAS would then be pumped to the belt filter press for dewatering prior to composting.

The existing composting system would continue to be used for Class A biosolids treatment.

This alternative can be accomplished with minimal modifications to the existing aerobic digester complex. For the most part, the technology employed by this alternative will be similar to the existing technologies in use at the facility. Because most of the improvements for this alternative reuse existing infrastructure, the impact on existing site constraints is minimized.

A phased approach to the improvements was developed during evaluation of this alternative. The first phase of improvements would include the following:

- A two-story, 55-foot by 25-foot building for housing the thickening units, pumps and related equipment
- One gravity belt thickening unit
- Polymer make-down and feed equipment
- Two thickened sludge pumps
- Filtrate treatment and pumps
- Jet mixing/aeration in the existing digesters

The second phase of would include the following:

- A second gravity belt thickening unit; and,
- Conversion of existing post-equalization tank to unthickened WAS storage.

A summary of probable construction and capital costs for the biosolids improvement alternative Phase 1 and Phase 2 is presented Table ES 8.

Table ES 8 Engineer's Opinion of Probable Construction Costs (EOPCC) – Biosolids Alternative

Engineer's Opinion of Probable Construction Costs (EOPCC)		
Description	**PHASE 1**	**PHASE 2**
Mobilization, Bonds, Insurance	$328,000	$94,000
Site Work	$247,000	$71,000
Un-thickened WAS (1)		$558,000
Thickening Improvements	$2,267,000	$624,000
Aerobic Digesters	$1,856,000	
Subtotal	$4,698,000	$1,347,000
Construction Contingencies	$705,000	$202,000
Undeveloped Design Details	$470,000	$135,000
Construction Subtotal	$5,873,000	$1,684,000
Engineering, Legal, Administration	$940,000	$269,000
Total Construction Cost Estimate	**$6,813,000**	**$1,953,000**

(1) Does not include Phase 1 improvements to digesters, those improvements are accounted for in the aerobic digesters line item.

A summary of the probable Operations, Maintenance, Repair and Replacement Costs improvement alternative Phase 1 and Phase 2 is presented Table ES 9**Error! Reference source not found.**.

Table ES 9 Engineer's Opinion of Probable OMR&R Costs

Description	Phase 1 Increase	Phase 2 Increase	Total Increase
Annual Labor Cost	$80,000	$0	$80,000
Annual Power Cost	$18,000	$33,000	$51,000
Annual Maintenance Cost	$34,000	$10,000	$44,000
Annual Replacement Cost	$91,000	$28,000	$119,000
Annual Chemical Cost	$31,000	$15,000	$46,000
Annual Total	**$254,000**	**$86,000**	**$340,000**

In order to maintain the ability to produce a Class B biosolids, stabilize the organic material going to the downstream composting operation, and to limit the frequency of compositing operations, we recommend making the improvements detailed in this TM.

The first phase of biosolids facility improvements do not have to be included in the Phase I WRRF Expansion and Upgrade, since the impact of postponing the work is operations workload, but as flows and loads increase to the WRRF eventually it will become more advantageous to move forward with the project than to continue to hire operators to generate compost with biosolids that have not been digested as well as they could be.

TM 9 Odor Control Evaluation

The District has, at times, received nuisance-odor complaints. However, the extent to which odors have been observed and reported has not been extensive enough to make odor control improvements at the WRRF a high priority for the Phase I Expansion and Upgrade. Additionally, the District has not reported the existence of high concentrations of hazardous compounds, or odors that have elevated to a level which would cause concern for public health.

Fenceline air-emissions are not regulated for concentrations of odor-producing compounds in Montana. Predicting odor generation from the WRRF Expansion and Upgrade is a difficult task with a low level of confidence and accuracy. To assess the actual odors produced by a physical and operational process, this Technical Memorandum recommends waiting for future upgrades to be completed before implementing any odor control measures. A site assessment for odors can be done after the Phase I project, to assess both site-specific and process-specific odor generation. The results of a future odor assessment will drive decisions for the best odor control strategies in the future.

In the meantime, the District should continue monitoring for odors (especially for hazardous compounds such as hydrogen sulfide) to be sure the District is not exposing workers or the public to dangerous concentrations of odor compounds. Dangerous levels of H_2S should be mitigated if they are discovered. If odors or specific compounds, such as hydrogen sulfide, present increasing nuisance-odor complaints or corrosion concerns in the interim period, TM No. 9 describes some alternatives which the District can evaluate for implementation.

It is also recommended that the District implement a communications plan to respond and evaluate future nuisance-odor complaints, educate the public and community stakeholders on the sources of odors, and ease concerns regarding potential health effects. This will help the District gain credibility and trust in the public until future odor improvements can be completed.

Effluent Reuse and Discharge Study (TMs 10 through 15)

The Effluent Reuse and Discharge Study is comprised of five technical memoranda, not including TM 10, which is an Executive Summary of the Effluent Reuse and Discharge Study, so these TMs will not be summarized here.

The goal of the Effluent Disposal Study was to identify the key issues with obtaining new reuse or discharge capacity (environmental studies, estimated reuse or discharge capacity, infrastructure needs, and timelines for implementation) for groundwater infiltration (subsurface discharge), snow-making, and direct discharge to the mainstem of the Gallatin River.