Technical Memorandum

SMCSD Headworks, Primary and Secondary Treatment Pre-Design

Subject: **TM 7: Secondary Upgrades**

Prepared For: SMCSD

Prepared by: Mark Takemoto

Reviewed by: Steve Clary

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The purpose of this technical memorandum (TM) is to present the evaluation and preliminary design of the secondary, polishing (including wet weather) treatment processes to be implemented at the Sausalito-Marin City Sanitary District (SMCSD) Wastewater Treatment Plant (WWTP). This TM is intended to be included as an appendix to the Recommended Project Summary, which includes a summary of major recommendations. All drawings referenced in this TM are bound together as a separate attachment. This TM is organized as in the following sections:

1 Summary of Findings and Conclusions

To provide additional redundancy and reliability, SMCSD is currently evaluating alternatives to provide additional secondary, polishing and wet weather facilities in order to minimize blending and to improve plant performance in wet weather. Upgrades to the polishing process would replace the existing continuous backwashing filters, which are nearing the end of their useful life. Approaches to minimizing blending consisted of the following:

- On-site equalization
- Increasing secondary treatment capacity
- Adding wet weather treatment for blended flows
- Increasing tertiary treatment capacity

Based on input from District staff, the recommended secondary process upgrade configuration will include equalization storage. Equalization storage will allow the plant to avoid "blended" treatment during peak wet weather flow events up to 12.3 MGD (five year instantaneous flow event). The recommended process configuration is:

- Add equalization storage (~0.6 MG) as part of the headworks structure
- Upgrade the fixed film reactors (FFRs) to 9.0 MGD hydraulic capacity
    - Upgrade FFR feed pumps
    - New FFR media

    - FFR odor control cover
- Replace existing 1.0 MGD sand filters with 6.0 MGD of rotating disk filters.

The rotating disk filters would have the lowest construction cost and would require the smallest footprint.

2 Background

The existing wastewater treatment plant (WWTP) includes the following treatment units: primary clarifiers, fixed film reactors (FFR), secondary clarifiers, effluent screens, side-stream granular media filters (up to 1 MGD), chlorine contact basins, and an outfall which discharges to San Francisco Bay. The treatment plant was designed to provide treatment for 1.8 MGD of average dry weather flow, 6.0 MGD of peak day flow and a peak instantaneous hydraulic flow of 10 MGD.

Recent wet weather events have produced influent flows closer to 13 MGD during peak events. Based on planned improvements in the conveyance system to the WWTP, it is estimated that the 5-year peak wet weather event will 12.3 MGD, including wastewater flow from Fort Baker.

2.1 Wet Weather Blending

During peak wet weather event, the influent flow to the treatment plant can exceed the process capacity of the fixed film reactors (FFRs). Although the FFRs were designed for a 6.0 MGD peak flow, the maximum flow currently to the FFRs is 6.8 MGD, which is the maximum capacity of the FFR feed pump station. Above 6.8 MGD, primary effluent is passively routed around the fixed film reactors and directed to the secondary clarifiers. The operational strategy of mixing primary effluent and secondary effluent is commonly referred to as “blending” and is currently allowed under SMCSD NPDES permit. However, when the WWTP is blending, additional sampling, data collection and record keeping is required. In addition, the Regional Water Quality Control Board (RWQCB) has required SMCSD to look at alternatives to blending which include equalization, increasing secondary treatment capacity and/or adding treatment specifically for blended flows.

2.2 Existing Secondary and Polishing Treatment Facilities

An evaluation of the SMCSD treatment plant process capacity during peak wet weather events was completed using an approach similar to the average dry weather flow analysis completed by CH2M Hill (*Operational Audit Preliminary Design Report*, March 2006). The initial evaluation included a comparison of current process operating parameters during wet weather to the original plant design criteria and typical design criteria. The process criteria comparison is presented in Table 1.

Table 1: Process Loading Comparison

	Units	Flow Condition		Typical Peak Flow Design Value [a]
		Design Average Day	Design Peak Day Wet Weather	
Flow				
Influent Flow	MGD	1.5	6.0	---
Primary Clarifiers				
Units in Service	--	1	1	--
Side Water Depth	ft	9.5	9.5	14
Surface Area	ft2	2,376	2,376	--
Surface Overflow Rate	gal/day-ft^2	631	2,525	2,000-3,000
Fixed Film Reactors (FFR)				
Total Surface Area of Units	ft^2	2,514	2,514	---
Organic Loading Rate	lbs BOD/day-1000 ft^3	23.9	52.2	37-200
Hydraulic Loading Rate	gal/min-ft^2	1.66[d]	1.66	1.0 – 2.0
Secondary Clarifiers				
Total Surface Area	ft^2	3,520	3,520	---
Surface Overflow Rate	gal/day-ft^2	426	1,705	1,000-1,200
Solids Loading Rate [b]	lbs TSS/day- ft^2	0.70	1.24	2
Granular Media Filters [c]				
Total Surface Area	ft^2	256	256	---
Surface Loading Rate	gal/min-ft^2	2.7	2.7	2-8

Notes:
[a]Typical design criteria taken from Metcalf and Eddy, Inc, *Wastewater Engineering Treatment, Disposal and Reuse*, 3rd edition.
[b]Estimated based on assumed solids removal through the primary clarifier and solids produced from the FFRs.
[c]The granular media filters were added as a side stream treatment process after the secondary treatment plant was constructed. Maximum flow through the granular media filters is 1.0 MGD
[d]Assumes one FFR online with recirculation equal to the influent flow

Fixed Film Reactors (FFR)

The fixed film reactors were designed to treat a maximum flow of 6 MGD. Flows higher than the FFR capacity are passively routed around the FFRs and recombined with the FFR effluent prior to the secondary clarifiers. District review of past operating data and pump curves for the fixed film reactor feed pumps indicates that historically up to 6.8 MGD of flow has been sent to the fixed film reactors, which is above the original design value for the secondary treatment plant. As shown in Table 1, even with the increased flow, the FFRs are currently operated within typical organic and hydraulic loading rate ranges.

Secondary Clarifiers

At current peak day flow, the surface overflow rate is slightly above the typical design values of 1,000 to 1,200 gal/day-ft^2. During blending events, when flow into the plant exceeds the FFR capacity, blended flow is still routed through the secondary clarifiers. Therefore the peak wet weather flow (PWWF) through the secondary clarifiers is the same as the peak flow into the treatment plant. At the current hourly PWWF, the surface overflow rate is more than double the typical design values. The increased overflow rate reduces suspended solids removal efficiency of the secondary clarifiers.

Sand Filters

The District currently has continuously backwashing sand filters (shown in Figure 1) which are used to remove additional suspended solids from the secondary effluent. The granular media filters were added as a side stream process that can treat a maximum flow of 1.0 MGD. The surface loading rate on the filters at the maximum flow rate of 1.0 MGD is 2.7 gal/min-ft^2, which is within the typical design values of 2-8 gal/min-ft^2. However, during peak wet weather flows, the sand filters are only capable of treating a small portion of the flow and therefore do not have a significant effect on plant performance. Currently, no chemicals are added to the filter influent to promote coagulation. The District has worked to optimize the filters over the years and they are currently performing adequately as a polishing step. However, the filters have been in service for approximately 25 years and are approaching the end of their useful life.

Figure 1: Existing Sand Media Filters at SMCSD

3 Alternatives

Peak wet weather flows to the SMCSD treatment facility tend to have sharp peaks and relatively short duration, therefore blending only occurs a few times per year. The alternative components presented below were specifically developed to address infrequent peak wet weather flows. The specific components evaluated include:

- On-site equalization
- Increasing secondary treatment capacity
- Adding wet weather treatment for blended flows
- Increasing tertiary treatment capacity

3.1 Equalization

The District previously evaluated the feasibility of adding equalization storage in the conveyance system. However, due to implementation issues, conveyance system equalization is not currently a viable option. Another option would be to add equalization storage at the treatment plant site. The main benefit of equalization storage would be to reduce peak wet weather flows to a maximum of 9.0 MGD which, with improvements to the secondary process, would allow the District to avoid blending. If blending can be avoided, the need to have an additional wet weather treatment process for treating blended flow could also be avoided. Equalization would also provide additional operational flexibility during non-peak events. Equalization storage could be used to shave diurnal peaks and allow for temporary shutdowns if needed for maintenance or emergencies.

The volume of equalization required is dependent on the peak flow rate and duration. The hydrograph from an estimated (modeled) 5-year event and actual influent flow from the December 31, 2005, event are presented in Figure 2.

Figure 2: 5-Year Event Influent Flow Hydrograph

Note: For the actual flow data during this period the WWTP flow meter was unable to record flows above 10 MGD.

The resulting peak flow, duration, and equalization volume based on the 5-year and 10-year flow events are presented in Table 2.

Table 2: Estimated 5 and 10-Year Peak Flow Event Information

Flow Event	Peak Influent Flow	Duration above 9.0 MGD	Total Volume Above 9.0 MGD
5-year	12.3 MGD	6.50 hours	0.6 MG
10-year	13.0 MGD	20.25 hours	2.0 MG

With a secondary capacity of 9.0 MGD, 0.6 MG of storage would prevent the District from having to blend for influent flows up to and including the 5-year event. Although there is a relatively small increase in peak flow between the 5-year and 10-year events, there is a significant increase in the duration and volume (above 9 MGD) between the two events.

A 0.6 MG equalization storage tank could be incorporated beneath the proposed headwork structure without increasing the footprint of the facility. With 0.6 MG of storage volume, approximately once every 6 to 10 years, the influent flow would exceed the capacity of the equalization volume. During this event, the District would need to blend or provide additional treatment capacity.

To prevent blending during the 10-year event, the District would need to have 2.0 MG of equalization storage. A 2.0 MG equalization storage tank would require a large construction area and would have a greater unit cost (per MG) than a 0.6 MG storage tank located within the proposed headworks structure. There would also be limited value to installing 2.0 MG of storage volume since the additional volume would only be needed approximately once every 6 to 10 years.

3.2 Secondary Capacity Increase (Fixed Film Reactor Upgrades)

Currently, blending is needed because peak wet weather flow into the WWTP exceeds the capacity of the secondary process, specifically the FFRs. As stated in Section 2, the existing fixed film reactors are currently limited to a capacity of 6.8 MGD and were originally designed for a hydraulic loading of 1.66 gal/min-ft^2. Because peak wet weather flows are the result of inflow and infiltration, the additional flow does not necessarily increase BOD mass loadings to the treatment plant. Therefore, blending could be avoided by increasing the hydraulic capacity of the FFRs, while maintaining the current level of biological treatment.

Sending the full 5-year event flow (12.3 MGD) to the FFRs would result in a hydraulic loading of 3.4 gpm/ft^2, which would be much higher than typical design peak hydraulic loading rates of 0.25 to 1.5 gpm/ft^2 (WEF MOP 8, 5th Ed). Because FFRs are an attached growth process, the main concern with increasing the hydraulic loading to 3.4 gal/min-ft^2 would be that the biofilm would be scoured off the media. Scouring of the biofilm could result in large amounts of TSS in the effluent and difficulty in providing biological treatment after the peak event. However, the District currently operates the FFR distributors on an automated flushing schedule, where the rotational speed of the distributor is slowed significantly and flow is focused over a specific area. The flushing schedule helps to prevent the buildup of excess biofilm and would be similar to scouring that would occur during a peak wet weather event.

A more moderate increase in flow to the FFRs during peak wet weather events would allow the District to increase the secondary treatment capacity while minimizing the concerns associated with hydraulically overloading the FFRs. More specifically, a hydraulic loading rate of 2.5 gpm/ft^2 may be acceptable for a limited duration (e.g. 2 or 3 days). At a 2.5 gpm/ft^2 loading rate, the FFRs would have a capacity of 9.0 MGD. Stress testing of a single FFR could be performed to confirm the adequate process operation at 2.5 gpm/ft^2 hydraulic loading rate. Implementation of the capacity upgrade to 9.0 MGD would involve the following upgrades:

- Replace existing FFR feed pumps to provide 9.0 MGD to the FFRs.
- Replace the FFR media

New or upgraded FFR feed pumps would be needed to provide 4.5 MGD of flow to each FFR. The pump upgrade would include new motors and variable frequency drives (VFDs). The distributer mechanisms on the FFRs were recently upgraded to mechanically driven units. The existing distributers were designed to allow up to 7.2 MGD of flow through the distributer arms. Flows in excess of 7.2 MGD are designed to overflow the center column on the distributer mechanisms. The existing FFR media was installed 30 years ago. The manufacturer will not guarantee that the media will not be damaged at a hydraulic loading rate of 2.5 gpm/ft^2. Given the age of the media and the additional hydraulic loading, it is recommended that the FFR media be replaced. The new cross flow media would have a similar specific area to the existing media (approximately 31 ft^2/ft^3), but would be constructed of thicker material to withstand the additional hydraulic loading.

3.3 Polishing and Wet Weather Treatment Improvements

To better accommodate peak wet weather flows, provide redundancy, and add tertiary capacity, the replacement and expansion of the existing polishing treatment process is being evaluated. The tertiary process would be added after secondary clarification to help remove additional TSS and BOD to meet NPDES permit limits. Also, depending on the configuration and capacity of the secondary treatment process, the tertiary process may be used to provide wet weather treatment of blended flows. The treatment of blended flows, including the treatment technology selected, would need to be vetted with the RWQCB as part of the District's NPDES permitting process.

3.3.1 Process Loadings

The estimated TSS concentrations for primary effluent, tertiary polishing (secondary effluent) and wet weather blended flow treatment are shown in Table 3.

Table 3: Typical TSS Concentrations During Wet Weather Months

	Average (mg/L)	Max (mg/L)
Primary Effluent	155	244
Secondary Effluent	38	83
Calculated Blended Effluent (50% Primary and 50% Secondary Effluent)	76	164

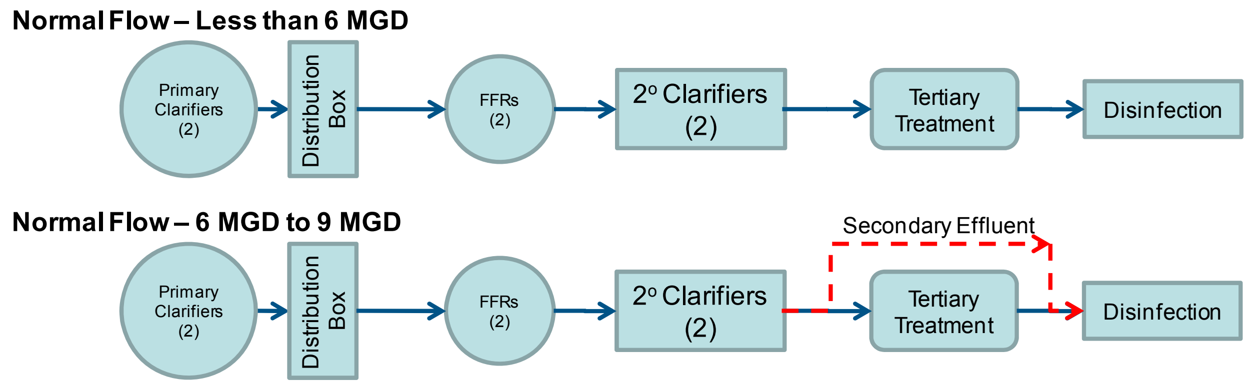
Note: Data from select wet weather months from October 2010 and March 2011.

For the data presented in Table 3, the daily average influent flow averaged 2.6 MGD with a maximum of 5.7 MGD. The existing sand filters typically reduce the secondary effluent TSS concentration to an average of 21 mg/L (~45% TSS removal). The upgraded tertiary process would be designed to have a similar removal percentage.

3.3.2 Process Configurations

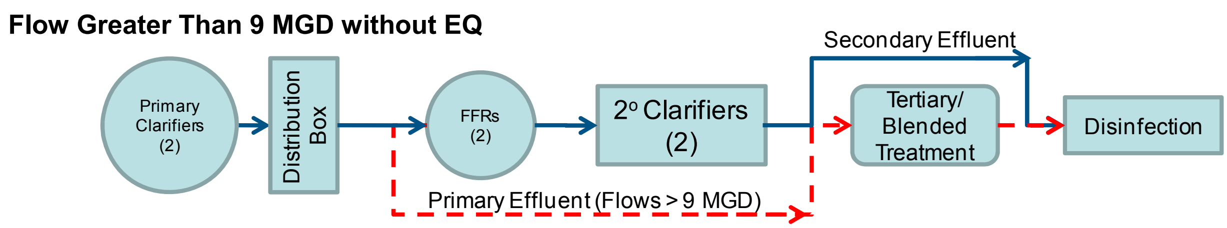
With, or without, flow equalization, the normal process flow path for flows up to 6 MGD will include tertiary treatment as shown in Figure 3. For flows between 6 MGD and 9 MGD, secondary effluent flow greater than the tertiary treatment capacity would be routed around the tertiary treatment process as indicated in Figure 3.

Figure 3: Normal Flow Treatment Flow Path for Flows Up to 6 MGD and 9 MGD



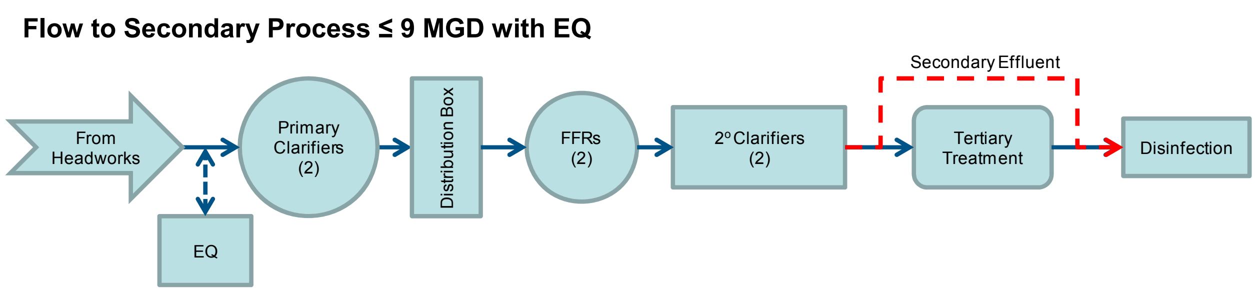
If equalization is not provided, wet weather flows would exceed the capacity of the secondary treatment process (9.0 MGD with the recommended secondary process upgrades). Above 9.0 MGD, primary effluent would be routed around the secondary process and directly to the tertiary/blended treatment process as indicated in Figure 4. Secondary effluent in excess of tertiary/blended treatment capacity would be routed directly to disinfection. It would also be possible to route primary effluent around just the FFRs and add it in front of the secondary clarifiers. Although it would provide an additional treatment step for the primary effluent, it would also increase the hydraulic loading to secondary clarifiers, which would reduce their treatment performance. After the improvements are implemented, the District can decide which mode of operation works best.

Figure 4: Flow Path at Greater Than 9 MGD (without Equalization)



With equalization, flow to the secondary process would be limited to 9.0 MGD; therefore blended treatment would not be required. The flow path with equalization is shown as Figure 5.

Figure 5: Flow Path with Equalization



3.3.3 Blending Treatment

There are two potential scenarios for the function of the polishing process upgrade: 1) dual duty with tertiary treatment and treatment of blended flow (i.e. primary effluent routed around the FFRs) or 2) tertiary treatment only. The option selected will be influenced by whether flow equalization is provided and by RWQCB acceptance.

Blending will be required for influent flows greater than 12.3 MGD with equalization, or for influent flows greater than 9 MGD without equalization. Equalization would essentially allow secondary treatment of all influent flow up to the 5 year wet weather event, which would limit blending to less than once every 5 years. Without equalization and an increased secondary capacity of 9.0 MGD, the District would need to blend approximately 1.5 times per year for a total of 4.2 hours, based on historical data. The District is also continuing to pursue inflow and infiltration (I/I) reduction improvements in the conveyance system, which over a period of time is expected to reduce the peak and duration of peak wet weather events. Based on the expected frequency of use, there would be limited value to providing blended flow treatment for flowrates above 12.3 mgd (assuming equalization), compared to conveyance system I/I improvements.

The decision on whether to treat blended flows will be a policy decision by the District based on the cost of providing treatment for infrequent blended flows and would need to be coordinated with and approved by the RWQCB. If treatment of blended flow is required, high rate clarification would be the preferred technology because it can more readily handle the additional solids loading. If only tertiary treatment is needed, any of the three proposed technologies may be used.

3.3.4 Process Technologies

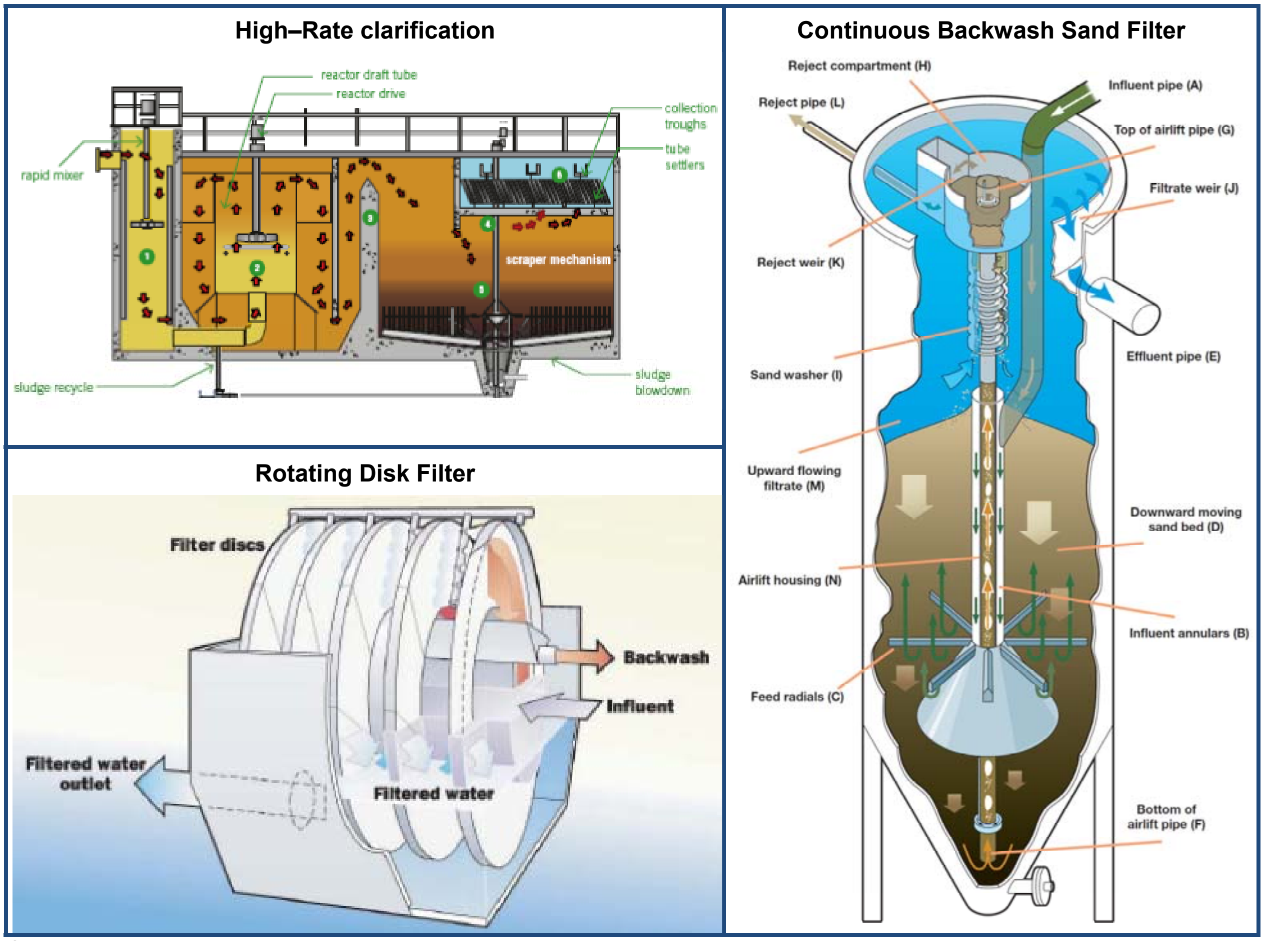
Due to the limited amount of space available on the WWTP site, compact technologies were considered as part of the evaluation. A preliminary list of potential compact technologies was developed and included the following:

- Upflow Continuous Backwash Sand Filter (e.g. Dynasand)
- High–Rate clarification (e.g. Densadeg or Actiflo)
- Rotating Disk Filter (e.g. Hydrotech Disk Filter)

Illustrations of each of the technologies are presented as Figure 6. High-rate clarification is a sedimentation process that includes coagulation and flocculation to facilitate solids settling. The remaining three technologies are all physical separation (filtration) technologies that physically screen out solids from the wastewater.

Based on the space available at the existing sand filter location and the frequency of peak wet weather events (typically 30 hours above 6 MGD per year), it is recommended that the tertiary process be sized with a capacity between 4.5 and 6 MGD depending on the selected operation mode for the process.

Figure 6: Potential Tertiary Treatment Technologies



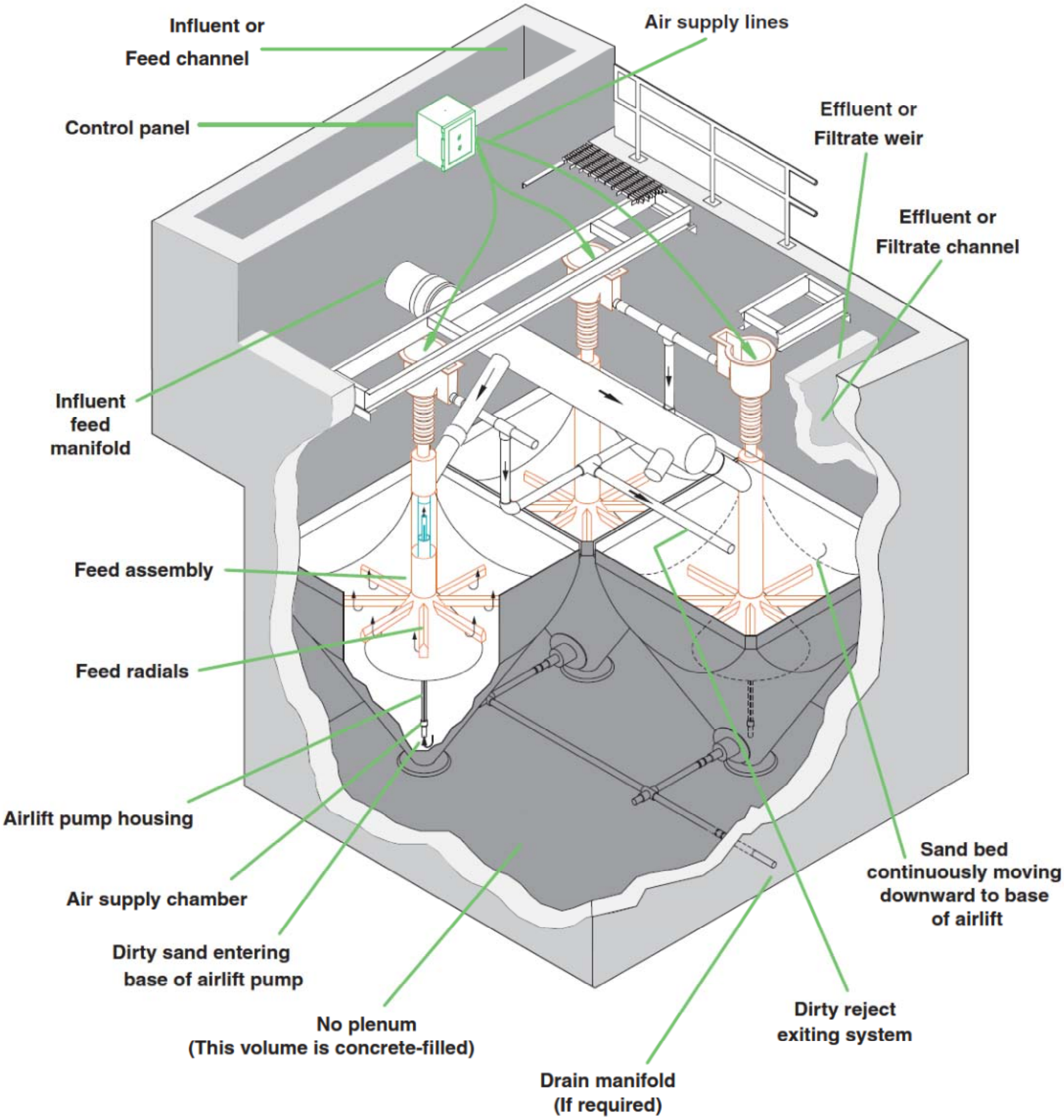
Source: Hydrotech Disk Filter, Densadeg, and Dynasand Product Brochure

Sand Filtration

The District currently uses continuously backwashed sand filters for tertiary treatment. A continuous backwashing filter is an upflow granular media filter that provides continuous filtration while simultaneously backwashing the media and producing a side waste stream. Filter influent enters the filter through a supply pipe that distributes the flow in an upward direction through the filter media. Ultimately, the filtered water flows over the effluent weir prior to flowing into the effluent discharge pipeline. While filtration is occurring, granular media is continuously extracted from the bottom of the filter and scoured with air and water. The washwater is captured and the media settles to the top of the filter bed. Support equipment for the upflow continuous backwash sand filters included air compressors and air dryers.

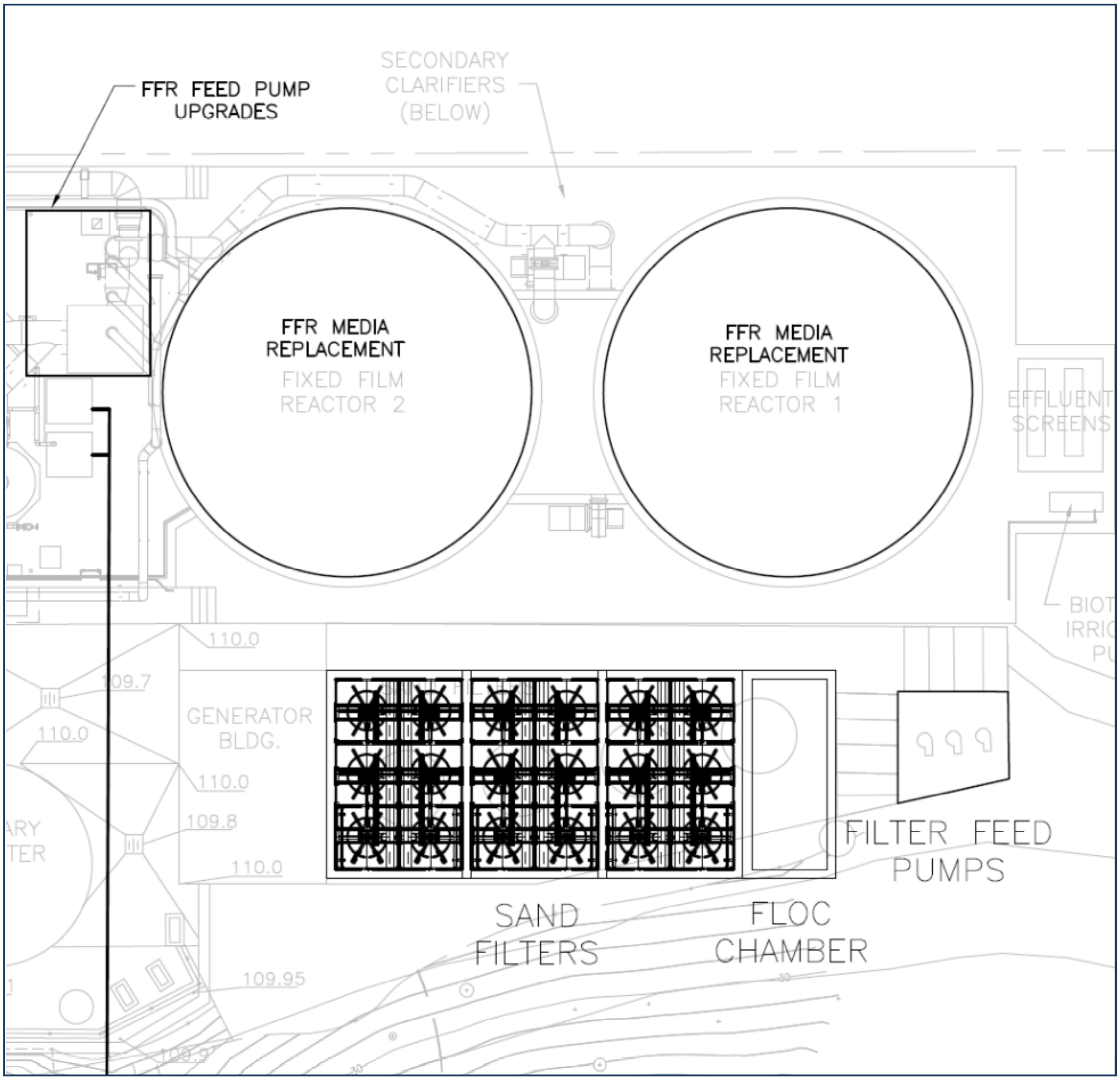
Several options for installation of new tertiary filters were considered, including constructing new concrete tanks and purchasing stainless steel tanks. Although stainless steel tanks would be the quickest to construct and install, they have a relatively high cost and would not have as efficient a layout when compared to concrete tanks. An illustration of a concrete tank installation is presented in Figure 7.

Figure 7: Upflow Continuous Backwash Filter Installed in Concrete Tanks (Parkson Dynasand)



With a concrete installation, approximately 5.0 MGD of filtration capacity can be installed with the existing sand filter process area. The 5.0 MGD capacity is based on 900 ft^2 of filter area operated at approximately 4.0 gpm/ft^2. The current sand filters are operated at a lower loading rate without chemical addition. A flocculation chamber would also be provided along with chemical addition to achieve the higher loading rate. A preliminary layout for a sand filter upgrade is shown in Figure 8.

Figure 8: Preliminary 5.0 MGD Sand Filter (Upflow Continuous Backwash Type) Layout

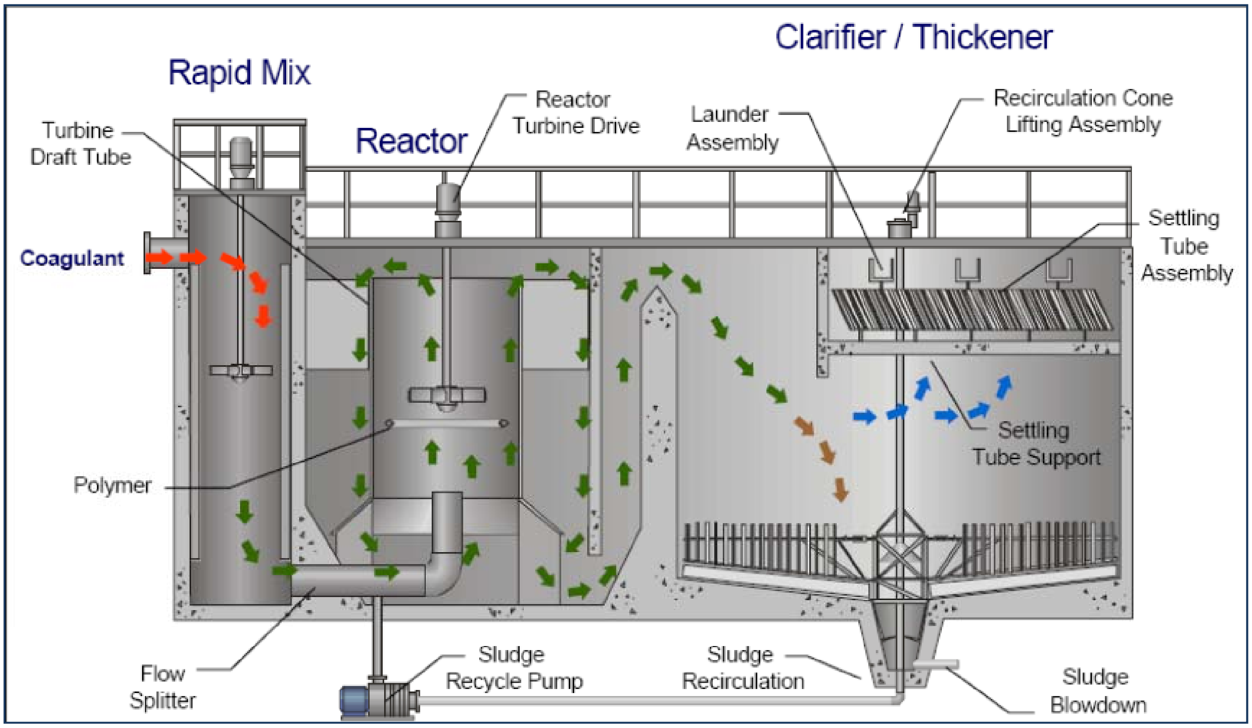


High-rate Clarification / Ballasted Flocculation

High-rate clarification (HRC) could be used to provide tertiary treatment for wet weather blended flow. High-rate or flocculating clarifiers are manufactured equipment packages consisting of a flash mixing vessel, a chemical reaction vessel and a clarification/thickening vessel. Coagulant is added before the flash mixing vessel. In some versions of this process ballast, in the form of sand, is added to provide ballasted flocculation. Coagulated flow then moves to the reactor vessel where polymer is added and flocculation occurs. The coagulated/flocculated water then moves to the clarification/thickening vessel. Clarified water is collected through a series of launders and discharged into the effluent trough. Solids collected from the bottom of the clarifier could either be thickened in the high-rate clarifier, then sent directly to digestion or they could be sent back to the primary clarifier. The high-rate clarifier can be installed either in concrete basins or in a steel tank. High-rate clarification would be effective at removing suspended solids and BOD associated with either secondary effluent or blended wet weather flow, however it would not be effective at removing soluble BOD. An illustration of a high-rate clarifier is shown as Figure 9.

The use of ballasted flocculation for treatment of flows that bypass biological secondary treatment has been cited by EPA as a tentative means of meeting their blending policy. Obtaining their project-specific formal approval of its use to meet the EPA blending policy is recommended.

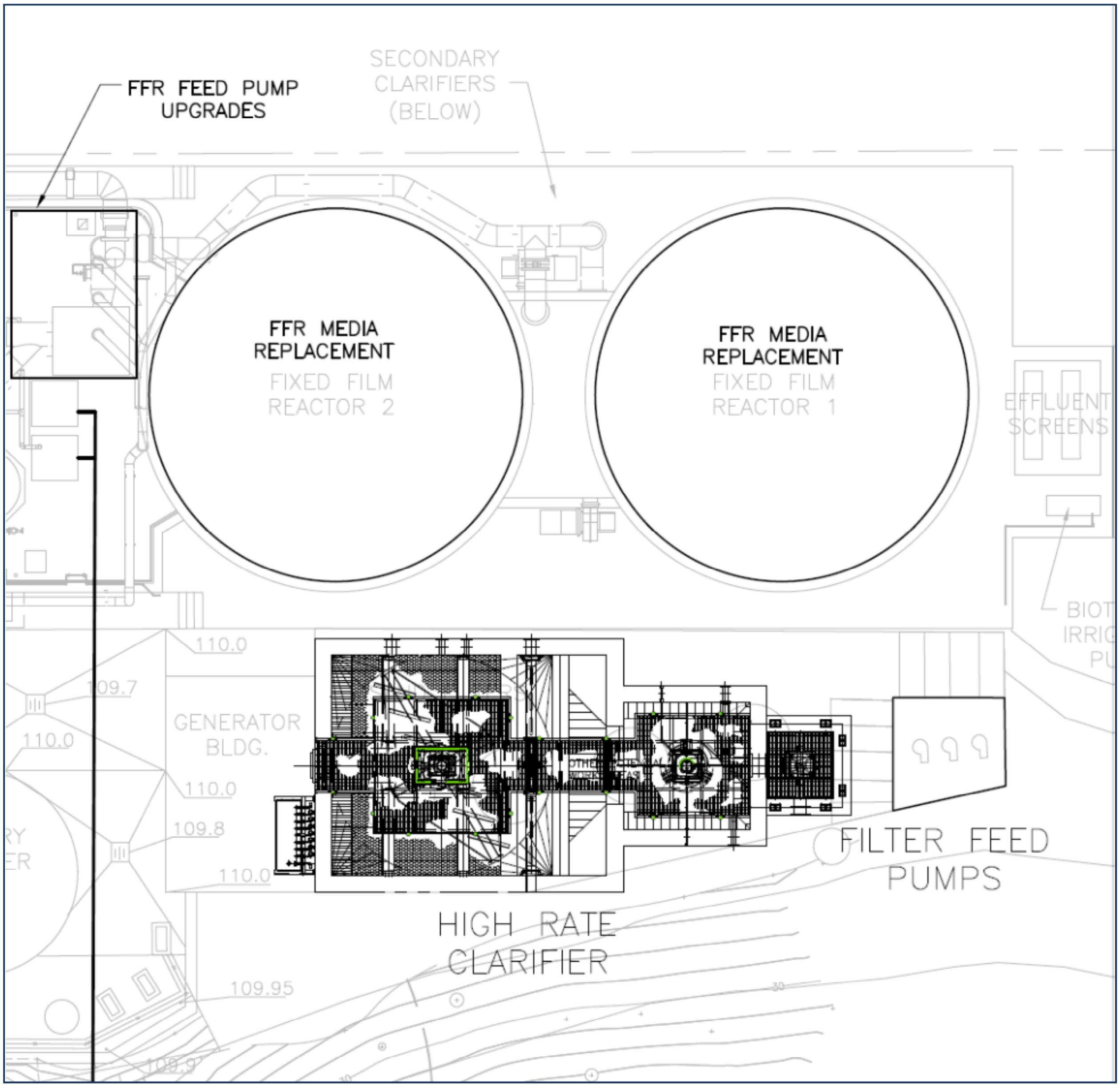
Figure 9: High-Rate Clarification



Source: Infilco Degremont, Inc.

Although it is more compact than traditional clarifiers, the maximum sized HRC that could be installed in the area where the existing sand filters are located is 4.5 MGD. If additional capacity is needed, more space would be need on the treatment plant site. A preliminary layout for a 4.5 MGD HRC is shown on Figure 10.

Figure 10: Preliminary 4.5 MGD High Rate Clarifier Layout

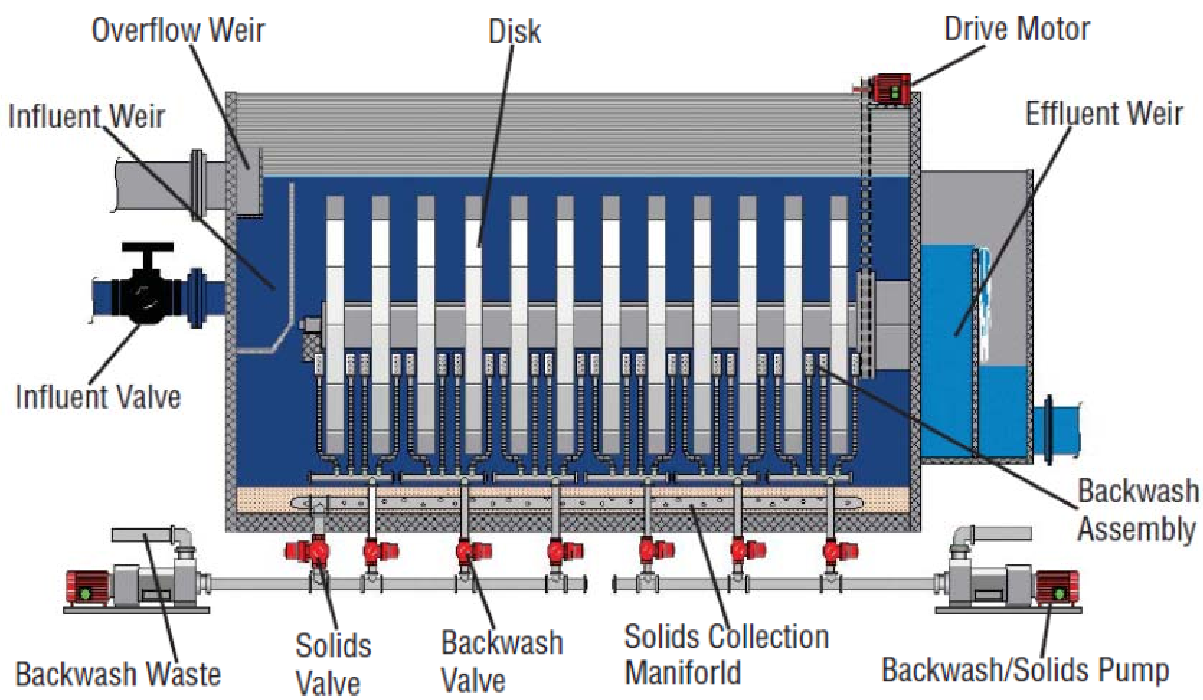


Consideration was given to using the high rate clarifier to provide additional secondary clarifier capacity in addition to polishing or blended flow treatment. However, doing so would create a more complex flow path and require additional process footprint that would be difficult to accommodate on the treatment plant site.

Rotating Disk Filter

Rotating disk or cloth media filters utilize random weave fabric, nylon mesh or stainless steel mesh with a pore size of 10 microns to filter particles from wastewater. There currently are three main manufactures of cloth media filters, Aqua-Aerobics (cloth), Kruger (nylon mesh) and Nova (stainless steel mesh). The configuration of each manufacturer's filter is unique; however the overall concept and treatment process are similar. In general, six pie-shaped sections of the filter media make up one disk, which is mounted vertically, along with other disks, on a tube inside a tank or basin. Tanks may be constructed out of concrete or stainless steel. Wastewater enters the tank or basin and passes by gravity through the cloth membrane. The solids accumulate on the cloth, forming a mat and causing the liquid levels within the basin to increase. Heavier solids settle to the bottom of the tank and are intermittently wasted. The filtered water enters the internal portion of the disk where it is discharged. The filters are designed to backwash automatically based upon a predetermined water level differential and are able to maintain constant filtration during backwash. The disks will only rotate during the backwash process, during which solids are backwashed from the surface of each disk by liquid suction from both sides of the disk. Figure 11 illustrates the basic components of the rotating disk filter.

Figure 11: Rotating Disk Filter



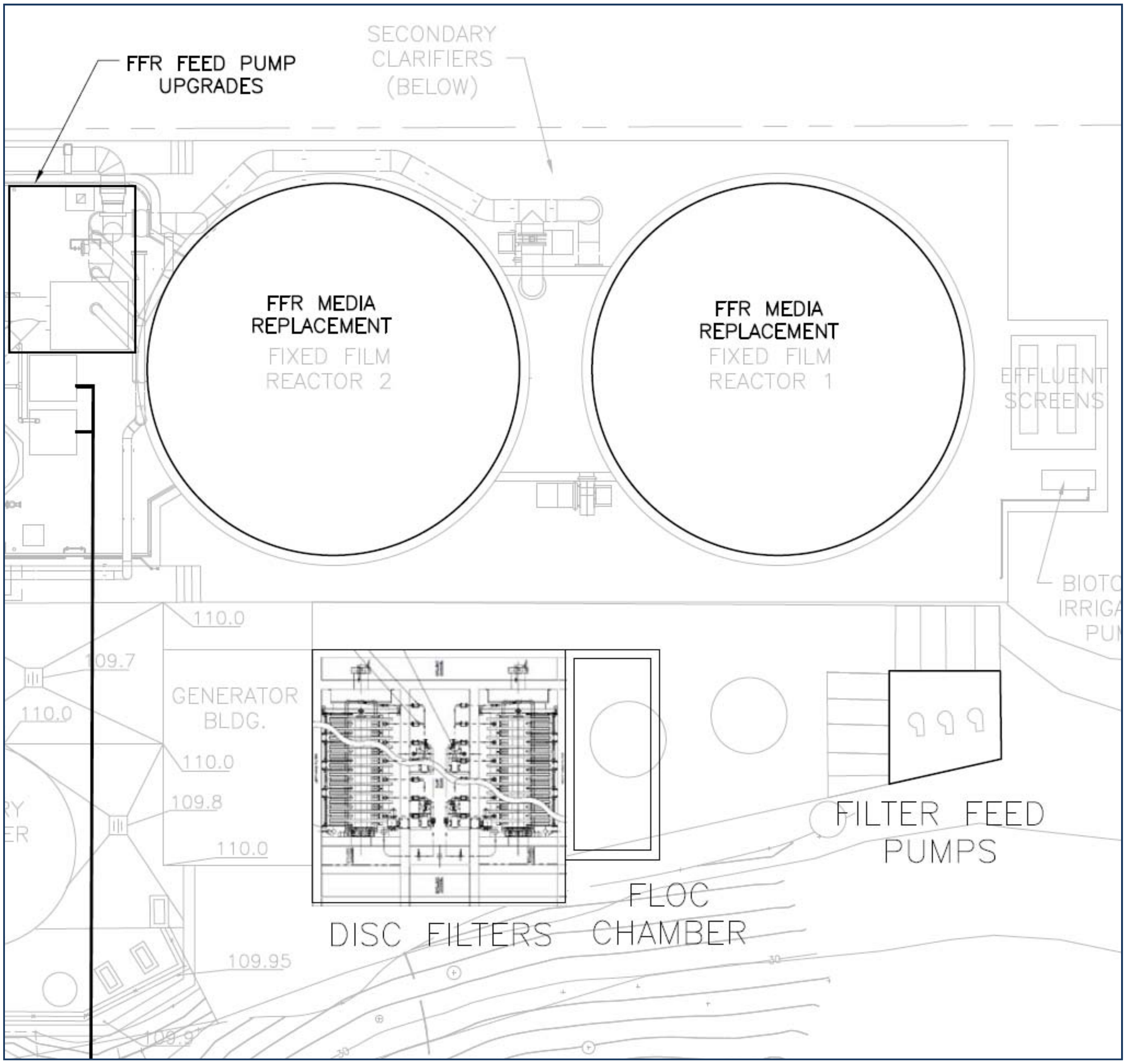
Source: Kruger, Hydrotech Discfilter Brochure

The filter is composed of up to 12 disks, a tank, a drive and a backwash system. Depending on the manufacturer, the disks are either fully submerged or at 60 percent submergence. The water flows by gravity into the individual filter segments that surround the outside of the center drum. As the water flows through the filter panels, the solids are retained within the filter basin. This allows only clean water to pass through the filter into an effluent channel or pipe. When the water level in the influent channel reaches a specified set point, a backwash cycle is automatically initiated. The filtered effluent is used to backwash the discs via a spray header and nozzles as the disks slowly rotate.

The most common application for rotating disk filters is the production of Title 22 recycled water. Even though the rotating disk filter has a successful history for recycled water production, they have had difficulty meeting the low turbidity limits on effluents with low sludge residence times including activated sludge and trickling filter effluents. The difficulty is primarily due to the presence of fine colloidal material that can pass through the filter. Although the District's application would be for tricking filter effluent, the disk filter would not be required to meet Title 22 turbidity effluent limits. Rotating disk filters are not widely used as a polishing treatment step on trickling filter effluent in the United States. There is a wastewater treatment facility operating in the Village of Honeoye Falls, NY, which is using a disk filter for polishing on trickling filter effluent. In addition, there are approximately 40 treatment plants using the disk filter for this application in the United Kingdom. Application summary sheets for three installations in the United Kingdom are included as an appendix.

The rotating disk filter would have the smallest footprint of any of the proposed treatment technology. A 6.0 MGD capacity (and possibly larger) rotating disk filter could be installed in the location where the existing sand filters are installed. The 6.0 MGD capacity is based on two process trains of 12 disks operating at a 3.25 gpm/ft^2 loading rate. A larger capacity installation could be installed within the existing sand filter area. However, benefits of a larger installation are limited due to the amount of time more than 6.0 MGD of capacity would be needed. A 6.0 MGD disk filter facility is shown on Figure 12.

Figure 12: Preliminary 6.0 MGD Disk Filter Layout



3.3.5 Process Comparison

The key factor influencing the type of treatment technology is whether equalization is added to limit flow to the secondary process to 9.0 MGD thereby avoiding the need for blended flow treatment. If treatment of blended flow is required, high rate clarification would be the preferred technology because it can more readily handle the additional solids loading. If only tertiary treatment is needed, any of the three proposed technologies may be used. A summary comparison of the three technologies is presented in Table 4.

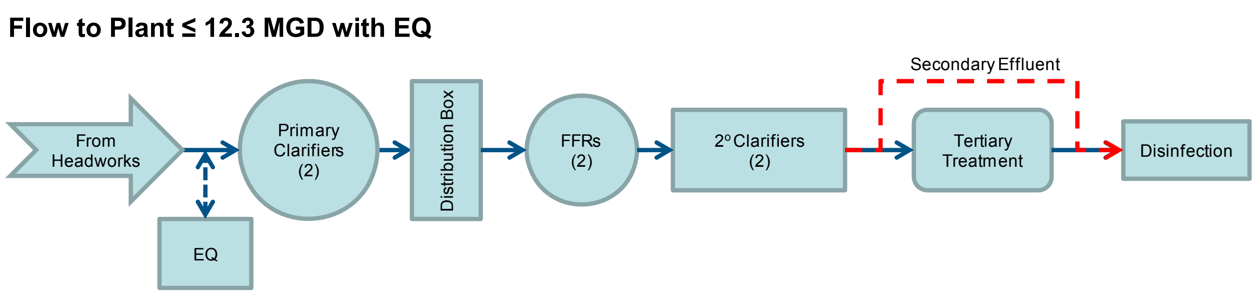
Table 4: Tertiary/ Blended Flow Treatment Process Comparison

Feature	Sand Filtration	High Rate Clarification	Rotating Disk Filter
Performance on Blended Flow	Poor	Good	Poor/Unknown
Removal of Fine Colloidal Material (Typical Found in Trickling Filter Effluent)	Poor	Good	Poor
History of Use on Trickling Filter Effluent for Tertiary Polishing	Good (Proven at SMCSD)	Good (Several Title 22 installations)	Limited in US (40 UK installations)
Chemical Use	Low/None	High	Low/None
Capacity that Can Fit within Existing Sand Filter Area	5.0 MGD	4.5 MGD	6.0 MGD+
Ease of Operation	Moderate	Moderate/Difficult	Moderate
Construction Cost	$0.65M per MGD capacity	$0.47M per MGD capacity	$0.36M per MGD capacity

4 Recommendations

Based on input from District staff and the information presented in Section 3, the recommended secondary process upgrade configuration will include equalization storage. Therefore, blending for wet weather flows less than or equal to 12.3 MGD will not be required. The flow path with equalization is shown as Figure 5.

Figure 13: Flow Path with Equalization



With equalization and tertiary treatment, the recommended process configuration is summarized below:

- Add equalization storage (~0.6 MG) as part of the headworks structure
- Upgrade the FFRs to 9.0 MGD hydraulic capacity
  - Upgraded FFR feed pumps
  - New FFR media
- Replace existing 1.0 MGD sand filters with expanded tertiary process located within the same footprint with capacity between 4.5 MGD and 6.0 MGD.

The final tertiary process to be used will be selected during the design phase. However, it is recommended that the rotating disk filer be used pending further evaluation to confirm their suitability for use at SMCSD. The rotating disk filters have the lowest construction cost and require the smallest footprint. They also offer the potential of operation without chemical addition, which would need to be confirmed specifically on the District's effluent. The performance goal for the tertiary process would be to provide a similar level of effluent TSS (22 mg/L) as is currently achieved by the existing sand filters. This level of performance provides a modest level of cushion for meeting the District's NPDES permit limit of 30 mg/L monthly average TSS.

The three main disk filter manufacturers were contacted to set-up bench scale tests of their filter media on secondary effluent from the SMCSD WWTP. At the time of this TM, the results from one of the manufacturers are available. The results of the bench scale test results as well the approximate performance of the existing sand filters are presented in Table 5.

Table 5: Bench Scale Disk Filter Comparison

Parameter	Units	Existing Sand Filters*	Aqua-Aerobic Disk Filter
Media Type	-	Sand	nylon pile cloth
Media Opening	μm	-	10
Chemical Dose	mg/L	0	0
Filter Loading Rate	gpm/ft^2	2.4	3
Filter Influent TSS	mg/L	38	36.0
Filter Effluent TSS	mg/L	22**	21.7
TSS Removal	%	42%	39.7%

*Based select wet weather data from 2010 and 2011
**Includes TSS that occurs in the chlorine contact basin

The bench scale results from the Aqua-Aerobics filter indicate that their disk filter media can provide similar TSS removal performance to the District's existing sand filters. In addition to TSS measurements, Aqua-Aerobics also performed a particle size distribution analysis on the filter influent (SMCSD secondary effluent) and filter effluent. The results of the particles size distribution analysis is presented in Table 6.

Table 6: Aqua-Aerobics Particle Population Reduction – Bench Scale Test Results

Particle Range (μm)	Influent (counts/100 mL)	Filter Effluent (counts/100 mL)	Particle Removal (%)
2-4	764,500	1,017,033	-33.0
4-6	590,300	731,000	-23.8
6-10	941,540	941,280	0
10-15	484,753	302,530	37.6
15-20	221,003	95,947	56.6
20-25	82,626	29,043	64.9
25-30	28,022	8,900	68.2
>30	26,422	6,733	74.5

As indicated in Table 6, the majority of particles in the District's secondary effluent are in the 10 μm or less range (often referred to as colloidal material), which is typical of trickling filter effluent. Because the filter media has an opening of 10 μm, particles at this size and smaller are not removed by the filter media, which is evident by the removal rates shown in Table 6. However, the filter media was effective at removing particles greater than 10 µm and the net result was a 39.7% reduction in TSS, which is similar to District's current tertiary performance.

It may be possible to use a smaller than 10 µm media, however there would be some operational impacts with the small opening, such as increased backwashing and lower surface loading rates. Chemical addition, along with a coagulation/flocculation step upstream of the filters would also help improve the removal efficiency.

The recommended next steps would be pilot testing of a rotating disk filter unit. It is also recommended that SMCSD staff visit an operating disk filter facility to obtain feedback on the units. If it is determined that the disk filters cannot be used, it is recommended that continuous backwashed sand filters be used.

The new tertiary treatment process will be located where the existing sand filters are currently located. All of the existing mechanical equipment, including the sand filter feed pumps, would be removed. A layout of the proposed secondary treatment upgrades is shown on Drawing S-20.

4.1 Equalization

The equalization storage tank would be integrated into the new headworks structure and would have the capacity to store a minimum of 0.6 MG of primary influent. The final volume will be determined during final design based on the volume that can be readily made available within the headworks structure. The equalization tank would be configured to store primary influent, which would be controlled by an adjustable weir gate in the primary influent distribution box. In order to minimize cleaning and maintenance, the equalization tank will be compartmentalized into either two or three separate basins. Overflow weirs would be provided in each basin so that flow will enter the next basin when full. Each compartment would also include sloped floors and a tipping trough to facilitate wash down and cleaning.

It may also be possible to utilize the equalization tank to store primary effluent which would require a pipeline connection from the FFR feed pumps to the equalization storage tank. The benefit would be that primary effluent would be stored in the equalization basin, which would have fewer solids than primary influent. This arrangement will be confirmed during the design phase.

An equalization return pump station would be provided to return flow from equalization storage to the primary influent distribution box located just after the grit chamber. The return flow from the equalization basin would be metered back over a period of time (e.g. 14 to 24 hours) to minimize overloading of the treatment plant.

Controls

Flow to the equalization storage tank will be controlled by a motorized weir gate which will control when flow will spill to the equalization basin based on influent flow to the plant or manual operation. The gate can also be used to divert flow to the equalization storage during other flow conditions to allow for shutdowns or maintenance activities. Each equalization compartment would include level monitoring and high level alarms.

Cleaning Mechanism

The cleaning mechanism for the equalization basin will consist primarily of a tipping trough. When needed, the tipping trough will be filled with plant recycle water over a period of time. When full the trough would be "tipped" which will release a deluge of water down the floor of the equalization basin, carrying accumulated solids towards the equalization return pump station.

Equalization Return Pump Station

Water in the equalization basin will be directed towards the equalization pump station intake. The equalization pump station will consist of a duty and a standby pump that will return flow back to the primary influent distribution box.

4.2 FFR Upgrades

Upgrading the secondary treatment capacity to 9.0 MGD will reduce the number of blending events. Implementation of the capacity upgrade to 9.0 MGD would involve the following upgrades:

- Replace existing FFR feed pumps to provide 9.0 MGD to the FFRs.
- Replace the FFR media
- FFR odor control covers

The District should consider stress testing of a single FFR to confirm adequate process operation at 2.5 gpm/ft^2 hydraulic loading rate. New or upgraded FFR feed pumps would be needed to provide 4.5 MGD of flow to each FFR. The pump upgrade would include new motors and variable frequency drives. The existing distributer was designed to allow up to 7.2 MGD of flow through the distributer arms. Flows in excess of 7.2 MGD are designed to overflow the center column on the distributer mechanism. It is possible to retrofit the existing distributor to raise center column and add more orifices to provide flow distribution above 7.2 MGD. However, the additional orifices would result in less even flow distribution at lower flow, which is where the majority of flow conditions occur. Based on the limited frequency of flows above 7.2 MGD and the impacts on normal flow distribution, modifying the distributor is not recommended. The FFR tank walls should be evaluated to confirm they are able to accommodate the additional load. Given the age of the media and the additional hydraulic loading, it is recommended that the FFR media be replaced. Although the FFRs have an odor control connection, which creates a downdraft through the FFRs, occasionally wind over the top of the FFRs can cause air from the FFRs to be carried to Fort Baker Road and other surrounding areas. A cover would be added to the existing FFRs to help control odors.

4.3 Tertiary Polishing

Rotating disk filters would be installed where the existing sand filters are located. The existing filter feed pumps would be upgraded to provide additional flow. The rotating disk filters were described in Section 3.3.4.

Controls

The tertiary filtration process will be supplied as a package system including controls for filter operation. The controls from the filtration equipment package will be integrated into the overall treatment plant control system. The control system will monitor water level in the process tank and initiate backwash cycles to reduce headloss across the filters.

Chemical Addition

The addition of coagulant and/or polymer upstream of the filters may be used to increase filter loading rates. Coagulant and/or polymer could be added to the influent to the filters via the conveyance pipe between the filter feed pump station and the rotating disk filters. The dosing amounts for the coagulant and polymer are summarized in Table 7.

Table 7: Coagulant and Polymer Dosing

	Coagulant (Ferric Chloride)	Polymer
Minimum Dose	30 mg/L	0.1 mg/L
Maximum Dose	140 mg/L	5 mg/L
Average Dose	80 mg/L	1 mg/L

The chemical feed area will be adjacent to the filters and within the existing footprint of the sand filters. SMCSD may be able to operate at either a lower chemical dose or without any chemical addition depending upon the filter loading rate needed to meet capacity requirements. For the purposes of this evaluation, it was assumed that only a coagulant would be used.

Backwash Pump Station

The rotating disk filters have a backwash (reject) line to remove organic and inorganic contaminants from the filter disks. The backwash water from the filters will be conveyed back to the head of the treatment plant. The backwash pump station will be adjacent to the filters and within the existing footprint of the existing sand filter area.

As a conservative assumption, backwash water is assumed to be 5 percent of the total amount of filtered water. The backwash pump arrangement will consist of two horizontal end suction pumps, both duty with no standby. The pumps will each be capable of conveying half of the backwash flow from the total filter capacity.

4.4 Odor Control

Odor control covers will be added to the FFRs. The process upgrades in the tertiary process area will have a minimal potential for odor generation; therefore odor control will not be provided. There is some potential for odor generation during the filling and operation of the equalization storage basin. Depending on the frequency of use, it may be necessary to connect the equalization storage basin to the plant odor control system.

4.5 Design Criteria

The process loading for the upgraded secondary treatment process and the tertiary filtration process are presented in Table 8.

Table 8: Process Loading Comparison

		Flow Condition		
		Design Average Day	Future Max. Secondary Capacity	Typical Peak Flow Design Value [a]
Flow				
Influent Flow	MGD	1.5	9	---
Fixed Film Reactors (FFR) [b]				
Total Surface Area of Units	ft^2	2,514	2,514	---
Organic Loading Rate	lbs BOD/day-1000 ft^3	23.9	52.2	37-200
Hydraulic Loading Rate	gal/min-ft^2	1.66	2.49	1.0 – 2.0
Secondary Clarifiers				
Total Surface Area	ft2	3,520	3,520	---
Surface Overflow Rate	gal/day-ft^2	426	2,557	1,000-1,200
Solids Loading Rate [c]	lbs TSS/day- ft^2	0.70	1.24	2
Rotating Disk Filters				
Total Surface Area	ft^2	1280	1280	---
Surface Loading Rate	gal/min-ft^2	0.82	3.25	2-6

Notes:
[a]Typical design criteria taken from Metcalf and Eddy, Inc, *Wastewater Engineering Treatment, Disposal and Reuse*, 3rd edition.
[b]Maximum flow through the Fixed Film Reactors (FFRs) is 9.0 MGD.
[c]Estimated based on assumed solids removal through the primary clarifier and solids produced from the FFRs.

A summary of the recommended design criteria for the equalization, secondary treatment and tertiary treatment process are presented in Table 9.

Table 9: Secondary and Tertiary Treatment Design Criteria

Criteria	Value	Unit
Equalization		
EQ Storage Tank		
Compartments	2	-
Volume (Total)	0.6 (min)	MG
EQ Return Pumps		
Type	Centrifugal	-
Number	2	-
Capacity (Each)	695	gpm
TDH	45	feet
Motor Size	15	HP
Secondary Treatment		
FFR Feed Pumps		
Type	Centrifugal	-
Number	3	-
Capacity (Each)	3,125	gpm
TDH	62	feet

Criteria	Value	Unit
Motor Size	75	HP
Fixed Film Reactor		
Media Type	Cross Flow	-
Media Surface Area/Volume	32	ft^2/ft^3
Reactor Surface Area (Total)	2,514	ft^2
Media Depth	32	ft
Volume (Total)	81,060	ft^3
Tertiary Treatment		
Filter Feed Pumps		
Type	Centrifugal	-
Number	3	-
Capacity (Each)	2,085	gpm
TDH	20	feet
Motor Size	20	HP
Tertiary Filtration		
Type	Rotating Disk	-
Units	2	-
Disks Per Unit	12-18	-
Filter Area Per Disk	54-60	ft^2
Total Submerged Filter Area	1,280	ft^2
Design Loading Rate	3.25	gpm/ft^2
Maximum Loading Rate	6.0	gpm/ft^2
Maximum Backwash (% of average flow)	5	%
Filter Backwash Pumps		
Type	Centrifugal	-
Number	2	-
Capacity (Each)	150	gpm
TDH	20	feet
Motor Size	5	HP

4.6 Layout and Arrangement Options

Equalization would be added within the new headworks process structure. The layout for the equalization storage tank and return pump station is shown in Drawings M-10, M-11, M-12 and M-14. The FFR upgrades would be installed in the location of the existing process and equipment. There are various options for the layout and arrangement of the tertiary process improvements. The recommend layout and arrangement is shown as Drawing M-20.

4.7 Secondary Upgrades Cost Estimate

The estimated construction costs for the equalization storage tank is $1.9 million and consists mainly of structural costs. The estimated construction cost for the FFR upgrades is $1.4 million. The estimated construction cost of the tertiary process upgrade is $2.3 million. The estimated construction cost for the secondary process upgrades is included in the Recommended Project Summary TM.

4.8 Operation and Maintenance (O&M)

The addition of screening process facilities will require increased operation and maintenance labor as well as power consumption to run the equipment. Operation and maintenance associated with the screening process and equipment is presented in the following sections.

4.8.1 O&M Labor

Some annual maintenance will be required for normal servicing and infrequent failures. The required labor is expected to be similar to the labor requirements for the current FFR and tertiary processes; therefore the upgrades are not expected to have a net increase on labor requirements. Because SMCSD is already familiar with the O&M labor requirements for the FFR process, only the estimated labor costs for equalization and the rotating disk filter are presented in Table 10.

Table 10: Estimated Required Process Labor

Labor Type	Process Labor (Hours/week)	Process Labor (Hours/Year)
Operation	3	156
Maintenance	0.5	24
Total	3.5	180

4.8.2 O&M Cost Estimate

The new equalization storage and rotating disk filter will have a small impact on the O&M costs relating to the following items:

- Operation and maintenance labor
- Energy
- Repair parts and service

The estimated O&M cost associated with the secondary upgrades are presented in Table 11. The chemical cost is based on chemical dosage for typical tertiary applications however the dose can be refined during actual operation. SMCSD may be able to operate the rotating disk filter at a lower coagulant dose and a lower filter loading rate.

Table 11: Estimated O&M Costs

O&M Items	Quantity	Units	Unit Cost	Total Cost	Notes
Consumables					
Equipment Consumables	$640,000		1.0%	$6,400	% of Equipment Purchase Cost
Mechanical Consumables	$49,752		1.0%	$500	% of Mechanical Purchase Cost
Subtotal Consumables				$6,900	
Power					
Disk Filter	14,659	kwh	$0.15	$2,200	
Filter Feed Pumps	97,724	kwh	$0.15	$14,700	
Backwash Pumps	8,144	kwh	$0.15	$1,200	
EQ Return Pumps	335	kwh	$0.15	$100	
Subtotal Power				$18,200	
Labor					
Operator	3	hr/week	$45	$7,000	
Maintenance	0.5	hr/week	$45	$1,100	
Subtotal Labor				$8,100	
Chemicals					
Chemicals	38,964	Dry LB	$1.05	$40,900	
Subtotal Chemicals				$40,900	
Total Annual O&M Cost				**$74,000**	

Drawings

Drawing M-20

Drawing M-10

Drawing M-11

Drawing M-12

Drawing M-14

Appendix

United Kingdom Disk Filter Summary Sheets

Hydrotech

Discfilter Project Profile

Croockhall STW

Product: **Hydrotech Discfilter**

Model: **2 x HSF2108/7-1F**

Client: Northumbrian Water

Maximum Flow: 40 l/sec

Completion Date: March 2005

Project

The contract for Crookhall STW was for the design and installation of a new tertiary treatment plant as part of an upgrade to the existing works. The existing works consist of inlet screens, primary tanks, trickling filters followed by humus tanks. The Hydrotech Discfilters, placed after the humus tanks, are designed to treat flows of 40 l/sec with a maximum solids load of 60mg/l and produce a final effluent to meet a 15mg/l design standard.

The contract included the design, supply and installation of two Hydrotech Discfilters complete with local control panels. Veolia Water Solutions & Technologies were responsible for the installation and commissioning with the principle contractor responsible for the civil design and construction.

Contract Arrangement

NEC Option A

Sonning Common STW

Product: **Hydrotech Discfilter**

Model: **1 x HSF2204-1F**

Client: Thames Water

Maximum Flow: 30 l/sec

Completion Date: March 2004

Contractor: MJ Gleeson

Project

The contract for Sonning Common STW was for the design and installation of a new tertiary treatment plant to meet a tighter consent standard. The existing works consisted of inlet screens, primary tanks, trickling filters followed by humus tanks. The Hydrotech Discfilter placed after the humus tanks was designed to treat inlet flows of 30 l/sec with a maximum solids load of 45mg/l and produce a final effluent to meet a 25mg/l design standard. Since installation the actual final effluent from the Discfilter has been in the region of 10 mg/l.

The contract included the design and supply of one Hydrotech Discfilter complete with local control panel. Veolia Water Solutions & Technologies were responsible for the installation and commissioning with the principle contractor responsible for the civil design and construction.

Contract Arrangement

IChemE Yellow book contract

Discfilter Project Profile

Wisley STW

Product: **Hydrotech Discfilter**

Model: **2 x HSF2212/11-1F**

Client: Thames Water

Maximum Flow: 169 l/sec

Completion Date: November 2003

Project

The contract for Wisley STW was for the design and installation of a new tertiary treatment plant to meet a tighter BOD consent. The existing works consisted of inlet screens, primary tanks, trickling filters followed by humus tanks. The Hydrotech Discfilters placed after the humus tanks were designed to treat inlet flows of 169 l/sec with a maximum solids load of 29mg/l and produce a final effluent to of 10mg/l to meet a BOD consent of 8mg/l.

The contract included the design and supply of two Hydrotech Discfilters complete with local control panels. Veolia Water Solutions & Technologies were responsible for the installation and commissioning with the principle contractor responsible for the civil design and construction.

Contract Arrangement

IChemE Yellow book contract

Hydrotech AB, Mejselgatan 6, 23532 Vellinge, Sweden. Tel: +46 40 42 9530
www.hydrotech.se

VEOLIA WATER Solutions & Technologies