

**Appendix E**  
**TCWTP Process Modeling**

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# Tryon Creek Wastewater Treatment Plant Process Modeling

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## Objectives

This technical memorandum documents process modeling conducted for the Tryon Creek Wastewater Treatment Plant Facilities Plan Update project.

Biowin, a commercially available process modeling software, was used to predict performance of the existing plant under various projected flows and loads. In addition, CH2M HILL's proprietary, MS-Excel based, steady-state whole plant simulator Pro2D was used to simulate plant operations and provide a check to Biowin modeling results. In order to obtain meaningful modeling results, both Biowin and Pro2D process models were calibrated to recent plant records and sampling results.

Process modeling was used to predict the capacity of the secondary treatment. Operating capacity at other process units are analyzed based on stated industry criteria.

## Data Used for Model Calibration and Process Capacity Analysis

The plant operates to meet secondary treatment requirements for Five-Day Biochemical Oxygen Demand (BOD<sub>5</sub>) and total suspended solids (TSS) removals. The monthly average summer or dry weather season (May to October) BOD<sub>5</sub> and TSS concentration limits are 20 mg/L with a weekly average limit of 30 mg/L. The monthly average winter or wet weather season (November to April) BOD<sub>5</sub> and TSS concentration limits are 30 mg/L with a weekly average limit of 45 mg/L.

In a number of similar projects, CH2M HILL's experience is that there are sometimes noticeable differences in influent characteristics between summer dry weather season and winter wet weather season. The factors contributing to these differences include 1) higher inflow/infiltration and higher inert suspended solids fractions during wet weather period, 2) higher degree of sewage fermentation in the collection system in dry weather period, due to longer retention time and higher temperature, and 3) seasonal changes in influent sources such as the industrial wastewater contribution. To count for potentially seasonal differences in influent characteristics, both summer and winter data were examined to calibrate the models separately.

The most recent available data from year 2011 were analyzed and used for model calibration. Plant data from January 1 to February 28 were examined to calibrate the model for winter operations and data from August 1 to September 30 for summer operations. These two operational periods were selected because the operations were relatively steady.

A 2-week sampling effort was performed to obtain data that are not available from routine plant monitoring but necessary for influent fractionations and tracking various types of organics and particulates.

After the process models are calibrated, the process unit performance recorded from the most recent three year period, years 2009 to 2011, were analyzed for performance and operating parameters for various unit processes and used to predict secondary process operation under future projected flows and loads.

## Approaches of Process Modeling

The plant influent flows and loads, as well as operational parameters and performance of various process units were input to the process model in accordance with plant data during the calibration periods. Results from the 2-week sampling effort were used to assist in estimating modeling parameters that are not routinely monitored. For modeling parameters for which direct measurements are not practical, the COD fractionations were adjusted based on typical range for domestic wastewater to obtain the best match between model predictions and plant records. Emphasis was given to obtaining a close match for liquids streams results, because plant data on liquids streams are measured more frequently and thus more reliable, compared to solids stream data.

Major model input parameters that were determined in the process models are described as follows:

1. Influent conditions
  - a. Flows, temperature and loads in terms of BOD<sub>5</sub> and TSS based on average values of plant data recorded during the calibrated periods. Ammonia-Nitrogen, Total Phosphorus, and Total Kjeldahl Nitrogen (TKN) loads were estimated based on the BOD<sub>5</sub> loads and the ratios of respective constituents to BOD<sub>5</sub> concentrations, which were measured during the 2-week sampling effort. The average influent alkalinity concentration from the 2-week sampling results was used for all flow and load conditions, because alkalinity typically depends on the water source characteristics and is relatively independent of wastewater strengths.
  - b. Flow and load peaking factors under various maximum month, maximum week, and maximum day conditions are in accordance with analysis results in this Facilities Plan Updates project, which is discussed in a separately *in the Wastewater Flows and Loads TM*.
  - c. Volatile suspended solids (VSS) fraction: 92 percent is used for summer calibration, based on the 2-week sampling results, which was conducted in May and is consistent with the VSS fraction data on the thickened primary sludge (TPS) for summer calibration period. 87 percent volatile fraction was used for winter operations based on the TPS's VSS fraction data recorded for winter calibrated period.
  - d. Other modeling parameters that are determined based on the 2-week sampling results include flocculated filtered COD fraction or filtered COD fraction, unbiodegradable soluble COD fraction, and COD to BOD<sub>5</sub> ratio. Note these parameters may be slightly adjusted to achieve better matches to plant data during the calibration periods.
2. Primary clarifiers
  - a. Surface area: 14,140 sf in total, including two 140-ft long by 18-ft wide clarifiers and two 140-ft long by 23.5-ft wide clarifiers.
  - b. TSS removal and primary sludge quantity: based on primary influent and effluent TSS quantity data. Since the plant influent sampling location is upstream of all plant recycles, slight adjustments may be made to reflect the additional TSS removal from the solids in the recycle streams.

- c. Primary sludge concentrations: not monitored, but expected to be relatively dilute. There is not much of a thickening hopper in the bottom of the primary clarifiers – the sludge is collected via a cross collector. Assumed 10,000 mg/L in process modeling.
  - d. Primary sludge is pumped to two sludge degritters. Degrittied primary sludge is routed to the gravity thickeners. Thickened Primary Sludge is pumped consistently to Digester 1.
  - e. Maximum Surface Overflow Rate (SOR): approximately 2,500 gpd/sf maximum at peak hour flows.
3. Aeration Basins:
- a. Size: Four aeration basins with a total volume of 2.79 MG per sheet G2 of the 2000 Aeration Basin Modifications project. Note that the basin dimensions on the same sheet are given as 108-ft long, 54-ft wide, and 16.5-ft deep, which would result in 2.88 MG total basin volume. The smaller of the two values, 2.79 MG, was used in the model to be conservative. 2.79 MG volume corresponds to a shallower water depth of 16 ft, which would be more conservative in air demand calculations.
  - b. Process configuration: There are two identical aeration trains; each includes 2 aeration basins. Each basin has a volume of 0.698 MG. For aeration train consisting of Basin 1 and Basin 3, for example, the aeration basin influent flows through Zones A, B, C, and D in Basin 1 and then Basin 3, where the complete mix condition is expected to prevail. Each of the zones A, B, C, and D is  $\frac{1}{4}$  of an aeration basin volume. Zones A and B are swing zones and capable of functioning as anaerobic selector to improve sludge settling at the secondary clarifiers. When additional volume is required (but less than a second train), the plant is able to utilize Basin 3 or 4 as additional aerated volume following the end of an aeration train. There is limited capability to implement coarse step feed primary effluent to Zones A and B. RAS re-aeration can also be implemented by returning RAS to Zone A, while bypassing the primary effluent around Zone A and directly feeding it to Zone B. Step feed or re-aeration can be used in wet weather during high flows to retain biomass inventory in the aeration basins. Fine bubble 9-in membrane disk diffusers are installed at all zones. Flow from each train is combined in a common effluent channel and is then split via two flumes to two secondary clarifiers.
  - c. Aeration Blowers: three blowers each rated at 3,750 scfm, with a firm capacity of 7,500 scfm.
  - d. Air demand: Air consumption data were not available during the process modeling. Air supply capacity was identified to be one of the factors limiting the secondary process capacity. In lieu of detailed air consumption data, typical diffuser oxygen transfer performance was used to predict air demand, as follows.
    - i. Alpha values were estimated based on the oxygen uptake rate (OUR)
    - ii. 0.8 Diffuser fouling factor was conservatively assumed.
    - iii. Standard oxygen transfer efficiency (SOTE) was estimated based on air flow per diffusers for a given condition
    - iv. Diffusers were conservatively assumed to be 1 foot above the basin floor.
    - v. DO: 2 mg/L for aerated zones under maximum month load conditions, but allowed to drop to 1 mg/L under the maximum day load conditions to conserve

aeration energy. Lower DO in a short period of time would not significantly impact the sludge settling property.

- e. Air supply predictions: air supply predictions directly taken from Biowin models can underestimate the air demand without an elaborate aeration parameter adjustment. For this process modeling work, the air demand were calculated separately using above listed aeration parameters and the OUR and oxygen transfer rate (OTR) output from the Biowin models. OUR values under peak loads were predicted by performing dynamic modeling using Biowin, with the steady state operating conditions solved under the maximum month loads as the starting point. Air demands predicted by the Pro2D models were also compared.
- f. Solids retention time (SRT): estimated based on biomass inventory calculated from the MLSS data, and waste activated sludge (WAS) quantity that was estimated based on the thickened WAS TSS data and hauled TWAS volume.

#### 4. Secondary Clarifiers:

- a. Surface area: two 110-ft diameter clarifiers, with 13 ft side water depth.
- b. Effluent TSS: averaged less than 5 mg/L during both wet weather season and dry weather season in the 3 year period from 2009 to 2011. 5 mg/L TSS was used for Pro2D model calibration but 10 mg/L TSS was conservatively used during the capacity analysis. Biowin models simulate clarifier behavior and predict secondary effluent TSS using the default modified Vesilind settling flux model.
- c. Sludge volume index (SVI): averages of 195 mL/g during the wet weather season and 235 mL/g during the dry weather season in the 3 year period from 2009 to 2011. For process capacity analysis using Pro2D models, 200 mL/g SVI was used for wet weather conditions and 250 mL/g SVI for dry weather conditions.
- d. Maximum solids loading rate: The clarifiers are relatively shallow. The 2000 Aeration Modification project estimates that the clarifiers can handle maximum solids loading of approximately 20 lb/day/sf. In the process modeling work conducted for the Facilities Plan update project, state analyses of the settling flux was conducted using a CH2M HILL's proprietary tool for peak flow and loading conditions to ensure that clarifiers operate acceptably. The actual maximum flux rate is normally about 80% of the theoretical limiting solids loading to account for sludge removal mechanism inefficiencies. For this process modeling work, the applied solids loading to clarifiers at peak day flow and MLSS levels resulting from the corresponding maximum month loads is conservatively allowed to be up to approximately 70 percent of the theoretical limiting solids loading, to account for relatively shallow side water depth, and SVI potentially being higher than the historical average value. The theoretical limiting solids loadings are determined based on specific clarifier operating conditions and a typical solids settling curve.
- e. SOR: approximately 1,000 gpd/sf maximum at peak day flows. SOR at the peak hour is allowed to be higher, as long as the solids flux state analysis shows acceptable solids loadings to the clarifiers.
- f. RAS rate:
  - i. RAS pumping: three pumps each rated at 4,000 gpm, with a firm capacity of 8,000 gpm. The capacity is adequate as the maximum beneficial RAS rate for the plant is

estimated to be approximately 10 mgd, based on the shape of a typical solids settling curve.

- ii. RAS rate used for model calibration are based on plan records.
- iii. RAS rate used for secondary process capacity analysis: 50 percent of influent for the dry weather season and approximately 30 percent of influent for the wet weather season were used. Generally higher RAS rates are not beneficial, which increase the solids loading to the clarifiers without significantly improving the solids loading allowable at the clarifiers.

#### 5. Primary Sludge Thickening Using Gravity Thickeners (GT)

- a. Thickened primary sludge (TPS) solids concentration: 6 to 9 percent per plant data from 2009 to 2011. Adjusted as necessary to better match digester feed flow data during model calibration.
- b. Solids capture: 90 to 95 percent per typical GT performance. The solids capture calculated based on TPS flow and solids data, as well as the estimated primary sludge quantity, did not provide reasonable values (likely a function of poor quality of that data) and thus were not used. 95 percent solids capture was calibrated in solids balancing by trial and error. 90 percent solids capture was conservatively used for capacity analysis.

#### 6. WAS Thickening Using gravity belt thickeners (GBT)

- a. Solids capture: WAS quantity data are not available, so the GBT solids capture was based on typical GBT performance and adjusted as necessary in calibration for solids balancing through trial and error. 98 percent capture resulted in model calibration. 95 percent solids capture was conservatively used for capacity analysis.
- b. Thickened WAS (TWAS) solids concentrations: averaged at approximately 5 percent per plant data from 2009 to 2011.
- c. The GBT operates 5 days/week. TWAS is loaded directly into trucks and taken to another facility for digestion.
- d. GBT wash water: 40 gpm assumed for the 2-meter GBT that is currently installed.

#### 7. Anaerobic Digesters:

- a. Primary digester: Digester 1 (D1) is heated and mixed. D1 is 50-ft diameter and approximately 25-ft sludge depth, according to digester drawings. It is operated full and transfers via gravity into the secondary digester Digester 2 (D2).
- b. The secondary digester D2 is not heated or mixed. D2 is operated full (except when level is drawn down due to loading of solids trucks) and supernatant from tank is returned to primary influent channel, effectively dewatering the digested biosolids to a degree.
- c. For modeling purposes, the secondary digester D2 is not treated as a digester due to limited digestion expected without heating or mixing. The decanting operation was taken into account and simulated. 95 to 99 percent of solids capture during the decanting appears to simulate well the level of digested biosolids dewatering occurring at the digester D2. 95 percent solids capture was used for capacity analysis to be conservative.
- d. Percent of active volume after accounting for space taken by grit accumulation: 90 percent were assumed.

## Biowin Model Calibration Results

Table 1 compares key Biowin model input and parameters for the liquids streams with the winter plant data from January 1, 2011 to February 28, 2011.

Table 1. Comparisons of Biowin Model Winter Calibration with Liquids Streams Plant Data

Parameter (unit)	Plant Data/ Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
Influent Flow (mgd)	7.5	Input		
Influent BOD (ppd)	11,575	11,874	-3%	
Influent TSS (ppd)	13,547	13,616	-1%	
Influent VSS (%)	85%	85%	0%	Based on 2011 winter TPS VSS/TSS ratio of 85%; 2-week sampling results of 92% was not used because the sampling was done in May, more representative of summer conditions.
TKN/NH3	0.66	0.66	0%	based on 2-week sampling result
NH3/BOD	0.11	0.11	2%	based on 2-week sampling result
TP/TKN	0.13	0.13	0%	based on 2-week sampling result
Influent NH3-N (ppd)	1,318	1,320	0%	based on 2-week sampling result
Influent TKN (ppd)	2,001	2,002	0%	based on 2-week sampling result
Influent Total P (ppd)	263	263	0%	based on 2-week sampling result
Influent Alkalinity (mg/L)	126	input		based on 2-week sampling result
SVI (mL/g)	200	N/A		rounded up to nearest 100s;
Temperature (C)	12.1	input		
<i>Primary Effluent</i>				
PE TSS (lb/d)	4,155	4,600	-11%	standard deviation: 1566 lb/d
PE BOD (lb/d)	5,903	6,852	-16%	standard deviation: 1452 lb/d
TSS Removal (%)	69%	68%	2%	
BOD Removal (%)	49%	44%	10%	
PE TP (mg/L)	-	4.9		
PE OP (mg/L)	-	1.8		
PE NH3-N (mg/L)	-	22.0		
<i>Aeration Basin</i>				
No. of Basins Operating	2.00	2		
SRT (days)	3.64	3.40	7%	Average SRT estimated per MLSS inventory data and the WAS quantity estimated based on TWAS data and calibrated GBT solids capture
RAS Flow (% of Inf)	22%	21%	5%	
RAS TSS (mg/L)	8,562	8,307	3%	Estimated per data on RAS rate and MLSS concentrations.
MLSS (mg/L)	1,571	1,511	4%	
MLVSS (mg/L)	-	1,212		
Volatile fraction (%)	-	80%		2-week sampling result of 88% was not used, which reflects more of summer conditions
<i>Secondary Effluent (SE)</i>				
SE TSS (mg/L)	3.5	6.0	-71%	standard deviation: 1.6

Parameter (unit)	Plant Data/ Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
SE BOD (mg/L)	6.4	4.7	26%	standard deviation: 2.7
SE NH4 (mg/L)	-	21.4		not measured in winter
SE TKN (mg/L)	-	23.0		not measured in winter
SE NO2 (mg/L)	-			not measured in winter
SE Nitrite/Nitrate (mg/L)	-	0.02		not measured in winter
SE TP (mg/L)	-	0.31		not measured in winter

Table 2 compares key Biowin model input and parameters for the solids streams with the winter plant data from January 1, 2011 to February 28, 2011.

Table 2. Comparisons of Biowin Winter Calibration with Solids Streams Plant Data

Parameter (unit)	Plant Data /Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
<i>WAS Thickening</i>				
TWAS quantity (ppd)	4,949	5,023	-2%	based on hauled TWAS volume and TSS, which feature relatively high variations. WAS thickening is performance 5 days/week, so 7-day average TWAS amount was used in calibration.
Thickening solids capture (%)	-	98%		calibrated to get resulting WAS, SRT, and MLSS to match plant data
.TS of cake (%)	4.87	4.9	0%	
<i>Primary sludge (PS) thickening</i>				
Thick PS quantity (ppd)	8,133	9,219	-13%	Calculated based on feed flow and TSS concentration data. Standard deviation 1,237 ppd. The estimate is not as accurate because TSS concentrations were measured weekly and have seen standard deviation of 39% of the average value.
Thick PS VSS/TSS (%)	87%	85%	2%	
Thick PS flow (gpd)	12,698	15,936	-25%	Standard deviation 1,548 gpd.
Solids capture (%)	-	90%		Calibrated per typical gravity thickener performance.
Thick PS solids (%)	6.3%	6.9%	-10%	TSS were measured weekly and had standard deviation of 1.8% solids, or 25% of the average value.
<i>Digester</i>				
Digester feed flow (gpd)	12,698	15,936	-25%	Standard deviation 1,548 gpd.
Digested sludge TS (%)	3.1	3.0	3%	Standard deviation 0.8%.
Digested sludge VS (%)	2.3	2.0	14%	Standard deviation 0.8%.
<i>Dewatering - Decanting at Digester 2</i>				
hauled digested biosolids volume (gpd)	4,837	7,896	-63%	standard deviation 4,125 gpd
hauled digested biosolids quantity (ppd)	3,178	3,373	-6%	hauled sludge based on Digester 2 TSS, which was only measured three times in the

Parameter (unit)	Plant Data /Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
				calibrated period. The calculated hauled digested solids have relatively high standard deviation of about 23% of the average value
hauled digested biosolids solids (%)	6.1%	7.6%	-25%	Only measured three times in the calibrated period; standard deviation 1.2%.
Solids Capture at digester 2 decanting (%)	-	95%		calibrated

As shown in Table 1, most of the liquid stream operational parameters used and resulting plant performance predicted by the model are within 10 percent of the plant data, indicating good calibration of the model. There are a couple of exceptions for data that tend to have higher variations in measurement. Secondary effluent BOD<sub>5</sub> and TSS are small values and thus tend to have to relatively larger deviation from averages. But the differences between the predicted results and plant data averages are still within the standard deviations.

As shown in Table 2, model predictions on key solids stream operational data, such as TWAS, TPS and digested biosolids quantities, are within approximately 10% of each other. Compared with liquids stream data, solids stream data not monitored, or are monitored weekly or monthly and thus feature much greater degree of variations. There are several parameters for which model predictions are more than 10% different from the plant records, mostly sludge flows. However, model predictions are generally still within the standard deviations of corresponding plant measurements. More details related to variations of specific data are noted in Table 2.

Less consistent solids stream data and higher degree of deviation between the model predictions and plant data on solids stream performance are not a concern, because they would impact the digestion process more heavily, with a limited effect on liquid processes. Currently the digested biosolids are trucked to another treatment facility for further digestion, where abundant digester capacity is available. For this reason the plant staff has specifically advised that the process modeling should minimize the effort on digester modeling.

If the same influent stoichiometric parameters as determined from the winter calibration are used to simulate summer operations from August to September, 2011, significant deviations in solids mass balance would result. To account for seasonal differences in operations and influent characteristics, a separate summer calibration was done using summer data, independently from the winter data.

Table 3 compares key Biowin model input and parameters for the liquids streams with the summer plant data from August 1, 2011 to September 30, 2011.

Table 3. Comparisons of Biowin Model Summer Calibration with Liquids Streams Plant Data

Parameter (unit)	Plant Data/ Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
Influent Flow (mgd)	4.0	Input		
Influent BOD (ppd)	9,980	9,551	4%	
Influent TSS (ppd)	11,575	11,504	1%	
Influent VSS (%)	92%	0.91	0%	based on 2-week sampling results, which are consistent with 2011 summer TPS VSS/TSS ratio of 91%

Parameter (unit)	Plant Data/ Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
TKN/NH3	0.66	0.66	0%	based on 2-week sampling result
NH3/BOD	0.11	0.12	-5%	based on 2-week sampling result
TP/TKN	0.13	0.13	0%	based on 2-week sampling result
Influent NH3-N (ppd)	1,137	input		based on 2-week sampling result
Influent TKN (ppd)	1,725	input		based on 2-week sampling result
Influent Total P (ppd)	227	input		based on 2-week sampling result
Influent Alkalinity (mg/L)	126	input		based on 2-week sampling result
SVI (mL/g)	200	N/A		rounded up to nearest 100s; 170 per data
Temperature (C)	20.0	input		
<i>Primary Effluent</i>				
PE TSS (lb/d)	3,180	3,037	5%	
PE BOD (lb/d)	5,027	5,534	-10%	
TSS Removal (%)	70%	74%	-6%	70% removal if not consider TSS in plant recycle
BOD Removal (%)	48%	43%	12%	
PE TP (mg/L)	-	4.9		
PE OP (mg/L)	-	2.9		
PE NH3-N (mg/L)	-	35.5		
<i>Aeration Basin</i>				
No. of Basins Operating	2	input		
SRT (days)	3.44	3.67	-7%	average SRT estimated per MLSS inventory data and WAS quantity estimated based on TWAS data and assumed 95% solids capture at GBTs
RAS Flow (% of Inf)	26%	26%	0%	
RAS TSS (mg/L)	6,380	5,947	7%	estimated per data on RAS rate and MLSS concentrations. 9186 mg/L average RAS TSS measured during 2-week sampling
MLSS (mg/L)	1,353	1,260	7%	generally inline with 1572 mg/L average MLSS TSS measured during 2-week sampling
MLVSS (mg/L)	1,196	1,090	9%	estimated based on VSS/TSS of 0.88 during 2-week sampling
Volatile fraction (%)	88%	87%	2%	per 2-week sampling
<i>Secondary Effluent</i>				
SE TSS (mg/L)	4.9	3.0	39%	standard deviation: 2.3
SE BOD (mg/L)	10.2	2.5	76%	standard deviation: 7.2
SE NH4 (mg/L)	15.8	17.0	-7%	standard deviation: 4.5
SE TKN (mg/L)	17.3	18.4	-6%	standard deviation: 4.5
SE Nitrite/Nitrate (mg/L)	7.77	13.82	-78%	standard deviation: 2.5
SE TP (mg/L)	0.81	0.25	69%	standard deviation: 0.7

Table 4 compares key Biowin model input and parameters for the solids streams with the summer plant data from August 1, 2011 to September 30, 2011.

Table 4. Comparisons of Biowin Model Summer Calibration with Solids Streams Plant Data

Parameter (unit)	Plant Data/ Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
<i>WAS Thickening</i>				
TWAS quantity (ppd)	5,119	3,858	25%	Based on TWAS hauled volume and TSS, which feature relatively high variations. WAS thickening is performed 5 days/week, so 7-day average TWAS amount was used in calibration. The standard deviation of the estimate TWAS is approximately 45% of the average TWAS amount.
Thickening solids capture (%)	-	98%		calibrated to get resulting WAS, SRT, and MLSS to match plant data
TS of cake (%)	5.29	5.2	2%	
<i>Primary sludge thickening</i>				
Thick PS quantity (ppd)	7,821	8,661	-11%	calculated based on feed flow and TSS concentration data. The estimate is not as accurate because TSS concentrations were measured weekly and have seen standard deviation of 20% of the average value.
Thick PS VSS/TSS (%)	91%	91%	0%	calculated based on feed flow and TS concentration data
Thick PS flow (gpd)	12,035	12,758	-6%	
GT Solids capture (%)	-	95%		Calibrated.
Thick PS solids (%)	7.2%	8.1%	-13%	TSS concentrations were measured weekly and have seen standard deviation of 39% of the average value.
<i>Digester</i>				
Digester feed flow (gpd)	12,035	12,758	-6%	
Digested sludge TS (%)	2.4	3.7	-52%	only measured once in the calibrated period; 2011 average value of 4.6%
Digested sludge VS (%)	1.6	2.9	-88%	
<i>Dewatering - Decanting at Digester 2</i>				
hauled digested biosolids volume (gpd)	7,249	8,906	-23%	standard deviation 12,171 gpd
hauled digested biosolids quantity (ppd)	1,894	3,373	-78%	Hauled sludge based on Digester 2 TSS which was only measured once in the calibrated period. The calculated hauled digested solids have relatively high standard deviation of about 25% of the average value
hauled digested biosolids solids (%)	2.7%	5.2%	-90%	only measured once in the calibrated period; assumed 5.2%, which is close to 2011 average value of 4.6%
Solids Capture at digester 2 decanting (%)	-	0%		calibrated

Similar to the winter calibration, most of the liquid stream operational parameters used and the resulting plant performance predicted by the summer model are within 10 percent of the plant data. Good matching between plant data and model results on MLSS concentration, biomass volatile fractions, and primary treatment process provide a good validation of the model calibration. Greater deviations from

plant data are shown for data that tend to have larger variations in measurement. Secondary effluent TSS, BOD<sub>5</sub> and nutrients (TP, nitrite and nitrate) are small values and thus tend to have to relatively greater deviation from averages. But the absolute values generally match between model predictions and the plant data, with differences within standard deviations of the respective data. The effluent nitrite and nitrate concentrations are different from average plant data, however since influent nutrient loads are not available, this is not surprising. In addition, closely monitored nitrogen species along the process streams would be necessary to accurately simulate nitrification process. Both the plant data and the process model show partial nitrification under the summer operating conditions. Biowin simulates the nitrification process as a two-step process with two bacterial groups, ammonia nitrifiers and nitrite nitrifiers. It predicts nitrite being dominant nitrogen species under summer operating conditions. This prediction will have to be verified with plant monitoring if more accurate nitrification process modeling is required in future. For the purpose of the process modeling in this project, more in-depth study or monitoring of the nitrification performance of the secondary process would only be needed if the system capacity was limited by its aeration capacity, which is not the case as shown in following discussions in this technical memorandum.

Similar to the model calibrated for winter conditions, many solids stream operational parameters used and predicted by the summer model are relatively close to the plant data. Solids stream data are monitored weekly or sometimes monthly and thus feature much greater degree of variations than liquid stream data. Greater deviations from plant data are shown for parameters that are less reliable due to infrequent monitoring and/or their estimate nature because they are not directly measured. For these parameters, the differences are generally within standard deviations of corresponding plant measurements. More details related to variations of specific data are noted in Table 4.

Table 5 presents key model parameters determined in winter and summer calibrations that are adjusted from the default values. Ranges for typical wastewater characteristics are also listed.

Table 5. Comparisons of Calibrated Biowin Modeling Parameters and Typical Wastewater Influent Fractionations

Name	Default	Winter Calibration	Summer Calibration
Fbs - Readily biodegradable (including Acetate) [gCOD/g of total COD]	0.16	0.057	0.055
Fac - Acetate [gCOD/g of readily biodegradable COD]	0.15	0.186	0.191
Fxsp - Non-colloidal slowly biodegradable [gCOD/g of slowly degradable COD]	0.75	0.75	0.685
Fus - Unbiodegradable soluble [gCOD/g of total COD]	0.05	0.062	0.064
Fup - Unbiodegradable particulate [gCOD/g of total COD]	0.13	0.09	0.16
Fna - Ammonia [gNH <sub>3</sub> -N/gTKN]	0.66	0.659	0.659
Fpo4 - Phosphate [gPO <sub>4</sub> -P/gTP]	0.5	0.303	0.303

As shown in Table 5, Fbs, Fus, Fna, and Fpo4 are based on 2-week sampling and essentially the same for both calibrations. The slight differences in Fus and Fbs between two calibrations result from influent COD values calculated based on BOD<sub>5</sub> concentrations and calibrated fractions of various types of COD and BOD<sub>5</sub> components. In essence, influent under summer and winter conditions is characterized with roughly the same fractions of soluble COD.

For summer conditions, influent solids turned out to be less biodegradable, as indicated by the higher non-biodegradable VSS fraction. This appears to be counter-intuitive in that longer fermentation period in the collection system in summer might have made the particulates more biodegradable. This

adjustment was necessary, however, to match the higher sludge yield in summer. The sludge yield is estimated based on the plant data at 0.91 lb TSS/lb primary effluent BOD<sub>5</sub> vs. 0.85 lb TSS/lb primary effluent BOD<sub>5</sub> in winter, both at approximately 3.5 day SRT. Typically sludge yield for same influent wastewater would be higher in winter due to lower endogenous decay at lower temperature. The observation of higher sludge yield in summer suggests the presence of seasonal changes to influent characteristics, likely due to variations in seasonal contribution of industrial wastewater sources. If more accurate process modeling for denitrification/nitrification or phosphorus removal becomes necessary in future, the seasonal difference in influent characteristics warrant further verification by intensive sampling in parallel to routine plan monitoring. For the high level process capacity analysis in this project, the plant data and 2-week sampling results are adequate as the sludge yields observation and model prediction are within the range typically seen for treatment plants at similar SRTs.

## Pro2D Model Calibration Results

Table 6 compares key Pro2D model input and parameters for the liquids streams with the winter plant data from January 1, 2011 to February 28, 2011.

Table 6. Comparisons of Pro2D Model Winter Calibration with Liquids Streams Plant Data

Parameter (unit)	Plant Data/ Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
Influent Flow (mgd)	7.5	input		
Influent BOD (ppd)	11,575	input		
Influent TSS (ppd)	13,547	input		
Influent VSS (%)	85%	input		Based on 2011 winter TPS VSS/TSS ratio of 85%; 2-week sampling results of 92% was not used because the sampling was done in May, more representative of summer conditions.
TKN/NH3	0.66	input		based on 2-week sampling result
NH3/BOD	0.11			based on 2-week sampling result
TP/TKN	0.13			based on 2-week sampling result
Influent NH3-N (ppd)	1,318	input		based on 2-week sampling result
Influent TKN (ppd)	2,001	input		based on 2-week sampling result
Influent Total P (ppd)	263	input		based on 2-week sampling result
Influent Alkalinity (mg/L)	126	input		based on 2-week sampling result
SVI (mL/g)	200	input		rounded up to nearest 100s;
Temperature (C)	12.1	input		
<i>Primary Effluent</i>				
PE TSS (lb/d)	4,155	4,129	1%	standard deviation: 1,566 lb/d
PE BOD (lb/d)	5,903	5,723	3%	standard deviation: 1,452 lb/d
TSS Removal (%)	69%	72%	-4%	
BOD Removal (%)	49%	53%	-8%	
PE NH3-N (mg/L)	-	23.0		
<i>Aeration Basin</i>				
No. of Basins Operating	2.00	input		
SRT (days)	3.64	3.60	1%	Average SRT estimated per MLSS inventory data and the WAS quantity estimated based on TWAS data and calibrated GBT solids capture

Parameter (unit)	Plant Data/ Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
RAS Flow (% of Inf)	22%	input		
MLSS (mg/L)	1,571	1,612	-3%	
MLVSS (mg/L)	-	1,252		
Volatile fraction (%)	-	78%		2-week sampling result of 88% was not used, which reflects more of summer conditions
<b>Secondary Effluent (SE)</b>				
SE TSS (mg/L)	3.5	5.0	-43%	standard deviation: 1.6
SE BOD (mg/L)	6.4	6.9	-7%	standard deviation: 2.7
SE NH4 (mg/L)	-	0.68		not measured in winter
SE TKN (mg/L)	-	22.8		not measured in winter
SE Nitrite/Nitrate (mg/L)	-	0.68		not measured in winter
SE TP (mg/L)	-	0.22		not measured in winter

Table 7 compares key Pro2D model input and parameters for the solids streams with the winter plant data from January 1, 2011 to February 28, 2011.

Table 7. Comparisons of Pro2D Winter Calibration with Solids Streams Plant Data

Parameter (unit)	Plant Data /Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
<i>WAS Thickening</i>				
TWAS quantity (ppd)	4,949	4,635	6%	based on hauled TWAS volume and TSS, which feature relatively high variations. WAS thickening is performance 5 days/week, so 7-day average TWAS amount was used in calibration.
Thickening solids capture (%)	-	input		calibrated to get resulting WAS, SRT, and MLSS to match plant data
.TS of cake (%)	4.87	input		
<i>Primary sludge (PS) thickening</i>				
Thick PS quantity (ppd)	8,133	10,619	-11%	Calculated based on feed flow and TSS concentration data. Standard deviation 1,237 ppd. The estimate is not as accurate because TSS concentrations were measured weekly and have seen standard deviation of 39% of the average value.
Thick PS VSS/TSS (%)	87%	85%	2%	
Solids capture (%)	-	90%		Calibrated per typical gravity thickener performance.
Thick PS solids (%)	6.3%	8.1%	-28%	TSS concentrations were measured weekly and had standard deviation of 1.8% solids, or 25% of the average value.
<i>Digester</i>				
Digester feed flow (gpd)	12,698	14,137	-11%	Standard deviation 1,548 gpd.
Digested sludge TS (%)	3.1	2.3	25%	Standard deviation 0.8%.

Parameter (unit)	Plant Data /Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
Digested sludge VS (%)	2.3	1.6	27%	Standard deviation 0.8%.
<b>Dewatering - Decanting at Digester 2</b>				
hauled digested biosolids volume (gpd)	4,837	4,985	-3%	standard deviation 4,125 gpd
hauled digested biosolids quantity (ppd)	3,178	2,621	18%	Hauled sludge based on Digester 2 TSS, which was only measured three times in the calibrated period. The calculated hauled digested solids have relatively high standard deviation of about 23% of the average value
hauled digested biosolids solids (%)	6.1%	6.3%	-3%	Only measured three times in the calibrated period; standard deviation 1.2%.
Solids Capture at digester 2 decanting (%)	-	95%		calibrated

Similar to the Biowin model calibrated to the winter conditions, Table 7 shows that most of the liquid stream parameters predicted by the Pro2D model are within 10 percent of the plant data, indicating good calibration of the model. The only exception is the predicted secondary effluent TSS, which are relatively small numbers and tend to have larger variations in measurement. The difference between the model prediction and the plant data averages is still within the standard deviation of the plant data.

On the solids stream, the key solids stream parameters, such as TWAS and TPS quantities, show close matching between the model predictions and plant records, with differences generally within 10%. The predictions in digested solids quantity, digested sludge solids and volatile solids concentrations show higher level of deviations from the plant records. This might be attributed to the limited numbers of these measurements and the associated high degree of data variations. However, the model predictions for these parameters are still within the standard deviations of corresponding plant measurements, as noted in more details in Table 7.

Similar to Biowin model calibration, for summer process simulation the Pro2D model had to be calibrated separately to achieve meaningful results. Table 8 compares key Pro2D model input and parameters for the liquids streams with the summer plant data from August 1, 2011 to September 30, 2011.

Table 8. Comparisons of Pro2D Model Summer Calibration with Liquids Streams Plant Data

Parameter (unit)	Plant Data/ Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
Influent Flow (mgd)	4.0	input		
Influent BOD (ppd)	9,980	input		
Influent TSS (ppd)	11,575	input		
Influent VSS (%)	92%	input		based on 2-week sampling results, which are consistent with 2011 summer TPS VSS/TSS ratio of 91%
TKN/NH3	0.66	input		based on 2-week sampling result
NH3/BOD	0.11	input		based on 2-week sampling result
TP/TKN	0.13	input		based on 2-week sampling result

Parameter (unit)	Plant Data/ Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
Influent NH3-N (ppd)	1,137	input		based on 2-week sampling result
Influent TKN (ppd)	1,725	input		based on 2-week sampling result
Influent Total P (ppd)	227	input		based on 2-week sampling result
Influent Alkalinity (mg/L)	126	input		based on 2-week sampling result
SVI (mL/g)	200	input		rounded up to nearest 100s; 170 per data
Temperature (C)	20.0	input		
<i>Primary Effluent</i>				
PE TSS (lb/d)	3,180	3,172	0%	
PE BOD (lb/d)	5,027	5,396	-7%	
TSS Removal (%)	70%	input		70% removal if not consider TSS in plant recycle
BOD Removal (%)	48%	46%	4%	
PE NH3-N (mg/L)	-	23.8		
<i>Aeration Basin</i>				
No. of Basins Operating	2	input		
SRT (days)	3.44	3.20	7%	average SRT estimated per MLSS inventory data and WAS quantity estimated based on TWAS data and assumed 95% solids capture at GBTs
RAS Flow (% of Inf)	26%	input		
MLSS (mg/L)	1,353	1,441	-6%	generally inline with 1572 mg/L average MLSS TSS measured during 2-week sampling
MLVSS (mg/L)	1,196	1,254	-5%	estimated based on VSS/TSS of 0.88 during 2-week sampling
Volatile fraction (%)	88%	87%	2%	per 2-week sampling
<i>Secondary Effluent</i>				
SE TSS (mg/L)	4.9	5.0	-2%	standard deviation: 2.3
SE BOD (mg/L)	10.2	3.4	67%	standard deviation: 7.2
SE NH4 (mg/L)	15.8	18.9	-19%	standard deviation: 4.5
SE TKN (mg/L)	17.3	20.9	-21%	standard deviation: 4.5
SE Nitrite/Nitrate (mg/L)	7.77	9.31	-20%	standard deviation: 2.5
SE TP (mg/L)	0.81	0.17	79%	standard deviation: 0.7

Table 9 compares key Pro2D model input and parameters for the solids streams with the summer plant data from August 1, 2011 to September 30, 2011.

Table 9. Comparisons of Pro2D Model Summer Calibration with Solids Streams Plant Data

Parameter (unit)	Plant Data/ Estimates	Model	Difference (%)	Comment: see calibration data file Tryon Creek Flow and Load_Calculation_3.LL for data during the calibration period, if not otherwise indicated
<i>WAS Thickening</i>				
TWAS quantity (ppd)	5,119	4,726	8%	Based on TWAS hauled volume and TSS, which feature relatively high variations. WAS thickening is performed 5 days/week, so 7-day average TWAS amount was used in calibration. The standard deviation of the estimate TWAS is approximately 45% of the average TWAS amount.
Thickening solids capture (%)	-	95%		calibrated to get resulting WAS, SRT, and MLSS to match plant data
TS of cake (%)	5.29	input		
<i>Primary sludge thickening</i>				
Thick PS quantity (ppd)	7,821	8,577	-10%	calculated based on feed flow and TSS concentration data. The estimate is not as accurate because TSS concentrations were measured weekly and have seen standard deviation of 20% of the average value.
Thick PS VSS/TSS (%)	91%	92%	-1%	calculated based on feed flow and TS concentration data
Thick PS flow (gpd)	12,035	12,847	-7%	
GT Solids capture (%)	-	input		Calibrated.
Thick PS solids (%)	7.2%	8%	-11%	TSS concentrations were measured weekly and have seen standard deviation of 39% of the average value.
<i>Digester</i>				
Digester feed flow (gpd)	12,035	12,847	-7%	
Digested sludge TS (%)	2.4	3.2	-34%	only measured once in the calibrated period; 2011 average value of 4.6%
Digested sludge VS (%)	1.6	3.0	-93%	
<i>Dewatering - Decanting at Digester 2</i>				
hauled digested biosolids volume (gpd)	7,249	7,151	1%	standard deviation 12,171 gpd
hauled digested biosolids quantity (ppd)	1,894	3,282	-46%	Hauled sludge based on Digester 2 TSS which was only measured once in the calibrated period. The calculated hauled digested solids have relatively high standard deviation of about 25% of the average value
hauled digested biosolids solids (%)	2.7%	5.5%	-69%	only measured once in the calibrated period; assumed 5.2%, which is close to 2011 average value of 4.6%
Solids Capture at digester 2 decanting (%)	-	95%		calibrated

Similar to the models calibrated for winter conditions, most of the liquid stream operational parameters used and resulting plant performance predicted by the summer model are within 10 percent of the plant data, which validates the model calibration. Greater deviations from plant data are shown for data that tend to have larger variations in measurement, including secondary effluent BOD<sub>5</sub> and nutrients (TP, nitrite and nitrate). There are small values and thus tend to have to relatively larger deviation from

averages. The differences between model predictions and the plant data for these parameters are still within standard deviations of the respective data. The effluent nitrite and nitrate concentrations are different from plant data averages because of the lack of closely monitored nitrogen species along the process streams, which are necessary for simulating nitrification performance.

Similar to the models calibrated for winter conditions, predictions of key solids quantities, such as TPS and TWAS mass rate, are within 10% of the plant data. Greater deviations from plant data are shown for parameters that are less reliable due to infrequent monitoring, such as flows and some solids concentration measurements, and/or their estimate nature. For these parameters, the differences are generally within standard deviations of corresponding plant measurements, as noted in Table 9 in more details.

Table 10 presents key model parameters determined in winter and summer calibrations that are adjusted differently from the default values. Ranges for typical wastewater are also listed.

Table 10. Comparisons of Calibrated Pro2D Modeling Parameters and Typical Values for Wastewater

Item	Summer Model	Winter Model	Typical Range
Non-Biodegradable VSS, % of Total VSS	30%	9%	20%-40%
Filtrate Non-Biodegradable COD, % of Total COD	6.6%	6.6%	5%-10%
Half Saturation for O <sub>2</sub> (K <sub>O</sub> ), mg-O <sub>2</sub> /L	0.5	0.5	0.5 – 1.5

0.5 mg O<sub>2</sub>/L half saturation oxygen concentration (K<sub>O</sub>) for nitrifier growth was used for both summer and winter calibrations. 0.5 mg O<sub>2</sub>/L K<sub>O</sub> value is typical for nitrification kinetics observed in aeration basins with anaerobic/anoxic selectors. In the calibrated models, operating Zone A as the anaerobic selector in summer was found to best match the secondary effluent nutrient concentrations. For winter calibration, Zones A and B were assumed operating as the anaerobic selectors to achieve the improvement in the sludge settling.

Note that for winter condition, the non-biodegradable fraction of VSS in the total VSS amount had to be lowered below the typical range to acceptably predict the sludge yield and biomass inventory. This agrees with the Biowin calibrations in that influent solids would be less biodegradable.

## Secondary Process Capacity Analysis

Influent flows and loads were incrementally increased from levels calibrated for year 2011, until the process models predict that one of the process unit limitations as discussed in previous section is reached, such as air supply capacity, maximum secondary clarifier solids loading, or maximum secondary clarifier hydraulic loading. Note that the hydraulic loadings to primary and secondary clarifiers would need to be within allowable ranges under the conditions assessed. Hydraulic limitations of these units are addressed in the *Treatment Plant Hydraulic Capacity Technical Memorandum* (CH2M HILL, 2012).

Four flow and load scenarios were simulated:

1. Maximum month wet weather (MMWW) flows and loads: used to determine MLSS levels and system performance in the wet weather season, when the temperatures are low and influent flows and loads are high, compared to corresponding maximum month dry weather (MMDW) conditions. Steady state modelings were performed using both Biowin and Pro2D simulators. Step feed with an even primary effluent split between Zone A and Zone B was used to maintain

the required biomass inventory while keeping the MLSS concentrations in the secondary clarifier feed low.

2. Maximum day wet weather (MDWW) flows and loads: used to predict air demand, hydraulic and solids loading to clarifiers at the peak conditions. When Biowin models were used, dynamic modeling was performed, with the steady state operating conditions under the corresponding MMWW flows and loads as the starting point. When Pro2D models were used, flow and loading peaking factor were input into the corresponding steady state modeling under the MMWW conditions to achieve conservative predictions for MDWW conditions. Maximum day solid loadings to secondary clarifiers were analyzed separately at MDWW flow and the MLSS levels resulting from the corresponding MMWW loads.
3. Average dry weather flow (ADWF) and maximum month dry weather (MMDW) loads: used to determine system performance in the dry weather season. One of the major objectives for this scenario is to confirm that the air demand is within the existing air supply and aeration capacity, because the oxygen transfer efficiency is low at the high wastewater temperature in summer.
4. Maximum day dry weather (MDDW) flows and loads: used to predict air demand, hydraulic and solids loading to clarifiers at the peak conditions. When Biowin models were used, dynamic modeling was performed, with the steady state operating conditions under the corresponding MMWW flows and loads as the starting point. When Pro2D models were used, flow and loading peaking factor were input into the corresponding steady state modeling under the MMWW conditions to achieve conservative predictions for MDWW conditions. Maximum day solid loadings to secondary clarifiers were analyzed separately at MDDW flow and the MLSS levels resulting from the corresponding MMDW loads.

For activated sludge processes that do not need to remove ammonia-nitrogen, 3 to 5 day SRTs are typical and recommended. Slightly shorter SRTs may be used in summer in order to avoid nitrification and associated high air demand but still achieve the required removal of the organic matters. However, much shorter SRT than 3 days should not be used, as young sludge may result in poor settling. For all the modeling scenarios, 3.5 day SRT was used to be conservative.

When Biowin models were used, the air demand were calculated separately based on OUR and OTR output from the models to capture the reduction in SOTE at high air flows per diffuser and the reduction in the alpha values at increased OUR values. The resulting air demand was compared with the air supply rate predictions directly from the Pro2D models. Pro2D model output on air demand was found to be very close to the calculated air demand under maximum month load conditions, but tend to be conservative at peak load conditions, mostly due to the use of higher DO concentration (2 mg/L vs. 1 mg/L under peak loads) and inclusion of oxygen demand resulted from reducing sulfide in the wastewater.

The modeling results are summarized in Table 11.

Table 11. Process Modeling Results

Modeled Scenarios	Flow (mgd)	Corresponding ADWF Flow (mgd)	Temp. (°C)	Primary TSS removal (%)	Primary Effluent TSS Load (lb/d)	Primary Effluent BOD Load (lb/d)	No. of Trains	SRT (days)	MLSS (mg/L) <sup>1</sup>	RAS recycle rate (%)	Clarifier solids loading (lb/day/sf) <sup>4</sup>	Clarifier solids loading per Pro2D (lb/day/sf)	Air Demand, per Biowin OTR (scfm) <sup>5</sup>	Air Demand, per Biowin (scfm) <sup>6</sup>	Air Demand, per Pro2D (scfm)
MMWF and MMWW load, step feed	13.4	6	13	62%	9,446	12,699	2	3.5	1,282	30%	9.6	10	3,892	3,684	4,203
MDWW Flow and Load, step feed	32.0	6	13	52%	25,202	29,817	2	3.5 <sup>3</sup>	1,379	30%	<b>23.6</b>	25.3	4,091	4,191	10,619
MMWF and MMWW load, without step feed	12.3	5.5	13	62%	8,659	11,642	2	3.5	1,305	30%	9.1	11.4	2,799	2,681	3,744
MDWW Flow and Load, without step feed	29.3	5.5	13	52%	23,062	27,295	2	3.5 <sup>3</sup>	1,546	30%	<b>25.9</b>	31.0	3,143	3,249	9,749
ADWF flow and MMDW load	6.0	6	18	65%	7,382	10,410	2	3.5	1,259	50%	4.8	5.6	3,550	3,306	4,581
MDDW Flow and Load	12.4	6	18	55%	25,202	21,318	2	3.5 <sup>3</sup>	1,643	50%	12.7	11	4,896	4,238	9,004
ADWF flow and MMDW load	8.0	8	18	65%	9,859	13,896	2	3.5	1,654	50%	8.4	10	5,304	4,681	6,529
MDDW Flow and Load	16.5	8	18	55%	23,759	28,386	2	3.5 <sup>3</sup>	2,100	50%	21.9	19	<b>7,321</b>	5,702	13,149

Notes:

1. For maximum month loads, average TSS removal of 65% for dry weather season and 62% for wet weather season was utilized, based on 2009 to 2011 plant data. TSS removals under corresponding maximum day flow and load conditions were assumed to be 10% lower.
2. For wet weather scenarios with step feed, values shown are the MLSS concentrations predicted in the last zone.
3. For maximum day conditions, WAS wasting rate is assumed to remain the same as required for maintaining 3.5-day SRT under corresponding maximum month load condition.
4. For maximum day conditions, maximum solids loading that would occur under maximum day flows and loads are shown.
5. Calculated separately based on Biowin output on predicted OURs and OTRs assuming maintenance of 1 mg/L DO concentration under maximum day conditions and 2 mg/L DO concentration under maximum month conditions.
6. For maximum day conditions, Biowin aeration modeling results shown are with same aeration parameters as those under maximum month conditions, i.e. at 2 mg/L DO concentration. The resulting peak air demand are sometimes lower than predicted by other methods, because the reduction in alpha values were not accounted for with the same aeration parameters settings.

As shown in Table 11, modeling predicts that the secondary process is capable of treating a maximum 12.3 mgd MMWW flow and load and 29.3 mgd MDWW flow. The solids loading to secondary clarifiers under corresponding MDWW conditions would be 23.6 lb/sf/day, somewhat greater than 20 lb/sf/day, the maximum solids loading limit used in the previous Aeration Modification project in 2000. The solids settling flux/state point analysis for the MDWW condition is shown in Figure 1 and predicts that the applied solids loading at the MDWW flow would be at approximately 68% of the theoretical limiting solids loading and therefore be acceptable. The solids loading at peak hour flows would be higher, causing a slight sludge blanket rise for a short period of time, but would not result in solids carry over in the effluent. Clarifier capacity can be predicted for a given set of conditions, however because the input variables (SVI, influent solids load, hydraulic flow rate, underflow rate) are dynamic, it is difficult to unequivocally define the absolute capacity, without the use of grossly conservative assumptions.

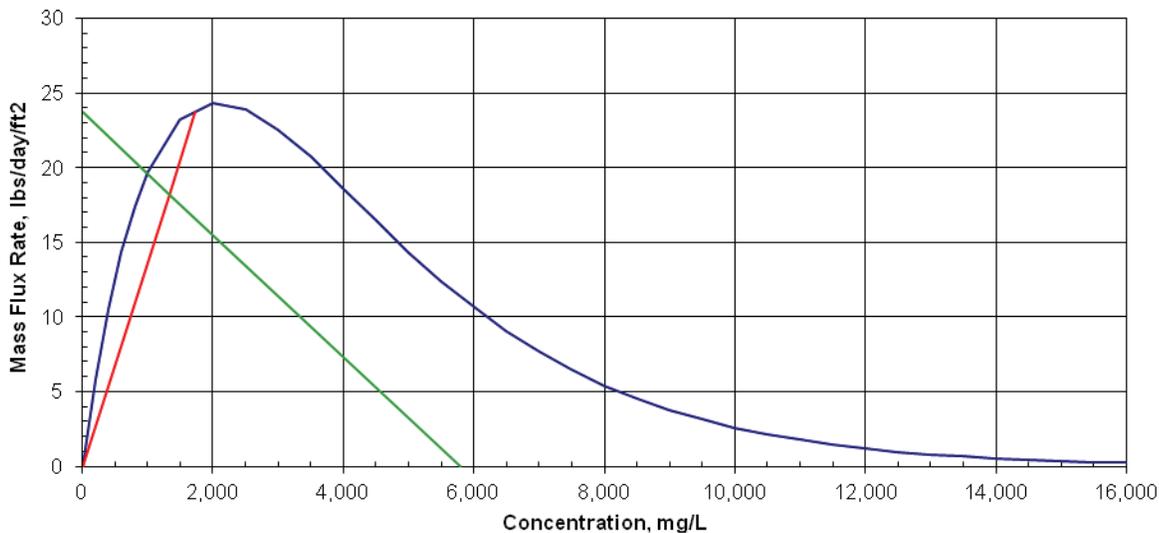


FIGURE 1  
Solids Flux/State Point Analysis at 29.3 mgd MDWW flow

If step feed, as currently configured, is practiced under wet weather conditions, lower MLSS concentration in the last zones of the aeration basins would exist, enabling the plant to treat an increased maximum MMWW flow of 13.4 mgd and MDWW flow of 32 mgd. The resulting solids loading at the MDWW flow would be at approximately 66% of the theoretical limiting solids loading.

The air demand separately calculated based on Biowin output on OUR and OTR values are considered most accurate and used for capacity evaluation. The air demands in Table 10 include some level of nitrification as predicted by process models, and thus are conservative. For all sustained and peak wet weather flows and loads associated with an ADWF flow of up to 6 mgd, the air demands are expected to be well within the capacity of the existing process air and aeration system.

Under the dry weather maximum month and maximum day flows and loads corresponding to up to 6 mgd ADWF, the air demand and secondary clarifier solids loading are expected to be well within the process capacity. As shown in Table 11, the plant would have excess capacity in dry weather conditions. It could handle up to 8 mgd ADWF flow and corresponding maximum month and maximum day flows and loads, provided that full nitrification is avoided by SRT control.

## Summary

The secondary process has capacity for all 2040 wet weather conditions except for maximum day and peak hour wet weather. The limiting factor under these conditions is the secondary clarifiers.

Implementation of step feed can maximize the system for the given clarifier capacity, however additional tools are required to allow for reliable operation in that mode.

The secondary process has excess capacity for 2040 dry weather conditions. It can treat all flow and loads associated with 8 mgd ADWF flow, at which point the blower capacity and the maximum allowable clarifier solids loading would be reached.