Treatment Plant Flows and Loadings Study Summary Report

FINAL

Prepared for

King County

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Introduction

To protect public health and deliver reliable clean water services, the King County Wastewater Treatment Division (WTD) regularly updates its projections of wastewater flows and loads and evaluates their impact on overall treatment plant capacity. This report summarizes the most recent projections and identifies the timing of capacity limitations for each major treatment process at each of WTD's regional wastewater treatment plants—West Point Treatment Plant (West Point), South Treatment Plant (South Plant), and Brightwater Treatment Plant (Brightwater)—by identifying capacity needs in the near term (the next 10 years), midterm (10 to 20 years), and long term (more than 20 years).

WTD has historically updated wastewater flow and load projections every 10 years. In 2014, during an updated assessment of the flows and loads to the plants, WTD noted that influent loads were increasing at a faster pace than flows. **Over the past few decades, water conservation efforts have reduced the amount of potable water used on a per capita basis. These reductions in water use directly impact the amount of wastewater flow, but do not impact the loads in the wastewater.** As a result of this change, the wastewater in WTD's system is now "stronger" than it was before (that is, it contains more load per flow).

The increase in loads compared to flows is significant because, in the past, wastewater flow was often used to determine treatment plant capacity. Now, however, wastewater loading is the driving factor in determining when more capacity is needed for WTD's treatment plants. Comparing the recent plant influent flows and loadings with each plant's overall rated flow and loading capacities confirms that WTD's treatment plants are now more load limited than flow limited. This comparison reinforced the need for a more thorough assessment of available capacity for the individual treatment processes within each plant, rather than simply comparing observed flows and loadings to a plant's overall rated capacity.

In addition to addressing the growth in loads compared to flows, a more detailed evaluation of capacity is also appropriate because of the amount of time that has passed since WTD last completed a significant expansion of treatment capacity. West Point and South Plant were both constructed in the 1960s and have each undergone expansions since then to meet the growth needs of the region and new regulations. **As Figure 1 shows, the County has historically expanded its regional treatment plants approximately every 10 years to keep pace with growth and regulatory requirements. However, the last major expansion at either South Plant or West Point was more than 20 years ago, in the 1990s.** Since that time, Brightwater was constructed in 2011, in part to provide additional treatment capacity for areas previously served by West Point and South Plant.

Results from this study will help WTD determine future capacity expansion options and budgeting needs.

FIGURE 1
WTD Historical Regional Treatment Plant Expansion Projects

Understanding flows and loads

Wastewater treatment plants are designed to treat wastewater based on both the volume of flow conveyed to them (typically measured in terms of millions of gallons per day, or mgd) and the amount of organic and solids load in the wastewater (typically measured in terms of pounds per day of biochemical oxygen demand, or BOD, and total suspended solids, or TSS). In the past, wastewater strength (the relative ratio between load and flow) was fairly static, so the capacity of a treatment plant could be summarized by using just the flow capacity. This is why the capacity of a treatment plant is often referred to in terms of million gallons per day, with an assumed amount of BOD and TSS that corresponds to that flow.

With the increase in influent loads compared to flows—together with significant growth in the Puget Sound region in recent years—plant capacity is becoming an increasing concern. Therefore, WTD initiated a more in-depth look at both flow and load capacity at each regional treatment plant, including a detailed evaluation of capacity needs at the treatment process level. **Assessing available capacity at each treatment plant on a process basis provides WTD more accurate information to plan for specific capacity expansion needs.** This report summarizes the in-depth evaluation of capacity detailed in the technical memorandum produced for each treatment plant. This summary report includes a description of the study approach used for the capacity analysis, the process-specific capacity and timing for when the capacity is anticipated to be exceeded at each treatment plant, and a summary of overall conclusions and next steps.

Study Approach

The Brown and Caldwell project team worked closely with WTD staff to define the process capacities at each of WTD's regional treatment plants. Before describing the approach used, it is important to understand how capacity was defined and describe the factors that affect the capacity of WTD's treatment plants.

Defining Treatment Plant Capacity

Treatment plants are complicated facilities, which makes defining the capacity of a treatment plant complicated. Generally speaking, capacity is defined as the amount of wastewater the treatment plant can safely and reliably treat. However, there is no one value that can adequately represent plant capacity. Many factors, such as the following, affect the capacity of a wastewater treatment plant:

- Treatment capacity is based on both hydraulics (flow) for physical processes (for example, pumps, pipes, and membranes) and on loading for biological processes (for example, secondary treatment and digestion).
- Capacity is also influenced by the duration of temporary peaks in flows or loads, with some processes needing to manage the maximum amount the facility receives, whereas, for others, a longer duration such as a maximum month condition is the appropriate parameter to use.
- How wet weather flows are managed within the treatment facilities and the ability to store or transfer flows between different facilities can further complicate defining a facility's capacity.

For a thorough discussion on how unit process capacities were defined for this study, refer to the technical memorandum developed for each treatment plant.

In this report, the capacity values presented are normalized to an influent flow or load condition (often either peak hour or maximum month). This approach simplifies the discussion and is also consistent with how regulators typically define the capacity of a treatment plant.

Factors Affecting Capacity

Beyond the strict capacity of individual processes, there are a number of other factors that can impact available capacity at a treatment plant. Although WTD can control some of these factors, others are out of WTD's control. These factors were incorporated into the capacity analysis and are summarized below. **It is important to account for these factors because the results and conclusions of the capacity assessments can be very sensitive to changes in these factors.** In addition, changes related to some of these factors are considered more likely to occur than others. For example, there is a high likelihood that some type of effluent nitrogen limit will be imposed on WTD in the future, which would have a significant impact on treatment capacity.

Factors affecting plant capacity include the following:

INFLUENT WASTEWATER CHARACTERISTICS

Characteristics of the wastewater coming into the treatment plant, or influent, strongly impact available capacity. Wastewater strength (the ratio of load to flow) is impacted by the type of sewer system serving the treatment plant (combined with stormwater collection or separated), water conservation efforts, infiltration and inflow (I/I) to the conveyance system, and the mix of residential and industrial users. Capacity is also impacted by the magnitude of peak flows, which is influenced by the type of sewer system connected to the facility and levels of I/I.

OPERATING CONSTRAINTS

For some treatment plant processes, full-time operation is not provided. This is often the case with biosolids dewatering, where part-time operation reduces staffing requirements and aligns with biosolids hauling availability. In these cases, staffing and other operating constraints can influence available capacity.

REGULATORY REQUIREMENTS

The Washington State Department of Ecology (Ecology) determines the effluent quality limits WTD must meet. More stringent limits typically require increased treatment, reducing the capacity of existing processes, and requiring additional or new treatment units. **For this study, capacity was determined assuming current regulatory requirements.** If regulations require increased treatment in the future (for example, nitrogen removal), the available treatment capacity of WTD's existing treatment plants would be significantly reduced without major modification and expansion of some of the treatment processes.

There are also regulatory requirements for the management of peak flows that impact secondary treatment capacity and conditions for bypass or split flow treatment.

Finally, biosolids classification requirements define the solids treatment process requirements and capacity. Higher levels of classification (for example, Class A biosolids) require increased treatment and would influence the available capacity of existing processes.

OPERATING CONFIGURATION

How a process is configured can impact the performance and capacity of the process. For example, operating the aeration basins in either plug-flow or contact reaeration mode, which differ in where the influent stream is routed in the basin, can influence the performance and capacity of the process. As another example, if chemicals are added to primary treatment to enhance solids removal, the primary and secondary treatment capacities can be significantly increased, but solids treatment capacities may decrease. It is important to understand the current process configuration and operating strategy (rather than simply the theoretical or design strategy) to define the current available capacity.

PROCESS PERFORMANCE

The performance of a treatment process directly influences the capacity of the process. For example, settleability of sludge is a measure of how quickly solids will settle by gravity in a clarifier. If settleability is poor, the capacity of the clarifier is reduced. An understanding of performance limitations for each process is needed to define the current process capacity.

It should be noted that while process performance affects capacity, it is typically a gradual process and does not result in an instant or well-defined change in capacity. Process performance is usually negatively impacted before the capacity limit is exceeded. For example, when settleability deteriorates, effluent concentrations would increase until the permit limits are exceeded.

RELIABILITY AND REDUNDANCY

Ecology has also established minimum reliability requirements to ensure satisfactory operation during an unanticipated event (for example, a power outage, equipment failure, or maintenance outage). Redundancy is applied to meet these minimum reliability requirements as well as industry best practices. Redundancy allows capacity to be maintained during an equipment failure or while maintenance is being performed by having one or more units in place than what are required just to meet capacity needs. In this way, most processes have more "installed capacity" than "firm capacity."

Understanding installed capacity versus firm capacity

Installed capacity is the total capacity with all units in a treatment process in service. Firm capacity is total capacity with the largest unit out of service and unavailable.

The following step-by-step approach was used to assess the capacity needs at each of WTD's treatment plants:

STEP 1
Project Flow and Loadings

WTD updates its flow and loading projections approximately every 10 years using population and employment forecasts provided by the Puget Sound Regional Council (PSRC) that reflect the most recent U.S. Census data. WTD also evaluates and updates other key planning assumptions such as water use, water conservation, and service area growth rate. WTD made projections in 2014 as part of the 2007–2013 Regional Wastewater Services Comprehensive Review. The projections extend from 2010 through 2060 and rely on 2013 PSRC forecasts, which are based on 2010 U.S. Census data. As part of this study, in 2018, WTD made revisions to the 2013 PSRC forecasts to reflect the higher-than-anticipated growth that has occurred in the region from 2010 to 2016. These revised flow and loading projections for 2010 through 2060 formed the basis for the capacity assessment at each treatment plant.

STEP 2
Review Data and Consult with Operators

Existing performance data provided by WTD for each treatment plant were reviewed and additional data and testing were identified, where needed, to properly identify process capacities. In addition to reviewing data, plant staff were consulted to identify current and future operational constraints that impact capacity. Collaboration with plant staff provided context to the data review and helped complete the picture of the current status at each facility.

STEP 3
Perform Process Modeling

With existing data, input from plant staff, and the additional data collected, biological process modeling of the secondary treatment process and plant-wide solids mass balances were performed for each treatment plant. To calibrate the process models, observed conditions at each plant were compared to modeled values.

STEP 4
Conduct Stress Testing and Sensitivity Analysis

Where the preliminary assessment indicated that further analysis and confirmation was needed, stress testing was conducted to measure the actual capacity of a process. Stress testing involves field testing equipment or a process by incrementally increasing the flow sent to that equipment or process until the maximum capacity of the system is observed. By monitoring process performance, stress tests allow for verification or updating of actual operational limits.

In addition, a sensitivity analysis was conducted to identify the impacts caused by changes in the assumptions used to determine capacity. There were many assumptions needed to conduct the capacity assessments. Although most of the assumptions were based on historical and recent operating data, uncertainties still exist. Therefore, the assessment for each plant included this analysis for the critical processes affecting overall plant capacity.

STEP 5
Review Results

The results from modeling and stress testing were compiled before being reviewed in workshop settings with WTD staff to confirm their validity. Where the results did not adequately represent the observed process performance or capacity, refinements were made to reconcile with the observations.

Key Assumptions

Numerous assumptions were made to complete the technical analysis of available capacity at WTD's regional treatment plants. Each treatment plant's technical memorandum provides details of these assumptions. The key assumptions that significantly impact the outcome of the analysis are as follows:

- The timing of capacity limitations is based on projections of future flows and loads. The projections developed by WTD assumed a 20-year recurrence period for peak flows and loads, which evaluates the peak capacity based on a flow or load that is expected to occur once every 20 years. If actual flows and loads are less than these projections, the timing for capacity limitations would be delayed.
- This study assumes that current regulatory requirements will remain unchanged through 2060. If more stringent effluent limits are required (for example, nitrogen removal), greater levels of treatment would be needed and the available capacity in existing processes would be reduced. WTD is currently conducting a nitrogen removal analysis to identify appropriate nitrogen removal alternatives for the three regional treatment plants and identify the most feasible alternatives based on life cycle cost and sustainability considerations. This analysis is anticipated to be complete in mid-2020.
- For this study, flows and loads in Brightwater's service area are assumed to require treatment at Brightwater. WTD currently has the flexibility to transfer flows to South Plant when Brightwater's capacity is reached or process flexibility is desired. The actual timing for capacity limitations at Brightwater will depend on the performance of its treatment process and the ability to convey flows to South Plant.
- Similarly, the South Plant capacity was evaluated assuming that all flows in Brightwater's service area are sent to Brightwater so that South Plant's capacity would not be partly used to treat those flows.

The capacity analysis for each treatment plant was completed using the steps and key assumptions described above. The following sections describe the results of those analyses.

South Plant Assessment Results

South Plant, located in Renton, treats wastewater mainly from separate sewer systems in communities located east and south of Lake Washington.

Process Description

Liquid-stream treatment processes at South Plant include preliminary treatment (screening and grit removal), primary clarification, an air activated sludge secondary treatment system, and disinfection using sodium hypochlorite. Disinfected effluent is pumped via the effluent transfer system (ETS) to a deep-water outfall in Puget Sound or treated further for recycled water applications.

Solid-stream treatment processes include dissolved air flotation thickening (DAFT), anaerobic digestion, and centrifuge dewatering. Class B biosolids are generated and trucked off-site for beneficial-use, while biogas generated in the digestion process is upgraded to renewable natural gas and used to meet plant heating needs or sold off-site.

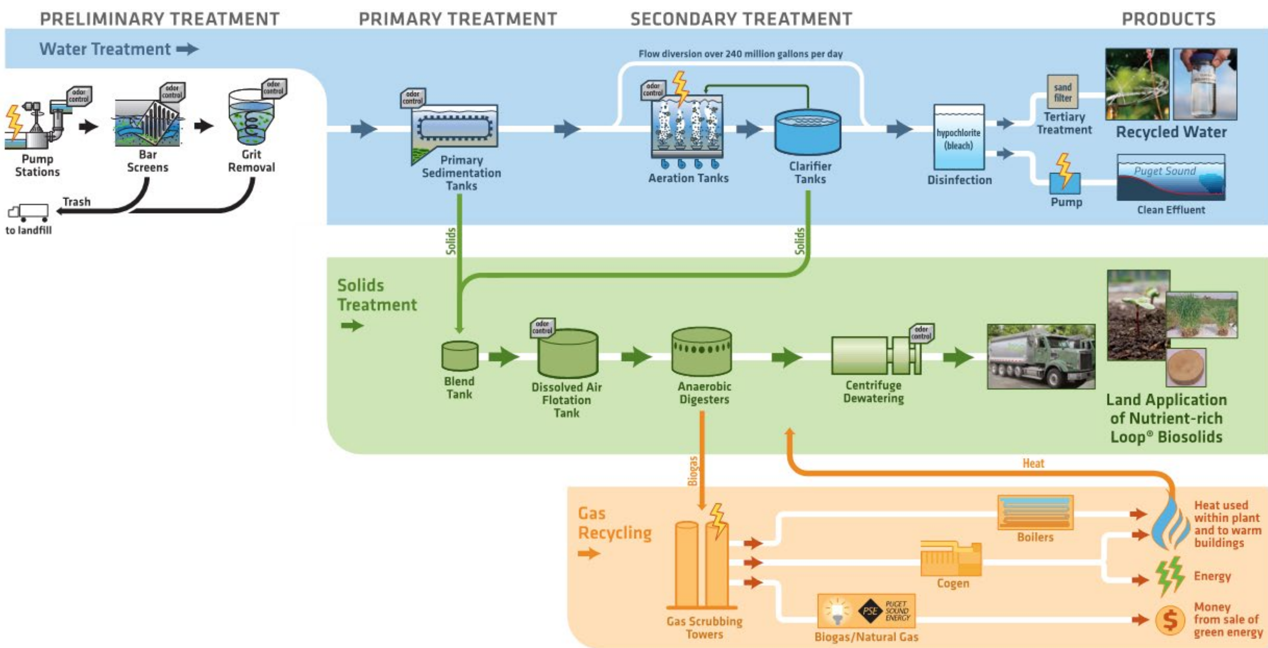


FIGURE 2.
South Plant Process Flow Schematic

Understanding the activated sludge process

The activated sludge process is a biological treatment process where organic materials are removed by microorganisms suspended in aerated tanks. Solids separation is typically achieved by settling in separate clarifier tanks. At South Plant, air is added to the aeration tanks (via a diffused aeration system) to provide oxygen to the microorganisms.

Historical and Projected Flows and Loads

The project team reviewed historical flows and loadings to South Plant from 2014 to 2018 and compared them with the projected 2010 to 2060 flows and loadings. In addition to domestic and commercial wastewater flows, South Plant also receives septage hauled to the plant and deicing wastes discharged to the sewer from SeaTac International Airport. The projections consider these additional flows and loads.

The historical and projected flows and loadings are plotted in Figures 3 to 5 (observed data shown as points; projections shown as solid lines).

Key Takeaways:

For the maximum month conditions, the observed values are lower than the projections. This is because the projections are based on storm events larger than those observed when the data were collected.

Influent flows are projected to increase more slowly over time than influent loadings. As a result, flows are not expected to approach design maximum month flow until after 2040. However, influent loadings are expected to approach the design maximum month loadings between 2025 and 2030.

FIGURE 3 Historical and Projected Flows to South Plant

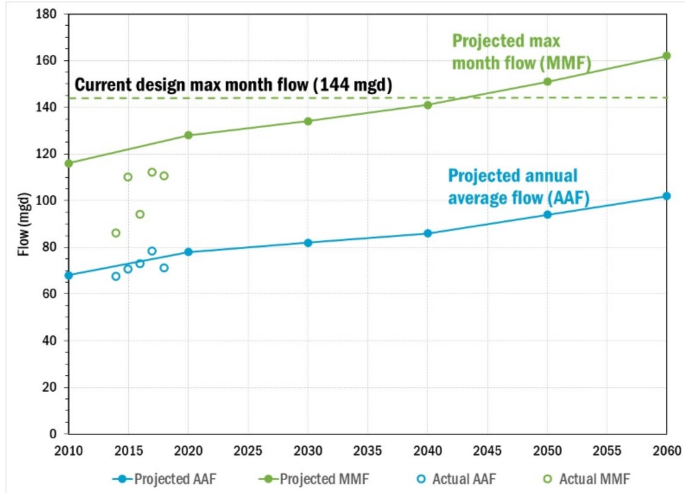


FIGURE 4 Historical and Projected BOD Loadings to South Plant

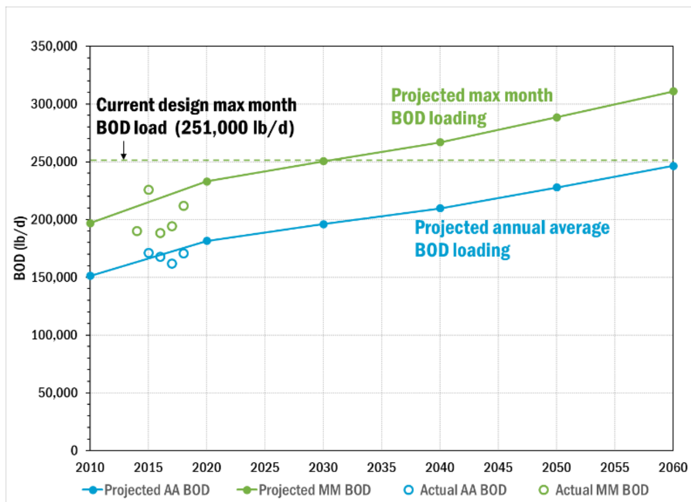
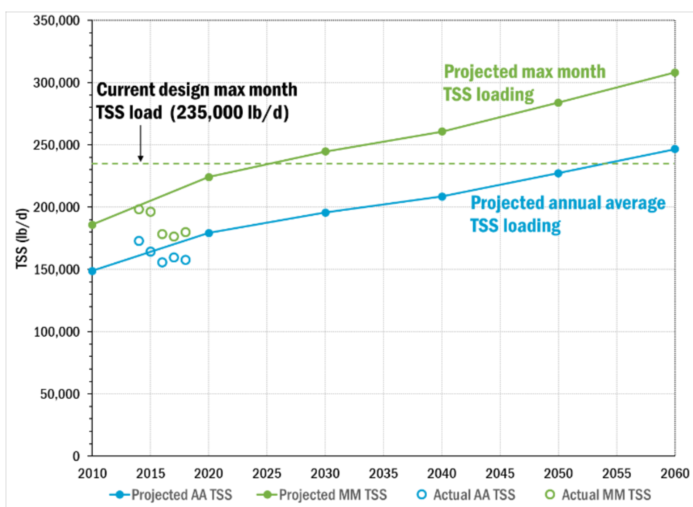


FIGURE 5 Historical and Projected TSS Loadings to South Plant



Capacity Assessment

Table 1 summarizes the results of the South Plant capacity assessment, organized by plant process area. Table 1 also includes the estimated timing for when the capacity limits will be reached. The capacity limits in the table are normalized in terms of plant influent flow and BOD loadings; a more thorough discussion of process capacity is included in the full technical memorandum describing the analysis.

Table 1. South Plant Maximum Capacities by Unit Process

Treatment Process	Capacity	Approximate Year Capacity Will be Reached
Raw sewage pumps	397 mgd [a]	Early 2040s
Grit removal (aerated grit tanks)	390 mgd [a]	Early 2040s
Primary clarifiers	320 mgd [a] (process capacity, with reduced removal efficiency) 510 mgd [a] (hydraulic capacity)	Currently at capacity After 2050
Secondary system	73 mgd, 240,700 lb/d BOD [b] (aeration blowers) 139 mgd, 263,200 lb/d BOD [c] (secondary clarifiers)	2033 2037
Effluent Transfer System (ETS)	325 mgd [a]	2037
Dissolved air flotation thickeners	More than 160 mgd, 310,800 lb/d BOD [c]	After 2050
Anaerobic digesters	133 mgd, 247,400 lb/d BOD [c]	2028
Centrifuges	More than 160 mgd, 310,800 lb/d BOD [c]	After 2050

[a] Capacity expressed as plant influent peak hour flow.
[b] Capacity expressed as plant influent average dry weather flow and summer maximum month BOD loading.
[c] Capacity expressed as plant influent maximum month flow and maximum month BOD loading.

Figure 6 summarizes the results of the capacity assessment on a timeline. The capacity limits are normalized in terms of maximum month plant influent flow, although not all process capacities are defined by the maximum month condition.

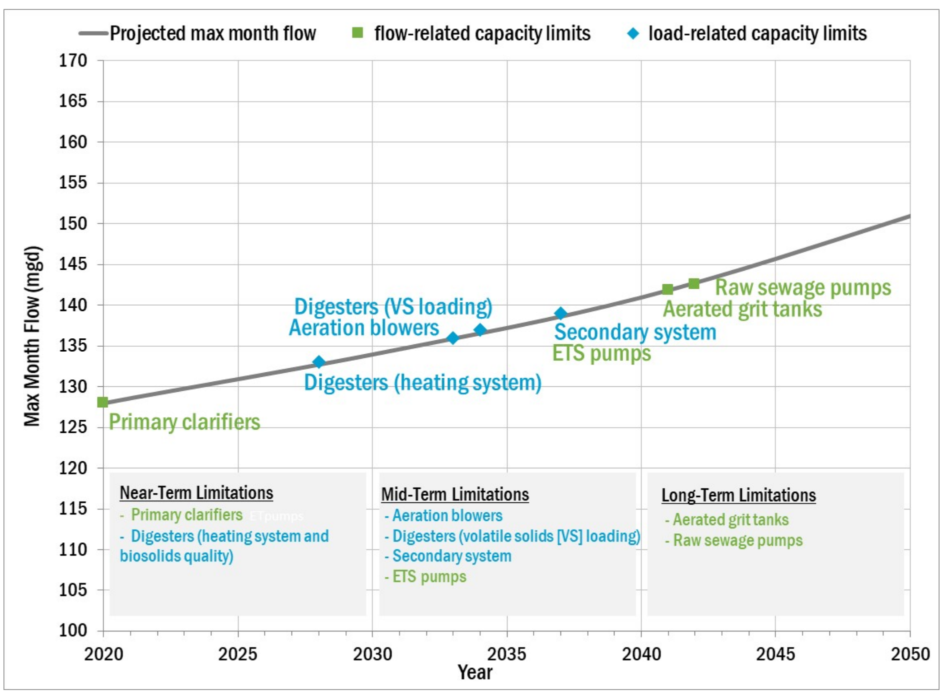


FIGURE 6
South Plant Timeline of Process Capacity Constraints

Key Takeaways:

The results from both Table 1 and Figure 6 show that, except for primary clarifier limitations, South Plant is not expected to have other capacity limitations until the late 2020s. After that, a number of treatment processes would be capacity limited between 2030 and 2040.

Below are summaries of South Plant capacity constraints for each phase, as shown in Figure 6.

Near-Term Capacity Limitations BETWEEN APPROXIMATELY 2020 AND 2030

Primary Clarifiers

The primary clarifiers are already at capacity due to surface overflow rate limitations. This is not considered a hard limitation because the clarifiers are not hydraulically limited until much later (after 2050) and higher flows will pass through the clarifiers. However, the removal efficiency will decrease, increasing loadings to the downstream secondary system. Further analysis and testing are recommended to evaluate performance at high overflow rates and potential options to enhance performance.

Digesters

Digesters will reach their capacity limit due to organic loading (volatile solids) limitation within the next 10 years. This limitation can be delayed by improving the digester heating system. Further analysis of specific heating system upgrade requirements would be needed, but may consist of new heat exchangers and new pumps. In addition, WTD's guidance on biosolids operation should be re-evaluated to optimize digester capacity.

Mid-Term Capacity Limitations BETWEEN APPROXIMATELY 2030 AND 2040

Aeration Blowers

South Plant has been operating with partial nitrification in the summer during the past few years. With partial nitrification, the secondary system is predicted to become limited by blower capacity by around 2033. Partial nitrification means that complete nitrogen removal is not being achieved. Because the plant currently does not have any nutrient limits, the partial nitrification operating mode is mainly used to evaluate the plant's ability to nitrify. Potential options to increase the overall blower system capacity include adding new blowers or replacing the existing blowers with higher capacity blowers. The air piping system also needs to be evaluated for its capacity to convey higher air flows. Alternatively, if nutrient limits are not imposed, then the secondary system can be operated to minimize nitrification, which will delay the blower limitation. If nutrient limits are imposed, then significant upgrades to the secondary system would be required.

Effluent Transfer System

The ETS pumps will become capacity limited in approximately 2037. Potential options to increase ETS pump capacity include replacing the peaking pumps with higher capacity pumps, replacing one of the duty pumps with a peaking pump, or adding a fifth peaking pump. ETS pipeline constraints would also need to be assessed at this time.

Digesters

With a heating system upgrade to address near-term limitations, the digester limitation would be delayed to approximately 2034. At that point, the digesters would be load limited. Potential options to increase the digester capacity include adding a new digester, converting the digestion system to an advanced digestion process, or including a pretreatment process that would allow operation at higher loading rates.

Secondary System

The secondary system will become capacity limited around 2037 due to limitations of solids loadings to the clarifiers. This limitation is highly sensitive to secondary sludge settleability. Currently, the secondary system typically operates with well-settling sludge. However, if the settling characteristics deteriorate due to changes in wastewater characteristics or operating conditions, the clarifiers would become capacity limited sooner. New secondary clarifiers would be needed to increase secondary system capacity. This limitation could also be addressed by adding a new aeration basin, but new secondary clarifiers may still be needed in the future to increase hydraulic capacity.

Long-Term Capacity Limitations APPROXIMATELY 2040 AND BEYOND

Grit Removal

The aerated grit tanks will reach their capacity limit in the 2040s. When the aerated grit tanks are operated above their capacity limit, grit carryover into downstream processes could occur, reducing the capacity of those processes. For example, grit accumulation in the digesters would reduce their hydraulic capacity.

Raw Sewage Pumps

The raw sewage pumps (RSPs) will reach their firm capacity limit in the 2040s. WTD is currently planning to replace one of the pumps with a higher capacity pump. This change would increase the overall RSP capacity and delay the need for additional capacity.

West Point Assessment Results

West Point, located in Seattle, treats wastewater from the combined sewer systems in Seattle as well as other communities in northwest King County.

Process Description

The West Point liquid-stream treatment processes include preliminary treatment (screening and grit removal), primary clarification, a high-purity oxygen activated sludge secondary treatment system, and disinfection using sodium hypochlorite. Disinfected effluent is pumped via the effluent pump station to the deep-water outfall in Puget Sound.

Solid-stream treatment processes include gravity belt thickening, anaerobic digestion, and centrifuge dewatering. Class B biosolids are generated and trucked to beneficial-use sites. Biogas generated in the digestion process is used on-site to meet heating needs, operate the raw sewage pumps, and produce renewable electricity.

Because West Point serves an area with combined sewers, the plant was not designed to treat all of the flows it receives to a secondary treatment standard. Instead, West Point is designed to provide secondary treatment for flows up to 300 mgd and primary treatment for flows greater than 300 mgd (up to a maximum of 440 mgd).

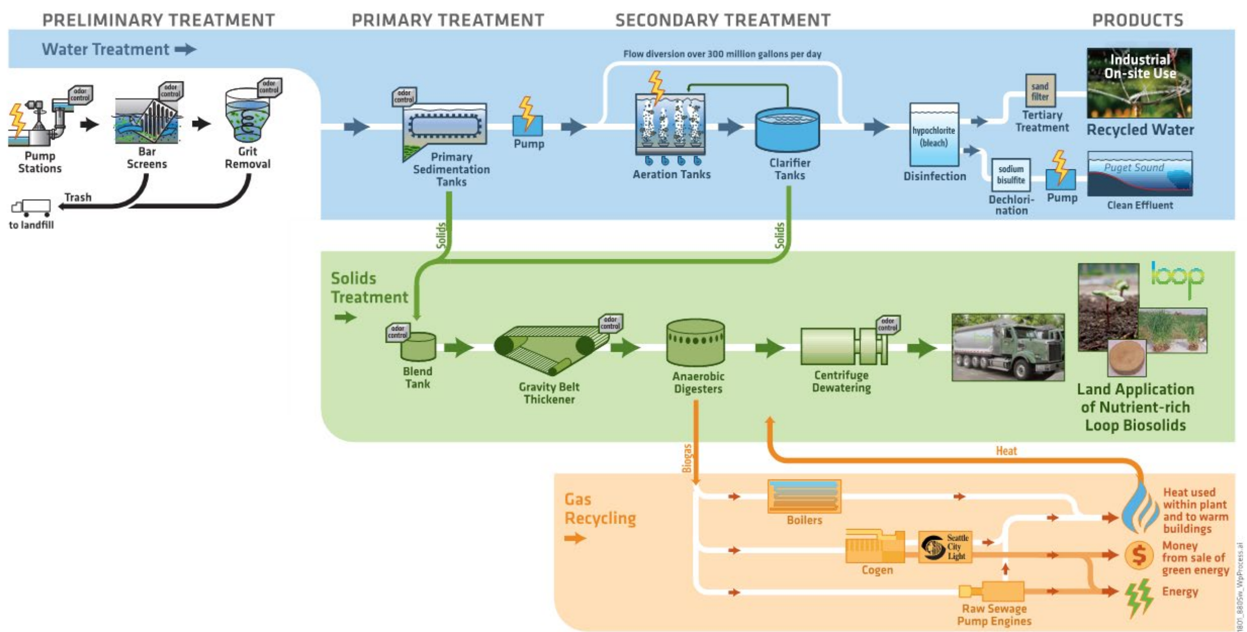


FIGURE 7
West Point Process Flow Schematic

Understanding the high-purity oxygen activated sludge process

In a high-purity oxygen (HPO) activated sludge process, the aeration basins are aerated using surface aerators with high-purity oxygen gas (over 90% oxygen) instead of air. The aeration tanks are covered and typically include four stages, with each stage equipped with an aerator. Oxygen is used instead of air to increase the efficiency of the biological treatment process and reduce the amount of space needed for the aeration tanks. With more than three times as much oxygen per unit volume than air, an HPO process can achieve more capacity within a smaller site footprint.

Historical and Projected Flows and Loads

The project team reviewed historical flows and loadings to West Pont from 2014 to 2016 and 2018 (2017 data were not included in this analysis because of the February flooding event) and compared them with the projected 2010 to 2060 flows and loadings. The flow and load projections for West Point account for future operation of combined sewer overflow control facilities. These facilities can have the effect of extending the period of peak flows at West Point and increasing annual average solids loadings.

The historical and projected flows and loadings are plotted in Figures 8 to 10 (observed data shown as points; projections shown as solid lines).

Key Takeaways:

For the maximum month conditions, the observed values are lower than the projections. This is because the projections are based on storm events larger than those observed when the data were collected.

Influent flow is projected to increase slowly over time and will not approach the design maximum month flow until around 2050. The influent loadings are already approaching the design maximum month loadings.

FIGURE 8 Historical and Projected Flows to West Point

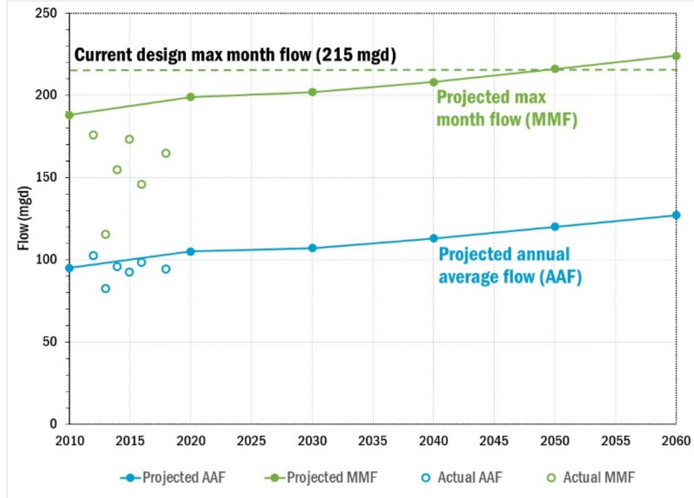


FIGURE 9 Historical and Projected BOD Loadings to West Point

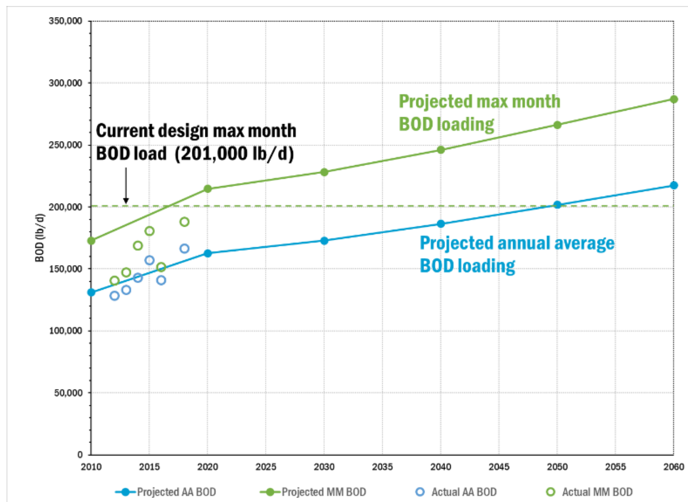
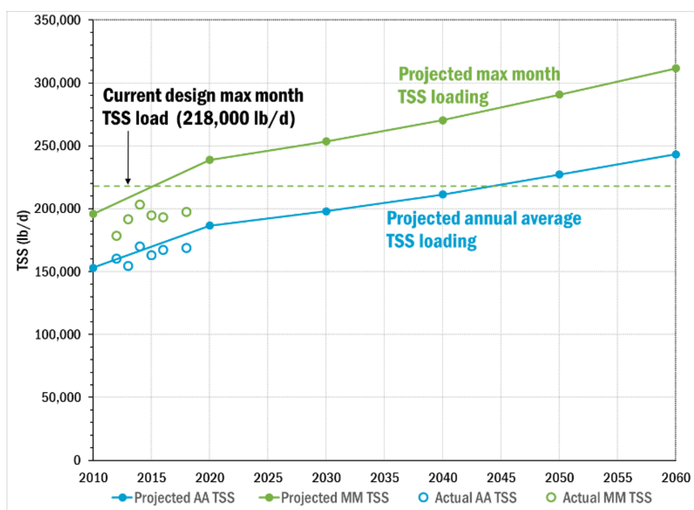


FIGURE 10 Historical and Projected TSS Loadings to West Point



Capacity Assessment

Table 2 summarizes the results of the West Point capacity assessment, organized by plant process area. Table 2 also includes the estimated timing for when the capacity limits will be reached. The capacity limits in the table are normalized in terms of plant influent flow and BOD loadings; a more thorough discussion of process capacity is included in the full technical memorandum describing the analysis.

Table 2. West Point Maximum Capacities by Unit Process

Treatment Process	Capacity	Approximate Year Capacity Will be Reached
Raw sewage pumps	358 mgd [a]	Currently at capacity based on firm capacity at peak hour flow
Grit removal (aerated grit tanks)	440 mgd [a]	N/A [d]
Primary clarifiers	440 mgd [a]	N/A [d]
Intermediate pumps	133 mgd [b]	After 2060
Secondary system	195 mgd, 197,000 lb/d BOD [b] (HPO stage 1 aerators) 203 mgd, 232,000 lb/d BOD [b] (secondary clarifiers)	Approaching capacity 2031
Effluent pumps	470 mgd [a]	N/A [d]
Gravity belt thickeners	more than 240 mgd, 287,000 lb/d BOD [c]	After 2060
Anaerobic digesters	198 mgd, 210,500 lb/d BOD [c]	Approaching capacity
Centrifuges	more than 240 mgd, 287,000 lb/d BOD [c]	After 2060

[a] Capacity expressed as plant influent peak hour flow.
[b] Capacity expressed as plant influent average wet weather flow (AWWF). The intermediate pumps, which have a total firm capacity of 300 mgd, were originally designed to provide 2.25 times the AWWF.
[c] Capacity expressed as plant influent maximum month flow and maximum month BOD loading.
[d] This unit process was designed based on the design peak hour flow of 440 mgd, which is projected to remain the same through 2060.

Because of restrictions within the conveyance system, the peak hour flow to West Point is projected to remain the same (440 mgd) through 2060. The raw sewage pumps, grit removal, primary clarifiers, and effluent pumps only need to provide 440 mgd of capacity throughout this planning period. Therefore, the processes shown as “N/A” in Table 2 were designed to and have capacity to handle the peak hour flow through 2060.

Figure 11 summarizes the results of the capacity assessment on a timeline. The capacity limits are normalized in terms of maximum month plant influent flow, although not all process capacities are defined by the maximum month condition.

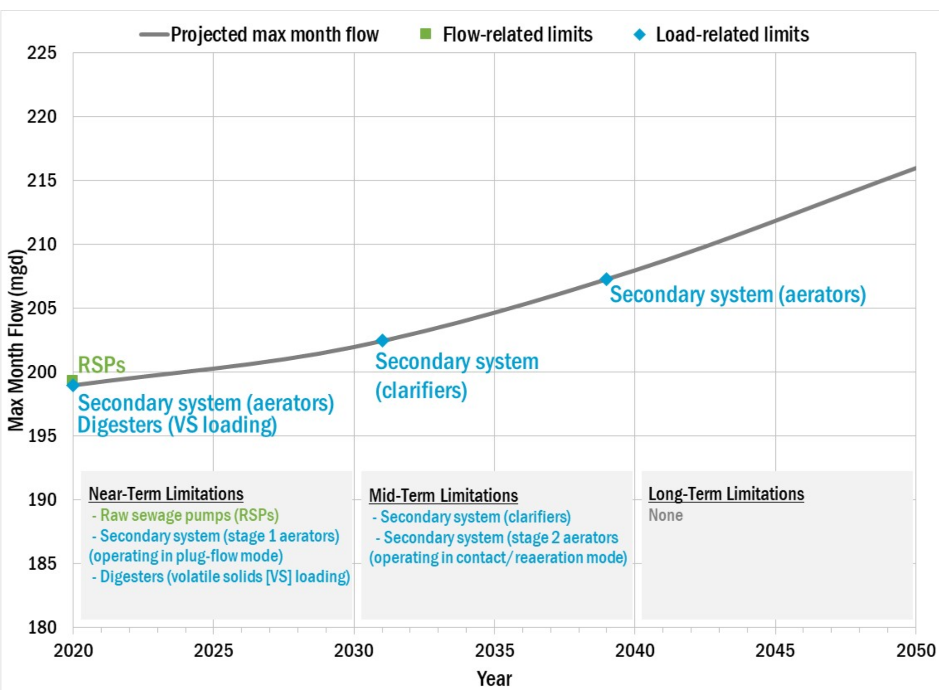


FIGURE 11
West Point Timeline of Unit Process Capacity Constraints

Key Takeaways:

The results show that West Point is currently operating at or near capacity for the raw sewage pumps, secondary system aerators, and digestion processes. Two other processes will become capacity limited between 2030 and 2040.

Below are summaries of West Point capacity constraints for each phase, as shown in Figure 11.

Near-Term Capacity Limitations BETWEEN APPROXIMATELY 2020 AND 2030

Raw sewage pumps

Although there is enough firm pumping capacity to meet West Point's secondary treatment needs (300 mgd), all four raw sewage pumps are needed during large wet weather events to pump the design peak hour flow of 440 mgd. WTD has a project currently underway to increase the raw sewage pump capacity so that a fully redundant pump is available during peak wet weather events.

Secondary system - HPO aeration tanks aerators

Stage 1 aerators are approaching their capacity limit. When their capacity limit is reached, the dissolved oxygen concentration in stage 1 of each aeration tank will drop and sludge settleability could deteriorate. Because there is currently excess secondary clarifier capacity, **this limitation would not pose an immediate plant capacity constraint.** To address the aerator capacity limitation without replacing the aerators, the aeration tanks could be switched to an alternative mode of operation. In addition, a project is already underway that may increase overall aeration capacity by replacing the existing aerators with new, higher-capacity aerators.

Digesters

The digesters are currently approaching their capacity limit due to organic loading limitation. This limitation ensures stable biological activity in the tanks. West Point has experienced digester foaming in the past, indicating that the digesters may already be approaching their limits of stability. Potential options to increase the digester capacity include the addition of a new digester, conversion of the digestion system to an advanced digestion process, or addition of a pretreatment process that would allow operation at higher organic solids loading rates.

Mid-Term Capacity Limitations BETWEEN APPROXIMATELY 2030 AND 2040

Secondary system - clarifiers

The secondary system will become capacity limited around 2031 due to limitations of solids loadings to the clarifiers. This capacity limitation could be delayed if the settling characteristics improve or if the aeration tanks are switched to a different mode of operation. Without these changes, either new secondary clarifiers or new aeration tanks (or both) would be needed.

Secondary system - HPO aeration tanks aerators

Even after switching to an alternative mode of operation, the stage 2 aerators will reach their capacity in approximately 2039. At that point, the aerators in all stages would likely need to be replaced with higher-capacity aerators. Replacing the aerators in all stages is being evaluated in the current aeration system upgrade project.

No capacity limitations were projected to be reached between 2040 and 2060 at West Point.

Brightwater Assessment Results

Brightwater, located near Woodinville, treats wastewater from the mostly separate sewer system in communities located east of Lake Washington and in south Snohomish County.

Process Description

Liquid-stream treatment processes at Brightwater include preliminary treatment (screening and grit removal), primary clarification, fine screening, membrane bioreactor (MBR) secondary treatment, and disinfection using sodium hypochlorite. Disinfected effluent flows through a deep-water outfall into Puget Sound or is used for recycled water applications.

Solid-stream treatment processes include gravity belt thickening, anaerobic digestion, and centrifuge dewatering. Class B biosolids are generated and trucked to beneficial-use sites. Biogas generated in the digestion process is used to meet plant heating needs.

Brightwater is designed to provide split flow treatment during wet weather events. In this treatment scheme, when flows exceed the capacity of the MBR system (as well as the available capacity for storage and diversion to other County treatment plants), a portion of the flow is bypassed around the MBR system. The bypassed flow receives chemically enhanced primary treatment (CEPT) and is blended with the MBR effluent before disinfection.

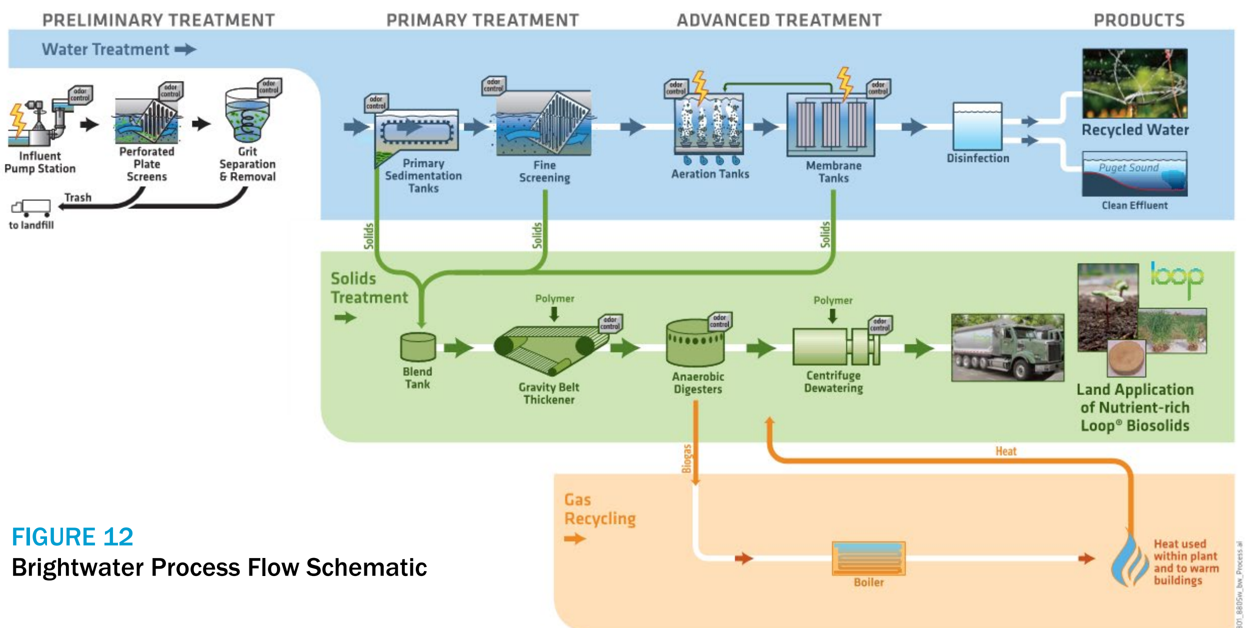


FIGURE 12
Brightwater Process Flow Schematic

Understanding membrane bioreactor technology

In an activated sludge system using MBR technology, solids separation is achieved using ultrafiltration or microfiltration membranes instead of clarifiers. The system typically consists of separate aeration and membrane basins. The membranes are installed as cassettes and are submerged in the basins. The use of membranes results in higher-quality effluent than a conventional activated sludge process and can provide more capacity within a smaller footprint.

Historical and Projected Flows and Loads

The project team reviewed flows and loadings to Brightwater from 2013 to 2018 and compared them with the projected 2010 to 2060 flows and loadings. The projections for Brightwater include consideration for planned projects that would transfer flows to Brightwater (mainly areas that are currently treated at South Plant).

The historical and projected flows and loadings are plotted in Figures 13 to 15 (observed data shown as points; projections shown as solid lines).

Key Takeaways:

For the maximum month conditions, the observed values are lower than the projections. This is because the projections are based on storm events larger than those observed when the data were collected.

Because Brightwater flows are diverted to South Plant when MBR capacity is limited, the observed flows and loadings underrepresent the amount of flows and loadings that were projected to be treated at Brightwater.

The influent flow is not projected to approach the design maximum month flow until around 2038, but the loading projections are expected to reach the design capacity between 2020 and 2023.

FIGURE 13 Historical and Projected Flows to Brightwater

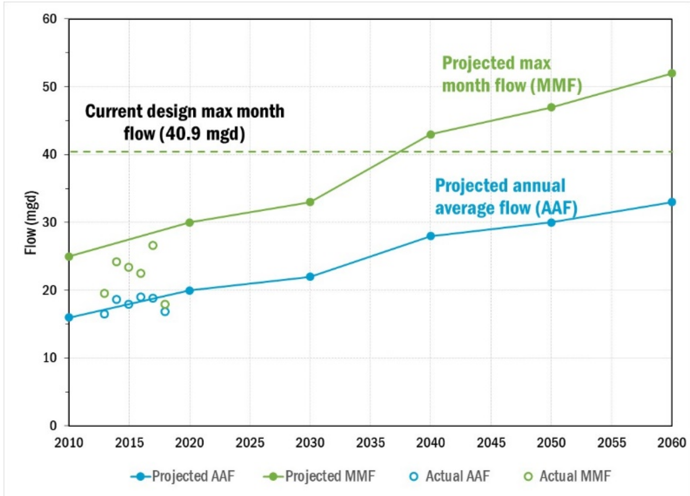


FIGURE 14 Historical and Projected BOD Loadings to Brightwater

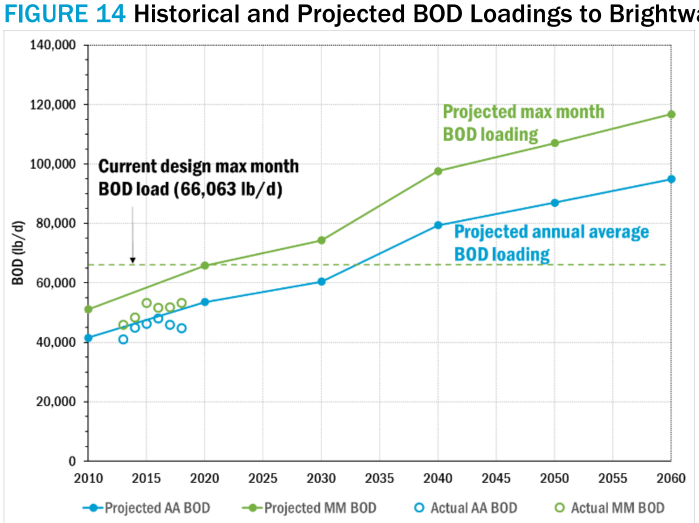
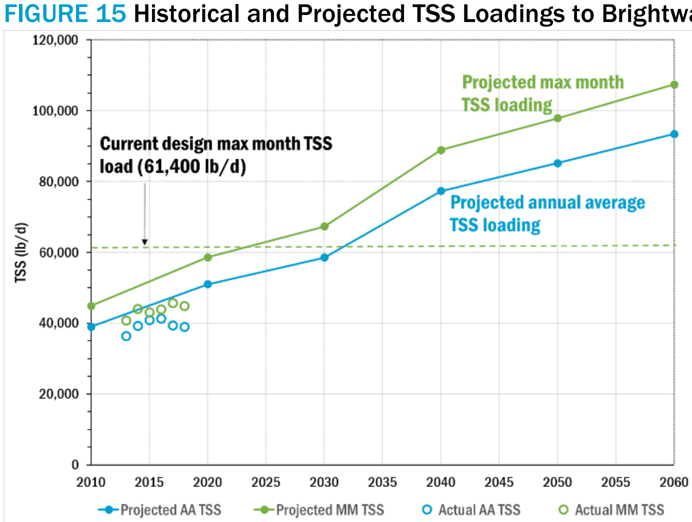


FIGURE 15 Historical and Projected TSS Loadings to Brightwater



Capacity Assessment

Table 3 summarizes the results of the Brightwater capacity assessment, organized by plant process area. Table 3 also includes the estimated timing for when the capacity limits will be reached. The capacity limits in the table are normalized in terms of plant influent flow and BOD loadings; a more thorough discussion of process capacity is included in the full technical memorandum describing the analysis.

Table 3. Brightwater Maximum Capacities by Unit Process

Treatment Process	Capacity	Approximate Year Capacity Will be Reached
Influent screens	130 mgd [a]	2040s
Grit removal (aerated grit tank)	110 mgd (CEPT mode) [a]	2035
Primary clarifiers	110 mgd (CEPT mode) [a]	2035
Fine screens	48 mgd [a, d]	After 2050
Secondary system	24 mgd, 46,000 lb/d BOD [b] (aeration system and aeration basins) 25 mgd [b] (membrane basins)	Currently at capacity Currently at capacity
Gravity belt thickeners	46 mgd, 104,000 lb/d BOD [b]	2040s
Anaerobic digesters	37 mgd, 84,000 lb/d BOD [b]	2034
Centrifuges	25 mgd, 51,100 lb/d BOD [b, c]	Currently at capacity

[a] Capacity expressed as plant influent peak hour flow.
[b] Capacity expressed as plant influent maximum month flow and maximum month BOD loading.
[c] Capacities shown are based on an operating schedule of 18 hours a day operation.
[d] Fine-screen capacity is less than the capacity of the influent screens because the fine screens only treat flows to the secondary system.

Figure 16 summarizes the results of the capacity assessment on a timeline. The capacity limits are normalized in terms of maximum month plant influent flow, although not all process capacities are defined by the maximum month condition.

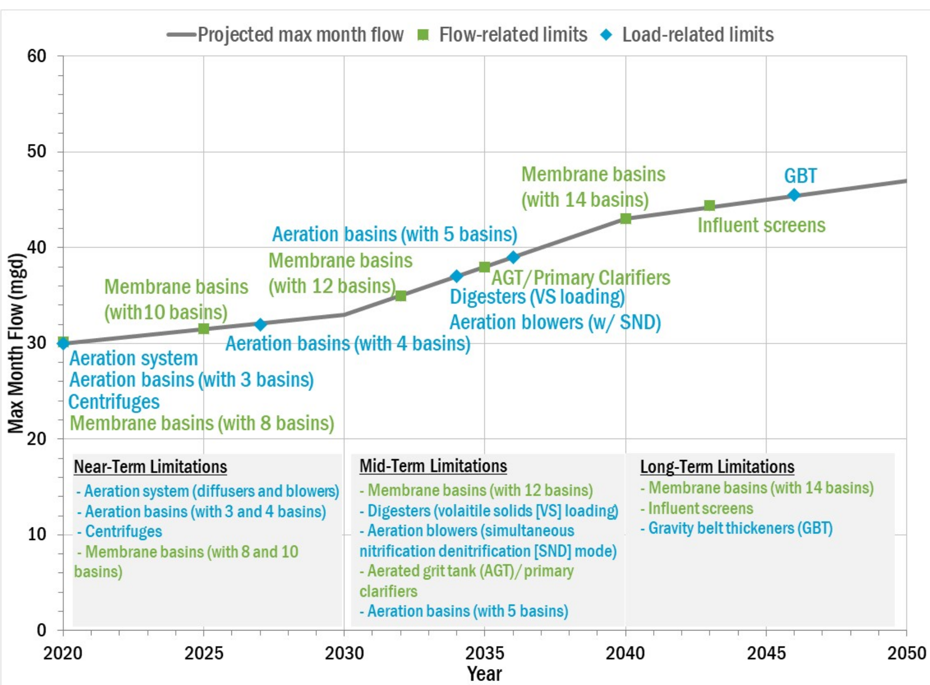


FIGURE 16
Brightwater Timeline of Unit Process Capacity Constraints

Key Takeaways:

The results show that Brightwater is currently operating at capacity for the secondary and dewatering processes. Several unit processes are also expected to become capacity limited between 2030 and 2040.

Below are summaries of Brightwater capacity constraints for each phase, as shown in Figure 16.

Near-Term Capacity Limitations BETWEEN APPROXIMATELY 2020 AND 2030

Although the results of the analysis show that Brightwater is currently operating at capacity for the secondary and dewatering systems, WTD has consistently met permit limits by using the built-in flexibility to transfer flows to South Plant when needed. The capacity limitations identified below presume that, in the future, flows and loads intended for Brightwater will be treated at Brightwater and not diverted to South Plant.

Membrane basins

Based on current performance, the membrane basins are currently at capacity. Since startup in 2012, the Brightwater MBR system has suffered from temporary reductions in capacity due to poor sludge filterability. The causes of poor filterability are unknown, but are believed to be linked to wastewater characteristics and operating conditions. WTD has been working on addressing the issues with poor filterability. Historical data indicate large variability in the membrane capacity. Based on recent performance, two more membrane basins (in addition to installation of membrane cassettes in basins 9 and 10) would be needed by 2025. If filterability improves and the membrane capacity is increased to match earlier performance data, then membrane cassettes would not be needed in basins 9 and 10 until sometime between 2025 and 2030.

Aeration basins and aeration system

The aeration basins and the aeration system are already capacity limited. Aeration basin 4 is currently needed and aeration basin 5 will be needed by around 2027. There is an existing aeration system improvement project underway, which may extend aeration blower capacity. Similarly, the need for additional aeration basin capacity could be delayed by operating the primary clarifiers in CEPT mode without blending (and thus, no bypass of the MBR system). The overall sludge production rates would increase in this mode because of the additional chemical sludge production, which would accelerate the timing of the solids treatment capacity constraints.

Centrifuges

The capacity of the centrifuges and, thus, the dewatering system is currently capacity limited. A third centrifuge is needed to increase the dewatering system capacity. The dewatering system is currently in operation 18 hours a day. If the operating schedule was extended so that dewatering was operated continuously, overall capacity would increase, but the system would still be at capacity.

Mid-Term Capacity Limitations BETWEEN APPROXIMATELY 2030 AND 2040

Digesters

The digesters are projected to become organic solids loading limited around 2034. This limit protects the process from instability, so operating above this limit could result in a loss of process control. Potential options to increase the digester capacity include adding a new digester, converting the digestion system to an advanced digestion process, or including a pretreatment process that would allow operation at higher organic solids loading rates.

Aeration basins and aeration system

Additional aeration basin and blower capacity will be needed around the mid-2030s. Aeration basin 6 will be required by about 2036. As mentioned above, if a currently underway aeration basin improvement project extends capacity, additional aeration blower capacity will be needed in the mid-2030s.

Grit removal/primary clarifiers

The aerated grit tank and primary clarifiers are predicted to reach their capacity limits in approximately 2035. Based on experience with CEPT operation at other facilities, the maximum capacity for these processes could potentially be much higher, which would delay the need for a new aerated grit tank/primary clarifier train. To date, CEPT has not been employed at Brightwater other than for testing purposes. As the CEPT process is operated, observations of actual performance should be closely monitored to determine impact on grit removal and primary clarifier capacity.

Membrane basins

Additional membrane basins will be needed in the early 2030s. If the causes of deteriorated filterability cannot be identified and addressed, membrane basins 13 and 14 will be needed around 2032.

Long-Term Capacity Limitations APPROXIMATELY 2040 AND BEYOND

Influent screens

Influent screening is predicted to become capacity limited in the 2040s. An investigation is recommended to determine whether the ancillary system for processing the screenings would limit the screen capacity.

Membrane basins

Additional membrane basins will be needed in the 2040s. If the causes of deteriorated filterability cannot be identified and addressed, membrane basins 15 and 16 will be needed around 2040.

Gravity belt thickeners

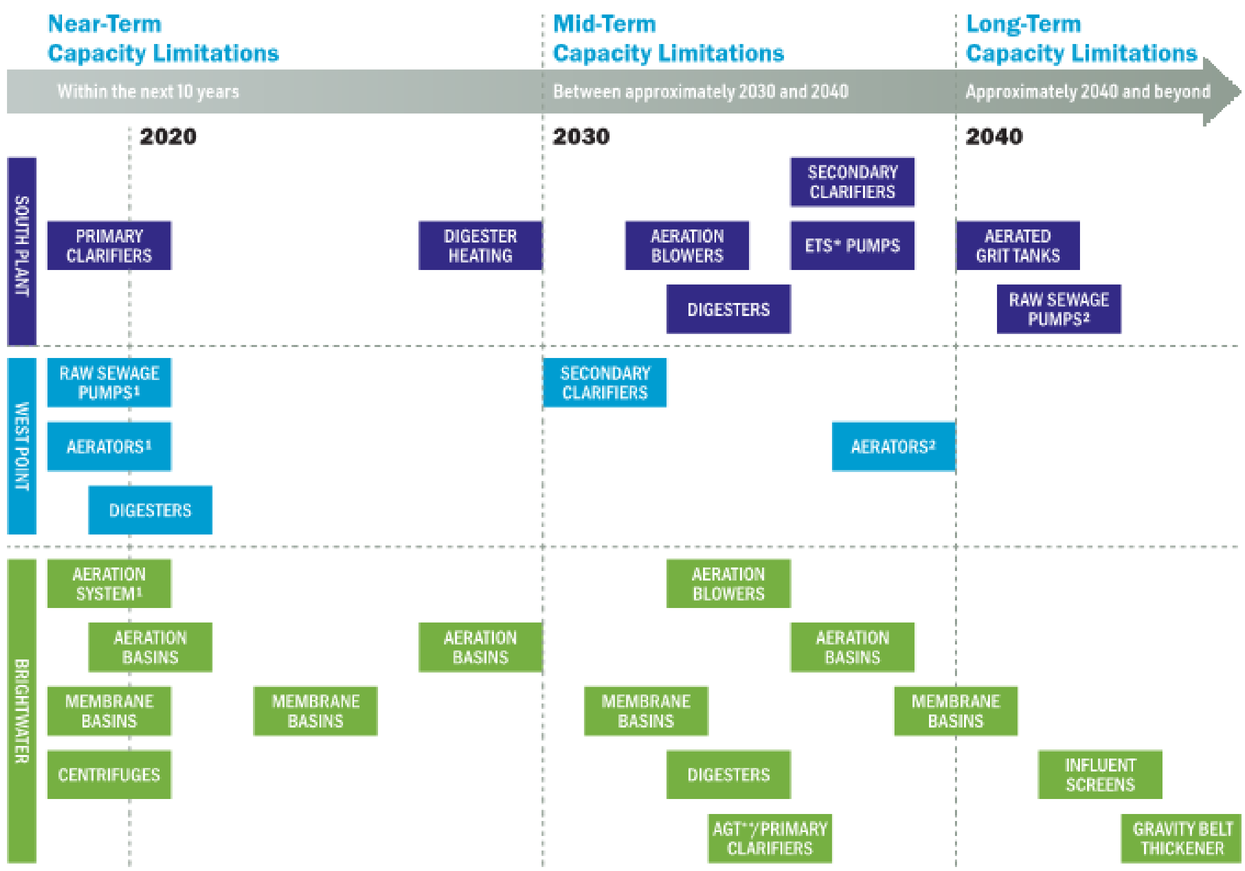
Solids thickening capacity is predicted to become limited in the 2040s. A fourth gravity belt thickener would be needed to increase the thickening capacity.

Conclusions

Figure 17 summarizes the capacity limitations for all three regional treatment plants on one timeline. The location of the boxes on the timeline indicate when a capacity limitation is projected to be reached, but do not indicate the sequence of projects that would be needed to address the limitation.

FIGURE 17

Projected Capacity Limitations by Process Area at South Plant, West Point, and Brightwater



NOTES:

1 Limitations may be addressed in a current project

2 Limitation may be addressed in an earlier project

*Effluent Transfer System

**Aerated Grit Tanks

Main Conclusions of the Study

- At West Point and Brightwater, several processes currently have capacity limitations, some of which may be addressed or partially addressed by existing projects. South Plant has two processes that will be capacity limited before 2030.
- For all three regional treatment plants, most capacity limitations are projected to occur in the 2030s, and most of those limitations are related to the digestion and secondary treatment processes.
- For South Plant and Brightwater, a limited number of processes will require additional capacity after 2040; no capacity limitations are projected for West Point. However, specific capacity needs at that time will depend largely on what efforts to increase capacity are made in the near term and midterm. For example, the amount of additional aeration basin capacity provided at Brightwater in the 2020s would directly influence when the next aeration basin capacity limitation would occur.
- Sensitivity analysis conducted for each plant indicates that the treatment process capacity constraints and the exact timing of those constraints are sensitive to a number of factors. For all three plants, the results are sensitive to the actual influent flows and loadings (as compared to the projections) and regulations regarding effluent quality (especially those related to nitrogen removal, which is currently being studied). Critical plant-specific factors include organic loading limits for the digesters, service requirements for digester maintenance, sludge settleability, and mode of operation for the secondary process. The ranges of capacity limits and timing for those limits determined from the sensitivity analysis are provided in the detailed technical memoranda.
- For Brightwater, the performance of the MBR system significantly influences the timing for Brightwater capacity needs. The actual timing could be delayed if MBR performance improves or until capacity at South Plant becomes limited and, thus, the ability to transfer flows to South Plant is reduced.

Next Steps

Evaluate options for addressing the **near-term** process capacity constraints.

All three regional treatment plants have existing or very near-term capacity limitations. This study identified capacity needs but did not identify specific approaches or projects to address these capacity needs. Detailed alternative analyses, including cost estimates and asset management considerations, are needed to determine specific operational or capital expansion projects. Impacts to upstream and downstream process capacity and operations should also be considered during alternative analysis. Since the planning, design, and construction of a major process expansion project can take 10 years or more, evaluating options and defining projects to address near-term process capacity constraints should be initiated soon.

When considering options to address capacity constraints, some processes may have multiple viable alternatives. For example, where additional digestion capacity is needed, WTD should consider whether additional digesters should be constructed or if an advanced digestion process should be implemented. In addition, efficiencies may be gained by “bundling” increases in capacity for one area of a treatment plant with other process areas. Such an approach can limit the disruption of construction activities on plant operations.

Determine timing to initiate options analysis for **midterm and long-term** process capacity constraints.

The planning, design, and construction of a major process expansion project can take 10 years or more. To address capacity needs in the 2030s, WTD will need to begin the planning process in the 2020s. In addition, changes to operations or increased capacity through addressing near-term limitations may impact the specific needs or timing of midterm or long-term capacity constraints. Planning and design of expansion projects related to future capacity constraints should take these changes into consideration.

Continue to regularly track actual flows and loadings and process performance.

Continue to track actual flows and loadings to the treatment plants on a regular basis (approximately every 5 to 10 years). If the observed conditions diverge from the projections used in this study, the timing of capacity limitations and planned expansion projects should be adjusted as needed. WTD already monitors process performance regularly. If process performance changes significantly from what was assumed in this study, the analysis should be updated to reflect the changes.