Predicting Sea Level Rise Impacts on Agricultural Production FINAL REPORT

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Executive Summary

Salmon recovery plans in many watersheds in the Puget Sound highlight the importance of estuary and floodplain restoration to restore juvenile habitat. Many of these landscapes are currently in agricultural production which means implementation of salmon recovery plans will result in loss of farmland. In the Stillaguamish and Snohomish River watersheds, this debate between salmon recovery and agricultural viability has had a negative impact on the goals of both interests - slowing habitat restoration and making it difficult to maintain agricultural land and infrastructure. The Sustainable Lands Strategy (SLS), a group of agencies, organizations and individuals, has been working to develop an approach to floodplain management that maximizes benefits to salmon habitat and agricultural viability. This group, however, lacks some of the tools and technical information necessary to develop this long-range strategy. The Snohomish Conservation District, with SLS partners, launched an effort to provide some of the technical information necessary to successfully engage in this multi-benefit planning effort. To this end, the District, with guidance from the agricultural community, developed the Agriculture Resilience Plan for Snohomish County. Through a combination of information gathering and sharing, creation of online planning tools, project scoping and design, project implementation, and farmland protection, the Agriculture Resilience Plan has proven to be a key component of multi-benefit floodplain planning.

To understand the impacts of climate change on farmland in the Snohomish and Stillaguamish River floodplains, the District initiated technical studies on flooding, groundwater levels, saltwater intrusion, land subsidence and aggradation, and crop impacts. ESRP funding supported assessments of the impact of sea level rise on saltwater intrusion and rising groundwater levels on agricultural lands as well as an assessment of land subsidence and river channel aggradation. The results of all associated studies and the spatial results for sea level rise impacts and flood predictions are available on the District’s website, www.snohomishcd.org/ag-resilience.

Land subsidence and aggradation study

Subsidence refers to the downward sinking of the ground surface. Subsidence of agricultural lands can occur from a lack of sediment inputs to the floodplain, soil compaction, groundwater withdrawals, and decomposition of soil organics. Aggradation refers to the rising of the ground surface and, in this study, refers to the accumulation of sediment within the river channel. Channel aggradation can increase the risk of flooding because it decreases the capacity of the river to carry flood volumes. Floodplain subsidence contributes to drainage issues in agricultural fields and can increase the risk of levee failure through settling and shifting. Therefore, aggradation within the river channel and subsidence of adjacent farmland can increase the flood and drainage impacts to some agricultural areas.

The Snohomish Conservation District partnered with Cardno to conduct subsidence and aggradation studies for the lower Snohomish and Stillaguamish rivers. To evaluate floodplain subsidence, Cardno re-surveyed previously surveyed landmarks and analyzed vertical difference using multiple LiDAR datasets. To evaluate channel aggradation, Cardno compared recent channel cross-sections to historical surveys.

The results of the subsidence analysis in the Stillaguamish and Snohomish River floodplains was inconclusive; it was unclear whether areas of the floodplain were subsiding given the error rates associated with the analysis. The accuracy of LiDAR data comparisons was suspected to be negatively influenced by varying heights of vegetation, making accurate conclusions difficult. The data shows little direct evidence for regional subsidence and limits the magnitude of localized subsidence to no more than 2.4 inches per decade, occurring primarily in areas with high organic soils. The study concludes that
the impact of sea level rise on groundwater levels and salinity as well as the impact of larger winter flood events should be a greater concern than subsidence.

The analysis of cross section data in both river systems indicated that aggradation is occurring in the lower Stillaguamish River and upper Snohomish River channels. In the Stillaguamish River, both the main channel and the Old Main Channel in the estuary experienced aggradation from 1997 to 2011. The general trend of aggradation is expected to continue into the future. Analysis of the Lower Snohomish River, in contrast, showed that the river channel has remained stable from year to year and has not aggraded. The exception is the upper reach of the river (from the SR-9 Bridge to the confluence of the Skykomish and Snohomish Rivers) where modest aggradation is expected into the future.

Saltwater intrusion study
Agricultural areas located near marine waters can suffer from saltwater intrusion, which occurs when saline waters move into groundwater aquifers. In the Lower Stillaguamish and Snohomish River floodplains, groundwater with increased salinity due to saltwater intrusion could affect the growing conditions for crops if that salinity reaches root zones. Sea level rise could increase saltwater intrusion into groundwater in these areas as the saltwater interface rises in relation to freshwater aquifers.

A groundwater study was completed by Cardno that assessed the impact of sea level rise projections on saltwater intrusion as well as groundwater levels on agricultural lands. Cardno measured salinity levels (measured as conductivity in mS/cm) in shallow groundwater wells for a period of eight months. In the Lower Stillaguamish, conductivity measurements suggest that crops in the lower estuary (Florence Island) may already be stressed by existing salinity conditions. These impacts are expected to increase in severity over the next 50 years. In contrast, agricultural land on Ebey Island in the Snohomish River floodplain may not experience significant increases in salinity intrusion to shallow groundwater due to being located further from marine waters.

Traditional pumping and infrastructure solutions to rising seas may not provide adequate protection for the future. For example, installation of pumps to reduce groundwater impacts to drainage could draw deep, salty groundwater upward, closer to the rooting zone of crops. Future improvements to pumps and drainage systems must consider groundwater salinity intrusion effects from rising sea levels. In the Snohomish River, pumping in the Marshland and French Slough Diking Districts is not likely to impact groundwater salinity, but additional analysis is recommended before implementing a more aggressive pumping approach further downstream on Ebey Island. In the Stillaguamish River floodplain, increasing the amount of pumping on Florence Island is not recommended unless additional groundwater analysis negates the findings of this study, as pumping could result in increasing the impact of salinity on agricultural land.

The interplay of sea level rise, groundwater, and surface water management for the lower Stillaguamish and Snohomish River floodplains is complex, and many uncertainties remain that have not yet been resolved. The study recommends a focused data collection effort to evaluate the degree to which salinity already affects crop yields in the region.

Groundwater level study
Groundwater levels are a major variable affecting agricultural operations in the lower Snohomish and Stillaguamish River floodplains. The timing and extent of groundwater saturation affects when farmers can get out on their fields in the spring with wetter years resulting in delayed access to fields and drier years allowing earlier access depending on crop types.
Climate change is expected to impact groundwater conditions and timing in both watersheds. A rise in relative sea level is expected to raise groundwater levels and extend the period of saturation in the spring, thereby delaying field access. The impact of sea level rise on groundwater levels may also shorten the agricultural season in the fall as groundwater levels return to pre-spring conditions earlier.

To better understand the impacts of sea level rise on groundwater, the Conservation District partnered with Cardno to assess the impact of rising sea levels on groundwater levels in the spring and fall on floodplain agricultural land. The study examined the lower Snohomish and Stillaguamish basin floodplains from the mouth upstream to the extent of tidal influence on groundwater levels for each river system and included installation of monitoring wells throughout these areas in addition to analysis of well data from partners.

Results indicate that rising sea levels are anticipated to delay the time when farmers access their fields in the spring. While natural variation will continue, sea level rise will generally increase the delay of start times for working fields and this increase will become more and more pronounced with time. For low-lying farmland, delays could reach three weeks by the 2050’s and four to five weeks by the 2080s. Areas closer to the Puget Sound coast (within a few miles) will feel the greatest effects of this change because of their proximity to rising marine waters.

Integration and multi-benefit planning
Through a robust community engagement process, farmers provided priority resilience needs for their specific reach which are included as Reach Summaries in Chapter VII in the Agriculture Resilience Plan. The major themes raised during this community engagement are directly related to the challenges associated with rising sea levels, land subsidence, and channel aggradation. Priorities include farmland protection, drainage infrastructure and maintenance, compensation for upland runoff, flood protection, access to irrigation water, drought resilience practices, and additional groundwater analysis.

An Integration Team was created as part of the Sustainable Lands Strategy process in Snohomish County where project practitioners meet to develop balanced and mutually beneficial project packages that support salmon recovery, flood protection and agricultural resilience. The agricultural needs and specific projects identified through the Agriculture Resilience Plan effort have been critical for the success of this group.
Introduction

Restoring fishery habitats and ensuring continued agricultural viability in Snohomish County's floodplains depends on collaboration between agencies and land managers in low-lying coastal landscapes. Projected sea level rise and increased flood intensity are anticipated to force retreat from these lands as groundwater drainage, saltwater intrusion, land subsidence, and high intensity flooding threaten agricultural viability. Government and private planners have no quantitative basis for considering these risks as long-range strategies for managing low-lying lands are developed, either for habitat restoration or protection of agricultural productivity. Forecasting future groundwater impacts, land elevation changes (land subsidence and river channel aggradation), and flood risks are helping decision makers design strategies that protect agricultural production, reduce flood impacts, and recover salmon populations.

Farmlands in the floodplains and estuaries of the Snohomish and Stillaguamish Rivers are predicted to experience increased flooding and drainage issues associated with climate change impacts. Outreach to farmers and diking district managers in these estuarine areas highlighted the need for studies on sea level rise impacts to groundwater levels and saltwater intrusion, flooding predictions, as well as a study of vertical land movement. Sea level rise is expected to increase the groundwater level on estuarine and floodplain agricultural fields, impacting the timing of spring tillage and ultimately the length of the growing season. This rise is also predicted to increase saltwater intrusion in the rooting zone, negatively impacting farmland productivity. Many farmers cited agricultural land subsidence and river channel aggradation as important factors that exacerbate drainage issues caused by sea level rise and increased flooding. Tillage and decomposition of soils with high organic content (typical of floodplain wetland soils) coupled with disconnection of the floodplains from their respective rivers is suspected to be resulting in sinking, or subsidence, of land. In addition, increased flooding, upriver landslides, and the cessation of channel dredging have resulted in changes to sediment dynamics in the rivers and potentially aggradation of river channels. To get a complete picture of how groundwater and flooding predictions will impact agricultural land into the future, these additional factors were studied.

The goals of this project were to use several methodologies to assess and map sea level rise impacts to groundwater levels and salinity in addition to historic floodplain and river channel land elevation changes and rates (subsidence and aggradation), investigate these methods as tools to predict future changes, and to gain a better understanding of the associated impacts to agricultural lands in the Snohomish and Stillaguamish floodplains related to sea level rise and land elevation changes. Focus areas for the groundwater analysis included estuary and floodplain farmland within the tidally influenced portions of the Stillaguamish and Snohomish rivers. Focus areas for the land subsidence study included portions of this same study area with high organic content soils (subsidence) and mainstem river channels (aggradation). These studies have provided technical information to salmon recovery project sponsors, local planners, and decision makers about the projected changes to land currently in agriculture that is needed for salmon recovery, including former estuary and floodplain land.

Study Outcomes

The Snohomish Conservation District has completed an Agriculture Resilience Plan for the county that examines future impacts to the resilience of agriculture and evaluates landscape-scale projects to increase resilience. This project contributed to development of the Resilience Plan and complemented ongoing flooding work completed with other funding sources. Mapped results of the groundwater and
flooding studies have been incorporated into an existing online tool – called the “Floodplains by Design Decision Support Tool” - created and maintained by The Nature Conservancy.

Land Subsidence and Channel Aggradation Study
See the following technical reports for details:


Summary
The Snohomish Conservation District’s farmers and residents have observed the subsidence of floodplain agricultural lands and levees and potential aggradation of river channels over time. Subsidence may be occurring from lack of sediment input to the floodplain, soil compaction, and decomposition of soil organics. The purpose of this study was to measure and evaluate the magnitude and rate of these changes on commercial agricultural lands in the floodplains of the Snohomish and Stillaguamish Rivers.

Methodology
Several techniques were used to determine change in vertical land movement on the agricultural floodplain land and in the river channels. The project began with a review of existing data and resulted in use of the following:

- 2001 topographic survey dataset from Snohomish County
- 2005/2006 LiDAR Puget Lowlands Quads DEM
- 2009 LiDAR Snohomish River Estuary
- 2014 LiDAR from the King County

Subsidence and/or aggradation rates of floodplain agricultural land were assessed using several methodologies and comparing their error rates. These included a GPS-based real time kinematic survey, LiDAR differencing, and InSAR (satellite radar).

Aggradation rates of river channels in both the Snohomish and Stillaguamish rivers were assessed using a recent study by R2 Resource Consultants (Devries, 2015) and the following data and models:

- Snohomish River – HEC-RAS one-dimensional (1D) model (2011)
- Snohomish River near Beck Dike – HEC-RAS two-dimensional (2D) model (2017)

Cardno compared recent channel cross-sections to historical surveys, evaluating 48 cross-sections of the Stillaguamish River and its tributaries and 19 cross-sections of the Snohomish River.

See Technical Memos for detailed methodologies (Cardno, 2019a; Cardno, 2019b).
Results

Land Subsidence

The results of the subsidence analysis in the Stillaguamish River floodplain were inconclusive; it was unclear whether areas of the floodplain were subsiding given the error rates associated with the analysis. The accuracy of LiDAR data comparisons was suspected to be negatively influenced by varying heights of vegetation and a short timeframe of comparison, making accurate conclusions difficult. The resurvey of benchmarks suggests localized subsidence in known locations but does not provide an indication of larger-scale agricultural land subsidence in the timeframe of data collection, although it may be that greater rates of subsidence occurred in the past. The data shows little direct evidence for regional subsidence and limits the magnitude of localized subsidence to no more than 2.4 inches per decade in some areas.

Potential subsidence in the Snohomish River floodplain was also assessed using LiDAR data as well as resurvey of benchmarks. This analysis showed a range of subsidence from 1 to 6 inches approximately every 10 years in some areas. In general, however, the uncertainty in the LiDAR comparisons exceed the magnitude of elevation change that may have occurred, so the datasets are not conclusive. As in the Stillaguamish River, the data limits the likely magnitude of subsidence to no more than 2.4 inches per decade, and primarily in areas with high organic soils on Ebey Island and in the Marshland and French Slough Flood Control Districts. Feedback from local farmers indicates that organic soils subside more quickly in the years after initial clearing, draining and cultivation than in subsequent years. Lower rates of subsidence within the timeframe of data collection may have been harder to detect but are an indicator of future subsidence rates.

Channel Aggradation

In the Stillaguamish River, cross-sections of the river channel showed that both the main channel and the Old Main Channel experienced aggradation from 1997 to 2011. The general trend of aggradation is expected to continue into the future. Dredging in the Lower Stillaguamish River is not considered to be an option for mitigating this risk because it would not reduce future sediment inputs that would continue to aggrade the river and because it would cause a negligible decrease in the peak flood stage.

Analysis of the Lower Snohomish River showed that the river channel has remained stable from year to year and has not aggraded. However, the upper reach of the river (from the SR-9 Bridge to the confluence of the Skykomish and Snohomish Rivers) showed aggradation. This reach may experience modest aggradation into the future.

See Technical Memos for detailed results (Cardno, 2019a; Cardno, 2019b).

Saltwater Intrusion Study

See technical report for details:


Summary

Agricultural areas located near marine waters can suffer from saltwater intrusion, which occurs when saline waters move into groundwater aquifers. In the Lower Stillaguamish and Snohomish River
floodplains, groundwater with increased salinity due to saltwater intrusion could affect the growing conditions for crops if that salinity reaches root zones. Though salts are crucial plant nutrients, high concentrations of any one salt or many different salts can be toxic to plants. Sea level rise could increase saltwater intrusion into groundwater in these areas as the saltwater interface rises in relation to freshwater aquifers. The groundwater study completed by Cardno assessed the effect of sea level rise on saltwater intrusion into shallow groundwater.

Methodology
Cardno measured salinity levels in shallow wells drilled for the groundwater study as well as analyzed data from partners’ wells. Salinity impacts are measured in millisiemens per centimeter (mS/cm), a metric that measures conductivity values as an indicator of salinity. Based on the salt tolerance of crops most commonly grown in the Stillaguamish and Snohomish River floodplains (corn, grass, beets, spinach, and cabbage) and the depth of the wells used in the study, it was assumed that 3 mS/cm would best indicate potential impacts of saltwater intrusion on agricultural production. The response of plants to 0-2 mS/cm is mostly negligible, while sensitive plants can experience yield impacts with 2-4 mS/cm. Most plants would be restricted by 4-8 mS/cm, and only tolerant plants can grow under conditions with 8 mS/cm or more.

See full groundwater technical report for detailed methodology (Cardno, 2019c).

Results
Geographic location is a key factor in saltwater intrusion impacts. Areas closest to the shoreline have the highest risk of increased groundwater salinity intrusion due to rising sea levels (Figure 1). Areas within 5,000 feet of the shoreline are especially vulnerable to groundwater salinity intrusion to the shallow rooting zone of crops but areas within 10,000 feet may also experience measurable increases in salinity over time.

In the Lower Stillaguamish, existing conductivity measurements at wells within 1,000 feet of Hatt Slough showed a range of 0.1 to 6.7 mS/cm in late August 2016. These readings suggest that crops in the lower estuary (Florence Island) may already be stressed by existing salinity conditions, and those impacts are likely to increase in severity over the next 50 years (Figure 2). Farmers in this area confirm that this is true in patches, but that much land is still highly productive. In contrast, agricultural land on Ebey Island in the Snohomish River floodplain may not experience significant increases in salinity intrusion to shallow groundwater due to its location further from marine waters. Because the Marshland and French Slough Flood Control Districts are greater than 20,000 feet from the ocean boundary and Ebey Island and DD13 are likely to remain 10,000 ft or more from the shoreline, sea level rise is not expected to cause significant increases in salinity intrusion to shallow groundwater in either part of the Snohomish Basin (Cardno, 2019c).
Figure 1: Combined summer salinity datasets from the Stillaguamish and Snohomish River basins. Shallow groundwater is influenced by seawater salinity only within a few thousand feet of the shoreline (Cardno, 2019c).

Traditional pumping and infrastructure solutions to rising seas may not provide adequate protection for the future. For example, installation of pumps to reduce groundwater impacts to drainage could draw deep, salty groundwater upward, closer to the rooting zone of crops (Thomas et al., 1997; Figure 3). Future improvements to pumps and drainage systems must consider groundwater salinity intrusion effects from rising sea levels. In the Stillaguamish River floodplain, increasing the amount of pumping on Florence Island is not recommended unless additional groundwater analysis negates the finding of this study, as pumping could result in increasing impact of salinity on agricultural land (See Map: Figure 4).

In the Snohomish River, pumping in the Marshland and French Slough Diking Districts is not likely to impact groundwater salinity, but additional analysis is recommended before implementing a more aggressive pumping approach further downstream on Ebey Island (See Map: Figure 5).

The interplay of sea level rise, groundwater, and surface water management for the lower Stillaguamish and Snohomish River floodplains is complex, and many uncertainties remain that have not yet been resolved. The study recommends a focused data collection effort to evaluate the degree to which salinity already affects crop yields in the region.
Figure 2: Sea level rise impacts to groundwater in Lower Stillaguamish River. This figure shows the projected level of late spring/early summer salinity intrusion in the Stillaguamish Estuary out to 2100 under the highest carbon emissions scenario (RCP 8.5). The shaded lines represent where the threshold for crop impacts is expected to reach for that year.
Figure 3: Effects of groundwater pumping. Increased pumping and drainage may cause further diffusion of salty groundwater upward (pink arrow at right) toward the rooting zone of crops (Cardno, 2019c; adapted from Thomas et al., 1997).

Figure 4: Agricultural districts in the Stillaguamish River floodplain. Results indicate salinity intrusion in the rooting zone of portions of Florence Island (indicated with purple box). Increased pumping to manage agricultural drainage could result in increasing the impact of salinity on agricultural land (Cardno, 2019c).
Figure 5: Agricultural districts in the Snohomish River floodplain. In the Snohomish River, pumping in the Marshland and French Slough Diking Districts is not likely to impact groundwater salinity, but additional analysis is recommended before implementing a more aggressive pumping approach further downstream on Ebey Island (Cardno, 2019c).

See full groundwater technical report for detailed results (Cardno, 2019c).

**Groundwater Level Study**

See technical report for details:


**Summary**

Groundwater levels are a major variable affecting agricultural operations in the lower Snohomish and Stillaguamish River floodplains. The timing and extent of groundwater saturation affects when farmers can get out on their fields in the spring - accessing when fields are too wet can cause damage to equipment and soils. Wetter years will result in delayed access to fields and drier years may allow earlier access depending on crop types. In the fall, rain and the associated rise in the groundwater table effectively ends the cultivation season.
Climate change is expected to impact groundwater conditions and timing in both watersheds. A rise in relative sea level is expected to raise groundwater levels and extend the period of saturation in the spring, thereby delaying field access. The impact of sea level rise on groundwater levels may also shorten the agricultural season in the fall as groundwater levels return to pre-spring conditions earlier.

The table below shows relative sea level rise projections at the Snohomish River and Stillaguamish River mouths (RCP 8.5 high emissions scenario).

<table>
<thead>
<tr>
<th>River</th>
<th>Year 2050</th>
<th>Year 2080</th>
<th>Year 2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snohomish River</td>
<td>0.8 feet</td>
<td>1.5 feet</td>
<td>2.2 feet</td>
</tr>
<tr>
<td>Stillaguamish River</td>
<td>0.7 feet</td>
<td>1.5 feet</td>
<td>2.2 feet</td>
</tr>
</tbody>
</table>

Methodology
Cardno examined the lower Snohomish and Stillaguamish basin floodplains from the mouth upstream to the extent of tidal influence for each river system, assessing the impact of rising sea levels on groundwater levels on agricultural land (Cardno, 2019c). For the Snohomish River, the study area extended from the mouth of Possession Sound to Thomas’ Eddy at river mile 16.1. The Stillaguamish River study area extended from the mouth of the river at Hatt Slough upstream to the Pioneer Highway Bridge at river mile 7.4.

In order to confirm assumptions about geology and to document groundwater levels across seasons, Cardno installed wells throughout the study areas. They also used data from existing wells operated by Snohomish County, the Stillaguamish Tribe, and the Washington Department of Fish and Wildlife. Cardno used the recently released *Projected Sea Level Rise for Washington State* (Miller et al, 2018) to incorporate projections of relative sea level rise into the analysis. Sea level rise was assumed to affect river channels up to the current extent of tidal influence.

Examination of existing groundwater conditions showed that groundwater at farms in both the Snohomish and Stillaguamish watersheds tend to decline about one foot per month through the spring. In the fall, higher river flows cause groundwater levels to increase to early-spring elevations. Based on this information about current conditions, the groundwater study was able to project delays in spring cultivation by calculating how long it would take future groundwater levels, raised by sea level rise, to fall to current spring conditions.

See full groundwater technical report for detailed methodology (Cardno, 2019c).

Results
Results indicate that rising sea levels are anticipated to delay the time when farmers access their fields in the spring. While natural variation will continue, sea level rise will generally increase the delay of start times for working fields and this increase will become more and more pronounced with time. For low-lying farmland, delays could reach three weeks by the 2050’s and four to five weeks by the 2080s. Areas closer to the Puget Sound coast (within a few miles) will feel the greatest effects of this change because of their proximity to rising marine waters. Figure 6 and 7 show groundwater projections for the Stillaguamish and Snohomish watersheds to the year 2080. The full groundwater technical report (Cardno, 2019c) provides maps for different time frames and emissions scenarios.

The study found that the effects of sea level rise on the timing of groundwater conditions in the fall are not likely to be significant because anticipated changes in levels would be within the range already
experienced under natural tidal cycles. Therefore, the delay in start times for working fields in the spring would not be made up in the fall.

A separate analysis was conducted for Ebey Island in the Lower Snohomish River floodplain. Because no groundwater data is available for Ebey Island, well data from nearby Smith Island was used as an analog. It was found that groundwater levels on Smith Island track the levels of Puget Sound tides and are within a foot of the height of the adjacent slough during summer months. If we apply this relationship to Ebey Island, it indicates that sea level rise could have a direct impact on groundwater levels. The analysis shows that a number of areas on the island would lie below the groundwater table and be inundated without active drainage and pumping (Figure 8). However, farmers on Ebey Island have stated that pumping and drainage effectively dry out all cultivated areas. This emphasizes the critical role pumping plays in maintaining agricultural viability, a role that will become even more important with sea level rise.

Figure 6: Sea level rise delay to spring crop cultivation, Stillaguamish River. The projected delay to spring crop cultivation due to sea level rise is shown in weeks (blue = 5 week delay; tan = 1 week delay) for the year 2080 under a high emissions scenario (RCP 8.5). See technical report for other scenarios (Cardno, 2019c).
Figure 7: Sea level rise delay to spring crop cultivation, Snohomish River. The projected delay to spring crop cultivation due to sea level rise is shown in weeks (blue = 5 week delay; tan = 1 week delay) for the year 2080 under a high emissions scenario (RCP 8.5). See technical report for other scenarios (Cardno, 2019c).
Figure 8: Future conditions depth-to-groundwater, Ebey Island. Projected depth-to-groundwater data for Ebey Island in 2080 under a high emissions scenario (RCP 8.5). See technical report for more scenarios (Cardno, 2019c).

See full groundwater technical report for detailed results (Cardno, 2019c).

**Data Integration and Resilience Project Prioritization**

**Integrating farmer feedback into resilience needs**

The agricultural community in Snohomish County is facing many current and projected challenges associated with increased development and a changing climate. Through a robust community engagement process, farmers provided priority resilience needs for their specific reach which are included as Reach Summaries in Chapter VII in the Agriculture Resilience Plan.

Below, the major themes raised during this community engagement process are documented. Many of these are directly related to the challenges associated with rising sea levels, land subsidence, and channel aggradation that were analyzed in this study.

Addressing the following resilience needs will require partnership building, innovative approaches to problem solving, creative thinking, and funding acquisition. Farmers highlighted the need for grant and/or loan funding to help them address many of these issues described below.
Priority agricultural needs include farmland protection, drainage infrastructure and maintenance, compensation for upland runoff, flood protection, access to irrigation water, drought resilience practices, and additional groundwater analysis. A Project List was created that specifies projects identified by farmers. This list will continue to be adapted through ongoing evaluations of priority, feasibility and cost-effectiveness.

Farmland conservation

Through a stakeholder led prioritization process, PCC Farmland Trust and partners on the Snohomish Farmland Conservation Working Group identified a 10-year protection target of 15,000 acres of high priority farmland. Much of Snohomish County’s commercial farmland is in the floodplain, where state and local regulations provide partial barriers to conversion of the land to other uses. Still, many farms in both the floodplains and upland areas continue to be lost to development, habitat restoration, businesses, and other uses. While this 10-year acreage target does include upland agricultural land protection goals, a focus on farms utilizing the highly productive soils of the floodplains is critical to ensure a viable agricultural system in the county.

Existing funding sources for Purchase of Development Rights (PDR) and Transfer of Development Rights (TDR) programs are insufficient to reach the 10-year protection target or satisfy farmer interest. In addition, the per acre easement payments to farmers through these two programs are often too low to incentivize participation. Potential options for increasing funding available include growing the TDR program, securing grants, and/or leveraging additional taxes.

Drainage infrastructure and maintenance

Diking, drainage, and flood control districts across the County consistently report insufficient funding to manage current drainage needs, citing runoff from upland areas and increased flooding as major impacts. Climate change projections indicate increased stormwater runoff and flood frequency and scale, highlighting the need for improvements to and increased capacity of drainage systems.

Many agricultural areas require a drainage needs assessment to inform projects that would increase capacity of existing culverts, tide gates, and pump stations as well as replace aging infrastructure. Assistance acquiring and complying with permits for infrastructure improvement projects as well as regular maintenance of drainage conveyances is critical. In addition, individual farms would benefit from increased technical and funding assistance for drainage improvements.

Compensation for upland runoff

Development of upland areas has resulted in increased runoff reaching floodplain areas, in many cases exacerbating drainage challenges for farmers. A few diking, drainage, and flood control districts have agreements with local jurisdictions to collect stormwater fees to help offset the costs associated with increased runoff and sediment, while most do not. There is a need to develop creative solutions to increasing revenue available for drainage maintenance.

Projects or initiatives to reduce upland runoff would also greatly benefit farmers. These potentially include use of green stormwater infrastructure, regulatory changes to county and city development codes, and education or incentives for urban and suburban landowners and developers to reduce runoff from their properties.
Flood protection

While farms in the floodplain are often inundated in winter months, damages are minimized and spring drainage made possible through a system of sea dikes, river levees, and riverbank protection projects. In many places, this flood protection infrastructure is in need of improvement or replacement, and in others, there is a need for additional protection. With flood frequency and severity predicted to increase, impacts to this infrastructure will increase.

In the upper reaches of the watersheds, flood protection (in the form of bank stabilization) is needed to protect against loss of farmland to a migrating river channel. In the lower floodplain, flood protection needs include levee maintenance, flood fencing and streambank planting to lessen sediment and debris deposition on farms. Larger landscape-scale projects or approaches to water management that increase the capacity of the floodplain or channel to store flood waters are also recommended if they lessen the impacts of flood events on farm infrastructure, protect banks, and improve agricultural productivity. Finding creative solutions to increasing water storage on farmland, while reducing the negative impacts of long-term inundation and meeting increased spring drainage needs, could provide a win-win for farm, flood, and wildlife interests.

Access to irrigation water

Many farms do not have legal water rights yet have a need for irrigation water to maintain their viability. Any withdrawal of surface water requires a water right and most commercial withdrawals of groundwater do as well. Climate change projections indicate the need for irrigation water will increase with less precipitation falling in summer months and with increasing temperatures. The Department of Ecology manages water resources in Washington State, including the issuance of water rights. At this time, applying for new water rights is not a feasible option for farmers as basins are closed to additional water withdrawals.

There is a need for creative approaches to providing access to water for farmers. Potential options include allowance of water withdrawals or capture during winter months, on-farm water storage, and/or the coordinated management and leasing of water rights at a landscape scale.

Assistance implementing drought resilience practices

There are numerous techniques that can be used to increase a farm’s resilience to drought or to reduce the need for irrigation. Existing incentive and grant programs through the state and federal government provide cost-share funding for practices that build soil water holding capacity, hold and/or store water, and increase irrigation efficiency. These programs, however, are often highly competitive or pay low rates. With climate predictions indicating hotter and drier summers, additional funding is needed to incentivize practices such as cover cropping, no-till, compost or biochar application and agroforestry. In addition, research and/or on-farm trials of newly developing drainage infrastructure, such as controlled release of water from drain tiles or drainage ditches, is needed.

Additional groundwater analysis

Further study of groundwater levels and saltwater intrusion are recommended in the estuaries of the Stillaguamish and Snohomish Rivers to validate predicted impacts of sea level rise on farmland.
In the Lower Stillaguamish River floodplain, projections for saltwater intrusion on Florence Island and in Drainage District 7 have been extrapolated from groundwater well data south of Hatt Slough. Cardno recommends collection and analysis of additional well data in these specific locations.

In the Lower Snohomish River floodplain, projections of groundwater levels on Ebey Island and in Diking Districts 2 and 4 have been extrapolated from groundwater well data on Smith Island. If increased pumping is considered as a tool to combat a rising groundwater table, further study is recommended to determine if this will result in upward migration of salty groundwater thus impacting crop yields.

For more detailed lists of prioritized resilience needs by reach, see Chapter VII in the Agriculture Resilience Plan (Snohomish Conservation District, 2019).

**Integrating agricultural priorities into multi-benefit planning**

The completion of the Agriculture Resilience Plan presents an exciting opportunity for floodplain and estuary planners to more successfully engage in multi-benefit planning with community support. Salmon recovery plans for both the Stillaguamish and Snohomish Rivers highlight the importance of estuary and floodplain restoration on lands that are in agricultural use. Having the agricultural needs and reach scale projects identified and prioritized allows planners to work with the agricultural community to achieve net gain for both agriculture and salmon recovery.

The Sustainable Lands Strategy is a stakeholder engagement effort in Snohomish County bringing together partners to achieve this net-gain for salmon recovery, agricultural resilience, and flood protection. Partners including agencies, local jurisdictions, tribes, the Conservation District, and local farmers meet to discuss and develop multi-benefit approaches to floodplain management. Within the last year, an Integration Team was created as part of this work where on-the-ground project practitioners work together to develop balanced and mutually beneficial project packages. The agricultural needs and specific projects identified through the Agriculture Resilience Plan effort have been critical for the success of this group. Near-term multi-benefit project lists have been created for the Stillaguamish and Snohomish River floodplains.
Works Cited


Appendix A: Stakeholder Engagement Summary

The Agriculture Resilience Plan is intended to be the farmers’ plan – a document that reflects the interests and priorities of farmers in Snohomish County. Therefore, outreach to and engagement with the farming community has been a key component of developing this plan and will continue to be central to its implementation. Input has been solicited through the formation of a Steering Committee of local farmers, outreach to existing agricultural groups and individual farmers, and the PhotoVoice project. The next phase of plan implementation will involve robust planning conversations with groups of farmers on the landscape to develop and scope landscape-scale projects that improve agricultural viability.

Snohomish Conservation District formed a Steering Committee for the Agriculture Resilience Plan in order to ensure that the plan is guided by the input of local farmers. The Committee is comprised of 10 Snohomish County farmers representing various types, sizes, and locations of farms. The Steering Committee meets quarterly and provides guidance to the direction and development of the plan and its implementation. The Committee reviewed the technical information gathered as part of the impacts assessment (including the studies discussed in this report) and assisted in prioritizing the needs of agriculture at the county-wide scale.

In addition to soliciting guidance from the Steering Committee, the Conservation District conducted extensive outreach to the local farming community. In fall 2016 and winter 2017, the District reached out to existing agricultural groups to ask for input into the scope of this project. Groups included the Snohomish Conservation District Board of Supervisors, Focus on Farming attendees, the Sustainable Lands Strategy Agriculture Caucus, the Snohomish County Farm Bureau, Snohomish County Cattlemen, the Snohomish County Agricultural Advisory Board, SnoValley Tilth, the Coordinated Diking Council, the Marshland Flood Control District, the French Slough Flood Control District, and the Stillaguamish Flood Control District.

In spring 2019, the District launched a broader community engagement effort, primarily focusing on commercial farmers in the river floodplains. Presentations were given for local diking, drainage, and flood control districts and community meetings were organized outside of these areas. The goals of this effort were to provide localized results from the risk modeling and assessment work and gather feedback on resilience needs and potential projects. The information presented included the predictions for future flood scenarios, an assessment of land subsidence and channel aggradation, and predictions for the impacts of sea level rise on groundwater levels and saltwater intrusion. This information was used to create Reach Summaries (Chapter VII of Agriculture Resilience Plan) that were then reviewed and revised by the farming community in summer 2019. In total, eight community meetings or presentations were organized and over 75 farmers provided input into the final recommendations in the plan.

In order to increase engagement of farmers in development of the Agriculture Resilience Plan, the Snohomish Conservation District and The Nature Conservancy conducted a PhotoVoice project. Seven farms took part in the project and participated in a series of four photography workshops. Participants were taught photography skills, then each took photographs to respond to two questions – “Why is agriculture important to our community?” and “What are the major challenges facing agriculture?” Themes that emerged in the photographs included farmland protection, increasing resilience to climate...
change impacts, improving drainage in the face of increased flooding, and the importance of local and sustainable agriculture. The photographs and accompanying captions were the centerpiece of an exhibition event attended by farmers, elected officials, and agency staff. The photos were presented to the Snohomish County Council and have become part of an exhibition that has been shown at venues and events throughout the county. Photographs and captions from the PhotoVoice project are included throughout this Plan.

The feedback gathered during these outreach efforts was organized into a set of county-wide priorities as well as specific reach summaries. The county-wide priorities are listed in the Data Integration and Resilience Project Prioritization section above and include farmland conservation, drainage infrastructure and maintenance, compensation for upland runoff, flood protection, access to irrigation water, assistance implementing drought resilience practices, and additional groundwater analysis (Snohomish Conservation District, 2019). Reach Summaries (Chapter VII) in the Agriculture Resilience Plan detail information gathered from the community including existing farming and infrastructure, projected impacts to agricultural viability, and prioritized resilience needs for eleven reaches in the Stillaguamish and Snohomish river floodplains.
Appendix B: Lessons Learned and Recommendations

Lessons Learned
This has been a multi-faceted, collaborative project that involved a robust community engagement effort and novel technical assessment approaches. As such, there have been many lessons learned over the past few years. These include:

- The importance of engaging the broader farming community. We originally envisioned most of the farmer input coming from the Steering Committee of eleven farmers but were quickly informed by this committee that a broader community engagement effort was needed. This effort involved over 8 community meetings and then follow-ups with several of these groups and individual farmers, prolonging the development of the Agriculture Resilience Plan by one full year. This effort, however, has been invaluable and as such, the Plan has garnered the support of the farming community, a key for project development and floodplain planning into the future.

- The need for contingency funding for technical studies. When using technical approaches that have not been tested such as the ones used for flood modeling, the groundwater level assessment, the saltwater intrusion study and the subsidence study, contingency funding was needed to adapt over the course of the studies.

- Ineffectiveness of remotely sensed vertical land movement technologies. The use of LiDAR differencing and InSAR did not result in specific enough data to indicate small changes in vertical land movement. Re-survey of previously surveyed points proved effective but was only possible in one small area where historic survey data existed.

- The importance of completing planning work quickly to maintain community support. The farming community is excited about the document created outlining their resilience needs, but they are anticipating immediate action. We pushed throughout this project to complete this Plan quickly and move into implementation. We were successful at this and secured funding to scope and design projects before the Plan was complete to ensure we continue to move forward.

Recommendations for future work
We have several recommendations based on the lessons learned above. They are as follows:

- Secure contingency funding for large technical studies to allow for adaptive management.
- When working with the larger community to complete a plan, move quickly and line up implementation funding before you complete the plan so you can keep momentum and excitement within the community.
- Use technical experts to explain climate predictions to landowners and do not shy away from providing scientific projections. Much respect has been gained from the agricultural community in doing so.
- Ask for direction from the community. It was critical that we develop a Steering Committee of local farmers to guide this work, present at farm group meetings, and host community meetings. It was also important to show responsiveness to their guidance.
- Don’t be afraid to reach out to the farming community at large. There may be disparate opinions and responses, but it is critical the community feels heard. Many relationships were built
through the process of educating farmers, listening to them, and then asking for their help in writing the Plan.

- Provide technical information for the community and to back up your plan recommendations. It was critical that we completed the flooding and groundwater work (in addition to temperature, growing season, and precipitation predictions in partnership with WSU) to both provide useful information for the farming community, but also to build credibility with partners.