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Aspect CONSULTING

MEMORANDUM

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To: Pete Stoltz, CalPortland Company

cc:

From: Owen Reese, P.E., Aspect Consulting, and
John Small, PLA, Anchor QEA

Re: **Summary of Cumulative Effects of DuPont Mining and Restoration Projects on Aquatic Habitat, Surface Water and Groundwater**

This document presents a summary of the cumulative effects of two proposed projects in the Sequalitchew Creek watershed: South Parcel Mine Expansion and Sequalitchew Creek Restoration. This summary focuses first on aquatic habitat, and then on the related surface water, water quality, and groundwater analyses that informed the aquatic habitat analysis. The emphasis is on presenting results, rather than describing the details of the methodologies used.

Overview of Projects

Mining Project

CalPortland's proposed South Parcel Mine Expansion would expand and extend the life of their existing DuPont mine by extracting 30 to 40 million tons of sand and gravel from a 177-acre parcel, termed the "South Parcel", adjoining the existing mine. Groundwater levels in the South Parcel are higher than in the existing mine. A dewatering system is proposed to capture groundwater upgradient of the South Parcel, allowing mining activity to be performed in dry conditions. The dewatering system would change area groundwater levels, including groundwater levels below Edmond Marsh and the upper portion of the Sequalitchew Creek ravine.

Restoration Project

The Sequalitchew Creek Restoration Plan ("Restoration Plan") seeks to restore and enhance streamflow and ecological functions from Sequalitchew Lake through Edmond Marsh into Sequalitchew Creek Canyon. Restoration of Sequalitchew Creek is necessary because of almost two centuries of human manipulation. Today portions of Sequalitchew Creek are dry, and the majority of what would be the natural flow in the creek is diverted out of the system. The Restoration Plan has been developed to sequentially restore diverted flows back to the creek, improve the sustainability of flows through the system, and restore aquatic habitat by removing flow-related fish passage barriers and increasing the habitat available to aquatic species.

Benefits and Impacts of Mining and Restoration Projects

Benefits

The cumulative effects of the mining and restoration projects on the Sequalitchew Creek watershed would be a reversal of fortunes for a mistreated creek. The benefits would be noticeable over a large portion of the stream and wetland habitats in the basin, and would largely restore lost ecosystem functions. The reconnection of Sequalitchew Creek to its historical primary source of flow, Sequalitchew Lake, addresses the root cause of the primary historical impacts to the system.

These projects have the potential to restore an annual average of 11.5 cfs to a 1,200-foot reach of Sequalitchew Creek that currently experiences little to no consistent flow. Seasonally, the flows in this reach are predicted to be between 2.6 cfs in August up to just over 23 cfs in April (Figure 1). Flows of this magnitude would re-establish a functioning stream in the now frequently dry channel, providing new aquatic and riparian habitat and a connection between the Sequalitchew Creek ravine and the marshes. This would provide a corridor for both aquatic and terrestrial species and provide new opportunities for species expansion and recovery.

In the Sequalitchew Creek ravine, the restoration and mining projects would result in a 7-fold increase in flow on an annual average basis, from the current 1.7 cfs up to 11.9 cfs. Peak flows could reach up to 60 cfs, sufficient to restore the natural channel-forming processes necessary to improve habitat conditions in the ravine. Currently, the flows in the ravine are inadequate to move sediment effectively, create pools, or scour finer-grained materials from the substrate to create conditions suitable for spawning. Peak flows could be adaptively managed by adjusting the weir at the diversion canal to prevent flooding or excessive flows through the wetlands or the stream channel.

The restoration project would also raise the water level and increase the size of Hamer Marsh, remove fill and improve aquatic habitat conditions at the Lake Outlet Area, and reconnect East and West Edmond Marshes by replacing a portion of the earthen trail separating the marshes with a pedestrian bridge. Conditions in much of the marsh today favor a scrub-shrub plant community. Restoration would affect the conditions sufficiently to allow more establishment of emergent vegetation in western extent of the complex where inundation will persist through more of the growing season. Restoration would also reduce minimize fluctuation in water surface through the growing season near the railroad grade, allowing enlargement of the forested wetland community. These effects would increase the diversity and complexity of habitats.

The increased flow through Edmond Marsh would also increase dissolved oxygen and reduce elevated iron concentrations in the center of the marsh, improving water quality in the marshes.

Impacts

Increasing the surface-water gradient between Sequalitchew Lake at the top of the ravine to restore the natural flow regime to the Sequalitchew Creek watershed, in combination with lower groundwater levels resulting from mining, would result in several impacts: a reduction in wetland area, increase in summer stream temperatures, and increased frequency of periods of low flow in summer.

Water levels in Sequalitchew Creek Marsh and Edmond Marsh would be adjusted to promote flow through the marshes (Figure 2), resulting in a shift from wetland habitats to wetland buffer habitats affecting up to 29 acres. This would also reverse a trend observed over the last several decades wherein wetlands have grown larger and deeper as a result of beaver activity.

Water originating from Sequalitchew Lake is warmer than the groundwater spring discharges that form the majority of flow in the Sequalitchew Creek ravine, because it is warmed by the sun as it flows slowly through the lake. The project would return flows in the ravine to a surface-flow dominated condition similar to what was present historically in the ravine. With the increased surface flow, warmer stream temperatures could approach or exceed biological criteria for Coho salmon during much of the spring and summer months (Figure 3).

Finally, during extended dry periods (when outflow from Sequalitchew Lake is typically low or non-existent), streamflows in the ravine would be lower than existing conditions. These dry periods are predicted to occur about 9 percent of the time, typically in August and September in particularly dry years. Flows during these periods currently average 0.63 cfs and do not provide aquatic habitat for anadromous fish. The average flows during these dry periods following mining and restoration is predicted to be 0.25 cfs.

Cumulative Effects Analysis

This section presents results of cumulative effects analyses for Sequalitchew Creek, then the wetlands, and finally groundwater and the intertidal springs. Each section is organized to discuss aquatic habitat first, followed by water quantity, then water quality.

Sequalitchew Creek

The combined effects of the mining and restoration projects on stream habitat would include a reestablishment of flow from Sequalitchew Lake through the marshes and into Sequalitchew Creek ravine. The projects would also result in reestablishing the ecosystem process, specifically, the movement of water, sediment, nutrients, biota, and dissolved gasses through the watershed from the headwater springs on Sequalitchew Lake to Puget Sound. This would allow greater ecosystem productivity to take hold in the creek as the stream energy necessary to create and maintain habitat is restored.

Reestablishment of peak flows and the associated sediment movement is key to restarting the arrested habitat-forming processes downstream of Edmond Marsh. Currently, even where flows persist perennially, they are inadequate to move sediment effectively, create pools, or scour finer-grained materials from the substrate to create conditions suitable for spawning. The input of sediment and organic matter will stimulate biological productivity and develop greater resources at the lower trophic levels. Restoration would also result in pool and riffle habitat formation over time. This habitat and development of lower trophic productivity are key to developing conditions sufficient to restore target species such as Chum and cutthroat trout in the system. Chum will also benefit from the restoration of a more varied hydrograph. Puget Sound stocks typically spawn in freshwater systems in November and December as flows rise in response to winter rains. This effect has been limited in the system due to the current lack of surface water connectivity.

Flow

The cumulative effect of the Mining and Restoration projects on streamflow was evaluated by predicting streamflows at two locations: in the dry reach between West Edmond Marsh and Sequalitchew Creek ravine, and in Sequalitchew Creek at the mid-ravine gage (formerly termed the "upper gage").

Dry Reach

Under existing conditions, the dry reach currently experiences no consistent flow passing through the entire reach. The bottom of the dry reach is above the current groundwater levels, so ground infiltration in the dry reach would not be affected by lowering of groundwater with mining.

The Mining and Restoration projects are predicted to result in an average flow of 11.5 cfs in the dry reach. The flow would vary seasonally from a monthly average of 2.6 cfs in August to 23.1 cfs in April as shown in Figure 1. Peak flows could be as high as 60 cfs, if all water is routed through the wetlands during peak flow events. To avoid flooding during peak flows, the highest flows could be directed to the Diversion Canal. The results presented here do not account for the diversion of peak flows.

After the projects are completed, there would be periods when water would not flow from West Edmond Marsh or in the dry reach. Post-project model results, based on hydrologic conditions observed over the 13-year period of record, indicate that water would not flow through the dry reach due to dry conditions on 241 days (or 6.4 percent of the time). These dry periods were predicted to last for multiple weeks and occurred in three of the 13 years simulated by the model (2004, 2005, and 2015).

Streamflow in the dry reach was calculated by adjusting the daily average outflows from Sequalitchew Lake from 2003 to 2015 by the estimates of the gains or losses that would occur in the wetlands based on the results of the water balance model summarized in the wetland section below and presented in detail in Aspect Consulting (2016b, in prep). The dry reach was assumed to have a sealed bed under restored conditions (either naturally or through contingent actions), so no gains or losses were assumed to occur in the dry reach.

Sequalitchew Creek at Mid-Ravine Gage

After passing through the dry reach, streamflows would enter the Sequalitchew Creek ravine. The vast majority of flow would originate from Sequalitchew Lake, but there would be contribution from springs within the ravine.

Streamflows in Sequalitchew Creek ravine were predicted at the mid-ravine gage location for comparison with the existing gage record. Streamflows were predicted by starting with the flows predicted for the dry reach, as described above, and adding in the observed spring flow occurring in the upper portion of the Sequalitchew Creek ravine adjusted to account for the effects of mining.

Spring flow in the upper reaches of the Sequalitchew Creek ravine would be affected by the lowered groundwater levels associated with mining. The groundwater model results for Step 4 of dewatering, the long-term condition that would persist after active dewatering has ceased, predict a reduction in spring flow of 77 percent, varying from 73 percent in January to 86 percent in summer. The reduction in spring flow was accounted for by scaling the average daily flow records from the mid-ravine gage record by the corresponding monthly percent reductions in spring flow. The scaled-down spring flow was then added to the predicted dry reach flow to create the predicted flow at the mid-ravine gage after mining and restoration.

On average, flow in Sequalitchew Creek at the mid-ravine gage would generally be similar to, but slightly higher (i.e., 0.4 cfs greater) than the flows in the dry reach, reflecting the input of spring flow. The annual average flow at the mid-ravine gage would be 11.9 cfs. Monthly average flows would range from 2.7 cfs in August to 23.7 cfs in April as shown in Figure 1. Peak flows would be generally the same magnitude (~60 cfs) as in the dry reach.

There would be periods when the cumulative effects of the mining and restoration projects are predicted to result in a reduction in flows at the mid-ravine gage when compared with the observed existing condition. Post-project flows are predicted to be lower during 38 periods, lasting a total of 349 days over the 13 years evaluated, or about 9 percent of the time. During 17 of those days, there would be no flow at the mid-ravine gage. Under observed existing conditions, there were 7 days with no measurable flow at the gage.

The median duration of a period when flows would be lower with mining and restoration (hereafter referred to as a "lower flow event") was 3 days, but there were 6 lower flow events lasting more than two weeks long. The longer events occurred in three of the 13 years simulated (2004, 2005, 2015). The longest single lower flow event was 57 days ending in August 2015. However, lower flow events dominated the summer and fall of 2005, when there were 5 lower flow events between July 15 and December 23 lasting a total of 139 days. Lower flow events occurred most commonly in July, August and September, but occasionally occurred all months except March and April. The average streamflow during lower flow events was 0.7 cfs under existing conditions and would be 0.4 cfs post-projects. The decrease in streamflow during lower flow events ranged from 0.1 cfs up to 0.6 cfs.

Sequalitchew Creek Temperature

The Mining and Restoration projects would affect stream temperature in the Sequalitchew Creek ravine by introducing a large quantity of surface water from Sequalitchew Lake. The effects would vary seasonally as the volume of water from Sequalitchew Lake and its associated temperature varies. In summer, the outflow from Sequalitchew Lake is warmer than Sequalitchew Creek; in winter, it is colder.

Sequalitchew Creek would experience warm temperatures in June, July and August, with temperatures reaching up to 21 °C and cool temperatures in winter, down to 5 to 6 °C as shown in Figure 3. The predicted stream temperatures would be considerably warmer than the current spring discharge in the creek for most of the year. The surface water quality criterion for temperature applicable to Sequalitchew Creek is 16 °C for the seven-day average of daily maximums. The analysis based on grab samples suggests that this threshold may be exceeded from May through September (see Figure 3).

Historically, the stream temperatures in Sequalitchew Creek were likely closer to those observed today in the lake outflow, and the steady, cool temperatures currently observed in the ravine reflect the proportionally greater input of groundwater resulting from diversion of the lake outflow from the system.

The change in stream temperature was evaluated quantitatively on a monthly basis by using a linear mixing equation with the observed temperatures for Sequalitchew Lake (with 1 °C added to account for warming in the marshes) and Sequalitchew Creek, and the estimated future flow rates from each source. Monitoring results indicate the temperature in the marshes is generally similar to Sequalitchew Lake, so adding an extra degree to allow for potential warming is conservative.

Wetlands

The Sequalitchew Marsh wetland complex has increased in size by around 30 acres since the late 1990s when efforts to maintain a channel through the system were abandoned and beaver dams began to raise water levels, preventing flow from reaching the ravine and redirecting nearly all flow to the Diversion Canal. A fundamental goal of the Restoration Plan is to direct flows from the Diversion Canal back down Sequalitchew Creek. This requires restoring the historic gradient from the outlet of Sequalitchew Lake to the top of the ravine. This will necessarily require a lowering of water levels in some parts of the wetland complex resulting in a reduction of wetland acreage.

During the stakeholder process the tradeoff between wetland impacts and creek flow was considered and the stakeholders recommended an aggressive approach to increasing gradient to improve creek flows over a less aggressive approach to maintain wetland acreage and potentially sacrifice some creek flow. The restoration of flow using flexible levelers in beaver dams would limit the losses of wetland area and wetland function relative to the approach used in the 1980s when an open channel was maintained through the system. Wetland conditions in the 1980s are representative of a more aggressive approach to maintain the gradient and flow through the system. Aerial imagery and wetland delineations from around that period are useful in understanding the habitat conditions at the extreme of effects that could occur as a result of the restoration project. A review of aerial photos from 1981 indicates approximately 99 acres of wetland area in Edmond Marsh, when the open channel was maintained. Aerial photos from 2015 indicate the wetland area has grown to 128 acres as beavers have blocked the channel and raised water levels. The difference (29 acres) provides an estimate of the amount of wetland area that may experience a shift in hydrology sufficient to affect the presence of wetland hydrology or promote the succession of vegetation to species that are more common in upland areas than within wetlands.

Some wetland and lake fringe habitats would be gained. Raising water levels in Hamer Marsh would compensate for some wetland loss by increasing the acreage of Hamer Marsh by approximately two acres. Removing fill from portions of Sequalitchew Creek Marsh and Edmond Marsh would also compensate for some wetland loss and more importantly improve connectivity and function in the wetland.

Wetland functions and values have been quantified using metrics developed by the Washington State Department of Ecology. These include wetland rating scores and a hydrogeomorphic assessment methodology. Predictions of the effects on habitat, water quality and hydrology were reviewed against the scoring criteria. In general, the changes related to the cumulative effects of mining and restoration were not sufficient to change scores. Of note is that the restoration of flow between Edmond Marsh and the ravine provides much greater opportunity to provide benefits of these wetland functions and values to existing habitats in the ravine, brackish marsh, and stream delta.

Cumulatively, the wetland restoration project and mine project change the existing hydrologic condition resulting in a net shift over time of up to 27 acres of wetland habitats to wetland buffer habitats. Comparing existing wetland acreage to conditions in the 1980s, when every effort was made to channelize the wetlands to improve flows and no effort was made to maintain wetland acreage in the system, likely provides a conservative estimate of potential wetland loss that could result from the projects. Careful management of flexible levelers would minimize the lost wetland acreage, allow for a greater diversity of wetland habitats in the complex, and most importantly develop greater ecosystem connectivity.

Wetland Water Levels

As outlined in the Restoration Plan, reconnecting flow from Sequalitchew Lake to the Sequalitchew Creek ravine will require lowering water levels in the marshes in between in order to establish a consistent downhill gradient. Currently, the water levels in Sequalitchew Creek Marsh and East Edmond Marsh are higher than the typical lake level of about 211.5 feet, preventing any outflow from the lake from reaching the marshes. Initial restoration planning (SPSSEG 2014), recommended target water levels for Sequalitchew Creek Marsh, and East Edmond and West Edmond Marshes of about 210.5, 209, and 206.5 feet, respectively.

These target elevations are significantly lower than the current water levels in these marshes. A comparison of the existing and future marsh water levels is shown in Figure 2. The target water levels of the Mining & Restoration scenario achieve a difference in water surface elevations of 5 feet between the lake (typically 211.5 feet) and West Edmond Marsh (target elevation 206.5 feet). Over the 8,700-foot flow path through the marshes these water levels would result in a hydraulic gradient of 0.0006 feet per foot. This is a very low gradient, and streams in systems with similar gradients are typically a coupled marsh/channel or in systems with higher sediment loads, multiple threaded channels. One or more broad (20+ feet), shallow (< 2 feet) channels at this gradient would have sufficient capacity to convey the peak outflows from Sequalitchew Lake. Flow velocities in this system would be low (<1 foot per second).

The results of a water balance model, developed for the marshes to evaluate the combined effects of the restoration and mining projects, indicate that there would be little variation in wetland water levels with the projects, as there would almost always be more than enough flow from Sequalitchew Lake to keep the wetlands full to their target elevations. However, there are several summers during the simulation period when water levels in Sequalitchew Creek Marsh would dip below the target elevations for a month or more. East and West Edmond Marshes would also experience occasional dips below the target elevation, but of lesser magnitude and much less frequently. The hydraulic gradient through the marshes would always be maintained, however, as the water level in Sequalitchew Creek Marsh never dips below the water level in East Edmond Marsh.

A second key output of the water balance model is an understanding of the gains or losses in flow that would occur as it passes through the marshes. As water travels through the marshes, it would still be subject to potential gains from precipitation, stormwater inflows, or discharge from groundwater, and losses to evapotranspiration or infiltration.

Model results indicate that most months of the year (October through June), the wetland system would add a small amount of water to the flow from Sequalitchew Lake, ranging from 1 percent in

June up to 16 percent in December. However, in the summer months of July, August, and September, some flow would be lost in the wetlands to evapotranspiration or infiltration. Losses range from 11 percent in September up to 20 percent in August. The magnitude of the summertime losses is smaller (typically -0.3 to -0.6 cfs) than the wintertime gains (typically 1 to 1.5 cfs), they occur at times when less water is present in the system. These monthly average losses were used in the predictions of streamflow in the dry reach and Sequalitchew Creek ravine described above.

The water balance model simulates the individual hydrologic processes that effect the wetlands, including precipitation, evaporation, surface inflows and outflows, subsurface flows, and groundwater recharge and discharge. The model predicts water level conditions on a monthly basis from 2004 to 2015, representing a range of climate conditions. The model was calibrated to observed water levels over that period, and was able to closely reproduce the water levels, typically matching the observed water levels within 2 to 3 inches. For all wetlands, the model was able to reproduce the seasonal pattern of water levels and capture differences between wetter and drier years (e.g., the model accurately simulated years where West Edmond Marsh was completely dry in summer versus years where some water remained). Generally, the model fit is best for Hamer and West Edmond Marshes and weakest for Sequalitchew Creek Marsh. The calibration is particularly strong in the first 8 years, before a decrease in the quality of data collection at the NWS Coop weather station used as the source of precipitation data. Additional details about the development and use of the water balance model are presented in Aspect Consulting (2016b, in prep).

Wetland Water Quality

The proposed mining and restoration projects would benefit the water quality in Sequalitchew Creek Marsh and Edmond Marsh by providing a high volume of high quality water. The anticipated changes were evaluated qualitatively by comparing the water quality conditions in the outflow from Sequalitchew Lake with water quality conditions in the marshes.

With the mining and restoration projects, the residence time in the wetlands would reduce significantly, decreasing from weeks to months, to days. Water quality in the wetlands would be dominated by the input from Sequalitchew Lake. As a result, dissolved oxygen would be higher, and the pH slightly more neutral. Temperature and turbidity have been about the same in the lake and marshes, so little change would be anticipated.

It is anticipated that the elevated iron concentrations observed in the center of Edmond Marsh would be resolved through flushing and dilution with Sequalitchew Lake water. The iron concentration in the outflow from Sequalitchew Lake was measured at 0.13 mg/L, well below the elevated levels of 3 to 5 mg/L concentrations observed in Edmond Marsh near the railroad trail bridge and related seeps. There is no state water quality criterion for iron in surface waters, but British Columbia has established a water quality guideline for total iron of 1 mg/L in surface water (Phippen et al., 2008). The marshes receiving flow from Sequalitchew Lake could be expected to have future iron concentrations near, but slightly above the concentration observed in the lake, and below the 1 mg/L guideline established in British Columbia.

Groundwater

Intertidal Springs

The Intertidal Springs habitat is currently affected by armoring associated with the adjacent railway. The area around the springs includes rip rap and gravel beach sediments. Productivity and species abundance is much higher than in similar areas of the shoreline (including the gravel beach to the south and the armored shoreline to the north). This increase in biotic productivity can be attributed to the input of nutrients such as nitrogen into the nutrient-limited marine environment.

The anticipated change in flow from the Vashon Aquifer, based on analysis in Aspect Consulting (2015) summarized in more detail below, is relatively small and unlikely to affect habitat conditions. Changes to water quality that are limited to temperature and dissolved oxygen in the Vashon Aquifer would be unlikely to affect nearshore species or habitat.

Intertidal Springs Flow

The Intertidal Springs are an expression of the flow from the Vashon Aquifer and Sea Level Aquifer (which combine downgradient of the Olympia Beds Truncation to form the Sequalitchew Delta Aquifer) along with saltwater that intrudes into the near shore areas during high tide and flows back to the Sound at low tide. Prior analysis (Aspect Consulting 2015) indicates the relative contributions of flow from these three sources shown in Table 1.

Table 1—Sources of Flow to Large Spring

Source	Estimated Percentage of Intertidal Spring Flow
Vashon Aquifer	0.2 - 14
Sea Level Aquifer	0.8 - 49
Puget Sound	36 - 99

The restoration and mining projects would not affect the Sea Level Aquifer (as it is a confined aquifer separated by an aquitard from the areas affected by the projects), or saltwater intrusion from Puget Sound. Thus the restoration and mining projects could only effect the intertidal springs through the Vashon Aquifer, which comprises no more than 14 percent of its total discharge.

There are several mechanisms by which the restoration and mining projects could affect the quantity of flow in the Vashon aquifer:

- Evaporation from the groundwater collection system at the toe of the mine.
- Increased infiltration of stormwater generated within the mine area resulting from clearing existing vegetation (in the near term) and impervious surfaces from post-mining development (in the long-term).
- Changes in aquifer recharge in the marshes resulting from lower groundwater levels beneath the marshes (which increases recharge) and smaller wetland areas (which decreases recharge).

Qualitatively, it is likely that the net effect of these factors would be a small increase in flow in the Vashon Aquifer, and thus a small increase in both the volume of discharge from the Vashon Aquifer to the intertidal springs and the proportion of total spring flow coming from the Vashon Aquifer. Conservatively, the increase in Vashon Aquifer flow is estimated to be no more than 5 percent (based in part on results from the water balance model), which would increase the proportion of discharge from the intertidal springs originating from the Vashon Aquifer to up to 14.5 percent.

Intertidal Springs Water Quality

Mining would briefly expose and re-infiltrate the Vashon Aquifer portion of the groundwater that ultimately flows from the intertidal springs along Puget Sound. After active dewatering has ceased, during passive dewatering (Step 4), groundwater seeping from the toe of the mine slope would be exposed to the atmosphere for a couple days as it is collects in new wetland habitats, then is conveyed to an infiltration pond and infiltrated back into the ground.

The exposed groundwater is likely to increase in temperature during the summer months and decrease in temperature during the winter months as it is conveyed between the springs where it emerges at the toe of the mined slope and the pond where it will be infiltrated back into the ground and mix with the larger flow of groundwater from the Sea Level Aquifer. Exposure of the groundwater to the atmosphere is likely to increase dissolved oxygen year round.

These changes have not been evaluated quantitatively, but are anticipated to be small and would be moderated during subsurface flow to Puget Sound through contact with the large thermal mass of gravel and mixing with the substantially larger flow of groundwater from the Sea Level Aquifer. At most, any changes in water quality resulting from exposure to atmosphere as a result of mining would only affect the portion of the flow originating from the Vashon Aquifer, estimated at no more than 14.5 percent of the total spring flow with the effects of mining and restoration.

Vashon Aquifer

Change in groundwater levels

The dewatering associated with the mining project will affect groundwater levels in the Vashon Aquifer by intercepting groundwater flow as it enters the South Parcel. The effects on groundwater levels were evaluated using a groundwater model, based on 12 years of monitoring data covering a range of climate conditions. More information about the development, calibration, validation, use and predictive results of the groundwater model is provided in the *Groundwater Model Update* (Aspect Consulting, 2016a, in prep).

The project entails the following four steps:

1. Step 1 is the pumping test.
2. Step 2 is an extended pumping test and preparation for mining.
3. Step 3 is active dewatering during mining.
4. Finally, Step 4 represents all pumping has ceased and groundwater passively discharges at the toe of the newly mined slope.

The effects of dewatering on groundwater levels are greatest at the point where dewatering occurs – at the wells during the active dewatering of Steps 1 through 3, and at the toe of the mine slope for the passive dewatering of Step 4 – and decrease with distance away from those locations. Table 2 compares the maximum change in groundwater levels (i.e., the worst month out of the 12-year modeled period) at key locations for each dewatering step.

During the pumping test (Step 1), the changes in groundwater levels would be notable within the South Parcel, but would be less than 0.5 feet beneath the west end of west Edmond Marsh and would taper off from there. The model results are consistent with the primary intent of the pumping test – to confirm the predictions of the groundwater model in a completely reversible way without causing environmental impact.

Table 2 – Maximum Decrease in Groundwater Levels from Dewatering

Dewatering Scenario	Number of Wells	Maximum decrease in groundwater level in feet			
		South Parcel Boundary (CHMW-2)	West Edmond Marsh - West (EM-1)	West Edmond Marsh - East (EM-2)	East Edmond Marsh (EM-3)
Step 1 – Pumping Test	10	9	0.4	<0.1 ft	<0.05 ft
Step 2 – Preparation for Mining	24	45	1.3	0.2	<0.05 ft
Step 3 – Active Dewatering during Mining	66	60	5.2	0.4	<0.05 ft
Step 4 – Cessation of Active Dewatering	N/A	49	5	0.4	<0.05 ft

With the addition of 14 more wells at Step 2, the change in groundwater levels at the north end of the South Parcel becomes significant (45 feet) as is necessary to prepare for mining that area. This results in a maximum change in water level beneath the west end of Edmond Marsh of 1.3 feet. The effects decrease toward the central region of Edmond Marsh (0.2 feet of drawdown), and locations farther to the east (<0.05 feet).

At the peak of active dewatering (Step 3), the maximum change in water levels in the South Parcel monitoring wells would be about 60 feet – sufficient to allow for mining to the level of the Olympia Beds. The dewatering would result in a maximum change under West Edmond Marsh of 5.2 feet, tapering to 0.4 feet in the central Edmond Marsh area.

After all pumping wells have been turned off and groundwater passively discharges at the toe of the newly mined slope, groundwater levels would recover slightly – increasing along the South Parcel boundary by about 10 feet, and increasing by 0.2 feet under West Edmond Marsh. The results for Step 4 represent the long-term condition that would occur after cessation of active dewatering and would persist into the future.

The predicted contours of groundwater drawdown after cessation of active dewatering (Step 4) are shown in Figure 4. Drawdown would be approximately 4 feet near the upper reaches of the Sequalitchew Creek ravine. Beneath Edmond Marsh, drawdown would taper rapidly from 5 feet at the westernmost lobe down to 0.4 feet in the central region. Drawdown beneath the southern lakes would be between 1 and 2 feet. Drawdown would be less than 0.05 feet beneath Sequalitchew Lake, and Bell, McKay and Hamer Marshes.

The changes in groundwater levels would not have an effect on area water supplies. The City of DuPont's wells are completed in a different aquifer and the change in water levels in the overlying Vashon Aquifer would be less than 0.05 feet near the locations of the City's wells. JBLM's water supply from the Sequalitchew Springs would not be affected because it is located far from where dewatering would occur and any change in water levels, even under the worst case, would be less than 0.05 feet.

Wetland 1D and Isolated Kettle Wetlands

Wetland 1D and the isolated kettle wetlands (including Pond Lake, Strickland Lake, Grant Lake, Old Fort Lake and Wetlands #8 through #11) would potentially be affected by the change in groundwater levels associated with mining. Restoration would not have an effect on the isolated kettle wetlands. The groundwater model predicts that groundwater levels beneath Wetland 1D would decrease by 2 to 3 feet (Figure 4). Toward the kettle wetlands located further south, the model predicts about 2 feet of aquifer drawdown beneath Pond Lake decreasing to closer to 1 foot near Wetlands #8-#11. Old Fort Lake would experience 1 to 1.5 feet of groundwater drawdown.

Surface water levels in Wetland 1D and the isolated kettle wetlands have generally been identified as fluctuating with the groundwater system. Since these wetlands do not have surface water outlets, for simplicity sake, the change in surface water levels in them can conservatively be assumed to be comparable to the decline in groundwater level.

Limitations

Work for this project was performed for the CalPortland (Client), and this memorandum was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This memorandum does not represent a legal opinion. No other warranty, expressed or implied, is made.

All reports prepared by Aspect Consulting for the Client apply only to the services described in the Agreement(s) with the Client. Any use or reuse by any party other than the Client is at the sole risk of that party, and without liability to Aspect Consulting. Aspect Consulting's original files/reports shall govern in the event of any dispute regarding the content of electronic documents furnished to others.

Figures

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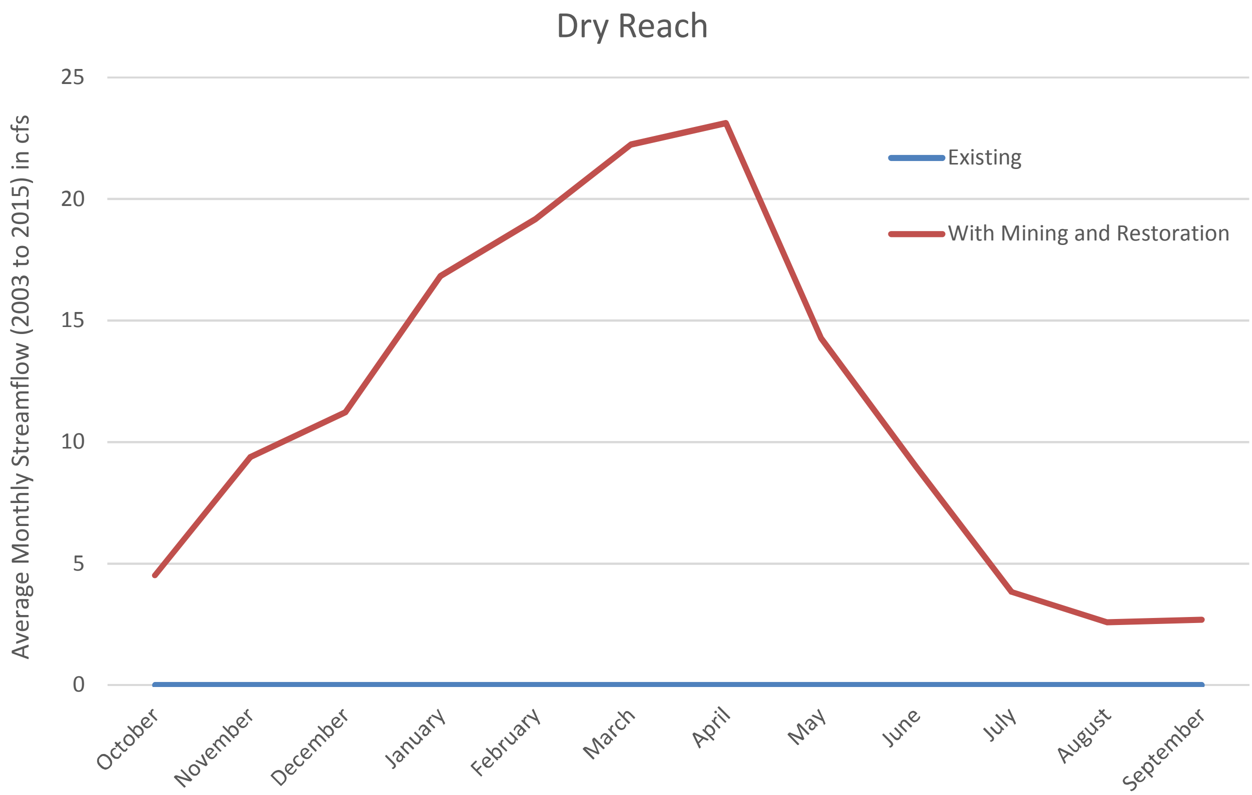

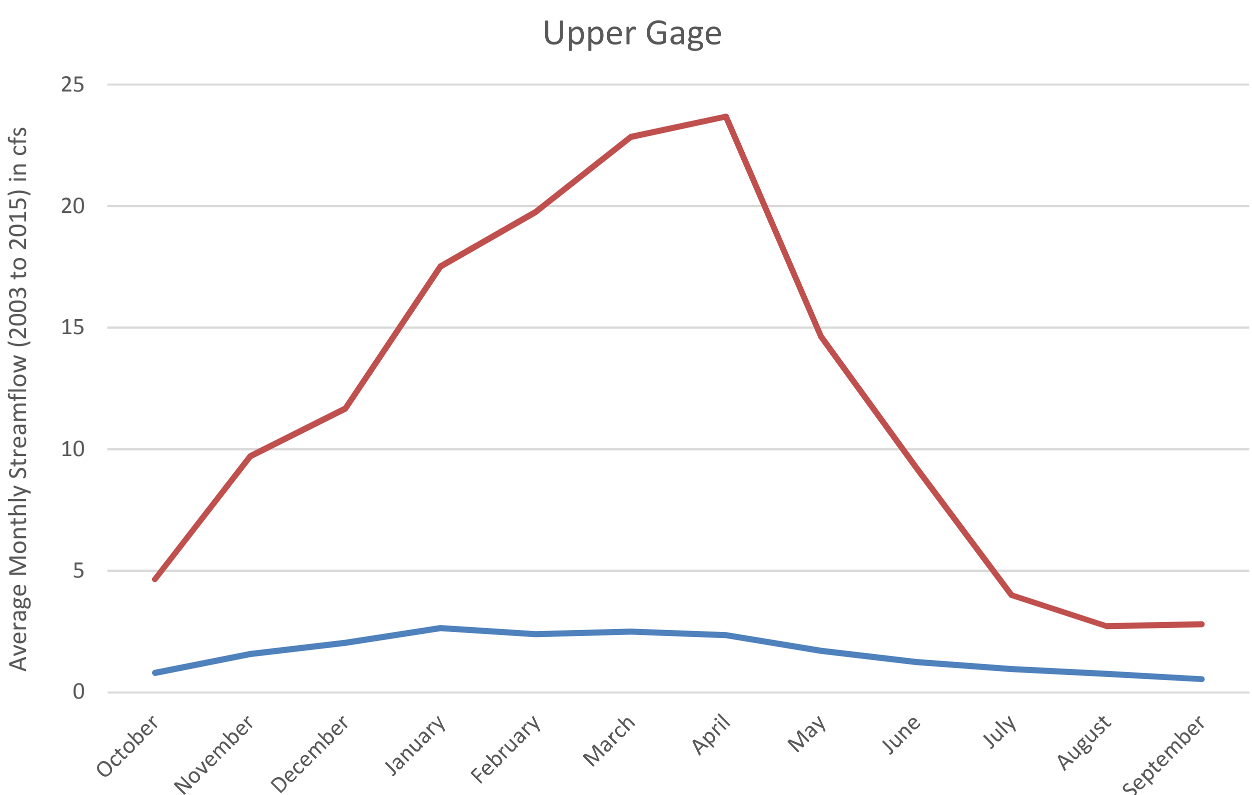

Figure 1
Predicted Annual Average Hydrograph in Sequalitchew Creek

Cumulative Effects Summary
CalPortland

Aspect Consulting
11/16/2016
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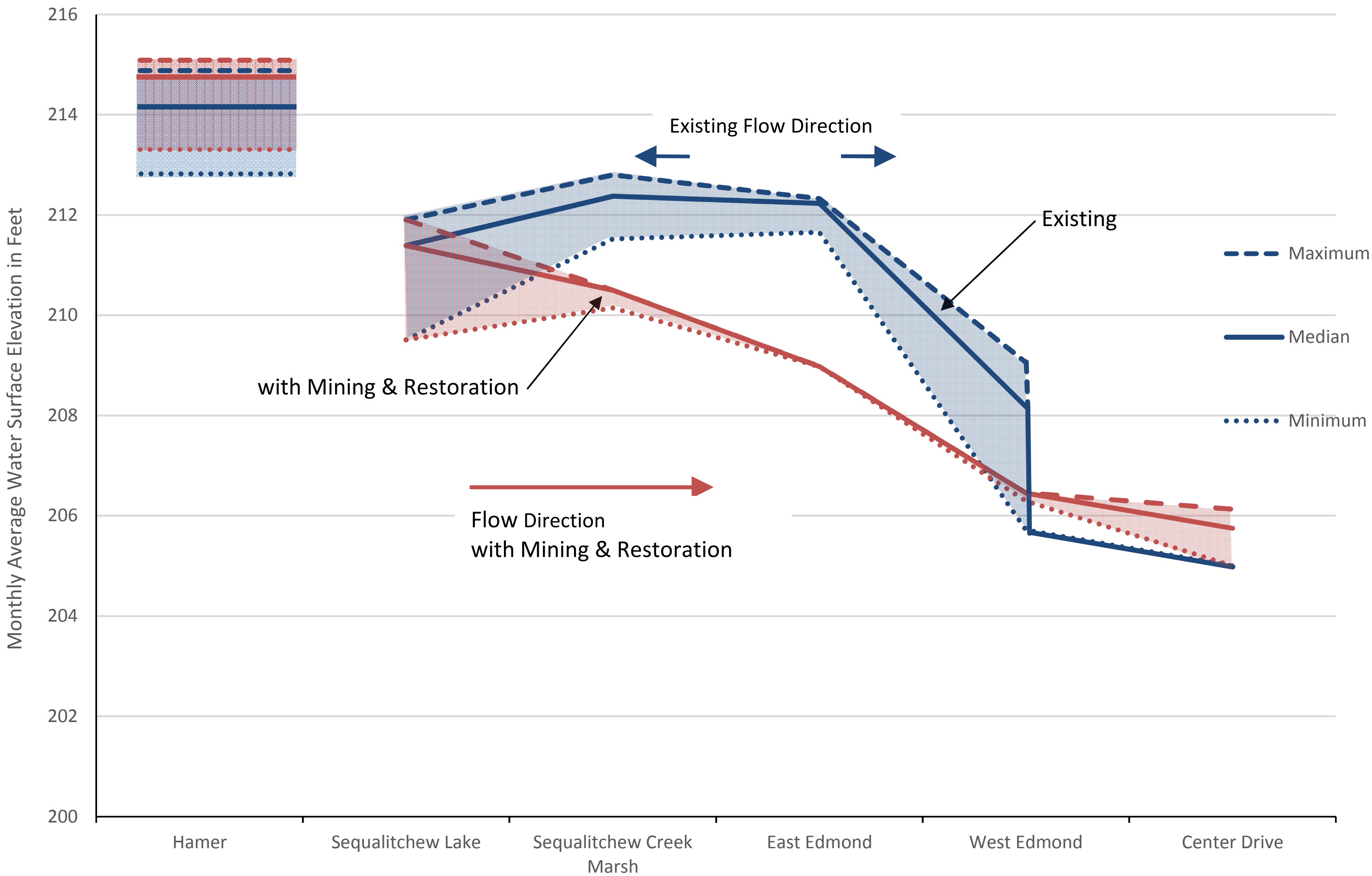

Figure 2
Comparison of Wetland Water Levels

Cumulative Effects Summary
CalPortland DuPont

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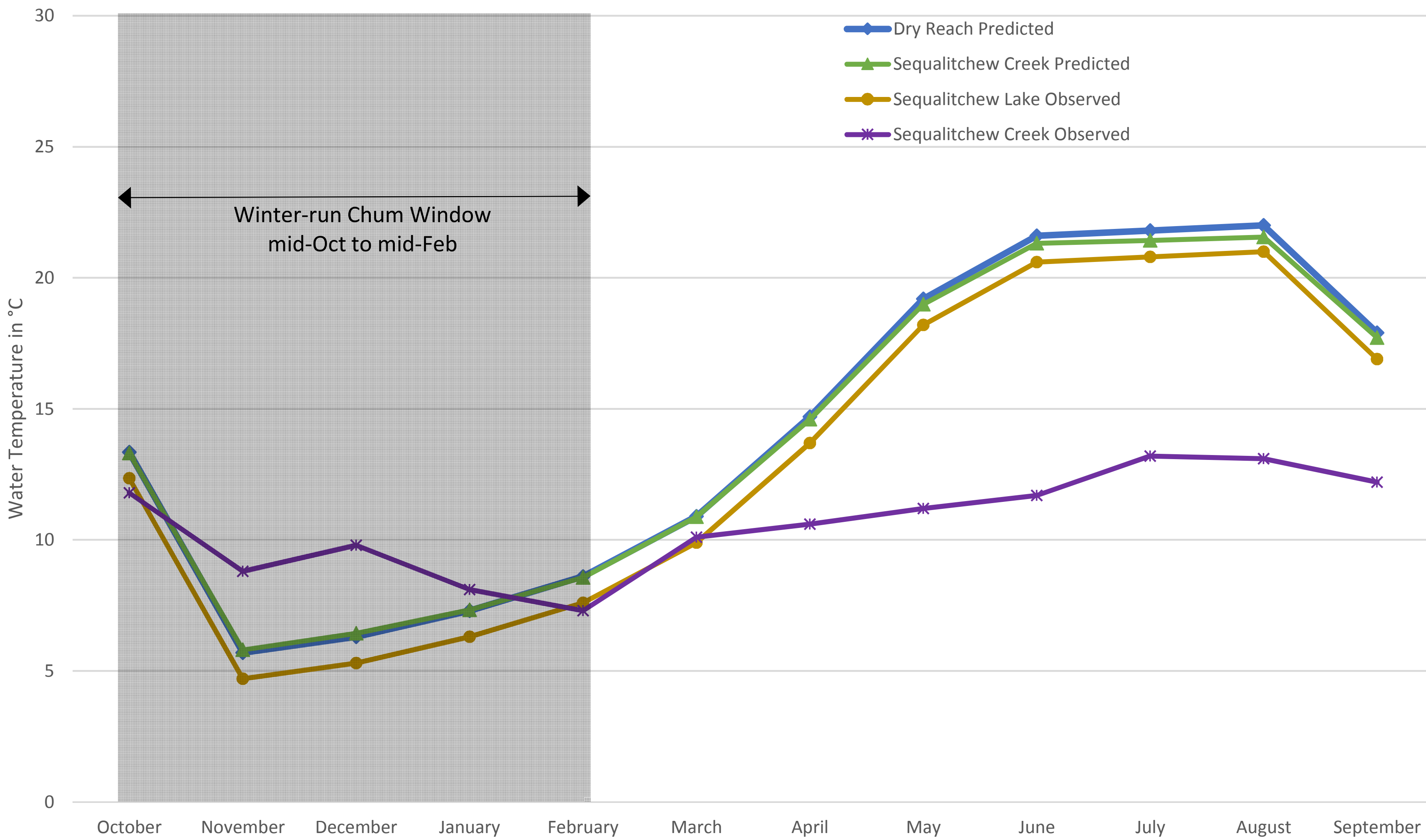

Aspect Consulting
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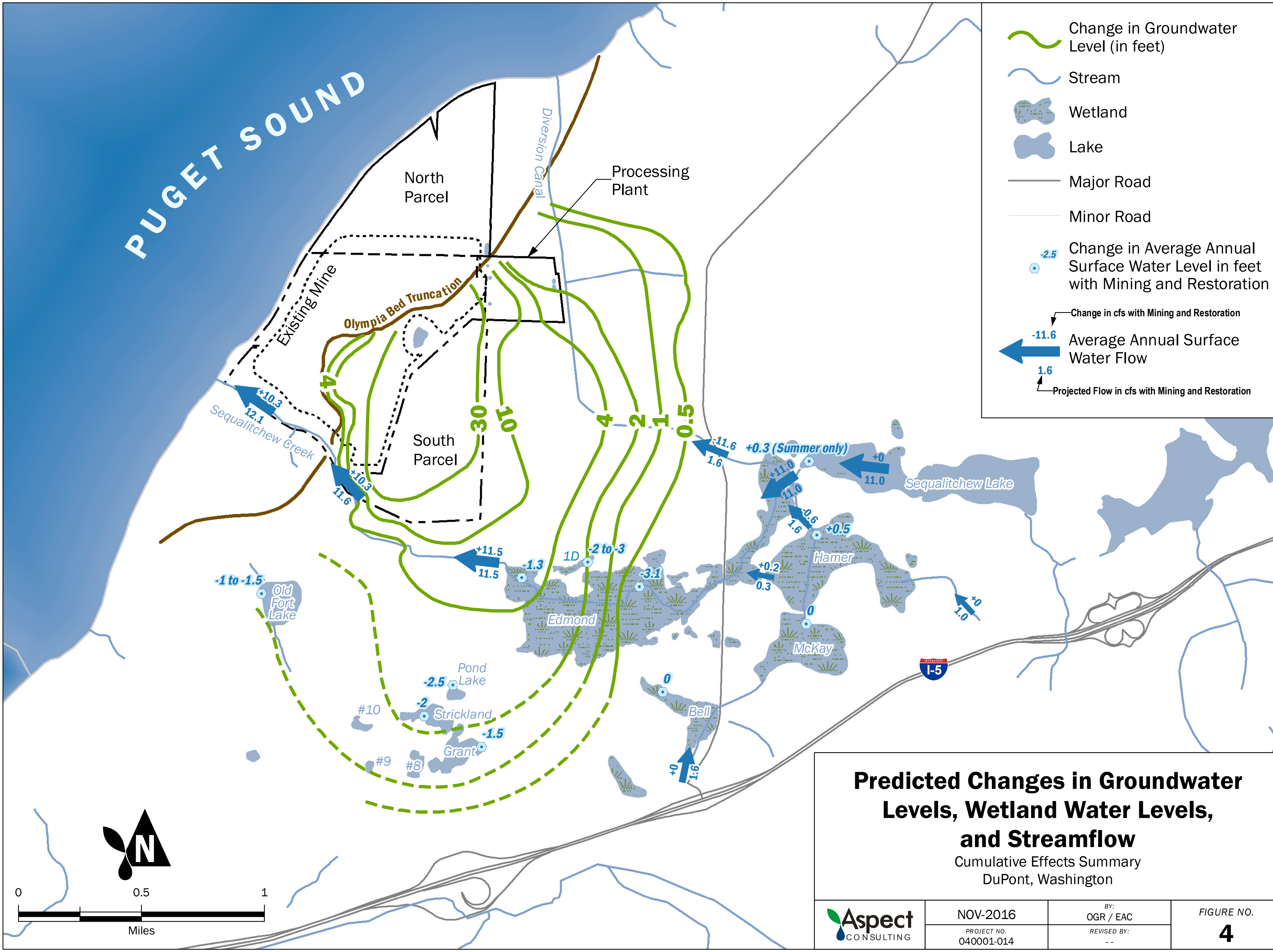
Figure 3
Predicted Effects on Stream Temperature in Sequalitchew Creek
Cumulative Effects Summary
DuPont, WA



Predicted Changes in Groundwater Levels, Wetland Water Levels, and Streamflow

Cumulative Effects Summary
DuPont, Washington

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