SOUTHEAST ALASKA POWER AGENCY

2019 Revised Operations Plan

Date: April 19, 2019

To: Trey Acteson, Chief Executive Officer

From: Robert Siedman, P.E., Director of Engineering & Technical Services

SEAPA 2019 Revised Operations Plan

Every year SEAPA presents the Operations Plan (Ops Plan) for Board approval in accordance with Section 5 of the Power Sales Agreement[1] (PSA). The annual plan forecasts expected reservoir levels for Tyee Lake and Swan Lake for the upcoming year by maximizing output from SEAPA facilities and optimizing water resources. Pursuant to the PSA, the Ops Plan gives first priority to the dedicated Firm Power Requirements of each Utility and optimizes Additional Dedicated Output as a second priority for additional power requirements. Optimization of water resources is achieved by an algorithmic math model as represented in Figure 1.

Water Resource Algorithmic Math Model Process

Step 1: Current lake levels

Step 2: Inflow Forecasts

1. NOAA
2. USGS
3. NINO3.4

Step 3: Load Forecast

1. Temperature Forecasts
2. Scheduled Maintenance
3. STICS/Historic Loads

Step 4: Iterative Math Model

1. Case Reservoir Plots
2. Optimized Water Resources

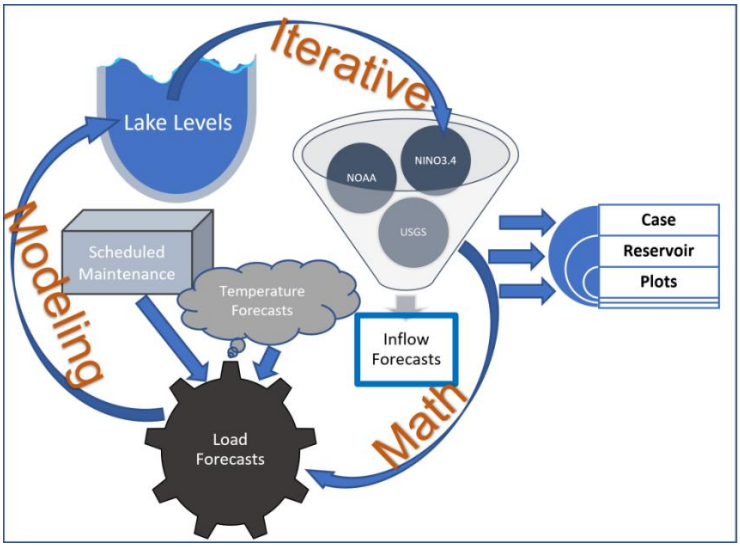

Figure 1: Math Modeling: Optimizing Water Resources

The iterative process utilized in the algorithm to optimize water resources was applied to a variety of cases. Each case was further analyzed, and curves were developed. Special consideration was made

[1] Section 5 of the Power Sales Agreement states that SEAPA shall prepare annually an Operations Plan to estimate the Firm Power Requirements of the Purchasing Utilities and identify Dedicated output to maximize utilization and optimize output of each facility.

to ensure optimization of water resources without risking dedicated Firm Power Requirements of the Purchasing Utilities. The process, assumptions, and results are discussed below.

Current Lake Levels

The lake level as of April 19 ,2019 was the lowest on record at Tyee Lake since the installation of the Swan-Tyee Intertie (STI) in 2009. This is due to a record low rain and inflow season. According to the latest Drought Monitor analysis (updated April 11, 2019), Southeast Alaska is still in a "Severe Drought" condition (Figure 2). This Drought condition has persisted since the summer of 2018. Although Southeast Alaska has transitioned from a moderate La Nina to a weak El Nino with south Sea Surface Temperatures (SST) above average, NOAA is predicting a 3-Month outlook to be above average temperatures with below average precipitation.

January-February-March of 2019 offered some relief to the ongoing drought condition however with a total of 27.4 inches of rain (for the period), precipitation was still 25% below the previous 5-year average of 36.6 inches (Data from NOAA weather station at Ketchikan Airport). In addition to lower-than-average rainfalls, a Polar Vortex caused extreme low temperatures in February resulting in high loads. As a result of the compounded extreme weather conditions, Tyee lake draft rate increased significantly in early February. A Diesel Campaign was thereby required in Petersburg and Wrangell (starting February 15) to slow down the rate of draft.

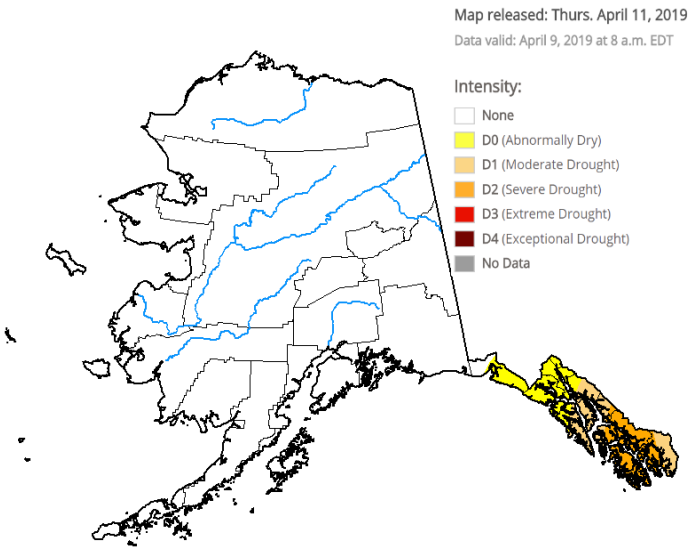

Figure 2: U.S. Drought Monitor-Alaska

The diesel campaign in Petersburg and Wrangell continued for a total of 5 weeks and ended on March 24, 2019. Throughout the duration of the diesel campaign, SEAPA's Board of Directors held weekly meetings to discuss lake levels and SEAPA Operations. On February 28, the Board voted to have SEAPA reimburse Petersburg and Wrangell for the cost of diesel and overtime incurred and expected to incur for February and March. As reported to SEAPA, a total of 7,010 MWhrs was produced by Petersburg and Wrangell combined from diesel generation.

In September 2018, SEAPA suspended generation from Tyee to Ketchikan. Due to the ongoing drought conditions, Tyee Lake generation was dedicated to Petersburg and Wrangell pursuant to the Power Sales Agreement (PSA) to meet their Firm Power Requirements. Without the support of Tyee generation, Swan Lake's draft rate increased and was unable too meet Ketchikan's energy demands. A Supplemental Diesel Campaign for Ketchikan was thereby instituted by KPU in September 2018 and has continued for the past 30 weeks. Lake elevations at Swan and Tyee as of April 19, 2019 were 293.5ft and 1262.4ft respectively.

Rain Fall – Inflows for 2019

As discussed in the preceding section, rainfalls for 2018 were extremely low. NOAA weather stations at Beaver Falls and the Ketchikan International Airport recorded approximately 106 inches of rain, nearly 30% below the previous 20-year average.

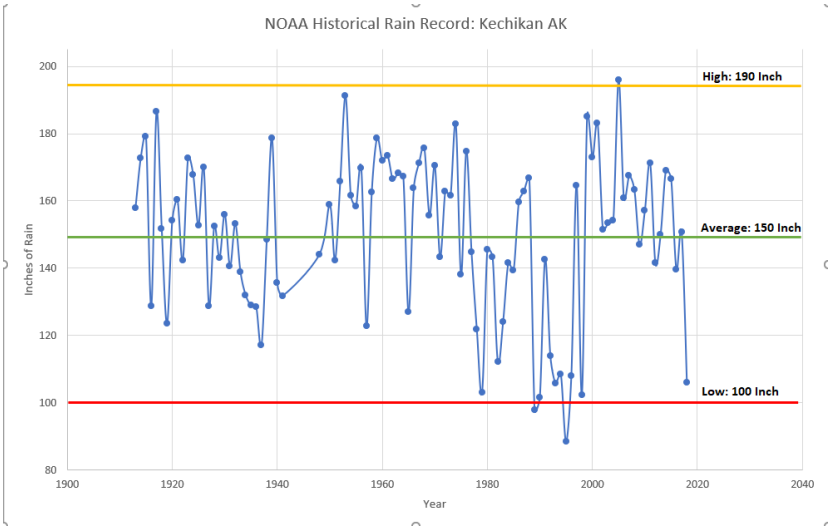

Figure 3: 100-Year Historical Rainfall: Ketchikan, AK

The chart on the left (Figure 3) illustrates a 100-year graph of precipitation recorded by NOAA for Ketchikan. As evidenced in this chart, 2018 precipitation was the lowest on record since the late-1990's. The below average rainfalls in the late 1980's to the late 1990's (approximately 20-years) were followed by above average rainfalls from 1997 to 2017. These periods appear to coincide with Pacific Decadal Oscillations (PDO) as discussed in further detail in the following sections.

Inflow Forecasts

Inflow predictions for calendar year 2019 were performed by utilizing NOAA, NINO3.4, Pacific Decadal Oscillation charts and historic USGS inflow data. NOAA forecasts for the months of May-June-July are predicting below-normal precipitation and above-normal temperatures. Figure 4 illustrates that NOAA is predicting with a 50-60% probability confidence a below-normal three-month outlook for rain.

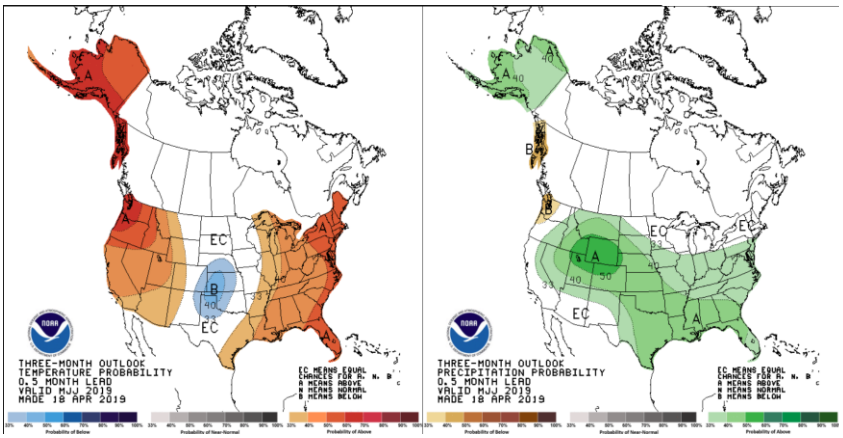

Figure 4: NOAA May-June-July Outlook

NOAA is predicting a weak El Nino to continue. The magnitude of the El Nino does not appear to be great enough to cause increased precipitation in Southeast Alaska.

There are dozens of institutions that have developed El Nino Southern Oscillation models (ENSO). Oceanographic temperature models such as ENSO's are used by NOAA to predict weather patterns.

The latest ENSO models show that we are currently maintaining a weak El Nino with Ocean temperatures currently 0.4–1.0 ˚C above-average temperatures. Warmer south ocean temperatures typically correlate to warmer weather and higher precipitation rates in the Northwest hemisphere.

Figure 5 illustrates the International Research Institute (IRI) and Climate Prediction Centers (CPC) ENSO model. Apparent to all participating institute forecasts is a continued above average ocean temperature. Although forecasts are predicting above-average temperatures in Southeast Alaska, they are predicting below-average precipitation.

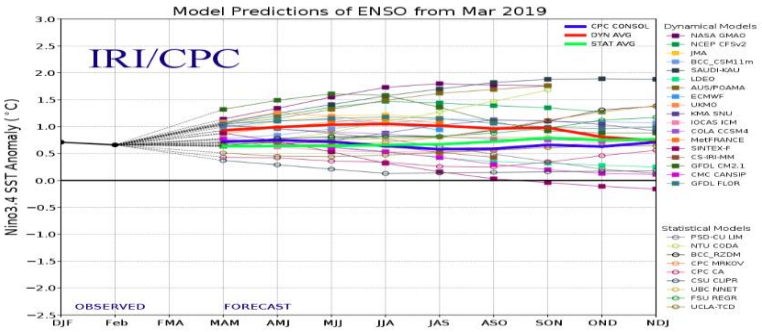

Figure 5: 2019 ENSO Model

Inflow seasons are cyclical and have a close correlation with ocean temperatures. El Nino and La Nina conditions impact precipitation in Southeast Alaska however a second oscillation discovered by scientist Steven Hare in 1996 called the Pacific Decadal Oscillation (PDO) also has an impact. In general, an El Nino will cause an increase in precipitation and a La Nina will cause a decrease in precipitation for Southeast Alaska. ENSOs (El Nino's and La Nina's) impact the standard deviation of precipitation from average, the PDO shifts the precipitation average up and down. As shown in Figure 6 below, in a Cold Phase (PDO), the average precipitation is approximately 160 inches whereas in a Warm Phase (PDO), the average precipitation is 125 inches. After superimposing Ketchikan rain data onto PDO and ENSO charts, data suggests that we are entering a Warm Pacific Decadal Oscillation Phase.

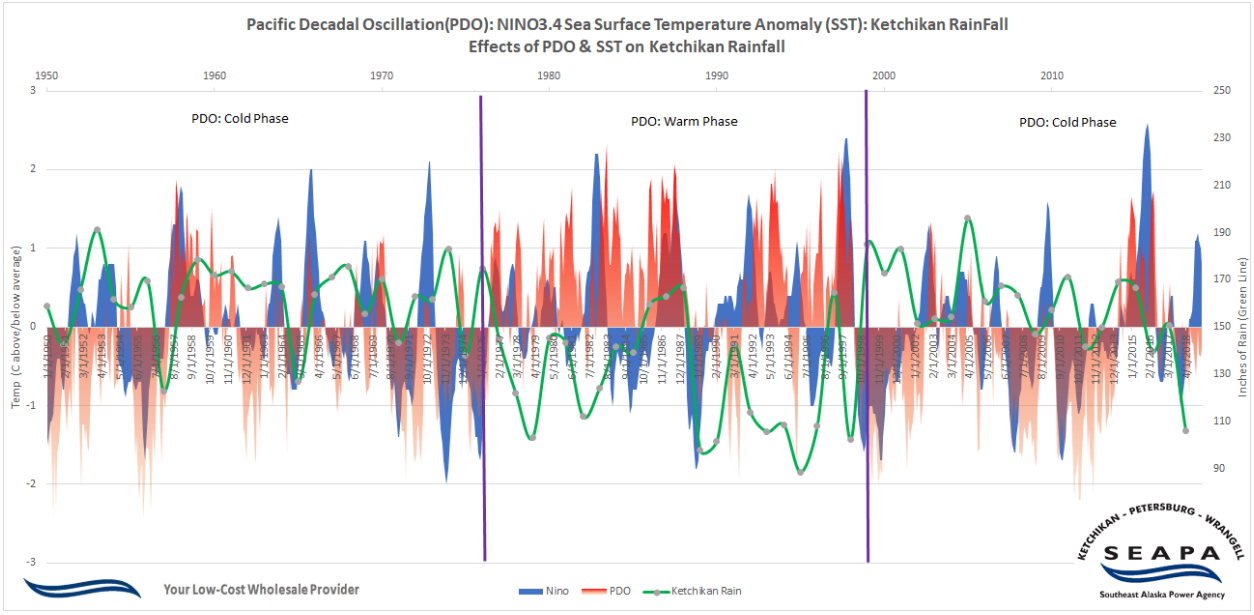

Figure 6: PDO Shifting of Average Rainfalls on 20-Year Cycles

If predictions from the PDO/ENSO models and historical trends hold true as discussed in previous sections, inflows will be approximately 22% below the previous 20-year averages and possibly continue for the next 20 years. Figure 6 in the PDO/ENSO records also explain with a certain degree of confidence the reason for the 2018 low inflow year. It is therefore prudent for SEAPA to consider inflow cases that are reflective of a Warm PDO phase as seen in the 20-year phase between the 1980's and 1990's.

Case / Month	(2018) SWL Low Inflow (avg day cfs)	(94-99) SWL Avg Inflow (avg day cfs)	(2018) TYL Low Inflow (avg day cfs)	(94-99) TYL Avg Inflow (avg day cfs)
apr	278.0	263.0	72.1	93.7
may	425.0	455.0	308.4	216.3
jun	387.0	465.0	160.0	207.7
jul	248.0	337.0	99.3	152.5
aug	274.0	308.0	74.1	127.0
sep	427.0	502.0	79.4	149.3
oct	416.0	387.0	132.0	145.1
nov	279.0	289.0	146.3	65.5
dec	359.0	351.0	120.3	59.3
jan	294.0	164.0	38.8	74.6
feb	152.0	139.0	26.7	50.7
mar	190.0	169.0	20.4	41.6
Average Annual	310.8	319.1	106.5	115.3

Table 1: SEAPA predicted Inflow Cases for 2019

Average Inflow (1994-1999) Cases

Table 1 illustrates SEAPA's predicted inflow cases that were used for the Swan Lake and Tyee Lake reservoir level models. As discussed previously, the inflow cases were selected based on NOAA and PDO predictions for 2019. The average annual cfs for Swan Lake was 319.1 cfs and the average annual cfs for Tyee Lake was 115.3 cfs.

Low Inflow (2018) Cases

The low (2018) inflow case for Swan Lake was inserted into the model with an average annual cfs value of 310.8 cfs. Low inflows were based on average 2018 inflows. The low (2018) inflow case for Tyee Lake was inserted into the model with a cfs value of 106.5 cfs. These were based on ongoing and predicted warmer/dryer conditions and SEAPA's predicted Warm Phase PDO.

Load Forecasts

Load forecasts and subsequent SEAPA deliveries were estimated for the 2019 calendar year with consideration to the NOAA May-June-July outlook (warmer average temperatures) and the 7-year SEAPA delivery schedule (2011-2018). Typically, the Operations Plan considers multiple load cases to balance the lakes across the Swan-Tyee-Intertie (STI) transmission line and maximize the outputs of Tyee and Swan Lake per the PSA. Under current lake level conditions however, balancing the lakes is not possible. Tyee Lake's Dedicated Output, pursuant to the PSA, will need to be reserved and remain dedicated to Petersburg and Wrangell to meet the Firm Power Requirements of the respective utilities until reservoir conditions support otherwise. As a result, net power transferred across the STI may not occur for the foreseeable future (see Tyee model section for caveats).

The forecasted Firm Power Requirements for the respective utilities, based on average loads, are as follows:

Swan Lake Expected Generation: **59,357MWh (Dedicated Output)**

Ketchikan Loads: **99,716MWh (Firm Power Requirements)**

Tyee Lake Expected Generation: **90,463MWhr**

PTG & WRG Loads: **85,511MWhr (Firm Power Requirements and Dedicated Output)**

Low Inflow Load Case

Table 2 illustrates the load forecasts for 2019 (starting in April) which demonstrates zero transfer of energy across the STI. Section 5 of the PSA discusses development of the Operations Plan on an annual basis with a caveat for the plan to be reviewed periodically as needed. Given the recent severe drought circumstances and inflow forecasts, SEAPA will continue to review lake levels weekly and recommends that the Operations Plan be discussed weekly during Operation Meetings.

	KTN			Swan Lake		STI		WRG-PSG			Tyee Lake	
	Expected Delivery	Required Generation	Required Generation	Expected Gen from Inflow	Expected Gen from Inflow	STI Expected (balance)	STI Expected (balance)	Expected Delivery	Required Generation	Required Generation	Tyee Expect Generation	Tyee Expected Generation
	MWh	MWh	Avg MW	Avg MW	MWh	MWh	Avg MW	MWh	MWh	Avg MW	Avg MW	MWh
APR	6594.8	6990.5	9.7	6.0	4320.0	0.0	0.0	6282.4	6659.3	9.2	9.2	6659.3
MAY	5054.7	5358.0	7.2	7.2	5356.8	0.0	0.0	4997.3	5297.1	7.1	7.1	5297.1
JUN	5730.8	6074.7	8.4	6.0	4320.0	0.0	0.0	4906.7	5201.1	7.2	7.2	5201.1
JUL	7670.2	8130.4	10.9	8.0	5952.0	0.0	0.0	7202.1	7634.2	10.3	10.3	7634.2
AUG	7011.9	7432.7	10.0	8.0	5952.0	0.0	0.0	7445.0	7891.7	10.6	10.6	7891.7
SEP	6544.5	6937.2	9.6	8.0	5760.0	0.0	0.0	5180.8	5491.7	7.6	7.6	5491.7
OCT	8095.6	8581.3	11.5	8.0	5952.0	0.0	0.0	6637.0	7035.2	9.5	9.5	7035.2
NOV	9143.1	9691.6	13.5	6.0	4320.0	0.0	0.0	7547.9	8000.8	11.1	11.1	8000.8
DEC	13644.7	14463.4	19.4	6.0	4464.0	0.0	0.0	10120.9	10728.1	14.4	14.4	10728.1
JAN	10870.4	11522.6	15.5	6.0	4464.0	0.0	0.0	9176.9	9635.8	13.0	13.0	9635.8
FEB	10862.0	11513.7	17.1	6.0	4032.0	0.0	0.0	8730.8	9167.3	13.6	13.2	9167.3
MAR	8493.3	9002.9	12.1	6.0	4464.0	0.0	0.0	7283.8	7720.8	10.4	10.4	7720.8
Total	**99716.0**	**105698.9**	-	-	**59356.8**	**0.0**	-	**85511.6**	**90463.2**	-	-	**90463.2**

Table 2: SEAPA 2019 Load Forecast

Scheduled Maintenance

SEAPA does not anticipate any extended outages in calendar year 2019. Typical line maintenance, generator unit annual maintenance and substation maintenance were considered when developing the load forecasts. Swan Lake station service switchgear upgrades and Swan Lake turbine runner repairs are anticipated in the future. However, for CY2019, typical outage durations and times were modeled.

Iterative Math Model

The Tyee Lake and Swan Lake models used to predict lake levels involve iterating through inflow scenarios and generation load sequences. Lake levels are inputted with actual levels on the day the models were ran. Once the inflow predictions were developed, adjustments to generation inputs is typically performed to maximize utilization of the outputs for Tyee and Swan. Guide curves are generally developed by averaging the probable inflow and low inflow cases, with a slight bias towards the low inflow case for early spring months. Under current conditions and until conditions change, the guide curves do not reflect balancing the lakes across the STI, and therefore the guide curve for Swan Lake is the Average inflow case (red line). The curves illustrated below demonstrate a band of operation that SEAPA predicts for Swan lake levels, with KPU diesel generation integrated.

Swan Lake Reservoir Plot (Expected Inflows)

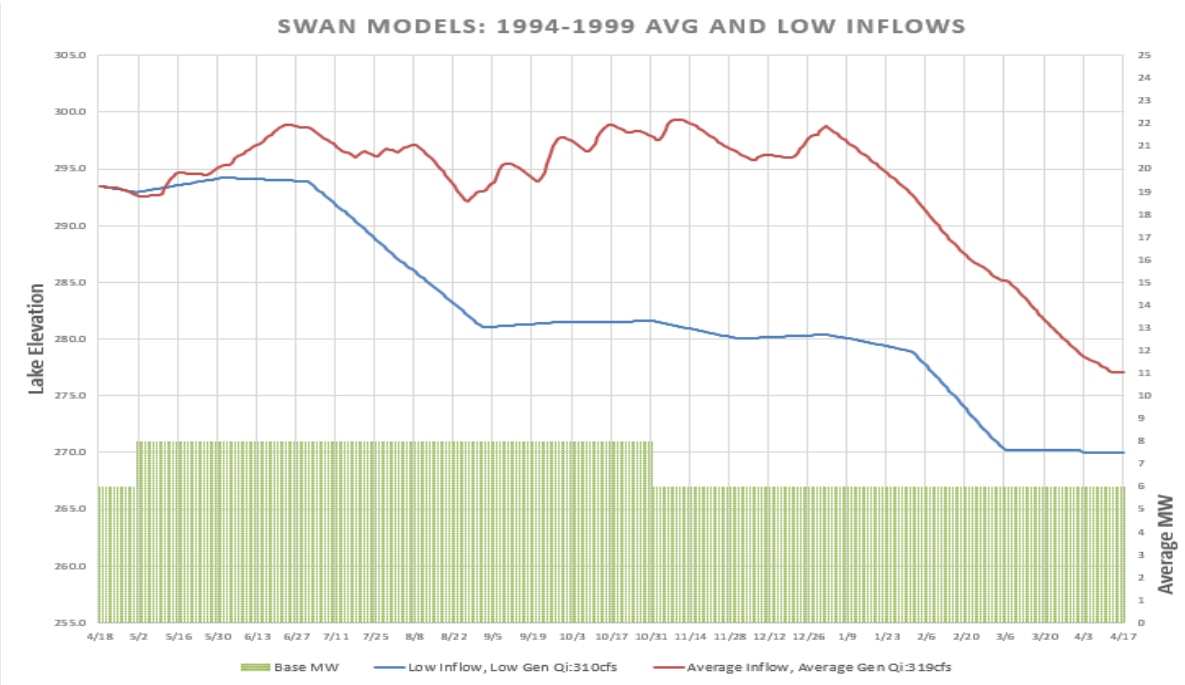

Figure 7: Swan Lake Reservoir Plot:

The 2019 Swan Lake reservoir model as illustrated in Figure 7 above illustrates the two case scenarios as discussed in preceding sections. Both scenarios were modeled to illustrate recovery scenarios for Swan Lake without the STI utilizing fixed outputs of Swan Lake generators. Modeling inflows using the low inflow (2018 averages) (red line) illustrate that Swan Lake will not recover for the duration of the 2019 calendar year if a repeat of 2018 inflows is realized. In the case of using 1994-1999 average inflows (as predicted), Swan Lake recovers partly in the Spring and remains between elevation 290-300 feet until December. The loads modeled were approximately 6MW output for the Spring and 8MW output for the Summer and Fall as illustrated by the green bar graphs on the bottom of the chart. KPU diesel generation may be required to supplement the remainder of Ketchikan's Firm Power Requirements.

Coordination of KPU Supplemental Diesel Generation

Ketchikan's Firm Power Requirements are typically provided by SEAPA in accordance with the PSA by utilizing Swan Lake's Dedicated Output and Tyee Lake's Additional Dedicated Output. However, under the current water conditions, Tyee does not currently have Additional Dedicated Output available. It was therefore prudent to formalize integration of KPU Supplemental Diesel Generation to ensure compliance with the Power Sales Agreement.

It is well known from historical lake levels and Ketchikan load profiles prior to the installation of the STI transmission line that Swan Lake does not have the capacity to meet the Firm Power Requirements of Ketchikan without Additional Dedicated Output from Tyee. On a typical year, Tyee Lake has capacity to provide Additional Dedicated Output. Pursuant to the PSA and with consideration of the current conditions, SEAPA coordinated with KPU to minimize overall use of diesel, maximize utilization of Swan Lake's output and avoid future spill. The outcome of coordinating KPU Supplemental Diesel Generation is discussed below with reference to the figure below.

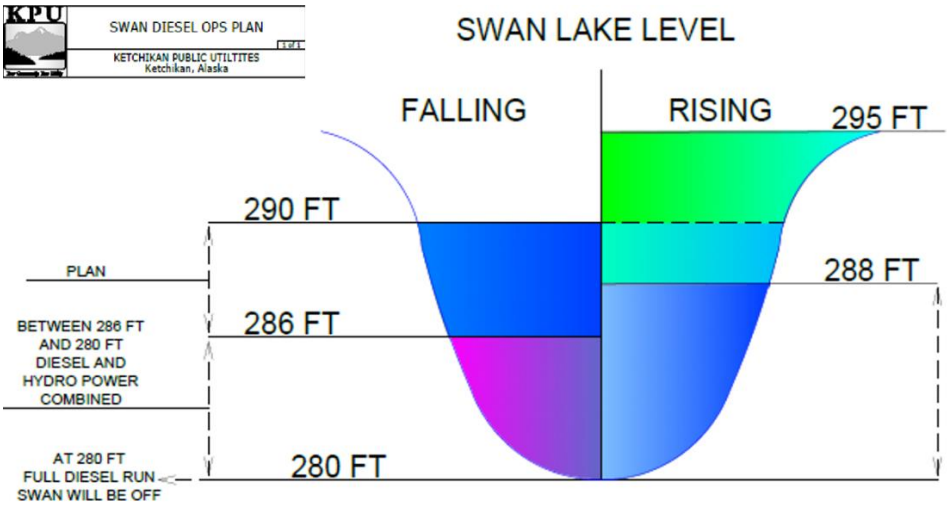

Figure 8: KPU Swan Diesel Ops Plan

During a drafting period of Swan Lake (typically early Spring), at an elevation of 286ft, KPU may utilize supplemental diesel generation to slow the draft rate at Swan Lake until the Draft Limit of 280ft is reached. Once the Draft Limit of 280ft has been reached, Swan Lake generators may remain off and KPU may utilize full diesel generation to meet Ketchikan's Full Power Requirements until an elevation of 288ft is reached. During a rising recovery period, KPU diesel generation shall be terminated at elevation 288ft and Swan Lake shall be utilized to meet the Firm Power Requirements of Ketchikan if Swan Lake has generating capacity to do so. At elevations above 288ft, SEAPA may utilize Swan Lake for balancing lakes to maximize utilization and optimize output by sending power from Swan Lake, across the STI, to Petersburg and Wrangell. Consideration of net annual Dedicated Output of Swan Lake to Ketchikan as shown in Table 2 shall be used to ensure the net annual Dedicated Output (total MWhrs) from Swan Lake is delivered to Ketchikan.

Tyee Lake Reservoir Plot (Operations Plan)

The 2019 Tyee Lake reservoir model (Figure 9) demonstrates 3 case scenarios, a guide/curtailment curve and a sales curve. All models represent Petersburg and Wrangell loads only, with three inflow cases. The Tyee 2018 inflow case with average loads represents the guide curve and will be considered as a curtailment curve. If Tyee Lake elevations fall below this curve (red line), Additional Dedicated Output will be considered unavailable and sales from Tyee to Ketchikan will be curtailed. Tyee will remain curtailed until Tyee Lake levels have reached the sales curve (green line). The area between the Sales curve and curtailment curve is considered the Tyee Operations Band. Once the elevation of Tyee Lake has reached the sales curve (green line), Additional Dedicated Output will be made available to Ketchikan for as long as Tyee Lake levels remain above the curtailment curve (red line). This Operations Plan is extremely conservative, using 2018 low inflow data and will maintain 30 feet in Tyee lake at maximum draft.

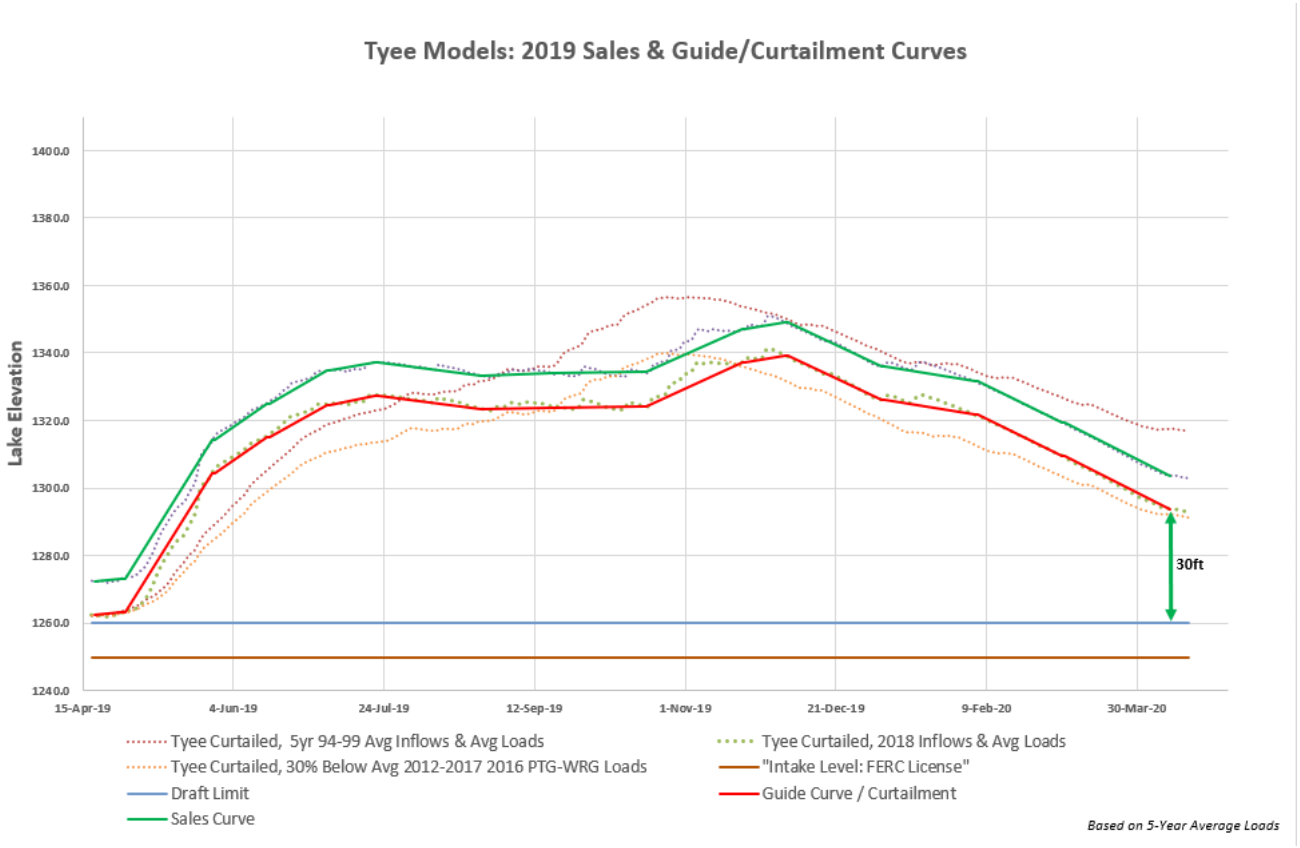

Figure 9: Tyee Lake Reservoir Plots

Optimizing Water Resources

Tyee Lake Draft:

Optimizing water resources is important for maximizing resource outputs as required by the Power Sales Agreement (Section 5: Operations Plan) and insuring FERC licensed limits are retained. It is however also SEAPA's mission to ensure Dedicated Outputs are delivered to meet the Firm Power Requirements of the Purchasing Utilities. In February and March of 2019, continued drought conditions in conjunction with a cold front (Polar Vortex) caused increased loads and reduced inflows at Tyee. As a result, Tyee Lake approached the Draft Limit constituting a diesel campaign in Petersburg and Wrangell.

The total MWhrs produced by diesel generation in Petersburg and Wrangell was 7,010 MWhrs. Combined with the 3,000 MWhrs that were sent from Swan Lake, Tyee Lake had a deficit of 10,010MWhr to meet the Firm Power Requirements of Petersburg and Wrangell. At an average of 415MWhr per foot of lake (at low levels), Tyee Lake would have required 24 additional feet of water to meet the Firm Power Requirements of Petersburg and Wrangell. The curtailment curve in Figure 9 illustrates utilizing a worst-case scenario (a repeat of 2018). For this inflow case, Tyee will have 30 feet of water in the lake at maximum draft. Because the models do not include Additional Dedicated Output from Tyee, which is typically used to modulate (balance) the lake, it is important to ensure that a deficit of 24 feet as realized in the winter of 2019 does not occur again in the late winter of 2020. The curtailment curve in this plan (red line) ensures diesel operations in Petersburg and Wrangell will not be required in the late winter and early spring of 2020.

Swan Lake Spill:

The maximum Swan Lake reservoir height was raised from elevation 330 ft. to elevation 345 ft at the end of 2016. Calendar year 2017 was the first year that the benefits of this effort were realized. In September 2017, Swan Lake reached an elevation of 335.8 ft. This added 3,723MWh of energy captured, that would have otherwise been lost to spill. With recent water conditions, the energy captured in 2017 has already and will in the future continue to displace Diesel Generation (up to the maximum energy captured). Similar to that of the 2018 Ops Plan, SEAPA plans to operate Swan Lake above elevation 330 ft. in the following manner:

- Elevations 330 ft. to 339 ft. - Both generating units will be fully available and the vertical gate will be operable. Water will be stored for future use.
- Elevations 339 ft. to 342 ft. - Both units will operate to their highest levels that loads permit to draft the reservoir back down to 339 ft. or below; this will most likely occur in spring and fall and assist with refilling Tyee Lake as increasing Swan Generation will reduce Tyee Generation for a given SEAPA delivery schedule.
- For the first few years, water above elevation 342 ft. will be immediately spilled by automatic operation. At elevation 335.8 ft. as seen in September 2017, there were little signs of Flashboard leakage. Testing is still required at higher elevations. Flashboards automatically release at elevation 347 ft.

Emergency Operations Plan Deviation

Deviation from this Operations Plan by SEAPA or a Member Utility shall not be permitted except under the following circumstances:

- Safety concerns whereas any human life is at risk of injury or death
- Declaration of an emergency by a Member Utility whereas immediate action is required to prevent rolling blackouts
- Equipment damage concerns whereas immediate action is required to prevent damage to SEAPA or Member Utility equipment or assets
- Supermajority vote of the Board of Directors dictates otherwise

In the event of a deviation, a Special Board Meeting shall be held as soon as practicable to discuss necessary actions. If a non-emergency deviation is requested by SEAPA or Member Utility, a Special Board Meeting shall be held for approval prior to any deviation.

Communications

SEAPA's Operations Manager is the primary point of contact for SEAPA operations. If the Operations Manager is not available, a designee will be assigned. For the purposes of Tuesday Operations Calls and disseminating information regarding SEAPA operations to respective Member Utility communities and prominent leaders, each respective Member Utility shall assign a primary point of contact. The primary point of contact or designee shall be provided to SEAPA. All SEAPA communications regarding Operations shall be routed through each Member Utility's established primary point of contact or designee. The Member Utility's primary contact will be responsible for disseminating information to the Tuesday Operations Call group and any other respective community leader as each Member Utility deems appropriate.

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2019 Revised Operations Plan Summary

Section 5 of the Long-Term Power Sales Agreement provides the following:

> **Operations Plan Development.** … The objectives of the Operating Plan shall include maximizing the utilization of the output of the Agency Facilities and optimizing the output of the Agency Facilities in order to serve the Purchasing Utilities' Firm Power Requirements as set forth pursuant to this Agreement, through the use of water management and other efficient dispatch procedures adopted by the Agency, subject to Dedicated Parties' priority access to Dedicated Output. … [Emphasis added]

For the reasons demonstrated in the proposed Operations Plan and pursuant to the Power Sales Agreement, SEAPA staff proposes guide/curtailment curve elevations be used by the scheduling group as guides. If lake levels fall below the guide curves, SEAPA will manage water resources, in consideration of current conditions, with an overall objective of restoring lake levels to their respective guide curves. As lake levels approach the annual minimum Board-approved draft limits (Tyee: 1260 ft. and Swan: 280 ft.), SEAPA and the dedicated resource holder(s) will enter into discussions as to whether curtailments will be issued by SEAPA. Guide curve elevations and minimum draft limits for Swan Lake and Tyee Lake are listed in Figure 7 and Figure 9 and correspond with the table below.

SEAPA 2019 Revised Operations Plan Guide Curve Values

Mth/Day	4/18	4/28	5/28	6/15	7/5	7/21	8/25	9/18	10/18	11/20	12/4	1/5	2/6	3/5	4/10
SWL Guide Curve Elevation (ft)	294	293	295	298	298	296	293	296	294	298	296	298	291	291	285
TYL Guide/Curtailment Curve Elevation (ft)	1262	1263	1304	1315	1324	1327	1323	1323	1324	1337	1339	1326	1321	1309	1290

For reference, past Operations Plan minimum draft limits are listed below. With the predicted low inflows for CY2019, the proposed 2019 Operations Plan proposes that Swan Lake and Tyee Lake draft limits be 280ft and 1260ft respectively.

SEAPA Historical Draft Limits						
	2014	2015	2016	2017	2018	2019
Swan Lake	275 ft.	285 ft.	275 ft.	273 ft.	273 ft.	280 ft.
Tyee Lake	1265 ft.	1280 ft.	1270 ft.	1261 ft.	1261 ft.	1260 ft.

Please consider the following suggested motion:

SUGGESTED MOTION
I move to approve the SEAPA 2019 Revised Operations Plan as presented in the April 22, 2019 Board packet.