APPENDIX
to the
Dungeness Water Resources Planning
Recommendations Summary
Approved by DRMT: August 10, 2022

This Appendix provides further detail on the topics and associated recommendations approved by the Dungeness Water Resources Technical Group (WRTG) in the Dungeness Water Resources Planning Recommendations Summary. The topics are organized in the order they were discussed by the WRTG. Each begins with related Recommendation(s) and is followed by three subsections: Background, WRTG Comments, and References. The Background subsections generally discuss the basis for the topics and related recommendations. The WRTG Comments provide individual member views related to anecdotal information or information for further research; or they represent either policy (which is outside of the WRTG's scope) or an opinion that did not elevate to a group recommendation. The References list the works cited in respective topic write-ups, as well as sources of further information, data, studies, or relevant websites for the potential volunteer action leads, or "Resource Teams''.

A Resource Team' subject line is included for each topic, the intent being to solicit volunteer expertise and interested parties to collaborate on advancing or implementing the recommended actions associated with each topic. Some WRTG members have already added their names to these lists, but additional volunteers are needed.

6.1 UPDATED GROUND WATER CHARACTERIZATION

Volunteer Resource Team (additional volunteers needed):
Ann Soule

Recommendations:

1. An effort should be undertaken to assess the current status of groundwater aquifer levels within the Dungeness watershed area. This effort should include identifying optimal well measurement locations and frequencies, and implementing continuous, automated water level monitoring and reporting.

2. Data analyses, similar to those performed by the USGS (Thomas, 1999) and by Pacific Groundwater Group (2009), including a revised (current) water budget, should include the relationship between aquifer levels, precipitation, recharge from the upland watershed region across the southern boundary of the existing numerical model, other forms of recharge, ground-surface water interactions, imported/exported water, discharge to salt water, and withdrawals.

3. An analysis of available groundwater chemistry information should be compiled in a database to provide a snapshot of water chemistry and then evaluated over time to determine parameters and regions of concern.

Background:

Tracking trends and updating outdated information and assumptions about groundwater levels and movement within the basin is needed. This is especially true as irrigation efficiency projects, shallow aquifer recharge projects, forest management practices, reclaimed water reuse, off-channel storage, increased water usage through development, and other new developments continue to affect the hydrology of the Dungeness watershed. The last comprehensive water study, describing hydrologic conditions across the Dungeness Peninsula, incorporated data collected only through 2007 (Pacific Groundwater Group, 2009). Further, some of that report's findings may still be relevant today. For example:

> *17. Groundwater levels in the shallow aquifer have declined at most locations. The greatest declines occurred over several square miles near where Highway 101 crosses the Dungeness River. In this area, groundwater levels declined about 3 to 9 feet from the late 1970s through the mid-1990s and about 8 to 17 feet from 1997 to 2007....*
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> *18. Current groundwater level monitoring in the middle aquifer is limited to only 5 wells. Moderate declines between 1997 and 2007 occurred in two areas: 7.7 to 9.7 feet of decline was noted in three wells near Gierin and Bell Creeks (including at the City's Port Williams Wellfield); and 7 feet of decline is noted in a well near Agnew....*

The paucity of updated data indicates the need for a new assessment; increased, and perhaps continuous, monitoring of an increased number of wells; and, a correlation analysis among

hydrologic factors to better inform planners about groundwater condition and investigate if trends can be linked to climate change and/or other effects.

WRTG Member and/or Adviser Comments:

[Tom Martin]

- Clallam County has initiated a groundwater database, which includes well location, well parameters, and some water chemistry information.
- When Ecology developed the mitigation calculator, they mentioned during public meetings that all models are always wrong, but some are better than others. It is important to acknowledge this, yet always strive for continuous improvement. It may be worthwhile to revisit the historical efforts taken to upgrade the model and assess the incremental improvements of its accuracy and the expansion of its practical applications.

[Ann Soule]

- I would say that models are never perfect but meant to be approximations and neither right nor wrong but helpful in providing tendencies and therefore direction. When finished in 2008, after extensive calibration work and sensitivity analyses, the Dungeness groundwater model was considered by all accounts to be very robust.
- Another common quote used in 2011-12 as the model was becoming more and more embedded in the process for how the rule should require mitigation for new groundwater use was, "live by the model, die by the model." I.e., you have to accept the imperfections if you want to utilize the benefits.
- [5-20-22] I propose we add a feasibility study to conduct an Airborne Electromagnetic (AEM) survey to 6.1 or 6.3. From one image of the data obtainable it appears to distinguish aquifer units, which would be important here. See related links:
  - https://data.cnra.ca.gov/dataset/aem
  - https://www.usgs.gov/centers/upper-midwest-water-science-center/science/airborne-electromagnetic-aem-survey-2022

[Peter Schwartzman]

- [Regarding #1] This is an entirely worthwhile effort. Is Ecology still monitoring the same network? The City of Sequim issues annual reports for Port Williams monitoring.
- [Regarding #2] Some of these analyses were included in the City's 2008 Hydrologic Monitoring Report. Note that this report was not limited to Sequim's monitoring networks but employed all available data.
- The model report has specific recommendations for further development and improvements, and notes limitations associated with its current design. One significant limitation is simulating the shallow aquifer SYSTEM as a single layer when in fact there are confining units between water-bearing units. There is also still more calibration to be done for inter aquifer connections. Agreed, we should strive for improvement, particularly in areas where we are trying to solve problems or answer questions. We may want to make a separate recommendations document for model improvements, but I will point out opportunities in these existing recommendation documents.

[Carol Creasey, 5/20/22]

- [Regarding #3] Some of this information is being collected and included in a County GIS database. Our progress has been slow but is ongoing.
- PGG's 2009 report should be updated with the monitoring results from Ecology's well monitoring program and the results from USGS' well cluster at Idea Place in the Carlsborg UGA.

Data/References:

Drost, B.W., 1983, Impact of changes in land use on the ground-water system in the Sequim-Dungeness Peninsula, Clallam County, Washington: U.S. Geological Survey Water-Resources Investigations Report 83-4094.

Elwha-Dungeness Planning Unit. 2005. WRIA 18 Watershed Plan. Section 3.1 Water Quantity Recommendations. http://www.clallam.net/environment/assets/applets/W18_3.1-WaterQuantity.pdf

Jones, M.A., 1996b, Delineation of hydrogeological units in the lower Dungeness River Basin, Washington: U.S. Geological Survey Water-Resources Investigations report 95-4008.

Krautkramer, F.M., 2018, Technical Memorandum Clallam County Department of Community Development hydrogeologic setting pertinent to processing water right application, prepared by Robinson Noble.

Krautkramer, F.M., 2020, Carlsborg Deep Test Well Construction and Testing Report, prepared by Robinson Noble.

Krautkramer, F.M., 2021, Technical Memorandum – Task 2E, Supplemental Testing, prepared for Carol Creasey, Clallam County by Robinson Noble.

Noble, J.B., 1960, A preliminary report on the geology and ground-water resources of the Sequim-Dungeness area, Clallam County, Washington: Olympia, Wash., Washington Department of Conservation, Division of Water Resources, Water Supply Bulletin No. 11.

Pacific Groundwater Group. 1995. Hydrogeologic evaluation and well yield analysis, City of Sequim Stone Well #1, Clallam County, WA.

Pacific Groundwater Group. 2009. City of Sequim 2008 Hydrologic Monitoring Report

Pacific Groundwater Group. 2009. 2008 Dungeness Groundwater Flow Model Design, Construction, Calibration, and Results. Prepared for Clallam County Department of Health and Human Services. Seattle, Washington.

Robinson & Noble, Inc., 1974, Development of a Deep ground Water source for the Weyerhaeuser Seed Orchard at Sequim, WA.

Schasse, Henry W.; Logan, Robert L., 1998, Geologic map of the Sequim 7.5-minute quadrangle, Clallam County, Washington: Washington Division of Geology and Earth Resources Open File Report 98-7, 22 p., 2 plates.

Schasse, Henry W.; Wegmann, Karl W., 2000, Geologic map of the Carlsborg 7.5-minute quadrangle, Clallam County, Washington: Washington Division of Geology and Earth Resources Open File Report 2000-7, 27 p., 2 plates, scale 1:24,000

Thomas, Blakemore E., et. al. 1999. Hydrogeologic Assessment of the Sequim-Dungeness Area, Clallam County, Washington. USGS Water Resources Investigations Report 99-4048.

6.2 EXPANDED MONITORING PROGRAMS

Volunteer Resource Team (volunteers needed):
Streamkeepers (suggested)

Recommendations:

1. A listing of historic data sources and current monitoring programs related to water resources should be created and be available online for reference and easy access. Key gaps should be highlighted and addressed.

2. An effort should be undertaken to create an historical graphical profile based on detailed measurements that show the trend lines for all forms of precipitation, including snowpack, rainfall along with streamflow. This information should be updated continuously as data becomes available and be provided to decision makers and include potential, near-term, weather impacts based on the historical profiles.

3. A standard format, collection time-period and graphical interface should be established so this complete data set can be displayed as overlays of the selected display parameters.

4. Initiate an expanded groundwater monitoring program, according to results of groundwater status assessment and analyses (Recommendations in Section 6.1).

Background:

While data related to precipitation has been generated for many years, continuous, integrated trends are not widely available. Most of this data is collected by different agencies and the lack of consistency in collection methods and reporting formats does not easily allow for overlay data comparisons. The data for our focus area are not available on a timely basis for managers to evaluate the criticality of specific conditions. The effects and timing of snowpack melt on groundwater and streamflow, as compounded by a change in seasonal weather patterns and average temperatures, are not firmly established.

WRTG Member and/or Adviser Comments:

[Lance Vail] Installing a set of Hobo sensors in Dungeness from outlet to as far as I can drag myself up in basin to log stream temps. Will retrieve after a year recording at a fine time interval. mostly just interested in temporal variability patterns and to help calibrate model.

[Hansi Hals] There are 5 Hobo sensors deployed by JST (soon to be 6). Can share map and data. Some analysis done in R (7 Day roll of Daily Average and Daily Max) for years 2001-2015.

[Shawn Hines] From 4/22 WRTG meeting: incorporate Streamkeepers involvement?

[Carol Creasey, 5/20/22]

- [Regarding #1] I suggest you look at Thurston County's water resources graphic interface and database as a possible start. I have disused their system in the past. They are okay with

helping other communities and having other communities clone their system. Kitsap County might have something that could be used, as well.
- Once this is available, this could be used as a model for setting up in other county watersheds.

Data/References: The scope should include the geographic focus area of the DRMT, which includes both the Dungeness and Sequim Bay watersheds and adjacent streams affected by the irrigation system between Bagley Creek and Miller Peninsula. Most of this area is in WRIA 18; a portion is in WRIA 17.

6.3 CHARACTERIZATION OF 4TH AQUIFER

Volunteer Resource Team (volunteers needed):

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Recommendations:

1. Compile any existing and new data from the Weyerhaeuser, Dungeness Spit, "Carlsborg Very Deep Well" (on Van Lan parcel), Graysmarsh, and any other deep wells drilled into or almost into Aquifer 4.

2. Define the geographical locations, geological character, predictive water quantity, recharge capabilities and expected demand requirements for the deep aquifer and incorporate data from Recommendation 1, above.

3. Guided by existing and new Aquifer 4 data and monitoring experience, design a combined study to monitor detectable impacts on all levels of the aquifer system to determine the interactions which may result when the 4th Aquifer is utilized as added supply.

4. An analysis should be undertaken to determine the permeability of multiple confining layers among all aquifers.

5. A study should be conducted to determine the nature of the water in the 4th Aquifer to determine its source age. The intent of such a study, possibly using carbon dating or nuclear isotope techniques, is to enable more accurate recharge predictions.

Background:

While the Water Resources Technical Group uses the common naming convention for the aquifer designations in the Dungeness watershed as "Aquifers 1-4," to avoid confusion in public discourse, the following narrative is intended to provide the scientific description of these systems.

The USGS survey of groundwater characterization in the Dungeness watershed (Myrtle Jones, USGS WRI 95-4008, 1996) indicates three groundwater aquifers: the upper (first), middle (second), and lower (third) aquifers. (These are also known as USGS Units 1, 3, and 5, respectively, with aquitards in between labeled as Unit 2 and Unit 4.) Below the lower, or third, aquifer is "undifferentiated unconsolidated deposits" (Unit 6) bound by bedrock (Unit 7). The data collected from wells drilled into Unit 6 show the presence of an aquitard and aquifer (Aquifer 4) underlying Unit 5 (third aquifer). Given the relatively sparse data on Unit 6 compared to Units 1 through 5, the east-west extent of Aquifer 4 is less certain than the extent of Aquifer 1 through 3 have been determined to be.

A test well (the "Carlsborg Very Deep Well") has been drilled into USGS Unit 6 and some testing has been conducted to examine additional supply capabilities in support of expected growth, including in the Carlsborg Urban Growth Area. As this aquifer level has not been fully studied, the extent, capacity and long-term recharge aspects should be determined scientifically to assess the

feasibility of sustainably developing this source to support future growth in the face of increasing climate instability.

WRTG Member and/or Adviser Comments:

[Alex Scaglitti] Do we know how permeable the confining layer is between aquifer units 5 and 7? It may be that we put too much hope into the deeper aquifer but if the unit 6 aquitard is "leaky", it may not be very beneficial - similar to the leaky layers in units 2 and 4.

[Peter Schwartzman]

- [Regarding #2] See the 2008 Model Report (section 3.2.1 and Table 3-1) for a description of 46 deep wells reviewed to interpret the occurrence of a deep aquifer. As of 2008, only 3 logs were interpreted as tapping water bearing sediments beneath the lower confined aquifer. How many new deep wells have been drilled since then? Note that testing the Weyerhaeuser Well suggested that the aquifer was not extensive as limited data suggested incomplete recovery. How did the Carlsborg very deep well do for recovery and suggestion of aquifer extent?
- [Regarding #3] Such a study could employ time-series water-level monitoring of deep wells and comparison with monitored trends in overlying aquifers (as done at Port Williams) and pumping tests in deep aquifer wells where lower confined aquifer monitoring wells are available nearby. Sustainability of water withdrawals from the deep aquifer should be a main focus, since the aquifer occurrence could be patchy (isolated zones) and recharge limited if sufficiently confined from above.
- [Regarding #4] One recommendation in the 2008 model report was looking at water level trends in all 3 aquifers (monitored at Port Williams) and calibrating the model to those trends to better estimate vertical permeability of confining units. Data from Port Williams can also be used to analyze drawdown in the middle aquifer from pumping in the lower aquifer (e.g. pumping test data)
- [Regarding #5] Such analysis has been performed for the Port Williams wells in the lower confined aquifer.

[Ann Soule]

- [Regarding #2] Ecology should have aquifer testing info for all water rights tapping the 4th aquifer. (all aquifers, for that matter)

[Lance Vail]: A resource protection well was drilled by Ecology on PUD (Idea Place) property in 2007 to a depth of 325 ft BG. It was screened for 10 ft down to 289 BG. In 2018 USGS started continuous reporting of water level data. Not surprisingly, there are pretty minor fluctuations, max 3 feet, but clearly some seasonal and interannual variability. But enough variation to suggest some possible connection to aquifers above it.

[Carol Creasey, 5/19/22]

- [Regarding #2] The "deep aquifer", according to the Mitigation Calculator, is for the Aquifer 3. So, Aquifer 4 would be better called the "very deep aquifer".
- [Regarding #3] This should also be done for Aquifer 3.

- [Regarding #5] From a water supply standpoint it would be better to evaluate the water chemistry.
- More study needs to be done regarding Aquifer 3, as well. All the aquifers need to be looked at for sustainability and water quality.
- [Regarding Alex's comment] This should also be done for leakage from Aquifer 2 to 3 and from Aquifer 3 to 4.

Data/References:

Drost, B.W., 1983, Impact of changes in land use on the ground-water system in the Sequim-Dungeness Peninsula, Clallam County, Washington: U.S. Geological Survey Water-Resources Investigations Report 83-4094.

Jones, M. A. 1996. USGS Water-Resources Investigations Report 95-4008. Delineation of Hydrogeological Units in the Lower Dungeness River Basin, Clallam County, Washington. U.S. Geological Survey Water-Resources Investigations report 95-4008.

Krautkramer, F.M., 2018, Technical Memorandum Clallam County Department of Community Development hydrogeologic setting pertinent to processing water right application, prepared by Robinson Noble

Krautkramer, F.M., 2020, Carlsborg Deep Test Well Construction and Testing Report, prepared by Robinson Noble.

Krautkramer, F.M., 2021. Technical Memorandum – Task 2E, Supplemental Testing, prepared for Carol Creasey, Clallam County by Robinson Noble.

Noble, J.B., 1960, A preliminary report on the geology and ground-water resources of the Sequim-Dungeness area, Clallam County, Washington: Olympia, Wash., Washington Department of Conservation, Division of Water Resources, Water Supply Bulletin No. 11.

Othberg, K.L., and Palmer, Pam, 1980, Preliminary surficial geologic map of the Dungeness quadrangle, Clallam County, Washington: Olympia, Wash., Washington Division of Geology and Earth Resources Open-File Report 79-18.

Pacific Groundwater Group, 2008, Dungeness Groundwater Flow Model Design, Construction, Calibration, and Results

Robinson & Noble, Inc., 1974, Development of a Deep ground Water source for the Weyerhaeuser Seed Orchard at Sequim, WA.

Thomas, Blakemore E. 1999. USGS Water-Resources Investigations Report 99-4048. Hydrogeologic Assessment of the Sequim-Dungeness Area, Clallam County, Washington.

Washington State Department of Ecology. 2006. Water Well Report for Graysmarsh deep well:

https://appswr.ecology.wa.gov/wellconstruction/map/WCLSWebMap/WellLogSearchResult.aspx?imageName=00452173.pdf&region=SWRO&folder=00454&xcoord=1014443&ycoord=1020369&search_scope=&result_num=0&welllogid=452173

6.4 UPDATED WATER DEMAND PROJECTIONS

Volunteer Resource Team (volunteers needed):
Student volunteers (suggested)

Recommendations:

1. An effort should be undertaken to compile available data on current water consumption by all sectors (e.g., residential, agricultural, commercial/industrial) on a monthly basis, and population changes on a quarterly basis (or monthly, if possible).

2. A comparison analysis should be conducted of the actual data (from Recommendation #1) to that which was historically projected for water demand and population growth during the same timeframe.

3. Using results from the above analyses, and incorporating additional relevant information (e.g., metering data, climate change projections, land use changes, fish and wildlife water needs, etc.), updated estimates of future water demand (e.g., at 5, 20, 50 years) should be prepared for review.

4. Metering records should be aggregated and analyzed to determine the current volume of water used per dwelling and/or household and applied to any future demand projections.

Background:

The City of Sequim, PUD and other related agencies have prepared growth predictions based on the best available data. The validity of these predictions have not been assessed as to their accuracy or reliability. Climate change, coupled with the desirability of the Olympic Peninsula as a safe haven against extreme climate impacts, is likely to induce increased development beyond current growth projections as people choose the Olympic Peninsula as a climate-protected area to live. Water consumption data is available from the plethora of metered wells, but metered wells generally only apply to households on public systems or wells put into use since 2013. Under both scenarios, water demand for metered wells could be considerably less than for the unmetered wells. Well withdrawal data is inconsistent and sparse as to the locations, depths and groundwater impacts. Climate change impacts, as well as land use conversions such as from agriculture to residential, will affect the availability of water. Future water resources planning for human and fish (stream flows) and wildlife needs will depend on the most up-to-date growth projections and residential and agricultural/farming water demand projections.

WRTG Member and/or Adviser Comments:

[Lance Vail] Establish 'trigger' tracking to see if actual population growth is running substantially outside the projections the County, City of Sequim, and PUD have developed in their resource planning. Could possibly be addressed by recommending that DRMT include an update of population and well permits, etc., on each month's agenda, similar to status updates on streamflow and SNOTEL numbers. Realtors could also inform on migration motivations. Motivation for topic was "resilience of water supply to meet future demands."

[Alex Scaglitti] I agree with Lance. Also in the same vein, what are the long-term implications for the land use change from ag to urban? I'm new to the area but old-timers tell me that the urban creep has reduced the amount of irrigated acres. To me, this means less GW recharge from irrigation, coupled with increased GW withdrawals for household use.

[Ann Soule] The net change to GW recharge from land use conversion is a good question to examine. There are many factors including radical changes in irrigation ditch leakage volume, more deep well withdrawals, more shallow GW recharge from septics, more impervious surfaces resulting in likely reduction in recharge/ increase in runoff, from incident precip.
Joe Holtrop would have good input on this.

[Scott Chitwood] Rural sprawl is a big concern in eastern Clallam County. There are a lot of straws in the ground and our understanding of the relationship between growth, water use/consumption and supply is somewhat rudimentary. Thus, the purpose of our committee as I think about it is to improve our understanding of this complex relationship.

When ag lands convert to residential not only do we lose space to grow food but we place other pressures on the landscape (e.g., impervious surfaces). Ben can help with the water question but if memory serves I recall him saying irrigation water use/consumption does not change dramatically when residential property takes over ag lands. What has always bothered me is that with our water laws, irrigation does not change regardless of this conversion. I can understand ag lands needing large volumes of river water to grow food but I do not understand or agree with large volumes of river water keeping new lawns green in August.

[Hansi Hals] I agree with Scott's comment that if/when acreage/property is converted to residential, that irrigation water right purpose has been translated to residential use. Could probably calculate the conversion by acres through today, and ac/feet of water/yr just for our information. I understand water law accepts the change to residential, but it is something to think about in consideration of climate exacerbated low flows.

[Ben Smith, 5/18/22] I would like to rescind my previous statement that acres converted from ag to residential utilize the same amount of water. I do not have an accurate use volume to report. This might be a good topic to add to your list to gain a more accurate number on.

[Robert Knapp, 5/20/22] This group did not explicitly discuss water conservation, but it could be mentioned here and in other topics, if not made a stand-alone topic of its own with related recommendations.

[Carol Creasey, 5/20/22]
- [Regarding #1] The county has a first cut on estimated water needs for buildout in WRIA 18. Once our method is worked out, we will be using it for buildout in the entire County.
- [Regarding #4] We could also compare this to the Group A system water usage in an area.
- Also need to consider financial trends such as housing prices and inflation/deflation, which will have an impact on growth.

- [Regarding Lance's comment] The County gets updated growth projections from the Office of Financial Management on a yearly basis that then can be verified by the decal Census data.
- As they are finding out in Arizona, crops use more water than people. Phoenix at least 5 years ago was able to keep up with increasing population because ag was being converted to housing.

Data/References:
For residential/municipal data: Use City and County Comp Plans, and City and PUD Water System Plans.

For metering data associated with new mitigated water uses: (Washington Department of Ecology).

For data on irrigation water diversions, water rights, and other restrictions: (Washington Department of Ecology, and Sequim-Dungeness Water Users Association).

For WRIA 18 Plan recommendations on land use:
http://www.clallam.net/environment/assets/applets/W18_3.6-LandUse.pdf

Climate change/migration (journal article): https://www.wired.com/story/as-climate-fears-mount-some-are-relocating-within-the-us/?utm_source=onsite-share&utm_medium=email&utm_campaign=onsite-share&utm_brand=wired
NOLT's presentation on their Land Resilience Study: https://northolympiclandtrust.org/land-resilience-study-findings-presentation/

NOLT's maps from Land Resilience Study showing projected stream flow and temperature changes with climate change:
https://northolympiclandtrust.org/wp-content/uploads/2022/02/Climate-Resiliency-Maps.pdf

6.5 CLIMATE RESEARCH ON IMPACTS TO FISH

Volunteer Resource Team (volunteers needed):

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Recommendations:

1. The climate change impact research (stream modeling) efforts initiated by PNPTC to predict impacts of warming scenarios on fish habitat should be supported and continued, including proposed next phases incorporating riparian vegetation impacts on stream temperatures, and changes to peak streamflow events.

2. A study task should be added to determine the potential climate change impacts on birds and land-dwelling animals.

3. A study task should be added to include the addition of temperature sensing, ideally in a variety of different stream settings (e.g., riffles, pools, shaded vs. unshaded, etc.) to obtain data on more relevant stream flows.

Background:

The Point No Point Treaty Council (PNPTC) has begun to study the climate change induced effects of increasing stream temperature beyond safe levels for fish reproduction. The data and models indicate increasing possibilities of such events into the future. The most current study is referenced herein: Effects of Forecasted Climate Change on Stream Temperatures of Fish-bearing Streams in Western Washington State Final Project Technical Report[1].

Excerpts from that report are included in the following narrative:
....Low-elevation portions of the affected area watersheds are likely to still have the warmest stream temperature magnitudes, as the air temperatures are warmer than at higher altitudes. However, many fish-bearing stream reaches in both low-lying and high relief watersheds are likely to regularly exceed safe migration and spawning temperature thresholds. By the end of the 21st century, the amount of stream habitat that annually exceeds safe temperature thresholds for salmonids is likely to more than double under a moderate warming RCP 4.5 scenario and more than triple for the high warming RCP 8.5 scenario. The projected warming has the potential to greatly reduce the amount of fish habitat available to migrating and spawning salmonids throughout the region....Adult migrating Pacific salmonids often experience health problems and increased risk of disease when weekly temperatures exceed 16°C, and temperatures above 21°C can be lethal depending on acclimation times (Table 3; Richter and Kolmes 2005; McCullough et al. 2001; Hicks 2000). Bull trout, which are usually found in the higher reaches of the watersheds, often require considerably cooler temperatures to thrive (McCullough et al. 2001). Spawning temperature requirements are lower still, with salmonids (including Steelhead) and bull trout generally requiring water temperatures less than 13°C and 9°C respectively (McCullough et al. 2001; Hicks 2000) ....

[1] Note, each study stream, including the Dungeness River, has a separate report, which can be viewed upon request to PNPTC.

Stream temperature is affected by many factors, including air temperature, snowpack, riparian shading, water velocity and volume, groundwater influence, slope, and aspect (e.g., Constantz 1998; Lisi et al., 2015). Fish habitats in complex mountainous watersheds such as the Dungeness can be particularly vulnerable to climate warming, as the snowpack plays an important role in supporting dry season stream flows and moderating stream temperatures. A reduction in snowpack (or simply a reduction in late spring and summer precipitation, such as is projected in lower-lying tributaries) can yield lower stream volumes during the warmer summer months, lowering the stream's heat capacity and making it more susceptible to atmospheric temperature changes (e.g., Brown, 1969). This, in combination with the already warming air temperatures due to climate change, can cause habitat loss for cold water fish species during critical migration and spawning life stages.

Because the Dungeness is a relatively fast-draining and high-relief watershed, the warming that exceeds safe temperature thresholds is likely to be mostly constrained to lower-elevation reaches and low-lying tributaries. Much of Matriotti Creek, for example, is likely to regularly exceed safe habitat temperature thresholds for much of the summer months by the end of the 21st century.

Regional stream temperature studies have found that warming in lower-elevation stream reaches can potentially be offset by stream restoration efforts and/or improvements in riparian vegetation (Lee et al., 2020; Seizas et al., 2018; Sun et al., 2015). PNPTC has initiated a new modeling project to test the sensitivity of stream temperatures with relation to riparian vegetation coverage in the Dungeness River (and other watersheds in the eastern Strait and Hood Canal areas). This study will assess stream temperature changes under a variety of riparian vegetation scenarios examining different tree types, heights, canopy thicknesses, buffer widths, etc. and comparing them to a baseline.

Phase 4 and Phase 5 of the research include Riparian vegetation impacts on stream temperatures and Peak streamflow event changes, respectively. These phases would include recalibrating the associated model, running multiple riparian coverage scenarios, incorporation of improved climate projections to assess riparian effectiveness under various possible warming scenarios, and determining which reaches are most susceptible to warming, determining which riparian scenarios are most resilient against impacts from moderating warming, determining if peak flows are likely to increase in magnitude, and studying how recurrence intervals of historical flood types change.

WRTG Member and/or Adviser Comments:

[Ryan Murphy, PNTPC]

- [Regarding #1] If there are specific riparian scenarios that the WRTG would like to see, please let me know. I am finishing up calibration and will start testing scenarios within the next few months. If there are specific stream reaches that the WRTG would like examined in more detail, please let me know.

Data/References:

Dungeness Specific:

- Jamestown S'Klallam Tribe DO/Temp Data: JST places temperature and dissolved oxygen sensors in Dungeness River as staffing allows. JST has this data.
- https://northolympiclandtrust.org/wp-content/uploads/2022/02/Climate-Resiliency-Maps.pdf (NOLT's maps from Land Resilience Study showing projected stream flow and temperature changes with climate change)
- PNPTC Projects relevant to Dungeness: http://climate.pnptc.org/our-research/reports-and-publications/
- PNTPC'a Phase 1 and Phase 2 research:
  - http://climate.pnptc.org/wp-content/uploads/2019/09/PNPTC_StreamflowModeling-_Phase1_TechnicalSummary_FINAL.pdf
  - http://climate.pnptc.org/wp-content/uploads/2020/06/PNPTC_RBMstreamTempModeling_TechnicalSummary_FINAL.pdf
- R2 Resource Consultants, Inc. May 31, 2007. Technical Memo: Task 4 Dungeness River Aquifer Recharge Habitat Technical Memorandum. Prepared for Clallam County EHS. Prepared by Ron Campbell. http://www.clallam.net/environment/assets/applets/R2_Habitat_Tech__Memo_5-31-07.pdf
- Washington State Department of Ecology Data: Ecology has a telemetry temperature gauge at RM 0.75 and data is available online.

Other References:

Beechie, T., Imaki, H., Greene, J., Wade, A., Wu, H., Pess, G., Roni, P., Kimball, J., Stanford, J., Kiffney, P., & Mantua, N. (2012). Restoring Salmon Habitat for a Changing Climate. River Research and Applications, 29(8), 939-960. https://doi.org/10.1002/rra.2590

Brown, G. W. (1969). Predicting Temperatures of Small Streams. Water Resources Research, 5(1), 68–75. https://doi.org/10.1029/WR005i001p00068

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Murphy, R. D., and Rossi, C. (2019). Modeling the Effects of Forecasted Climate Change on Fish-bearing Streams in Western Washington State – Final Project Technical Report. Point No Point Treaty Council (PNPTC). Technical Report 19-1. http://climate.pnptc.org/wp-content/uploads/2019/09/PNPTC_StreamflowModeling-_Phase1_TechnicalSummary_FINAL.pdf

Murphy, R. D., and Rossi, C. (2020). Effects of Forecasted Climate Change on Stream Temperatures of Fish-bearing Streams in Western Washington State – Final Project Technical Report. Point No Point Treaty Council (PNPTC). Technical Report 20-1. http://climate.pnptc.org/wp-content/uploads/2020/06/PNPTC_RBMstreamTempModeling_TechnicalSummary_FINAL.pdf

Ohlberger, J. et. al. 2018. *Effects of past and projected river discharge variability on freshwater production in an anadromous fish*. Freshwater Biology. Volum 63, Issue 4. Effects of past and projected river discharge variability on freshwater production in an anadromous fish - Ohlberger - 2018 - Freshwater Biology - Wiley Online Library

Seixas, G. B., Beechie, T. J., Fogel, C., & Kiffney, P. M. (2018). Historical and Future Stream Temperature Change Predicted by a Lidar-Based Assessment of Riparian Condition and Channel Width. JAWRA Journal of the American Water Resources Association, 54(4), 974–991. https://doi.org/10.1111/1752-1688.12655

Taking the temperature of salmon | Encyclopedia of Puget Sound (eopugetsound.org)

Wade, A. A., Beechie, T. J., Fleishman, E., Mantua, N. J., Wu, H., Kimball, J. S., Stoms, D. M., & Stanford, J. A. (2013). Steelhead vulnerability to climate change in the Pacific Northwest. Journal of Applied Ecology, 50, 1093-1104. https://doi.org/10.1111/1365-2664.12137

6.6 COMMUNITY SUPPORT THROUGH PUBLIC OUTREACH

Volunteer Resource Team (volunteers needed):
Ann Soule (Water Column Blog), Dungeness River Nature Center Staff (suggested), Clallam League of Women Voters (Story of Water Presentations, suggested)

Recommendations:

1. A coordinated effort, inclusive of the water manager community (CCD, City, County, JST, WUA, etc.) should be undertaken to intentionally improve and build upon community support within the Dungeness basin. Such efforts should include public education opportunities, volunteer outreach, public forums, events (e.g. booth at irrigation fest, short films about the Dungeness), as well as promoting previously successful outreach efforts (such as *The Story of Water* Lecture Series, *The Water Column Blog*, and the Dungeness River Nature Center's classes), etc.

2. Consider updating and redistributing Ecology's 2011/2012 *Dungeness Water Watch* series and Ecology's 2010 *A Guide to Water and How We Use It in the Dungeness Watershed* and establishing a designated program for new and continued public outreach on basic water resources topics relevant to this area.

3. Consider developing, as an outreach demonstration tool, a 3-D digital animation of the watershed that shows (and quantifies) changes to the amount of land surface area available for snow "storage" at different elevations (ie, as snow elevation increases with global warming, there is less surface area for snowpack storage).

4. As part of an existing or new curriculum on climate change for elementary and middle school, add an element to convey changes in glaciers, rivers and other water resources in the Pacific Northwest due to global warming and relate these changes with the pace of human settlement in this area.

Background:

The increased pressures of urban development, climate change and sustainment of healthy riverine ecosystems requires community understanding and involvement for the long-term sustainability of water resources within the basin. Research indicates that in areas that have management agencies actively investing in raising public awareness about community/environmental issues (building social capital), there is increased support for restoration, improved post-disturbance recovery (e.g., wildfire, floods) and more community involvement. Conversely, under-promoting or lack of community awareness about water projects and ordinances can lead to misinformation and backlash that may undercut future efforts to address water management challenges.

WRTG Member and/or Adviser Comments:

[Shawn Hines] Dungeness River Nature Center has done Ecology/Watershed outreach courses with various topics of focus. Could possibly incorporate some of the above themes into the River Center's work.

[Alex Scagliotti] Basically, the idea is acknowledging that there are multiple types of capital (financial, political, social, natural etc.) and that the success or support for a water management project will be in part based on social capital within the community. So intentionally improving social capital between relevant groups through outreach, stakeholder inclusion, events, dialogue etc. will build community support for future projects and hopefully reduce misinformation and backlash. One of my instructors in grad school was really big on this idea and he specialized in Water Conflict Management, so I thought I'd include it here!

Data/References:

Dungeness Off-Channel Reservoir Workgroup. 2014 - present. URL and video: http://www.clallam.net/publicworks/DungenessOCRProject.html

Encyclopedia of Puget Sound. 2020. Puget Sound's 'warm snow' makes region vulnerable to climate shifts | Encyclopedia of Puget Sound (eopugetsound.org)

Encyclopedia of Puget Sound. 2022. The retreating glaciers of Puget Sound | Encyclopedia of Puget Sound (eopugetsound.org)

League of Women's Voters of Clallam County. December 2019 - June 2020. *The Story of Water Lecture Series* (recorded). URL: The Story of Water Lecture Series

Soule, Ann. 2015-present. *The Water Column Blog*. URL: tps://watercolumnsite.wordpress.com/

Washington Department of Ecology. October 2011 - August 2012. *Dungeness Water Watch*. Monthly newsletter series. URL: http://wsldocs.sos.wa.gov/library/docs/ecy/dungenesswater/dungenesswater_home.aspx

Washington Department of Ecology. June 2010. *A Guide to Water and How We Use It in the Dungeness Watershed*. Ecology publication #10-11-018. URL: https://apps.ecology.wa.gov/publications/documents/1011018.pdf

Washington Water Trust. May 2022. "Restoring the Dungeness" Storymap: https://storymaps.arcgis.com/stories/bfd4c8ca9cee493a9dac9b1cfa0f0798

Example of idea related to the 3-D animation recommendation, but new idea would show elevation levels and amount of snow or SWE at different levels:
https://videohive.net/item/rocky-mountains-terrain-map-3d-render-360-degrees-loop-animation/34023870

6.7 INTERACTIVE HYDROLOGIC MAP

Volunteer Resource Team (additional volunteers needed):
Alex Scagliotti

Recommendations:

1. A groundwater database should be developed for the DRMT focus area. Using this data, an ArcGIS map should be created that displays, through a colorimetric scale, groundwater influent/effluent reaches of Dungeness basin streams and open irrigation canals. The tool should provide the capability of viewing a variety of layers, including at minimum one representative of typical irrigation season conditions, and one representative of off-season conditions. A map of the basin's recharge/discharge zones could then be referenced to support sustainable water management planning (see Data/Reference section for examples of such maps).

2. Well water depths in Aquifers 1, 2, 3 and 4 should be monitored continuously and the data included as a layer option on the ArcGIS map. The wells should be located across the Dungeness watershed, be equipped with pressure transducers and communicate wirelessly with a central data collecting entity. All available historic and current data, from as many wells as possible, should be included.

Example of one use for this tool:

- Relative elevations of groundwater could be compared to median background conditions based on current well monitoring plans (hopefully this will be expanded in the future)
    - Interpolations can be made for areas between wells to display a general groundwater elevation map of the basin
    - Baseline conditions are based on historic levels and not "the new normal"
    - If connected to a central database, these maps can be automatically updated with annual inputs of new data

Background:

The PGG (2009), Thomas et al. (1999), Simonds and Sinclair (2002), and Aspect/PGG (2004) (ditch leakage study) reports are useful tools, but some include outdated information or do not include existing new data; and some of the reports lack sufficient detail for the basin. For example, they do not include recent and former changes within irrigation conveyance systems, new infiltration chambers, as well as land use changes from agricultural to residential. An updated Hydrologic Monitoring Report (similar to the 2009 report) would provide the updated data necessary to develop the recommended ArcGIS product.

The creation of a groundwater database for the DRMT focus area would enable water managers to access the current status of groundwater on a continuous basis. In addition to providing water resource managers and citizens with reliable and current data, it would also identify the spatial data gaps and monitoring needs which can be applied to enhance and improve the model itself. The hydrologic map would also serve to eliminate confusion and anecdotal perceptions which currently exist. This information would be similar to what is included on Figures 16-29 in the

1999 Thomas et al. USGS Hydrogeologic Report. However, it would be significantly enhanced and result in a more user-friendly interface.

WRTG Member and/or Adviser Comments:

[Alex Scaglitti] Additional thoughts: the tool would allow for toggling on and off aquifer depths, natural recharge, groundwater movement, soil type, etc., and have the ability to view multiple layers at the same time, especially if there is updated data. Ideally, if ArcGIS Online could be updated periodically, as new data comes in, we could be sure that we'd always have the most up-to-date info to reference any time from a single website. As far as cost, I envision it using currently available and hopefully future data (6.2 and 6.1) but I'm not proposing additional studies necessarily.

[Carol Creasey, 5/20/22]

- [Regarding #1] This section could be combined with 6.2. Use software similar to Thurston county's, which has an interactive database.
- The County's GIS groundwater database could be combined with the interactive map ideas.

Data/References:

Aspect/PGG (2004). Ditch Leakage Study.

Associated Earth Sciences, Inc. 1997. Effects of Irrigation Ditch Shutdown on Graysmarsh Hydrology.

See Figures 4 and 6 which illustrate a recharge/discharge map possible for the Dungeness basin: https://www.esri.com/news/arcuser/0408/groundwater.html

PPG (2009. City of Sequim 2008 Hydrologic Monitoring Report: https://drive.google.com/file/d/1zMzWeuneQFSCOQYxKFE2xbMKDhuzc3Vy/view?usp=sharing

Perch, John. Ecology. Ecology's well data/database.

Simonds and Sinclair (2002) https://drive.google.com/file/d/1qpT2zIJf86fUHKoLwuQUr0uR6_sSMiyc/view?usp=sharing

Thomas, et. al. (1999) https://drive.google.com/file/d/1WtqR4sZzoluosOQCq2TMuooOezbuJKFX/view?usp=sharing

6.8 COMPREHENSIVE, INTEGRATED FORECASTING MODEL

Volunteer Resource Team (additional volunteers needed):
Tony Corrado

Recommendation: It is recommended that a feasibility study be initiated to determine if an integrated, data-based, predictive model can be developed to provide a continuous, seasonally based forecast of Dungeness River streamflow correlated to climate effects.

Background:

The Dungeness River is 28 miles long. It rises near Mount Constance in the Olympic Mountains within the Olympic National Park, flows through the Buckhorn Wilderness, passes by the town of Sequim, and empties into the Strait of Juan de Fuca at Dungeness Bay.

It is the primary surface water source in Dungeness watershed and provides water for aquatic wildlife, recreation and both potable as well as irrigation water for residential use, farms and ranches. It is a significant river for spawning and rearing salmon populations and provides habitat for birds and animals.

Precipitation, both snow and rainfall, patterns are changing in the Dungeness watershed. Winter snow accumulation is critical to the core baseline streamflow of all surface streams within the watershed. It appears that annualized snowfall amounts are decreasing with climate change. A comprehensive, integrated, model is required to enable predictive watershed impacts prior to critical events becoming manifest in diminished streamflow and higher stream temperatures.

The US government has remote sensing capabilities that can be used to collect, analyze and predict surface water impacts. These resources include multiple satellite sensed parameters. These sensors are multi-spectral (microwaves of different frequencies, infra-red and possibly, LIDAR, and others), and are available for data collection on a timely, repetitive basis. While it is not obvious which agencies collect specific data, NASA, NOAA and NRO all operate satellites with remote sensing capabilities. In addition, the National Snow and Ice Data Center (NSIDC) is one such agency that is currently collecting snow data. NOAA is also seeking an enhanced model, as referenced in https://water.noaa.gov/documents/wrn-national-water-model.pdf

The Dungeness watershed's geographic land surface can be surveyed, by satellite, during the summer season to determine the land area topography. During winter snowfall, this same area can be scanned with multispectral sensors to determine the area extent, depth and water equivalent content of the snow accumulations. Each scan can be used in a predictive model to update the streamflow impacts.

The Dungeness River flow is highly erratic as precipitation and snowmelt have a direct impact on flow. The river also has a longer period of sustaining inflow which appears to be the result of a longer-term percolation of both snow and rainfall. A parallel analysis should be conducted to characterize the time factor and primary flow path by which the accumulated snowfall melt transitions to river inflow over time. A similar analysis should be conducted for rainfall.

A predictive model would also include daily weather impacts and predictions in order to generate a best, most likely and worst-case scenario of river streamflow as the precipitation enters the river. Over time, the precision and ambiguities would be refined to reduce predictive errors.

WRTG Member and/or Adviser Comments:

[Tony Corrado] If an integrated model could be developed it would provide advanced notice of potential problem issues for all responsible agencies associated with water resources. i.e., if snowpack and rainfall were lower than normal and reduced earlier than normal, then such a model would suggest that increased awareness needed to be focussed on the potential impacts. Snowpack in particular needs a modern, satellite-based analysis tool.

[Jolyne Lea, NRCS National Water and Climate Center] Overall, this sounds like a good plan moving forward. Identify your needs as to the timeframe of the water supply you need and operational forecasts for daily water management. In addition, you need to determine climate scenarios and extremes that may increase severe storms in the area and assess the risk of those events. Regarding the "*parallel analysis to characterize the time factor and primary flow path by which the accumulated snowfall melt transitions to river inflow over time*", I agree this needs to be done to see if there are major groundwater storage or latent flow to find out the baseflow components and timeframe of water released.

[Ann Soule] For seasonal info, water managers get this info from NRCS and NOAA, who forecast streamflow for summer based on relative snow/ice volumes. I think their measurements are taken from Snotels, etc., not satellites.
https://www.drought.gov/drought-status-updates/snow-drought-current-conditions-and-impacts-west-4-7-22

[Carol Creasey, 5/20/22] This recommendation might be helpful in the management of the Dungeness Off-Channel Reservoir.

Data/References:

Basis for recommendation:
NOAA, 2016. Factsheet on National Water Model, Improving NOAA's Water Prediction Services.
https://water.noaa.gov/documents/wrn-national-water-model.pdf

NRCS forecasting tool:
https://www.nrcs.usda.gov/wps/portal/wcc/home/quicklinks/forecastCharts/#state=WA&basin=Olympic%20Penninsula&year=2022&pubDate=4-1&period=all&chartWidth=800&normalType=AVG&labelUnit=VOL&forecastLabels=ALL&showForecast=true&showForecastLabel=true&showObserved=false&showObservedLabel=false&showNormal=false&showNormalLabel=false&showMax=false&showMaxLabel=false&showMaxYear=false&showMin=false&showMinLabel=false&showMinYear=false&showNumberObservations=false&hideEmpty=true

Data sources:
The primary source of measured snow data is derived from the SnoTel site # 943 located at approximately 4,010' altitude: https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=943&state=WA

The primary source of measured Dungeness River flow data is from the USGS upper flow gage (USGS 12048000) at River Mile 11.8: https://waterdata.usgs.gov/nwis/uv?site_no=12048000 (sample graph from USGS data below)

NIDIS. Snow Drought Current Conditions. https://www.drought.gov/drought-status-updates/snow-drought-current-conditions-and-impacts-west-4-7-22

Other references:
Ohlberger, J. et. al. 2018. *Effects of past and projected river discharge variability on freshwater production in an anadromous fish*. Freshwater Biology. Volum 63, Issue 4. Effects of past and projected river discharge variability on freshwater production in an anadromous fish - Ohlberger - 2018 - Freshwater Biology - Wiley Online Library

Ward, et. al. (2011). NASA North Olympic Peninsula Solutions Network - Performance Evaluation, 2006-2011. Final Report. Battelle Pacific Northwest Division. Richland, WA. 99352. https://drive.google.com/drive/folders/1Y-cE5ao-SsR31Gf6spB002qTTJd26Y-T

Western Snow Conference Bibliography Database. There may be other references of similar studies in here: https://westernsnowconference.org/biblio

Wigmosta, M. et. al. 2007. Hybrid Model Development in the Dungeness Watershed. North Olympic Peninsula Solutions Network Report 07-02. Pacific Northwest National Laboratory, Idaho National Laboratory/

6.9 SALTWATER INTRUSION STUDIES

Volunteer Resource Team (volunteers needed):

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Recommendations:

An effort should be undertaken to obtain additional information on the extent of seawater intrusion along the coastline; identify seawater intrusion susceptible lands; and, use the data to plan/develop policies/programs to protect ecosystems and aquifer integrity. Specific tasks would include:

a. Design and implement a coastal well sampling program for chloride (at minimum), salinity, and water levels in wells identified 0.5 miles inland from the coast.
b. Use sampling results and climatic events (such as sea-level rise and/or storm surges) to identify location, extent, and severity of seawater intrusion impacts.
c. Assess vulnerability of wells and septic systems in seawater intrusion susceptible areas, and develop regulations and policies for new and old development that protect public health/drinking water and conserve/restore ecosystems.

Background:

In a changing climate, governmental entities need to consider the effects of salt water intrusion on existing and planned coastal development in order to protect public health by ensuring the availability of potable water and restoring or maintaining healthy ecosystem conditions. Further detailed information about the impacts of seawater intrusion are needed in order to plan for future and existing development with respect to the expected sea level rise and storm surges (Puget Sound Partnership, NTA Proposal #2018-00223). Seawater intrusion into Sequim Bay and Neah Bay/ Makah areas are anticipated. In 2014 the PUD's supply well was moved upland in response to sea water intrusion. A need exists to determine the levels in wells along the coast and to determine the location, extent, and severity of sea water intrusion in comparison to prior and future studies. It is imperative to identify those areas that are particularly susceptible to rapid climate change events.

WRTG Member and/or Adviser Comments:

[Peter Schwartzman] Regarding the well sampling program, the Island County model is one worth looking into! All new wells near the coast are sampled for chloride. Where elevated chloride concentrations are evidenced, more data collection may be required - such as surveyed wellhead elevation. Some wells are voluntarily incorporated into a saltwater intrusion monitoring network and fitted with water level data loggers. Full common ion analysis is used to better understand saltwater intrusion processes. Perhaps you could get former Island County hydrogeologist Doug Kelly to describe this program to the group.

[Ann Soule]

- I think Mike Gallagher would know who else to ask if we need additional details.
- Collecting chloride data from county building permit applicants near the shoreline is a very easy way to start collecting data, and also to alert the new well user to the potential issue.

[Lance Vail] Well at the lighthouse may be a possibility for continuous head and salinity monitoring.
[Ben Smith, 5/18/22] There was a saltwater intrusion study done ~25 years ago, so there is historical data to compare any new work to (See Forbes, 1993 in Data/References).

[Carol Creasey, 5/20/22]
- Recommend adding to recommendations: *Should also compare the latest round of coastal water chemistry monitoring to the several studies in the past to see changes and trends.*
- There is also a lot of useful information on salt water intrusion methodologies from the California coast.

Data/References:

Cusick, Daniel. March 17, 2022. Where Rising Seas Threaten Drinking Water, Scientists Look for Affordable Solutions. E&E News.

Dion, N.P. and S.S. Sumioka, Seawater Intrusion into Coastal Aquifers in Washington, 1978 Water-Supply Bulletin 56, WA Ecology, 1984.

Forbes, R.B. and CH2M-Hill, Preliminary Assessment of Seawater Intrusion in Coastal Water Wells in Eastern Clallam and Eastern Jefferson Counties, 1993. https://drive.google.com/file/d/1Tkbqz_bFxTV2VtKMWDoewAS_GvDmcx01/view?usp=sharing

Puget Sound Partnership 2018. Clallam County Submittal: NTA #2019-0223. Clallam County Seawater Intrusion Assessment, Planning, and Implementation

Walters, K.L., Reconnaissance of Seawater Intrusion Along Coastal Washington, WA Ecology Supply Bulletin #32, 1971.

WRIA 18 Watershed Plan (2005). Water Quantity Recommendation 3.1.4 B3 in the WRIA 18 Plan: http://www.clallam.net/environment/assets/applets/W18_3.1-WaterQuantity.pdf

Example Technical Tools for Project Managers:
- Standard simple saltwater intrusion equations: https://inowas.com/tools/t09-simple-saltwater-intrusion-equations/
- This is the model Dharma Water Institute is planning to implement on Dungeness Basin this summer. We selected it in part because it can easily handle salinity explicitly. I've used it on simulations of freshwater and hypersaline systems in South Florida. https://www.pnnl.gov/projects/stomp

Possible references for consideration:
- California regulator rejects desalination plant despite historic drought | Reuters
- California Coastal Commission meeting pg for May 11; includes video and agenda: Cal-Span –
- California Coastal Commission staff report: Th9a10a-5-2022-staffreport.pdf (ca.gov)

6.10 EXPANDED SNOWPACK STUDY

Volunteer Resource Team (additional volunteers needed):
Lance Vail, Ann Soule

Recommendations:

1. An effort should be undertaken to quantify the year-round ice and permanent snowfields in the upper Dungeness watershed.

2. Produce a report on estimated water supply derived from ice and snow melt over time, as it relates to summertime streamflow in the Dungeness River. The expected pace of permanent ice/snowfield decline should be included as a basis of this effort.

3. Relate estimated future streamflow in the Dungeness River to volume of aquifer recharge - annually, seasonally, or monthly.

4. Establish an online, real-time reporting tool for snow/ice parameters useful to Dungeness water managers in the future.

Background:

Snowpack in the Olympic Mountains is in decline according to monitoring as well as all visual accounts. Snow melt has been the driver of the evolution of the Dungeness Watershed ecosystem and aquifer system. Water managers and concerned citizens should study the potential impacts on streamflow and aquifer recharge resulting from progressively diminished summertime snowmelt volumes in the Dungeness River over coming decades.

WRTG Member and/or Adviser Comments:

[Jolyne Lea, NRCS National Water and Climate Center] This sounds good. One thing I would like to point out is that snow may be declining, but total precipitation may be the same or could be changing as well. It would be good to add in a look at the impact of the change in precipitation falling as rain. Rainfall would reduce the water in storage in the basin as snow in the winter. It would also impact reservoir operations to store or release water to consider any changes in winter atmospheric rivers as warm rainfall. Trends on snowpack decline should be considered, but other impacts should be considered (i.e., increase in severe storms, persistence of weather patterns). We could look into this further with you on historic changes at the snow courses/SNOTEL sites.

[Ian Miller, Washington Sea Grant] Comments from Ian Miller are incorporated, and Ian offered to refer interested parties to individuals within Climate Impact Group or elsewhere for further exploration in the future. Potential contacts at CIG include Guillaume Mauger and/or Matt Rogers.

[Ann Soule] For a hydrogeologist, Sequim is one of the most fascinating watersheds anywhere – and it is a privilege to work here. For most of the 20th century, every summer the prairie was drenched with mountain snowmelt - raising the water table during the dry season. As people

became aware of the need to conserve, shallow wells and springs dried up. Now that we're aware of the planet's warming our fascination becomes an urgent need to learn and adapt.

Data/References:

- UW CIG reports (see below) and NRCS info on snowpack trends, including ONP and North Cascades NP info
- Snow coverage data from satellites

Bumbaco, K.A., et al. 2021. 2020 Pacific Northwest Water Year Impacts Assessment. A collaboration between the Office of the Washington State Climatologist, Climate Impacts Group, Oregon State Climatologist, Idaho Department of Water Resources, and NOAA National Integrated Drought Information System.

Mauger, Guillaume. 2020. UW Climate Impact Group (CIG). Shifting Snowlines and Shorelines: The Intergovernmental Panel on Climate Change's Special Report on the Ocean and Cryosphere and Implications for Washington State.

NRCS Snow Survey information/data:
https://www.nrcs.usda.gov/wps/portal/nrcs/main/wa/snow/

Other UW CIG Special Reports: https://cig.uw.edu/resources/special-reports/

Other UW CIG Publications: https://cig.uw.edu/resources/publications/

6.11 MITIGATING POTENTIAL USE OF THE 4TH AQUIFER

Volunteer Resource Team (volunteers needed):

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Recommendation:

1. A new analysis, or adjustments to Ecology's current Mitigation Calculator ("Lookup Table"), should be considered to improve predictability of mitigation requirements[2] for potential developers of water supplies from "Unit 6" (the undifferentiated unconsolidated deposits, which includes the 4th Aquifer).

2. The County and PUD proposed a new method to estimate the impacts of pumping from Aquifer 4. The method uses new data collected from the drilling and testing of the Carlsborg Very Deep Well (the "Van-Lan Well") and data from the existing Mitigation Calculator. This method should be considered in evaluating the Draft Mitigation Plan for the PUD's specific (2006) water right application for expansion of the retail service area of their Carlsborg Water System.

3. An analysis should be undertaken to represent the 4th Aquifer in the Dungeness Model (to the extent that its occurrence is understood to be an "uncertainty analysis" based on various possible configurations) and then the model should be used to estimate mitigation requirement(s)[3] for pumping from the 4th Aquifer.

Background: Public water system managers use the Mitigation Calculator tool required by WAC 173-518 (Dungeness Instream Flow Rule) to determine the volume and location of mitigation associated with development of new well water supplies. The Mitigation Calculator was created in 2012 by running the 2008 Groundwater Model for withdrawals on each parcel[4] in the modeled area from each of four model layers: the shallow (first), middle (second), deep (third), and bedrock aquifers.

Users of the calculator find their parcel of interest and determine which layer their well should be assigned to, so a review should be completed of how the layers are defined in the model and how they are utilized in the calculator. If this review does not result in a solution to applying the calculator to wells between the "deep" and "bedrock" aquifers, a new tool or method should be pursued with assistance from Ecology that incorporates mitigation for use of the "4th Aquifer". The Elwha-Dungeness Rule, WAC 173-518, states: "If Ecology determines a better method in the future, then Ecology will apply the new method". WAC 173-518-070 (a) (i) also

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[2] Any update to the current mitigation analysis should be considered along with the original guiding principles for managing water in the WRIA 18 East – Dungeness Watershed set for in the February 15, 2011 Cooperators' Agreement (Clallam County, WUA, Ecology, 2011) and supported by the Jamestown-S'Klallam Tribe (JST, 2011).

[3] Ecology requires mitigation to be in compliance with WAC 173-518-070(3)(a)(i) and -518-070(3)(c).

[4] Values based on the Steady-State version of the model, interpolation between modeled withdrawals, and adjustment of model uncertainty (Mitigation Calculator Parcel Table with Lookup Table, Explanation Tab by Dave Nazy, WA Department of Ecology).

states “drilling to the middle or deep aquifer is encouraged”. Presumably this applies to Aquifer 4 as well.

Without a new or updated tool, mitigation for water supply development of sources deeper than the 3rd (“lower confined”) Aquifer (as recommended in various plans and in the Dungeness Instream Flow Rule) involves time-consuming and unpredictable negotiations with Ecology. If drilling deeper than the 3rd Aquifer is in fact a strategy that improves the sustainability of water supply development and minimizes the impact to the streams thus benefiting the fish, then a reasonable percent mitigation for the 4th Aquifer should be considered. Otherwise, there is a disincentive to drill deeper, especially considering the added cost of drilling deeper. The existing Groundwater Model and existing Mitigation Calculator suggest that drilling deeper increases the benefits to the streams.

WRTG Member and/or Adviser Comments:

[Mike Gallagher] Any new mitigation calculation tool or number representing the 4th Aquifer must be in compliance with WAC 173-518-070(3)(a)(i) and -518-070(3)(c) and WAC 173-518-075.

[Peter Schwartzman]

- [Regarding #1] The Mitigation Calculator for withdrawals from all 3 uppermost aquifers was based on model simulations at select locations in these three aquifers. For the 4th aquifer, the model should be run to obtain pumping impact estimates. However, the big caveat here is that such analyses should only be performed after the geographic extent and properties of the 4th aquifer are reasonably understood. Doing so before a reasonable understanding is available would not provide defensible results, though a variety of "realizations" could be run to provide "what if" analyses.
- The mitigation requirements should not lead the model, rather the model should lead the mitigation requirements. See prior comment about reasonable characterization of the aquifer before putting too much stock in model results, or acknowledging uncertainty to estimate range of pumping impacts.

[Tony Corrado] My concern regarding references to WACs is whether the team should be guided by any agencies' desires for compliance to what is in place instead of recommending a new look at these regulatory issues in view of climate change?

[Hansi Hals]

- Have to make clear that 6.3 analysis would precede 6.11.
- [Regarding #2] Agreed with Peter Schwartzman comment that it's Ecology’s role to consider the proposed method to estimate impact.

[Tom Martin]

- [Regarding #2] The evaluation of this plan for this specific water right application should not be delayed by any need to upgrade the existing Mitigation Calculator that the WRTG may identify.

[Alex Scagliotti] Has there been any investigation as to where withdrawing from the 4th aquifer would be most beneficial? Or is there an area where using the 3rd aquifer water is particularly impactful and could benefit from reduced withdrawals? If not, it's worth finding areas that could benefit most from reducing 3rd aquifer pumping – areas where it directly affects the shallow and middle aquifers. Last, a longitudinal study of potential impacts to shallower aquifers would be beneficial so we're not "robbing Peter to pay Paul," so to speak.

[Ann Soule]

- [Regarding #1] The mitigation calculator only includes bedrock below the "deep" aquifer, but the groundwater model actually has layers below the 3rd/deep aquifer. But I agree we should do 6.3 to find out if the model as constructed is appropriate before running it with potential new pumping scenarios.

[Carol Creasey, 5/20/22]

- [Regarding #3] This should occur only if there is enough data to reasonably calibrate the model to Aquifer 4.
- [Regarding Alex's comment about "*finding areas that could benefit most from reducing 3rd aquifer pumping,*" this could also apply to 2nd and 1st Aquifer pumping.]

Data/References:

2008 Dungeness Groundwater Model Final Report:
http://www.clallam.net/environment/assets/applets/PGG_2008_Dungeness_Model_Final_Report.pdf

Mitigation Calculator:
https://docs.google.com/spreadsheets/d/1vDCFFp5e0l1oRkjVwOB_QTTIDf3OXCBK/edit?usp=sharing&ouid=116929143402295772623&rtpof=true&sd=true

Cover Letter for Draft Carlsborg Mitigation Plan:
Martin, Tom. March 14, 2022. Clallam County PUD #1 Cover Letter to Michael Gallagher, WA Department of Ecology.

Draft Carlsborg Mitigation Plan:
Robinson Noble. March 2022. Revised DRAFT Carlsborg New Water Right G2-30364 Mitigation Plan.

Technical Documents Related to Analyzing Carlsborg Deep Well:
Krautkramer, F.M., 2018, Technical Memorandum Clallam County Department of Community Development hydrogeologic setting pertinent to processing water right application, prepared by Robinson Noble.

Krautkramer, F.M., 2020, Carlsborg Deep Test Well Construction and Testing Report, prepared by Robinson Noble.

Krautkramer, F.M., 2021. Technical Memorandum – Task 2E, Supplemental Testing, prepared for Carol Creasey, Clallam County by Robinson Noble.

WAC 173-518, Dungeness Instream Flow
Rule: https://apps.leg.wa.gov/wac/default.aspx?cite=173-518

Pacific Groundwater Group, 2008, Dungeness Groundwater Flow Model Design, Construction, Calibration, and Results

Clallam County, WUA, Ecology, 2011, WRIA 18 East – Dungeness Watershed, Guiding Principles for Managing Water, Cooperators' Agreement Among Clallam County, Sequim-Dungeness Water Users Association, Washington State Department of Ecology, February 15, 2011.

Jamestown S'Klallam Tribe. 2011. W. Ron Allen, Tribal Chairman/CEO, Letter to Washington Department of Ecology, February 5, 2011.

Drost, B.W., 1983, Impact of changes in land use on the ground-water system in the Sequim-Dungeness Peninsula, Clallam County, Washington: U.S. Geological Survey Water-Resources Investigations Report 83-4094.

Jones, M.A., 1996b, Delineation of hydrogeological units in the lower Dungeness River Basin, Washington: U.S. Geological Survey Water-Resources Investigations report 95-4008.

Noble, J.B., 1960, A preliminary report on the geology and ground-water resources of the Sequim-Dungeness area, Clallam County, Washington: Olympia, Wash., Washington Department of Conservation, Division of Water Resources, Water Supply Bulletin No. 11.

Othberg, K.L., and Palmer, Pam, 1980, Preliminary surficial geologic map of the Dungeness quadrangle, Clallam County, Washington: Olympia, Wash., Washington Division of Geology and Earth Resources Open-File Report 79-18.

Robinson & Noble, Inc., 1974, Development of a Deep ground Water source for the Weyerhaeuser Seed Orchard at Sequim, WA.

Thomas, B.E., Goodman, L.A., and Olsen, T.D., 1999, Hydrogeologic Assessment of the Sequim-Dungeness Area, Clallam County, Washington: U.S. Geological Survey Water-Resources Investigations Report 99-4048.

WRIA 18 East – Dungeness Watershed, Guiding Principles for Managing Water Cooperators' Agreement Among Clallam County, Sequim-Dungeness Water Users Association and the Washington State Department of Ecology.

6.12 SHALLOW AQUIFER RECHARGE EFFECTIVENESS

Volunteer Resource Team (additional volunteers needed):
Joe Holtrop, Alex Scagliotti, Lance Vail (adaptive management perspective), Ecology EAP Program Staff (suggested)

Recommendation: The shallow aquifer recharge (SAR) facilities installed over the past few years should be analyzed to determine how effectively they are achieving the intended objectives of mitigating the impacts of new well use and benefiting streamflows.

Background:

All new wells put into use since January 2013 in the Dungeness basin must mitigate their impacts on surface waters. SAR is the means by which new well use is mitigated. Several years of modeling resulted in the development of a "lookup table" to determine the impacts of wells on surface waters. This same table is also used to determine the benefits of SAR on these surface waters.

Washington Water Trust contracted with Pacific Groundwater Group (PGG) in 2014 to conduct a screening level feasibility assessment of the infiltration/storage potential of sites under consideration in the Dungeness basin. Prior to the feasibility assessment, Clallam County contracted with PGG to conduct a study of the effectiveness of shallow aquifer recharge (PGG, 2009). This study was conducted in the Carlsborg area. The results were inconclusive, partly because the volume of water infiltrated was not sufficient to be detected. The first significant SAR facility was constructed in Carlsborg in 2015. Since then, eight more facilities have been installed. Seven of the facilities are located east of the Dungeness River, and only four of the facilities are specifically for mitigation purposes; five are for general recharge/restoration or to mitigate impacts to Graysmarsh resulting from the piping of irrigation ditches.

It has been postulated that water infiltrated in some locations does not benefit surface waters as the well-impact groundwater model indicates it will. The 2008 model report notes that representation of the "shallow aquifer system" as a single (uppermost) model layer does not reflect conditions where the system is divided into more than one water-bearing zone and includes intervening aquitards. Such complexities (e.g., as observed along Bell and Matriotti Creeks) will affect the accuracy of model predictions of the fate/transport of SAR.

WRTG Member and/or Adviser Comments:

[Joe Holtrop] Another thing to take into account here is the groundwater impacts resulting from irrigation ditch piping. Considerable irrigation ditch piping has occurred over the past 20 years, mainly to reduce ditch losses, and thereby reduce withdrawals. A few of the ditch piping projects within the Graysmarsh "zone of contribution" (for its freshwater marsh created by a tidegate) have included aquifer recharge to mitigate for the lost ditch leakage water, but the vast majority of the projects have not included AR.

[Alex Scagliotti] Another note on this as far as mitigation. Gierin Creek has still lost out on flows over the past 3-5 years despite mitigation for piping leaky ditches. I think this underscores Joe's

point as well - that a SAR reevaluation is probably warranted. Another potential issue with mitigation for piping is that the quantities infiltrated are supposed to mirror average summer loss, but it doesn't include off-season maintenance flows and stock watering flows that happen in the fall and winter. I imagine this issue isn't unique just to Gierin Creek.

[Peter Schwartzman, Hydrogeologist] The natural recommendation would be to update the model by adding layers that support representation of aquifers/aquitards within the shallow aquifer SYSTEM. It should be noted that this would require quite a bit of effort for characterization. However, if layers are added, they can retain the simplified depiction where no new data exist but incorporate complexity where data are available.

[Ann Soule] I suggest we ask Ecology's EAP research branch to respond to this - they may have done similar work elsewhere or be able to take it on here.

[Ben Smith, 5/18/22] More priority by DOE on river gauge accuracy, quicker repairs when system is wonky, will be critical to monitoring the effects of aquifer recharge on river flow. Possibly a similar system to what the irrigators are required to do. Visual reading of staff gauges weekly/bi-weekly through irrigation season to confirm or correct instantaneous flow data being recorded.

[Carol Creasey, 5/20/22] Could the recharge information be able to be used to modify/enhance the 2008 model? Also, use the results of the MAR to evaluate how effective the 2008 model and the mitigation calculator are for determining MAR benefits.

Data/References:

Pacific Groundwater Group. 2009. Aquifer Recharge Feasibility Study. Prepared for Clallam County. http://www.clallam.net/environment/assets/applets/DungenessARFSFinal.pdf

Schwartzman, Peter (Pacific Groundwater Group). 2014. Technical Memorandum RE: Infiltration/Storage Screening Analysis for Dungeness River Augmentation. Prepared for Washington Water Trust. https://drive.google.com/file/d/1ahFBxlWAeNQSzmtRogQZcTR4O_raILP0/view?usp=sharing

6.13 FUTURE WATER SOURCING STUDIES

Volunteer Resource Team (volunteers needed):

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Recommendation: A study should be undertaken to consider future sources of water that can supplement existing sources. This study should include desalination, additional use of processed sewage effluent, and additional storage (above ground or underground) facilities.

Background:

The Dungeness Basin is completely dependent upon natural and local precipitation sources for water. The resulting streamflow from the Dungeness River and smaller streams, as well as the percolation and subsurface flow into the aquifer systems, constitute the totality of water resources. Dramatic temperature increases, decreased snowpack and decreased precipitation could have a near term impact on this supply system.

Clallam County has begun development of an off-channel reservoir that is intended to store winter seasonal river flow and runoff for use during the drier summer season. While such storage will provide near-term augmentation, the fundamental dependence on annual precipitation (including snowmelt) suggests that climate change induced weather extremes could threaten the sufficiency of water required to support the expected population growth on top of irrigation and fish/wildlife needs. Additional sources of supplementation would require additional governmental regulatory and funding support. Such planning and execution requires years before the necessary infrastructure can be established.

WRTG Member and/or Adviser Comments:

[Tony Corrado] A plan should be developed with responsible agencies that are located outside of WRIA-18 for determining the methodology for sharing water resources (inter-districts) in the event of natural shortages or localized disasters which may affect any of the individual agencies. . With advanced planning for such a contingency, water resources could be managed in an orderly and sustainable manner.

[Carol Creasey, 5/20/22]

- I would include in the study: “exploration of deep water bearing zones.”
- Research should be done to assess what other tools are used in water short areas such as Australia, etc.

[Robert Knapp, 5/20/22] This group did not explicitly discuss water conservation, but it could be mentioned here and in other topics, if not made a stand-alone topic of its own with related recommendations.

Data/References:

Elwha-Dungeness Planning Units. 2005. Elwha-Dungeness Watershed Plan (WRIA 18 Plan). Water Quantity Recommendations, 3.1 [Section 3.1.1 Future Water Supply Strategies for People and Fish]. http://www.clallam.net/environment/assets/applets/W18 3.1-WaterQuantity.pdf