Creating a Resilient Transportation Network in Skagit County

Using Flood Studies to Inform Transportation Asset Management

FHWA Pilot Project Report

WSDOT

2015

U.S. Department of Transportation
Federal Highway Administration

Washington State Department of Transportation

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Technical Report Documentation Page
Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY	2. REPORT DATE	3. REPORT TYPE AND DATES
	February 2015	Final Report

4. TITLE AND SUBTITLE
Creating a Resilient Transportation Network in Skagit County:
Using Flood Studies to Inform Transportation Asset Management

5. PROJECT ID NUMBER

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Washington State DOT (address above), and
Federal Highway Administration
1200 New Jersey Avenue, SE Washington DC, 20590

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public on the FHWA website at:
www.fhwa.dot.gov/environment/climate/adaptation/2015pilots/

12b. DISTRIBUTION CODE

13. ABSTRACT

This report presents the results of a Climate Resilience Pilot Project conducted by Washington State Department of Transportation (WSDOT) and sponsored in part by the Federal Highway Administration (FHWA). WSDOT received a grant from FHWA to develop options for improving the resiliency of transportation facilities or systems to climate changes and/or extreme weather events. The pilot project set out to meet FHWA's goal of helping further the state of the practice in applying vulnerability assessment results into decision making. This study builds on WSDOT's earlier pilot by examining adaptation options in an area of the state we previously identified as highly vulnerable: the Skagit River Basin (Basin). WSDOT chose this Basin because it is the focus of a major flood study by the U.S. Army Corps of Engineers (Corps). WSDOT knew important decisions about how and where to invest in levees and other flood risk reduction projects were being actively evaluated by the Corps and the local sponsor, Skagit County. WSDOT also knew that state transportation assets were likely to be affected but were not the focus of their study. WSDOT's pilot presented the opportunity to actively engage with the flood study and search for compatible long-term solutions that create a more resilient transportation system throughout the Basin. WSDOT's pilot shows transportation planners and asset managers how to leverage a federal flood study, like the Corps' Skagit River Flood Risk Management General Investigation Study (GI study), to improve the resiliency of our highways. The pilot demonstrates how WSDOT's Vulnerability Assessment results, used in combination with federal flood study data, can reaffirm known vulnerabilities and reveal other vulnerable assets. The pilot identifies adaptation strategies for the Basin and highlights future partnership opportunities with the Corps and local governments. This report includes a series of recommendations and lessons learned that will help other DOTs and regional transportation planning entities reach across jurisdictions and sectors to create integrated asset management strategies.

14. SUBJECT TERMS	15. NUMBER OF PAGES 42
climate change, adaptation	16. ACCOUNTING DATA

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

Acknowledgements

The Washington State Department of Transportation (WSDOT) would like to thank the following organizations for partnering with us in the development of this adaptation pilot project:

- Skagit County Public Works Department
- U.S. Army Corps of Engineers Seattle District
- Federal Highway Administration's (FHWA's) Offices of Environment, Planning and Realty, and the FHWA's Office of Infrastructure
- WSDOT Sustainable Transportation Leadership Team

WSDOT would also like to extend special thanks and appreciation to our primary contacts at Federal Highway Administration, our Pilot Project Team, and other WSDOT contributors:

- Sharon Love, FHWA Washington Division
- Michael Culp, FHWA Headquarters
- WSDOT Pilot Project Team (in alpha order): Todd Carlson, Brooke Hamilton (WSDOT/Axis Environmental LLC), Casey Kramer, Elizabeth Lanzer, Mark Maurer, Rebecca Nichols, Simon Page, Jim Park, Carol Lee Roalkvam, Sandy Salisbury, John Shambaugh, Elizabeth Sjostrom, and Stu Smith
- Other WSDOT contributors: Kim Glass, John Himmel, Tim Smith, and Gary Ward

Thanks to all of the people we interviewed, who shared their knowledge of existing flood concerns, including representatives of the following organizations:

- Skagit Council of Governments
- Skagit Emergency Medical Services
- City of Anacortes
- City of Burlington
- City of Concrete
- City of Mount Vernon
- City of Sedro-Woolley
- Swinomish Tribe
- Upper Skagit Indian Tribe
- Town of Lyman
- Town of Hamilton
- Dike District 1
- Dike District 12
- Dike Districts 17
- Puget Sound Energy

Acronyms

ACE	Annual Chance of Exceedance
ADT	annual daily traffic
AOC	areas of concern
CC	climate change
CIG	(Washington State) Climate Impacts Group
CIVA	(WSDOT) Climate Impact Vulnerability Assessment
DEIS	Draft Environmental Impact Statement
DEM	digital elevation model
EO	Executive Order
FTA	Federal Transit Administration
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GI	government investigation
GIS	geographic information systems
HQ	WSDOT Headquarters
MP	milepost
MPO	Metropolitan Planning Organization
NCHRP	National Cooperative Highway Research Program
NR	no regrets
PSE	Puget Sound Energy
SLR	sea level rise
SR	state route
TSP	tentatively selected plan
USACOE (Corps)	United States Army Corps of Engineers
USDOT	United States Department of Transportation
UW	University of Washington
WSDOT	Washington State Department of Transportation

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Executive Summary

The Washington State Department of Transportation (WSDOT) was fortunate to receive a grant from the Federal Highway Administration (FHWA) to develop options for improving the resiliency of transportation facilities or systems to climate changes and/or extreme weather events. This was WSDOT's second grant. In the first pilot, WSDOT tested FHWA's conceptual risk assessment model and successfully completed a statewide assessment of climate vulnerability of transportation assets. This second pilot project set out to meet FHWA's goal of helping further the state of the practice in applying vulnerability assessment results into decision making.

This study builds on WSDOT's earlier pilot by examining adaptation options in an area of the state we previously identified as highly vulnerable: the Skagit River Basin (Basin). We chose this Basin because it is the focus of a major flood study by the U.S. Army Corps of Engineers (Corps). We knew important decisions about how and where to invest in levees and other flood risk reduction projects were being actively evaluated by the Corps and the local sponsor, Skagit County. We also knew that state transportation assets were likely to be affected but *were not* the focus of their study. WSDOT's pilot presented the opportunity to actively engage with the flood study and search for compatible long-term solutions that create a more resilient transportation system throughout the Basin.

WSDOT's pilot shows transportation planners and asset managers how to leverage a federal flood study, like the Corps' Skagit River Flood Risk Management General Investigation Study (GI study), to improve the resiliency of our highways. The pilot demonstrates how WSDOT's Vulnerability Assessment results, used in combination with federal flood study data, can reaffirm known vulnerabilities and reveal other vulnerable assets. The pilot identifies adaptation strategies for the Basin and highlights future partnership opportunities with the Corps and local governments.

This report includes a series of recommendations and lessons learned that will help other DOTs and regional transportation planning entities reach across jurisdictions and sectors to create integrated asset management strategies.

The pilot team developed eleven site-specific vulnerability assessments and adaptation strategies, which are included in the appendices. Other appendices provide information about our GIS and Hydraulic analyses for those who want to explore the details.

Our work to create a more resilient transportation network in Skagit County is ongoing. This report is really the beginning of a conversation about integrated response to the threats of increased flooding in the Basin. WSDOT will use this pilot study to continue our collaboration with local, tribal, regional, and federal stakeholders.

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1 Introduction

The Washington State Department of Transportation (WSDOT) is a leader among state DOTs in the field of transportation asset management and infrastructure resilience. WSDOT is very fortunate to have strong support from Governor Inslee and Secretary Lynn Peterson to better prepare our state transportation systems for the impacts of climate change and extreme weather. We also enjoy federal support. Thanks to a Federal Highway Administration (FHWA) national pilot grant, WSDOT completed a statewide vulnerability assessment in 2011. In 2013, WSDOT received a second FHWA Climate Change and Extreme Weather pilot grant. Figure 1.1 shows our state's continued efforts at adaptation planning.

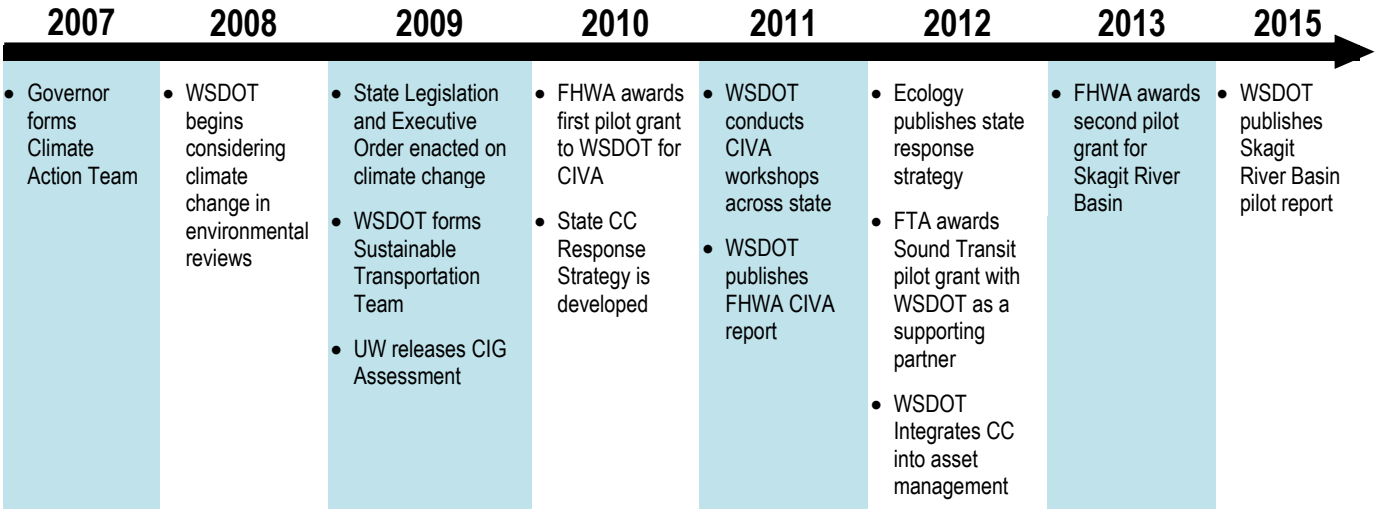


Figure 1-1 Washington's Adaptation Planning through the Years

WSDOT provides and supports safe, reliable, and cost-effective transportation options to improve livable communities and economic vitality for people and businesses. The department is responsible for over 18,500 highway lane miles (including 3,700 bridges) and the Washington State Ferry system, which served 22.8 million passengers in fiscal year 2014. WSDOT also oversees public-use airports, passenger- and freight-rail programs, and numerous public transit programs.

In addition to our climate preparation and emergency management efforts, WSDOT works to build climate-ready infrastructure today by considering climate threats during project-level environmental reviews. WSDOT works with our partners to incorporate long-term resilience strategies into transportation asset management.

This pilot project underscores the fact that state-owned transportation assets are just one piece of the very complex and interdependent fabric that makes up our communities and the transportation network. In western Washington, where so many of the hazards are related to extreme precipitation, flood protection through private, state, tribal, and federal investment is also critically important. We know that "projected regional warming and sea level rise are expected to bring new conditions to Washington State. By mid-century, Washington is likely to regularly experience average annual temperatures that exceed the warmest conditions observed in the 20th century. Washington is also expected to experience more heat waves and more severe heavy rainfall events."[1] The summer of 2014 was the second warmest on record for western Washington; however, it is anticipated that those temperatures will be the norm by mid-century.[2]

With the second FHWA pilot grant in 2013, WSDOT was able to focus on the lower Skagit River Basin (Basin). Major flooding in the Basin is typically a result of winter storms moving eastward across the Basin with heavy rains and warm, snow-melting temperatures. Several storms may occur in rapid succession saturating soils, increasing run-off and landslide risk, raising streams and rivers, and filling reservoirs and natural storage areas. Future extreme weather events will exacerbate this flood risk. The FHWA pilot grant gave us the opportunity to analyze options for adapting and improving the resiliency of our state transportation system. This report summarizes the Skagit River Basin pilot's findings and lessons learned.

1.1 Who should read this report?

Our main audience is other state DOTs, FHWA division offices, Metropolitan Planning Organizations, tribes, rural and urban planners, public works staff, and policymakers who want to get a jump-start on integrating adaptation strategies for transportation infrastructure by incorporating studies by other agencies or jurisdictions.

This report gives practical, hands-on tips and lessons learned for how to use existing flood studies to identify "no regrets" strategies. We hope that readers will learn from our experience and work with the wealth of flood hazard reduction information, so that transportation asset managers and flood control managers integrate flood hazard planning into their work.

[1] Snover, A.K., G,S. Mauger, L.C.Whitely Binder, M. Krosby, and I. Tohver, 2013. *Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers.* State of Knowledge Report, prepared for the Washington State Department of Ecology. Climate Impacts Group, University of Washington, Seattle. Executive Summary, page ES-4.
[2] Cliff Mass Weather Blog, August 20, 2014, and September 1, 2014

1.2 What is our pilot all about?

Across the country, site-specific flood studies are available to the public. These studies hold information that can be used by transportation agencies in their adaptation planning. Strategies for a more resilient transportation system need to be compatible with other proposed flood hazard reduction measures if we are to avoid missed opportunities or maladaptation.[3]

WSDOT's pilot shows transportation planners and asset managers how to leverage a federal flood study, like the U.S. Army Corps of Engineers' (Corps') Skagit River Flood Risk Management General Investigation Study (GI study), to improve the resiliency of our highways. The pilot demonstrates how WSDOT's Vulnerability Assessment results, used in combination with federal flood study data, can reaffirm known vulnerabilities and reveal other vulnerable assets. The pilot identifies adaptation strategies for the Basin and highlights future partnership opportunities with the Corps and local governments.

1.3 What are the goals and scope of our pilot?

WSDOT's team explored adaptation options for vulnerable state highways and Interstate 5 (I-5) concurrent with a major flood study in the Basin. The Corps and the local sponsor, Skagit County, are actively working on the Corps' GI study to address significant flooding and economic and life-safety threats that impact local communities in the Basin.

a. Pilot goals

The goals of this pilot were to:

- Advance FHWA's Draft Climate Change and Extreme Weather Vulnerability Assessment Framework (Figure 1-2) by developing adaptation strategies for the major transportation infrastructure in the Skagit River Basin.

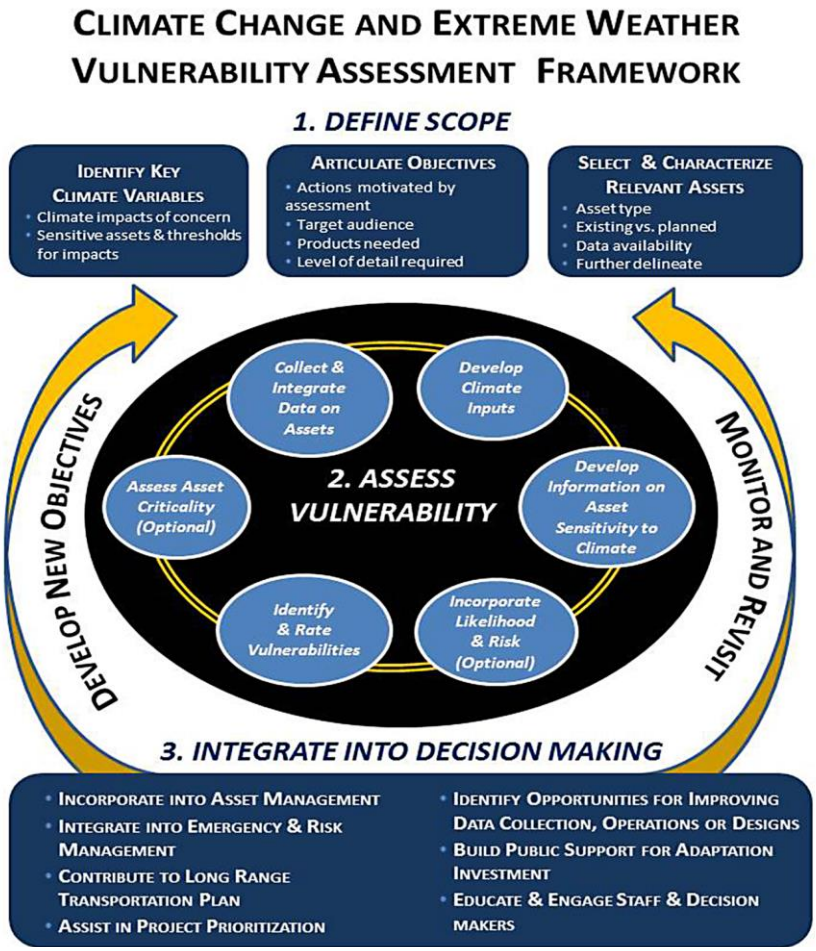


Figure 1-2 FHWA's Draft Climate Change and Extreme Weather Vulnerability Assessment Framework

[3] Maladaptation is a change that leads to an increase rather than decrease in vulnerability. It may also occur when an adaptation measure leads to the transfer of the vulnerability of one system to another. For more information, see: http://elibrary.worldbank.org/doi/pdf/10.1596/1813-9450-5568

- Engage with federal and local entities during a major flood study and integrate results into our planning, project design, and asset management processes.

b. Pilot outcomes

WSDOT achieved the following outcomes from the pilot:

- A replicable methodology using federal flood data and available highway data.
- A set of adaptation strategies for the state-owned and state-managed transportation infrastructure within the Basin.

1.4 What part of the state's transportation system did we assess?

The pilot area is in the Skagit River Basin, located in the northwest corner of the state, approximately 60 miles north of Seattle. The major cities in the pilot area are Mount Vernon, Burlington, and Sedro-Woolley.

The pilot area boundaries are shown in Figure 1-3 and include sections of I-5, State Route (SR) 9, SR 20, SR 11, SR 536, SR 538; and SR 534.

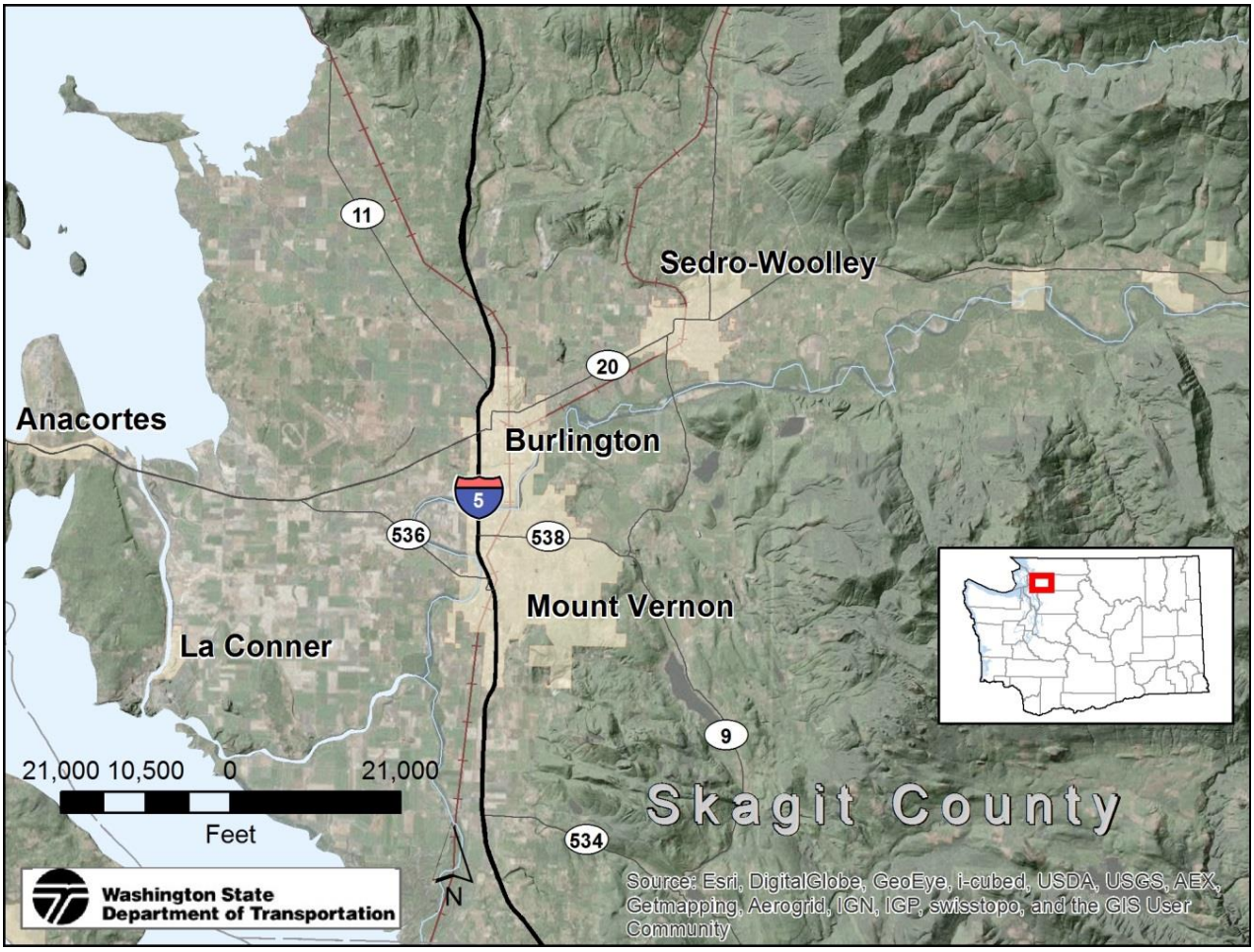


Figure 1-3 Vicinity Map

1.5 What are the key features of the Skagit River Basin?

Scenic view overlooking the Skagit River Basin

According to the Washington State Department of Ecology, the "Skagit River is one of the longest and most flood-dangerous rivers in the Pacific Northwest."[4] It is also the third largest river on the West Coast. The Basin experiences frequent flooding, resulting in damage to both rural and urban areas. It is susceptible to flooding when intense storms occur with heavy precipitation and warm, snow-melting temperatures. These conditions are expected to intensify with our changing climate. In addition, high tides that occur during a flood event or annual extreme high tides further increase the potential for flooding due to their restricting effect on river discharge flows.[5]

The Skagit River drains 3,115 square miles between the crest of the Cascade Range and the Puget Sound. There are five dams and several unregulated tributaries, most notably the Wild and Scenic Sauk and Cascade Rivers, which make up about 50% of the unregulated area before discharging into Skagit Bay. Figure 1-4 shows that 54% of the discharge is unregulated by dams.

There is a complex system of levees along the river, including 50 miles of nonfederal levees and 39 miles of sea diking. The existing levees are based on earthen levees built in the 1890s by the original European settlers. Many of these older levees have been raised and strengthened in recent years, but substandard foundation materials make them vulnerable to failure during major floods due to seepage and internal erosion.[6]

[4] Living with the River: A Guide to Understanding Western Washington Rivers and Protecting Yourself from Floods
[5] Skagit County Natural Hazard Mitigation Draft Plan, 2014. Page 88
[6] *Skagit River Flood Risk Management General Investigation, Skagit County, Washington. Draft Feasibility Report and Environmental Impact Statement*, U.S. Army Corps of Engineers and Skagit County, May 2014.

Figure 1-4 Map of Regulated and Unregulated Rivers in the Skagit Basin

The Skagit has a broad floodplain. It is bisected by I-5, which is a critical north/south trade route through Skagit County that carries goods between Mexico and Canada. Since its construction, flood events have not resulted in a closure of I-5 itself, but they have impacted the surrounding state routes and local roads. It should be noted that the largest flood to affect the basin since I-5 was built is a 4% ACE (25-year) storm. If, as anticipated, flood events are exacerbated by climate change to the extent that there is a closure of I-5, domestic and international movement of people and commerce will be severely impacted.

About 28% of the Skagit County population lives within the floodplain of the Skagit River. In order to serve the needs of the ever-growing communities, the majority of our transportation infrastructure is also located in the floodplain. This reach of the river also contains a large, productive agricultural community, which is a basis for tourism. Millions of tourists come for the annual Tulip Festival.

Tulip fields in Skagit Valley

The largest documented floods on the Skagit River occurred before the construction of any dams. Ross Dam was completed in 1949 and the Upper Baker Dam was completed in 1959. In 1990, two smaller, yet significant, floods occurred in November. Both floods broke through the Fir Island levee and inundated most of the island's farmland. They both required extensive flood fighting in the vicinity of Mount Vernon. Flood-fighting efforts during floods since 1990 have been successful at preventing levee failures. A flood occurred in November 1995, but this time the flood-fighting efforts were successful at preventing a levee failure at Fir Island and significant damage to downtown Mount Vernon. In 2003, there were two floods in October. Because of reservoir regulation and sandbagging efforts, levees at Mount Vernon and Fir Island were able to withstand the flood without failing. Based on the flood peaks at Concrete, the 1990, 1995, and 2003 floods had ACEs of approximately 10%, 4%, and 4%, respectively. However, future flood-fighting efforts may be overwhelmed in large flood events and are not sustainable for long-term flood risk reduction.

Flood-fighting efforts in Mount Vernon

Figure 1-5 shows flood flows over time as well as when the dams were constructed. The dams have reduced peak flows to the extent that recent flows have not exceeded the present dike system capacity. The available flood storage capacity may reduce the 4% ACE flood flow by up to 34,000 cfs and the 1% ACE flood flow by 51,000 cfs.

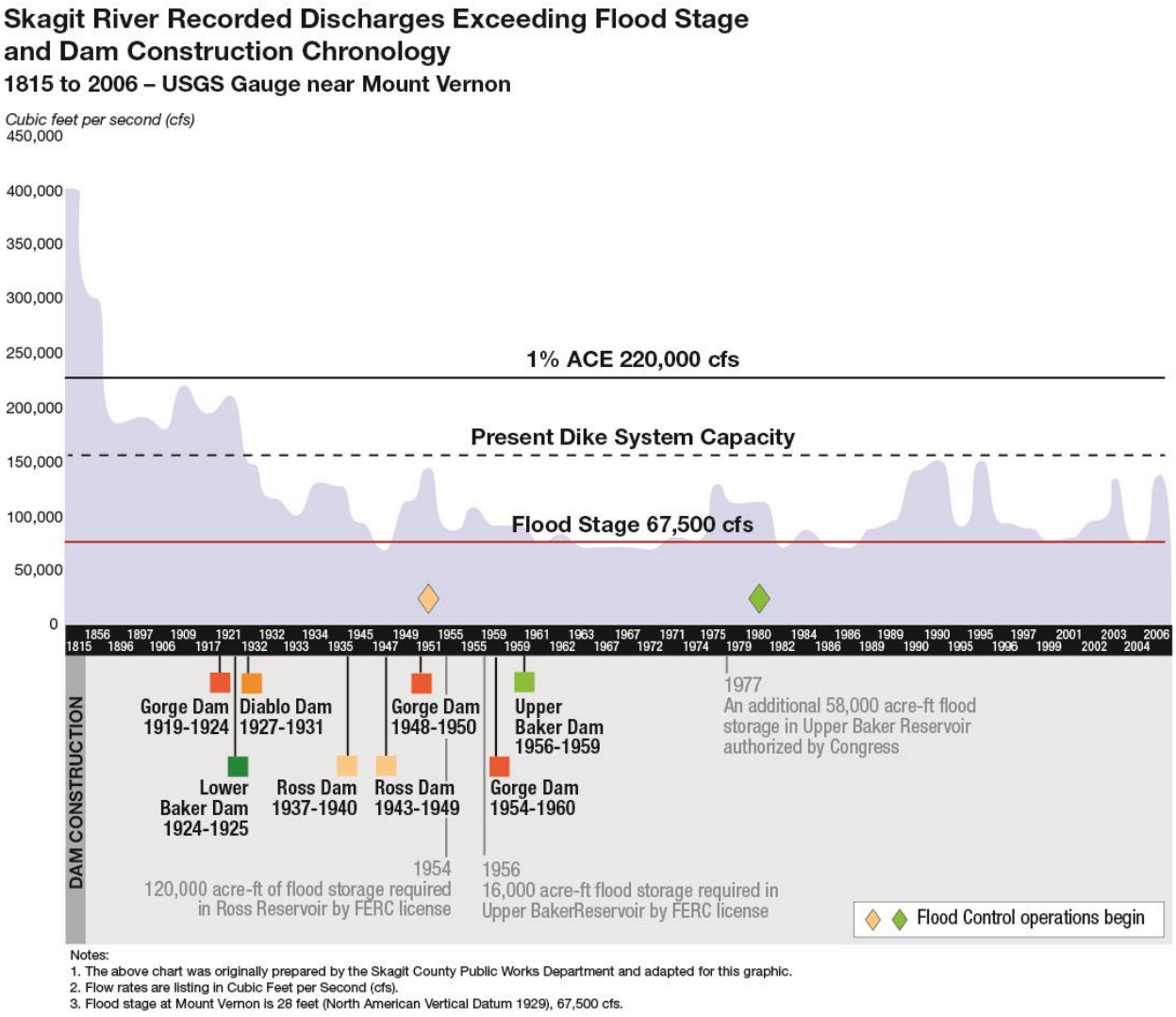


Figure 1-5 Flood Flows and Dam Building throughout the Years

Within the Basin, there are three diking districts responsible for construction, repair, and maintenance of the levee and dike systems, and four flood control zone districts. The Corps started its efforts in the Basin many years ago. In June 2014 the Corps issued the Skagit River General Investigation and Draft EIS outlining its proposed tentatively selected plan (TSP). This provided us with an excellent opportunity to address the known flood-related problems in the area and to create stronger partnerships. WSDOT's work with Skagit County and the Corps will continue into the future as we continue our adaptation and preparation efforts.

Who are our partners?

Our primary partners for this pilot were the sponsor and co-sponsor of the GI study: The U.S. Army Corps of Engineers Seattle District and the Skagit County Public Works Department. Funding was provided by the Federal Highway Administration (FHWA).

FHWA Washington Division staff participated at key milestones. WSDOT Northwest Region and Headquarters staff provided various types of support throughout the 18-month pilot project.

Tour of the Basin with FHWA, Skagit County, WSDOT

2 Approach

2.1 What was our process?

WSDOT had a strong entry point to begin this pilot, using the earlier vulnerability results and the FHWA Framework. For the Skagit River Basin (Basin), these results (Figure 2-1) showed that I-5, state routes, ferries, and rail assets are highly vulnerable to extreme flooding.

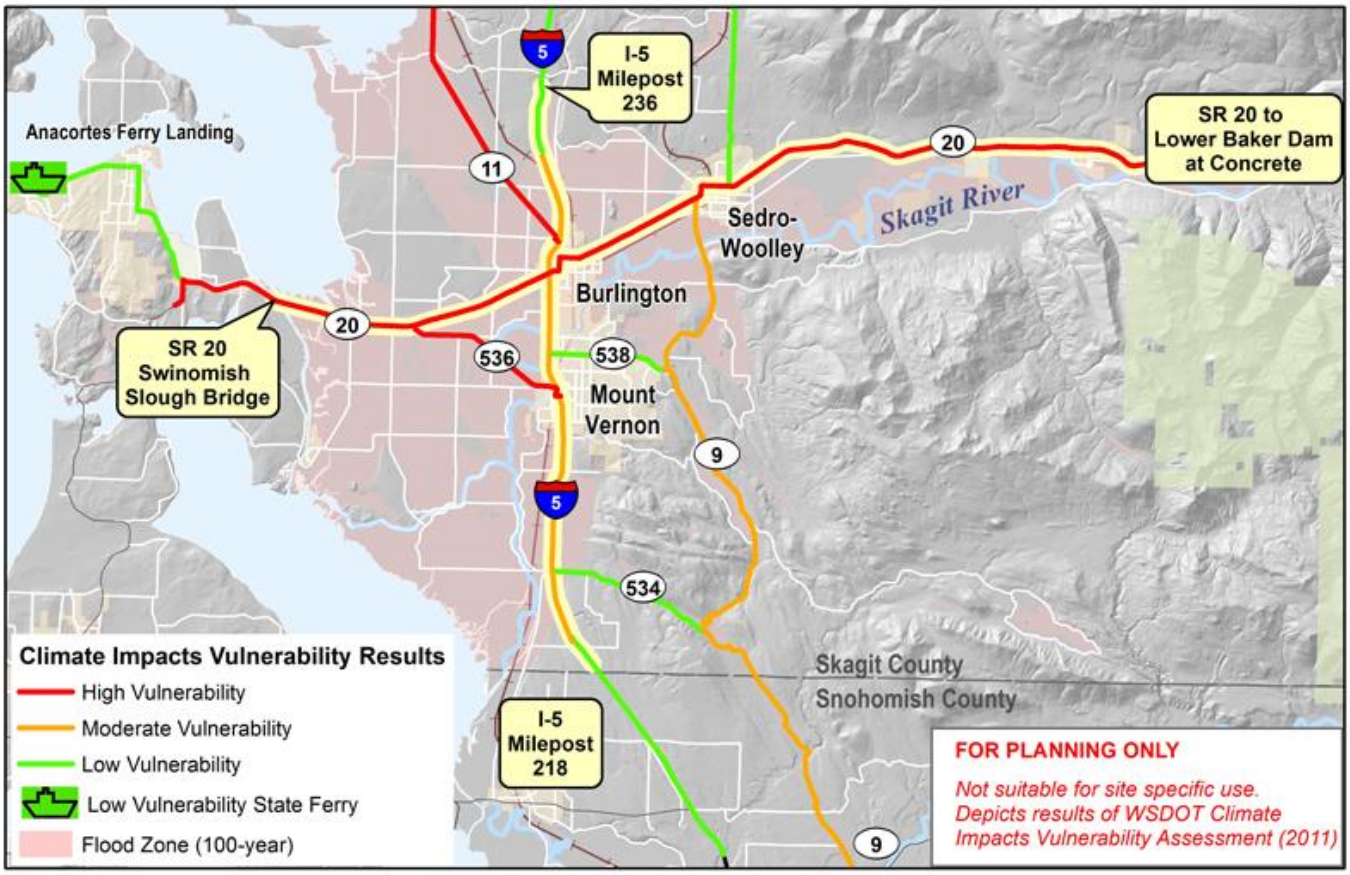


Figure 2-1 Climate Impacts Vulnerability Assessment Results in the Basin

As part of the earlier assessment, we compiled the climate data from the Washington State Climate Impacts Group (CIG) and other reports relevant to the Basin.

For the Skagit pilot, our initial step was to establish the team and define the scope of the effort. As envisioned in the grant proposal, we recruited WSDOT staff from both Headquarters and the region, and defined roles by physical location. Our team was a multidisciplinary, decentralized team of WSDOT planners, environmental staff, maintenance/emergency response experts, landscape architects, and engineers. The major phases of our pilot are shown in Table 2-1.

Table 2-1 WSDOT Pilot Climate Impacts Vulnerability Assessment Skagit River Basin Phases

Major Pilot Phases
1. Conducted 2011 Climate Impacts Vulnerability Assessment.
2. Gathered information and data.
a. Updated and localized climate forecasts (CIG)[7] b. Obtained flood data from Skagit County c. Screened and reviewed available geographic information system (GIS) data d. Conducted interviews
3. Reviewed and commented on Corps' GI Study and Draft EIS release.
4. Interpreted, integrated with WSDOT data, and analyzed hydraulic data from Corps.
5. Developed adaptation strategy – Assessed "no regrets" strategies.

The initial work plan called for us to evaluate the Corps' tentatively selected plan (TSP) once it was available. We had assumed that the Corps would do the hydraulic modeling for the TSP and release it with the Corps' GI study. However, the Corps determined that the TSP might change as a result of public comments, so only modeling of existing conditions was done. Our approach shifted to a detailed study of the Corps' hydraulic data on major flood scenarios under existing conditions (the primary data we received from the GI study). (See Section 2.3 for further explanation.)

2.2 How did we gather the data?

We began with WSDOT's qualitative vulnerability assessment results. We then added to that by conducting a series of interviews (Appendix A, Supporting Documents) with local community experts in the pilot area who are actively involved in flood hazard planning, maintenance, and operation of the transportation system, to set the stage for what we know today.

In July 2013, we met with the Corps' GI study's local sponsor, Skagit County Public Works, and toured the GI study area (see photos).

[7] University of Washington Climate Impacts Group

Key takeaways from the tour were:

- Significant infrastructure lies within the floodplain of the Skagit River.
- Local agencies have done considerable work on flood planning and preparation.
- There are potential impacts to state highways from the Future without Corps' Project[8] and three draft action alternatives coming out of the Corps' GI study.
- We have a better understanding of the local geography.

Using the qualitative vulnerability assessment workshop process, in September 2013 we met with County and City staff to (a) gather historic data and learn about their efforts and concerns regarding flooding, and (b) validate the information we already had. We posed the following questions to these partners:

1. What concerns you about hazard mitigation preparation in your community?
2. What locations are you most concerned with?
   - Have you done any work recently that improved this condition?
   - Do you have any improvement plans you are working on?
3. Are there state highway concerns that you have?
4. How do you think these issues should be handled?
5. What concerns do you have when it comes to emergency response?

County staff supplied detailed information on existing conditions and the Future without Corps' Project, including an infrastructure at-risk map, GIS depth files (existing condition) for all floods, a basemap with elevations for the basin, and the Hydrology Technical Document[9] from the Corps' GI study. This data was crucial to our pilot process.

We also reached out to internal and external stakeholders. We conducted interviews with local tribes, diking districts, City planning and public works staff, County emergency response staff, regional planners, and WSDOT maintenance staff. With their help, we identified initial "areas of concern" regarding flood hazards and anticipated extreme weather event impacts. We considered critical local infrastructure such as firehouses, fresh water and wastewater treatment plants, numerous water and gas pipelines, a hospital and medical clinics, and other municipal infrastructure. We asked the same questions we had asked the County in our first workshop.

We used face-to-face workshops at several key points in data collection and analysis. Several example workshop agendas are found in Appendix A.

Tip from FHWA's Framework: Successful engagement of internal staff requires listening and incorporating their feedback and perspectives. If these staff members are engaged and feel that they can take ownership of the strategy, they may be more willing to provide valuable insight and leadership. (FHWA Framework, Section 4.1.1)

[8] The Future without Corps' Project is the most likely scenario if no Corps' flood risk management project is implemented for the study time period from 2020 to 2050.

[9] Appendix B, Hydraulics and Hydrology Methodology, is available at: http://www.nws.usace.army.mil/portals/27/docs/civilworks/projects/skagit%20gi/skagitgi-appb-hh-may2014.pdf

Those interviews helped us to understand where problems have occurred in the past on state facilities and local roads, and what emergency response requirements were implemented during floods and other emergency events in the Basin. From this expert knowledge, we identified 23 areas of concern that would supplement the preliminary screening of assets done in the 2011 qualitative vulnerability assessment, and focused on step three of the FHWA model from this point on.

Note that the Skagit River Bridge emergency (see photo) came up frequently in our interviews. In those discussions, we learned a lot about our detour routes and the impact on local networks and businesses.

On May 23, 2013, a portion of the bridge collapsed into the Skagit River near Mount Vernon after being struck by an oversized load. Crews installed temporary spans and reopened the bridge to most traffic on Wednesday, June 19. (Source: WSDOT)

2.3 What data did we get from the Corps?

When the Corps' GI study and Draft EIS were released in June 2014, our work really shifted into high gear as we began to assess the Corps' data and analysis of impacts. The pilot team reviewed the Draft EIS and submitted comments (Appendix A, Supporting Documents). We met with the Corps and Skagit County and attended public meetings. The Corps Draft EIS provided detailed information on existing conditions, and conceptual (not detailed) information about the action alternatives and the Future without Corps' Project. The GI study and its associated data provided us with a wealth of information on water movement in the Basin. In particular, the County was able to share the following:

- A digital elevation model (DEM) of the land surface of the lower Skagit River floodplain.
- Output from the Corps' FLO-2D floodplain model. This output included water surface elevation and depth grids for 21 existing conditions: flood scenarios that represent various return interval floods (10%, 4%, 2%, 1%, 0.2% ACE flood) and levee failures.

Data we didn't get from the Corps

It is important to explain what data we did not get. The Corps' GI Study and Draft EIS did not include model output data for the "No-Action" or TSP alternatives. Nor did we get some of the other desirable FLO-2D output data, such as velocity and duration of inundation. The Corps is continuing to develop and refine the models for these conditions and will supply them to us when they are finished.

For our pilot project, we had to extrapolate how both the Future without Corps' Project and the tentatively selected plan may impact WSDOT's transportation infrastructure (we'll explain that in Section 2.4).

The Corps' GI study describes the climate change data the Corps used in its alternative selection process. The Corps estimated that hydrology changes due to climate change would be an average flood discharge increase of 33% by the end of the project planning period in 2070. The Corps assumed that by the end of its planning period, the existing 1% ACE would increase to about the 4% ACE, and the existing 0.4% ACE would increase to about the 1% ACE. That means larger storms will happen more frequently (i.e., a 0.4% ACE event will become a 1% ACE event and a 1% ACE event will become a 4% ACE event).

Sea level rise was considered in the Corps' analysis, but the extent that the increased sea level will affect floodwater levels is limited to downstream reaches of the river.[10]

The Corps identified the Comprehensive Urban Levee Improvement Alternative as its tentatively selected plan (TSP). This alternative would provide flood risk reduction for the urban areas of Burlington and Mount Vernon by raising existing levees along the Skagit River and constructing a new Burlington Hill Cross Levee along the eastern and northern edges of Burlington.

Generally, the TSP will reduce flood hazards in urban areas by improving and raising existing levees and by adding new levees. This is shown in Figure 2-2.

The Future without Corps' Project assumes that no project would be implemented by the Corps or local interests to achieve flood risk management objectives. The Future without Corps' Project is used throughout the Draft EIS as a baseline against which to compare action alternatives (ACOE, 2014). The Corps also evaluated two bypass alternatives, which they found had higher construction and real estate costs than the TSP.

[10]For this pilot, we did not consider the impact of sea level rise on coastal flooding and its effects on state highway infrastructure, because our focus was the Corps' GI study, which focused on riverine flooding.

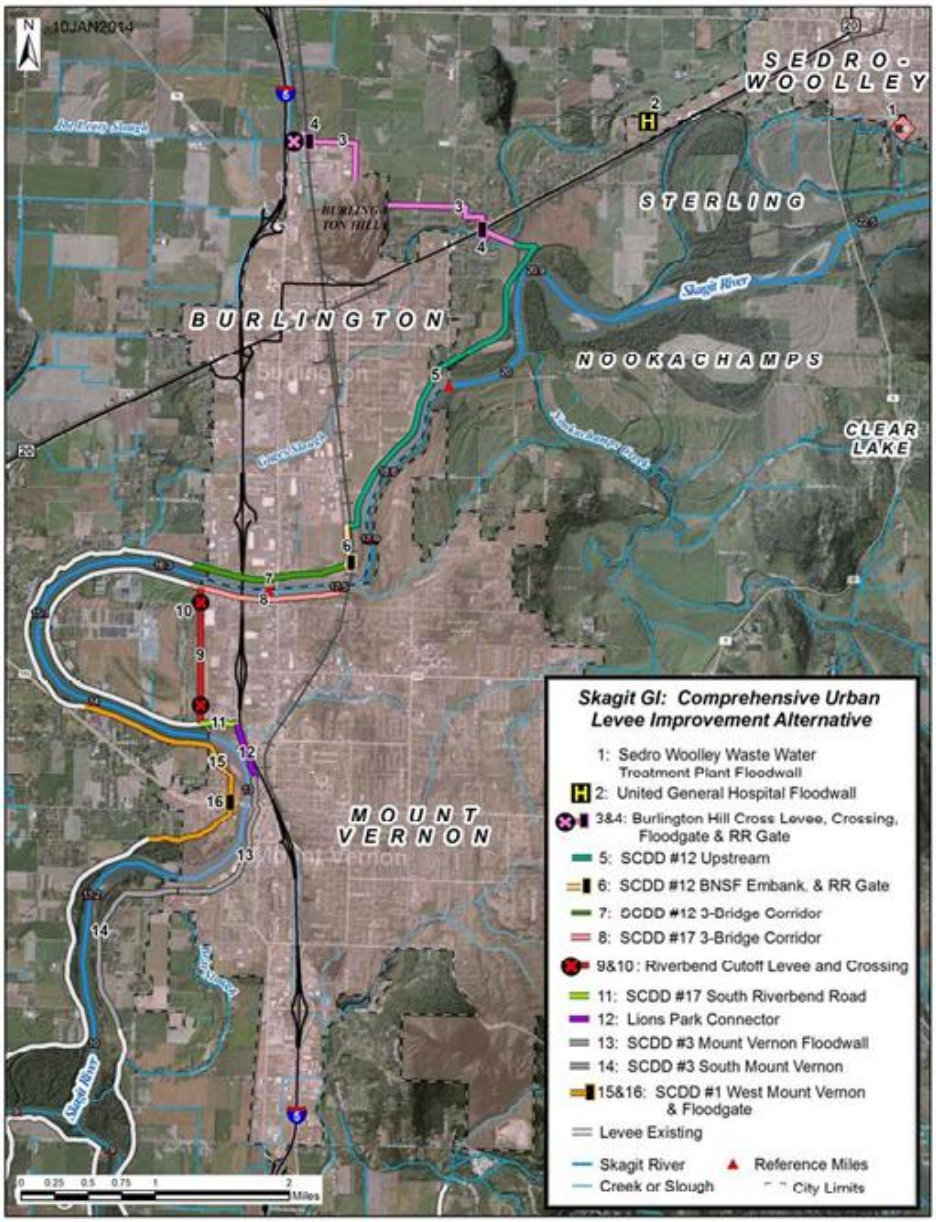


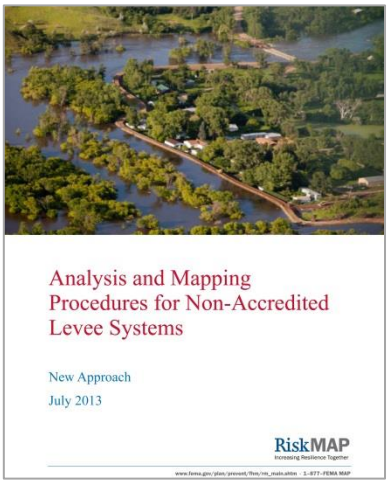
Figure 2-2 Skagit GI: Comprehensive Urban Levee Improvement Alternative

2.3.1 Why are the flood scenarios in the Corps study different from what we have experienced historically?

As the pilot team reviewed the data, we realized that it didn't line up with what our local expert interviews had found. It was essential that we rely on the same information the Corps used, while at the same time we needed to understand why there were some differences. The answer is in the methods used for the Corps study.

Many times the Special Flood Hazard Areas (SFHAs) shown on the Federal Emergency Management Agency's (FEMA's) Flood Insurance Rate Maps do not match the extent of historical floods; this is especially true in areas with complex levee systems. Recently, FEMA has adopted new guidelines to better address the flood hazards with non-accredited levees, like those found in Skagit County.

In July 2013, FEMA issued new guidelines for "Analysis and Mapping Procedures for Non-Accredited Levee Systems." The Corps modeling and mapping procedures used in the Skagit River GI study followed those new guidelines and the Corps implemented the "Structural-Based Inundation Procedure."



The revised method of SFHA mapping as applied in the Corps' GI study represents a worst-case analysis that is different from what has been observed or may be encountered during future flood events. ***It is important to remember that the SFHAs mapped in areas with complex non-accredited levee systems are areas at risk of flooding, not the areas that will flood during a particular event.***

A very simple example would be the case where levee freeboard does not meet standards. Freeboard requirements compensate for the uncertainty associated with the magnitude of future flood events and the possibility that floodwater levels may exceed the levee system design. If the flood level exceedes the freeboard requirement for a segment of levee, the special flood hazard area must be mapped as if that segment has failed. However, during an actual flood event, the floodwater level may encroach into the levee's freeboard without a failure. In recent years, significant flood-fighting efforts have prevented levee overtoppings and failures during floods estimated to have a 4% ACE.

2.4 What did we do with this data and information?

After engaging our partners and gathering data, we used a series of pilot team workshops over the next several months to answer the following key questions:

- What climate threats or extreme weather impacts most affect this Basin?
- What do we know about the "Future without Corps' Project" and "existing conditions"?
- What would the impacts be of the TSP, if it were built?
- What WSDOT-managed assets are of primary concern (and why)?
- How should we define focus areas or highway segments of concern?

At the same time, team members were analyzing and interpreting the data (see photo) so that it was usable for developing adaptation strategies.

Team workshop with Skagit County

2.4.1 What methods did we use to interpret and use the data?

With all the data gathered and analysis under way, we were able to move forward with finalizing our asset selection and defining the appropriate strategies. WSDOT GIS and hydraulics experts worked together to process the data into information that would be useful in determining impacts to our transportation infrastructure.

In our analysis, we looked at the return flood intervals for the 10%, 4%, 2%, and 1% ACE flood under existing conditions. This was the basis for our detailed look at current vulnerabilities and for brainstorming potential adaptation strategies. In the future, as we get more hydraulic data on the Future without Corps' Project and the TSP, we will carefully examine the Corps' new information about future conditions.

2.4.2 How did we refine the data sets and define our areas of concern?

We developed the areas of concern as described in Section 2.2. We then identified data sets, within the GIS, that would impact our evaluation of adaptation options.

The available data was screened for its relevance to WSDOT's adaption decision-making. We identified 35 data sets in our GIS database and overlaid them on the 23 areas of concern/sites from the interviews. Refer to Appendix A and Appendix B for the interview results and GIS methods, respectively.

This analysis showed us that there were many individual areas of concern that were impacted by similar events. In addition, the areas of concern were connected by a highway segment, and when one area of concern was affected on that segment, the same event affected other areas of concern as well.

We refined the list to 11 highway segments for further consideration.[11] Table 2-2 shows the segment names, numbers, corresponding milepost ranges. (See Appendix C, Segment Profiles, for the full GIS results and detailed segment descriptions.)

Table 2-2 Segment Names with Numbers, Mileposts, and GI Damage Reach #

Area Name	Segment Number	Mileposts	GI Damage Reach No.
Central I-5/SR 538	1	I-5 MP227.25 - 228.17 SR 538 MP 0 - 1	5A
East SR 20 Burlington	2	SR 20 MP 59.31 - 64.90	1A; 6; 1: 8
East SR 538 Nookachamps Basin	3	SR 538 MP2.35 - 3.22	6
I-5 Gages Slough	4	I-5 MP 228.61 - 229.86	1A
North I-5	5	I-5 MP 230.37 - 234.12	1
North SR 9 Skagit River Overflow	6	SR 9 MP 53.49 - 55.37	6; 8
South I-5/SR 534	7	I-5 MP 219.89 - 225.04 SR 534 0 - 0.5	4
South SR 9 Nookachamps Basin	8	SR 9 MP 50.92 - 53.57	6; 8
SR 11	9	SR 11 MP 0.14 - 9.06	1
SR 536 Mount Vernon	10	SR 536 MP3.3 - 5.36	2: 2A; 4A
West SR 20/SR 536	11	SR 20 MP51.51 - 58.98 SR 536 MP 0 -1.89	1

2.4.3 How did we use flood information from the Corps' GI study?

As noted above, the data from the Corps gave us a more in-depth understanding of the existing conditions. The County supplied us with depths to add to the existing floodwater surface elevations. For our pilot, we used a flood scenario that produced the maximum water depth for a highway segment rather than individually analyzing all 21 scenarios from the Corps.

- We determined the maximum depth of flooding per highway segment by subtracting the elevation of the highway from the water surface elevation using GIS.
- We used this to identify conditions of the highway system for the existing 10%, 4%, 2%, and 1% ACE flood.
- We identified the length of state highway flooded under the worst-case condition for each return interval flood.

By calculating the inundation of our assets, we found that most of the areas of concern identified during the interview process were consistent with the flood analysis results. Refer to Appendix D (Hydrology and Hydraulics Methodology) and Appendix B (GIS Methodology) for the details on this step-by-step process, identification of glitches in the data, and troubleshooting efforts related to our flood analysis.

[11] WSDOT is responsible for passenger operations that run on Burlington Northern Santa Fe railroad tracks in the Basin. However, for this pilot, we focused on infrastructure owned by WSDOT.

Table 2-3 Example of How We Looked at Flood Depths for Existing Conditions

Segment ID	Highway Segment	SR*	10 % ACE Ex.**	4% ACE Ex.**	2% ACE Ex.**	1% ACE Ex.**
1	Central I5/SR538	I-5	N/A	N/A	10.80	11.19
1	Central I5/SR538	538	N/A	N/A	14.93	15.33
2	East SR20 Burlington		1.69	7.85	6.33	9.54
3	East SR538 Nookachamps Basin		N/A	1.59	3.49	4.87
4	I5 Gages Slough		N/A	4.87	6.09	7.00
5	North I5		N/A	5.21	4.65	7.98
6	North SR9 Skagit River Overflow		7.62	10.52	12.26	13.02
7	South I5/SR534	I-5	N/A	10.62	N/A	15.23
7	South I5/SR534	534	N/A	12.13	N/A	14.83
8	South SR9 Nookachamps Basin		3.57	6.94	8.60	10.05
9	SR11		N/A	6.00	3.92	6.80
10	SR536 Mount Vernon		N/A	N/A	N/A	8.39
11	West SR20/SR536	20	N/A	10.25	10.50	12.00
11	West SR20/SR536	536	N/A	4.00	5.00	4.60

*If more than one SR in a given segment.
**Flood recurrence interval.

Note: This table shows our estimates of the flood impacts in maximum depth in feet for each highway segment

For each segment, the project team created a site-specific vulnerability assessment (which we called a profile). Each profile describes the key features of the segment in terms of highway location and functions; drainage issues; updated vulnerability assessment given Corps' hydraulic data; and discussion of the team's brainstorm of adaptation strategies (see Figure 2.3).

Segment 1, Central I-5/SR 538

Segment ID	Highway Segment	CIVA* Criticality	CIVA Impacts Base (High)
1	Central I5/SR538	L, H	L, M, (H)

Estimated AADT Max	Truck Percentage	DHV	Federal Function Class	Freight Class
69000	11.5%	11640	51, 54	T1, T3

Segment Description

Segment 1, Central I-5/SR 538: I-5 (MP 227.25–228.17), SR 538 (MP 0–1.00)

This segment is in Mount Vernon. The Skagit River bends around Mount Vernon and frames the southern and northern segment boundary. I-5 is the main north-south corridor for the West Coast, and this segment has an AADT of 69,000. 11.5% of the traffic is truck traffic and it carries more than 10 million tons of freight per year. SR 538 carries between 300,000 to 4 million tons of freight per year. The DHV for this segment is 11,640. I-5 is classified as an Urban Interstate and SR 538 is classified as an Urban Minor Arterial. There is one bridge in this segment as well as six culverts. Five bus routes traverse the segment. The CIVA impacts to this segment are low to moderate for the 2-FT SLR condition and high for the 6-FT SLR condition. This segment is within the Mount Vernon Urban Growth Area. The land use classification categories that surround this segment include commercial, industrial, some residential, Skagit County Public Works, Mount Vernon Police Station, Skagit County Emergency Management, Skagit Valley College. This segment experiences flooding in the existing 10%, 4%, 2%, and 1% ACE events. Maximum flood depths in the existing condition are:

	10% ACE	4% ACE	2% ACE	1% ACE
I-5	N/A	N/A	10.80'	11.19'
SR 538	N/A	N/A	14.93'	15.33'

This segment is not flooded during the 1% TSP event. The segment is listed in Flood Zone A and X500.

Adaptation Strategies

The flooding in this segment would be caused by a levee failure due to scour. This would be addressed by the TSP, and that is why no flooding occurs under the Corps' preferred plan. If this plan is built, then other alternatives are not needed to keep this segment functioning. However, if the TSP is not built, there are other options (in no particular order) that could make this segment more resilient:

- Work with local agencies and the Corps to purchase additional storage capacity behind the dams run by Puget Sound Energy.
- Work with the City of Mount Vernon to extend the floodwall to protect I-5, and SR 536.
- Raise I-5 on a causeway above the flood elevation.

Floodzones (Floodway)	Tsunami Zone	Discharge Points	Stormwater BMP Type (#)
A, X500	–	34	

Bridges	Under Crossings	Culvert Inventory (End Inv.)	Fish Passage
1	1	6	Unknown

Unstable Slope	Liquifaction	Hydrologic Soils Group	Hydric Soils Area (sf)
–	L-M, M-H, H	B, C, D	9391895

Bus Route	Park and Ride Lots	Land Use Zoning	Schools	Hospital
204, 205, 207, 513, 8		UGA-CL/IND/RES/Public	Skagit Valley College	

WSDOT Site (Type)		Haz Mat Sites	Historic Barns	Cemetery
	2		Y	

LEGEND

AADT	annual average daily traffic	DHV	design hourly volume
ACE	Annual Chance of Exceedance	GI STUDY	general investigation
CIVA	Climate Impact Vulnerability Assessment	I-5	Interstate 5
Corps	US Army Corps of Engineers	SLR	sea level rise
CUU	Comprehensive Urban Levee Improvement	SR	State Route

Figure 2-3 Segment 1 Example

2.4.4 How did our mapping inform our adaptation strategies?

Figures 2-5 through 2-10 show the results of our flood analysis. These images were created by the pilot team to see how the Corps' flood data for existing conditions would impact highways throughout the Basin. They show the maximum flood depth for each highway segment for the 4% and 1% ACE flood event for existing conditions. The figures also show the general direction of flow over the floodplain.

Figure 2-4 shows our pilot study area with the flood hazard locations for the 1%, 2%, 4%, and 10% ACE floods. The yellow boxes outline locations found in Figures 2-5 through 2-10 where we zoom in to take a closer look.

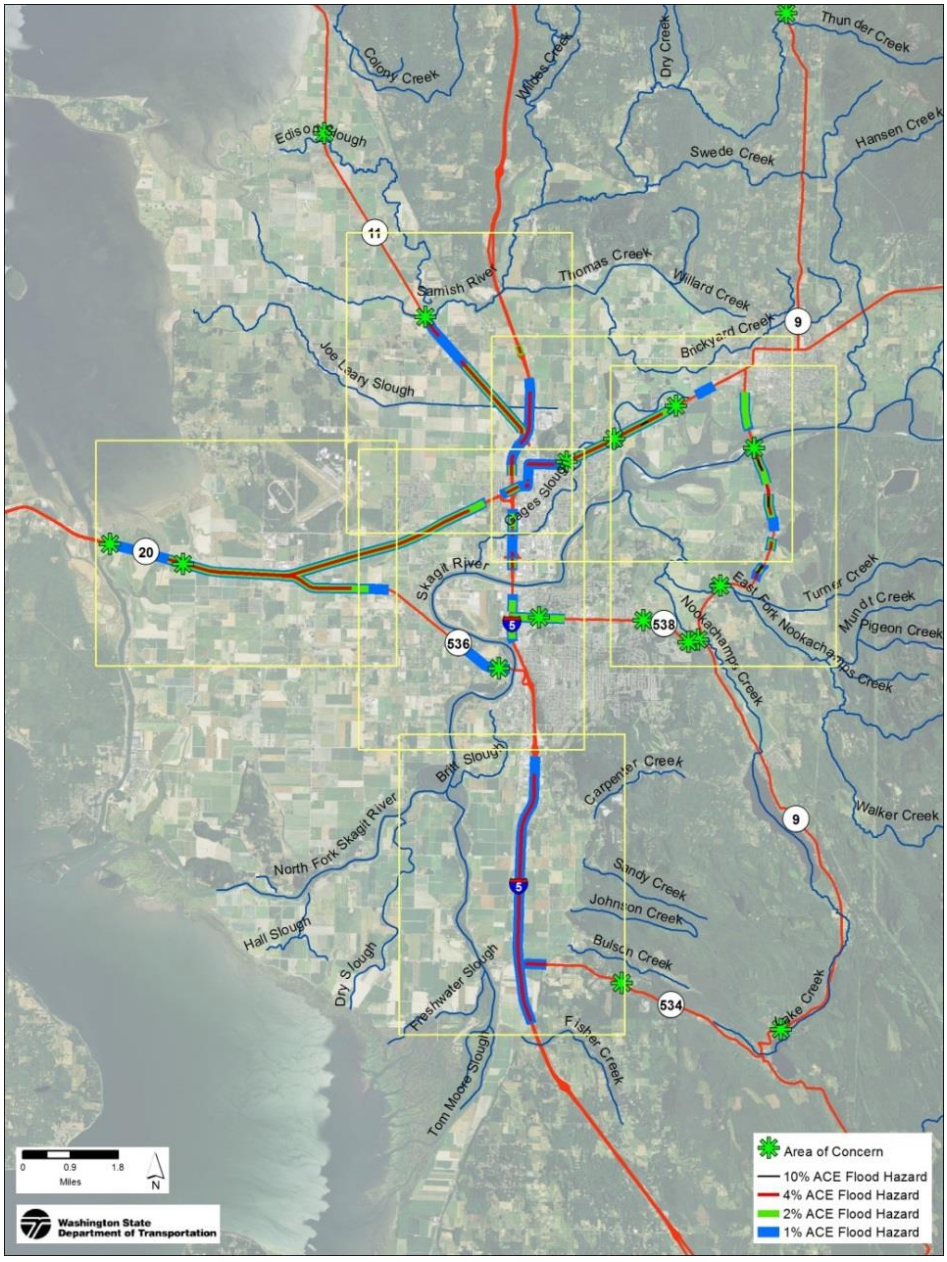


Figure 2-4 Map Key

Figure 2-5 shows the northern section of our pilot area. I-5 is shown from left to right and SR 20 and SR 11 are also shown. Arrows indicate the flow of water. We do not have information on volume at this point, so the arrow thickness does not indicate the volume of water, merely the presence and direction with the depth noted.

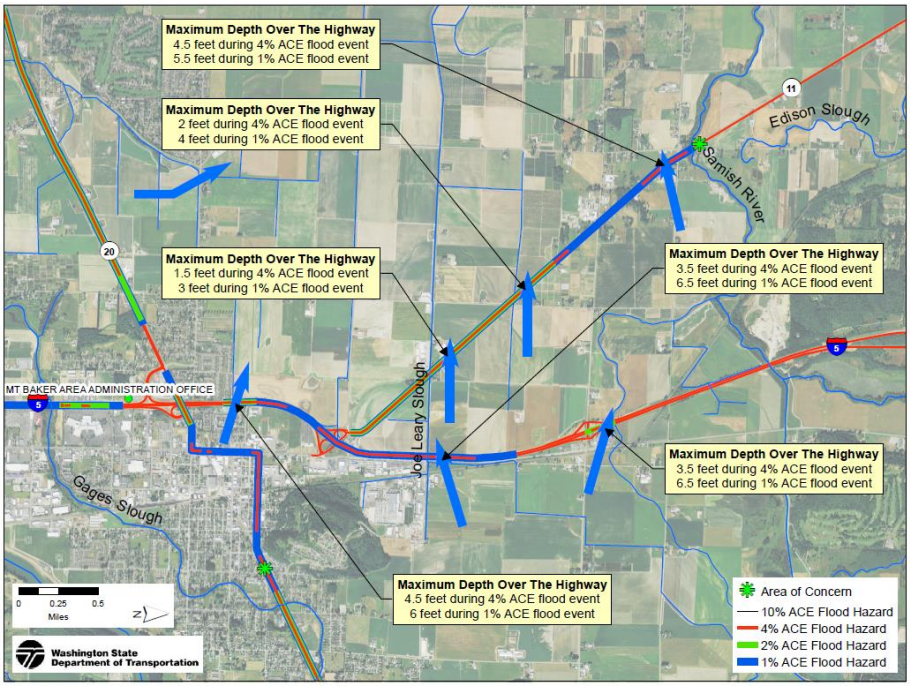


Figure 2-5 Northern Section of the Pilot Area

Figure 2-6 shows I-5 just south of the previous view. It shows the direction and depth of flows over I-5, SR 20, and SR 538.

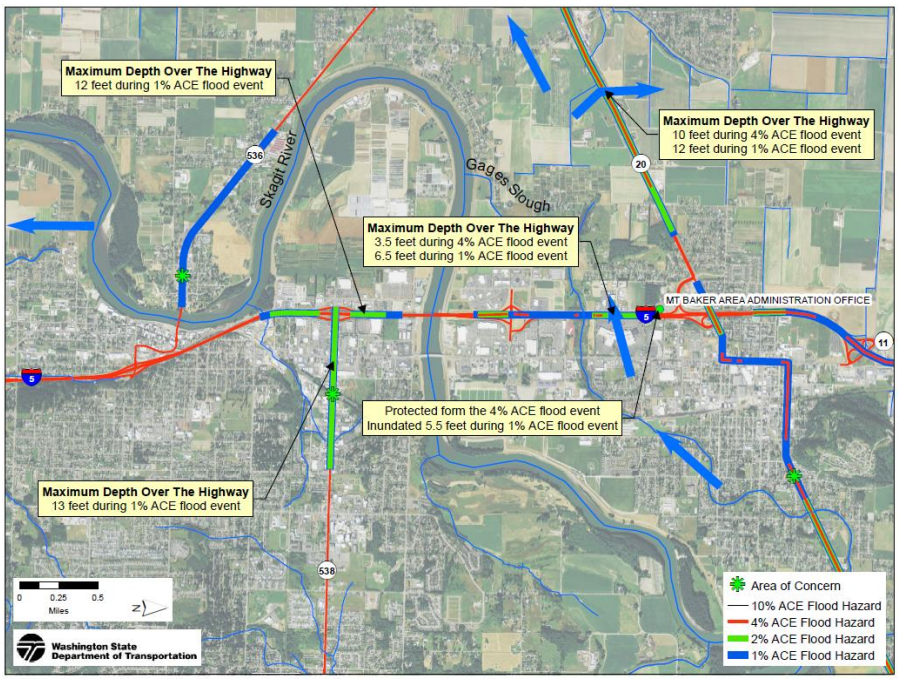


Figure 2-6 Central and West Sections of the Pilot Area

Figure 2-7 shows the flow of floodwater around I-5 and SR 534 south of Mount Vernon.

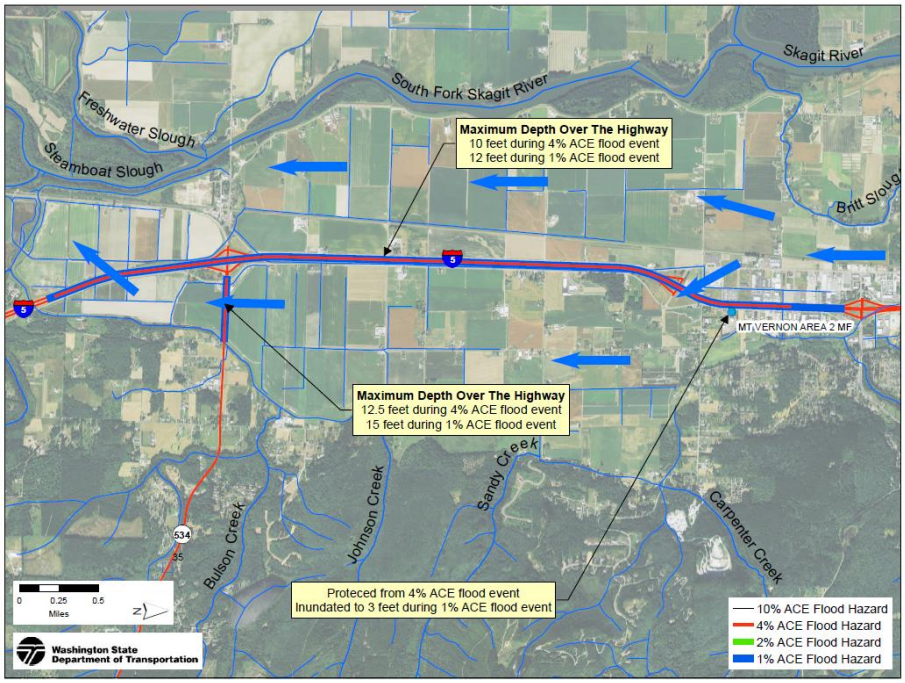


Figure 2-7 South Section of the Pilot Area

Figure 2-8 shows the flow of water to the west of I-5 and the City of Burlington, along SR 20 and SR 536.

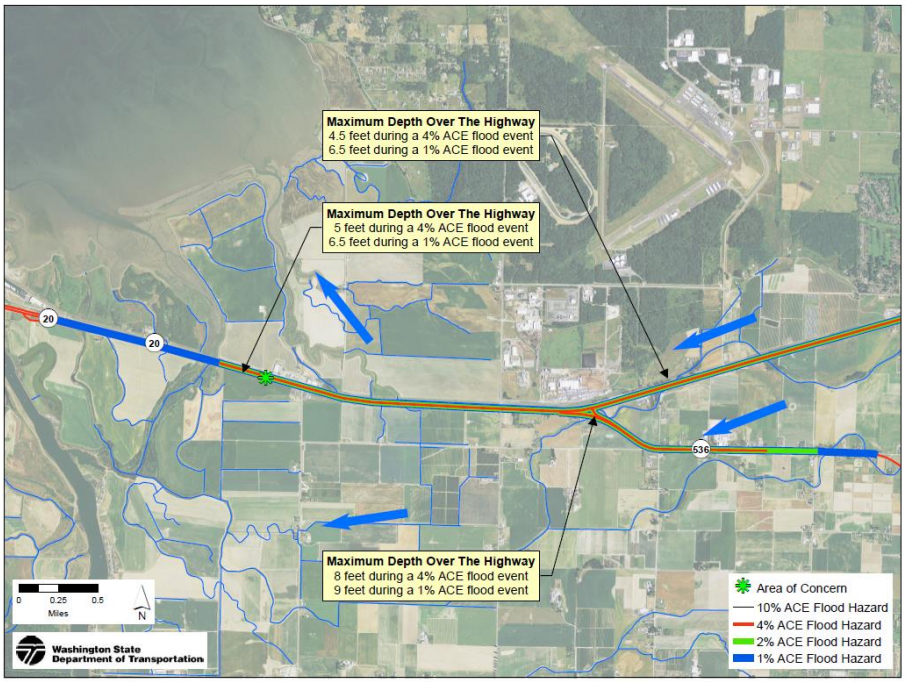


Figure 2-8 West Section of the Pilot Area

Figure 2-9 focuses on SR 20, including the cities of Burlington and Sedro-Woolley.

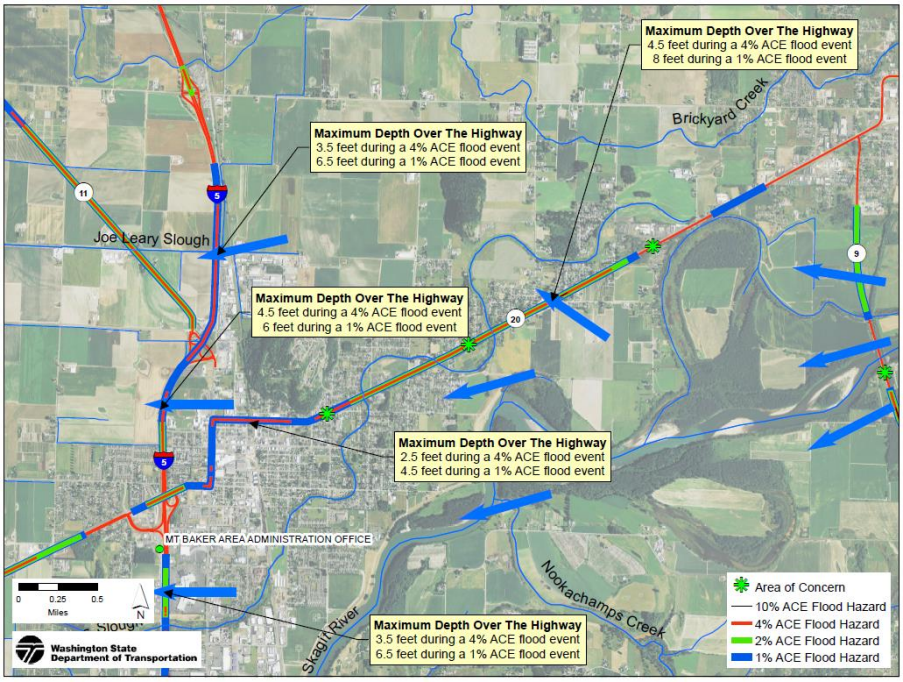


Figure 2-9 East Section of the Pilot Area

Figure 2-10 shows the area east of Burlington, including SR 538, SR 9, and SR 20.

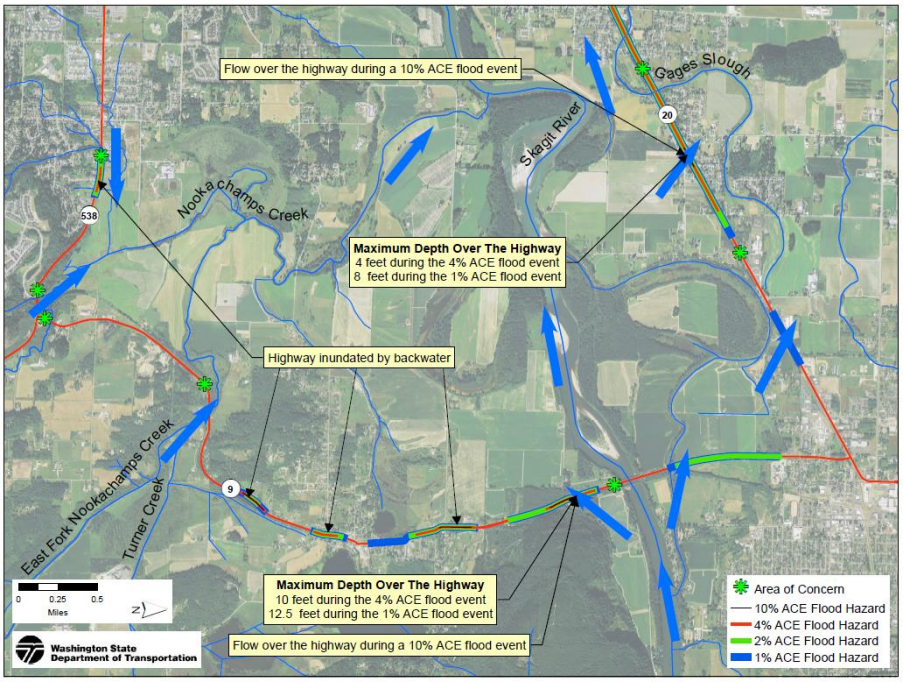


Figure 2-10 East Section of the Pilot Area

This series of maps allowed us to consider what we might do if and when a flood of this magnitude would occur.

2.5 How did we select our adaptation strategies?

After we analyzed and interpreted the data, we moved toward developing adaptation strategies. Our last series of pilot team workshops focused on developing adaptation options—particularly the "no regrets" strategies.

Ultimately, we developed structural and nonstructural adaptation strategies within a broad diagnostic framework. This was guided by three high-level principles, which were informed from many other pilots and the FHWA Framework:

1. Take a comprehensive decision-making approach that describes the steps engineers, planners, operations and maintenance personnel, and other highway officials can take to assess the range of climate change impacts on the transportation system as a whole and avoid piecemeal decision-making.
2. Take action incrementally within this broader comprehensive approach so that momentum is not lost seeking the total "fix."
3. Be sufficiently flexible to allow for the consideration of updated climate change forecasts and recently completed or proposed flood-related projects (new levees, flood walls, etc.), as well as an examination of a range of potential cost-effective practical solutions.[12]

We read other adaptation studies, such as those from San Francisco (BART), New York City, Baltimore, and Toronto, for examples of adaptation strategies. We used those examples to think about and formulate adaptation strategies for our infrastructure. During team workshops, we evaluated the 11 highway segments in the Basin. Some of those segments had subsegments that were impacted by different flood scenarios. We analyzed those smaller segments and developed adaptation strategies that responded to the specific threat (see Appendix C, Segment Profiles, and Table 3-1).

We walked through each segment and identified potential adaptation strategies that we could use with and without the Corps (TSP and Future without Corps' Project). The strategies included general broad structural (design and construction) actions and nonstructural (planning, detour routes, and partnerships) solutions.

Once the list of strategies was compiled, our hydrologist and stormwater engineer analyzed them using the available data to determine the feasibility of the structural strategies. We then refined (omitted or modified) the strategies based on their feedback.

FHWA defines "no regrets" actions as actions that improve resilience of assets to existing stressors, have co-benefits, or cost little relative to the overall value of the asset. They can build flexibility into designs to allow for changes in the future.

http://www.fhwa.dot.gov/environment/climate_change/adaptation

[12] *Strategic Issues Facing Transportation: Volume 2: Climate Change, Extreme Weather Events, and the Highway System: Practitioner's Guide and Research Report*. National Cooperative Highway Research Program. Report 750. 2014

We developed a list of strategies for both the existing condition and the TSP, but we really looked for "no regrets" strategies that would improve transportation infrastructure resiliency regardless of future work by the Corps or local governments. As more data becomes available and the TSP is further refined, we can improve our strategies as needed. Table 3-1 is an example of the iterative list of strategies by highway segment (see Appendix C, Segment Profiles, for details).

A summary of our process is shown in Figure 2-11.

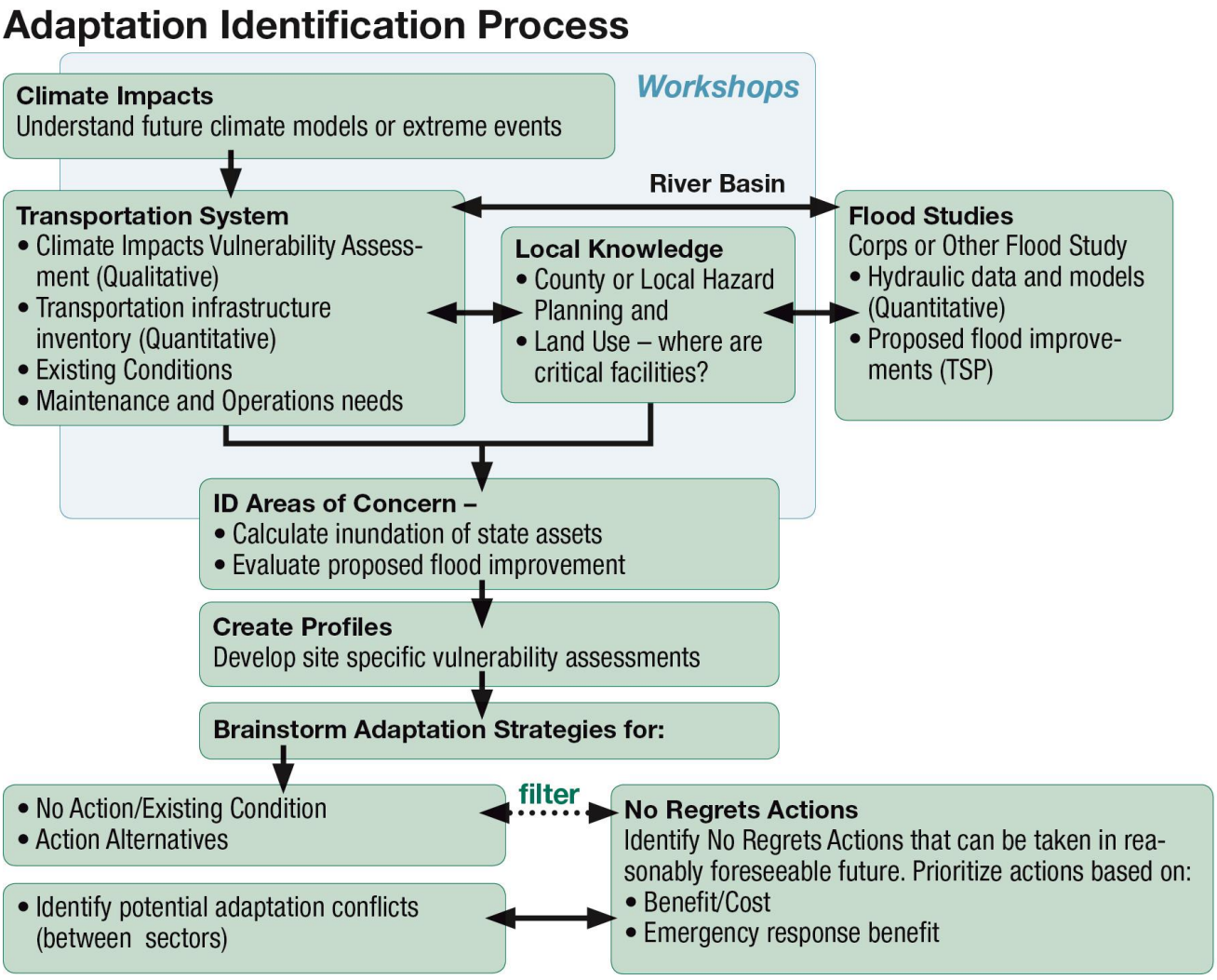


Figure 2-11 Summary Approach Diagram

3 Findings

3.1 What are the key findings from our analysis?

Our key finding is that transportation agencies must collaborate with flood risk managers during adaptation strategy development. We uncovered specific examples where WSDOT—if we had been unaware of the Corps' tentatively selected plan or local flood improvements—could have invested in the wrong place (aka: maladaptation).

This finding underscores the major recommendations of the recently released report from the President's "State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience." It is also consistent with the FHWA Framework (Section 4.1.1): "State DOTs and MPOs have a strong interest in integrating climate change adaptation, hazard mitigation, and transportation planning into a holistic planning process."

Our analysis of the Corps' GI study gives us the foundation for the necessary coordination, as federal, state, and local investments in flood hazard reduction are decided. We found that transportation infrastructure needs to be analyzed in the GI study both for impacts to the transportation system and as a partner in the solution. What one agency does affects the others. All levels of government need to create lasting partnerships in order to achieve community resilience.

Our analysis validated our workshop and interview process. We found through using our GIS and hydraulic analysis, most of the areas of concern identified during our 2011 qualitative vulnerability assessment and the interview process for this pilot were consistent with the flood analysis results. But the analysis found additional locations that the interviews didn't give us. Both processes complement each other and should be used together for watershed-level adaptation strategy development.

After conducting the analysis and reviewing the existing conditions, we discovered two locations, one on SR 20 and one on SR 9, where floodwater would flow over the highway during a 10% ACE flood. These were areas not revealed during our interviews, and were added as areas of concern. We recognized that, just because something has not happened in the past, doesn't mean it can't happen in the future.

Interestingly, large segments on I-5 and SR 534 are flooded under the 4% ACE and the 1% ACE floods, but not the 2% ACE flood. This occurs because the Corps identified the most likely locations for levee breaks, and they occurred in different places for different flood condition scenarios.

As shown in Figure 1-6 (timeline for dam building), there have been no flows in the river over 150,000 cfs, or approximately the 4% ACE. Because of this, no one that we interviewed has seen a 1% ACE event like the one modeled in the GI study.

Generally, the TSP will reduce flood hazards in urban areas by improving and raising existing levees and by adding new levees. Consequently, the transportation assets in these areas also benefit from the improvements. However, in more rural areas, transportation assets, including portions of I-5, SR 20, SR 11, and SR 9, will remain at risk with implementation of the TSP.[13] Our analysis revealed:

- Without the TSP, we estimate that about 90% of I-5 in Skagit County, as well as the rest of the highway system, is at risk of flooding.
- The TSP will eliminate issues on the southern and central portions of I-5 seen during the existing 1% ACE flood.[14]
- The TSP directs floodwaters to the northern section of I-5 near the Joe Leary Slough. This northern section of I-5, and SR 20 east of Burlington, were not identified in the qualitative vulnerability assessment as areas of high vulnerability.
- The TSP maintains or worsens conditions east of I-5 on SR 538 and SR 9, and west of I-5 on SR 11, SR 20, and SR 536.

3.2 What strategies did we develop?

For the 11 segments of highway that we identified as vulnerable, we developed a list of strategies for the Future without Corps' project, the TSP, and no regrets. Table 3-1 captures the strategies identified for each segment (See Figure 3-1 for map of segments). When we didn't have enough information about whether or not a strategy would work or solve a problem, we put a question mark (?). You can find all the specific details we considered for each segment in the profiles in Appendix C, Segment Profiles.

Generally, the project team brainstormed the following:

- Nonstructural solutions to help reduce impacts during flood events, like active traffic management, detour routes, etc.
- Solutions recommended in the Corps' GI Study and the TSP
- Other basin-wide ideas such as buying more water storage or flood easements
- Highway related solutions such as fixing culverts where potential blockage exists, hardening the road prism to allow the water to flow over it with minimal damage, realignment and/or raising the road out of the floodplain

[13] Corps, 2014
[14] The Corps used CIG data that assumes the current 1% ACE event will become the approximate 4% ACE event by 2085.

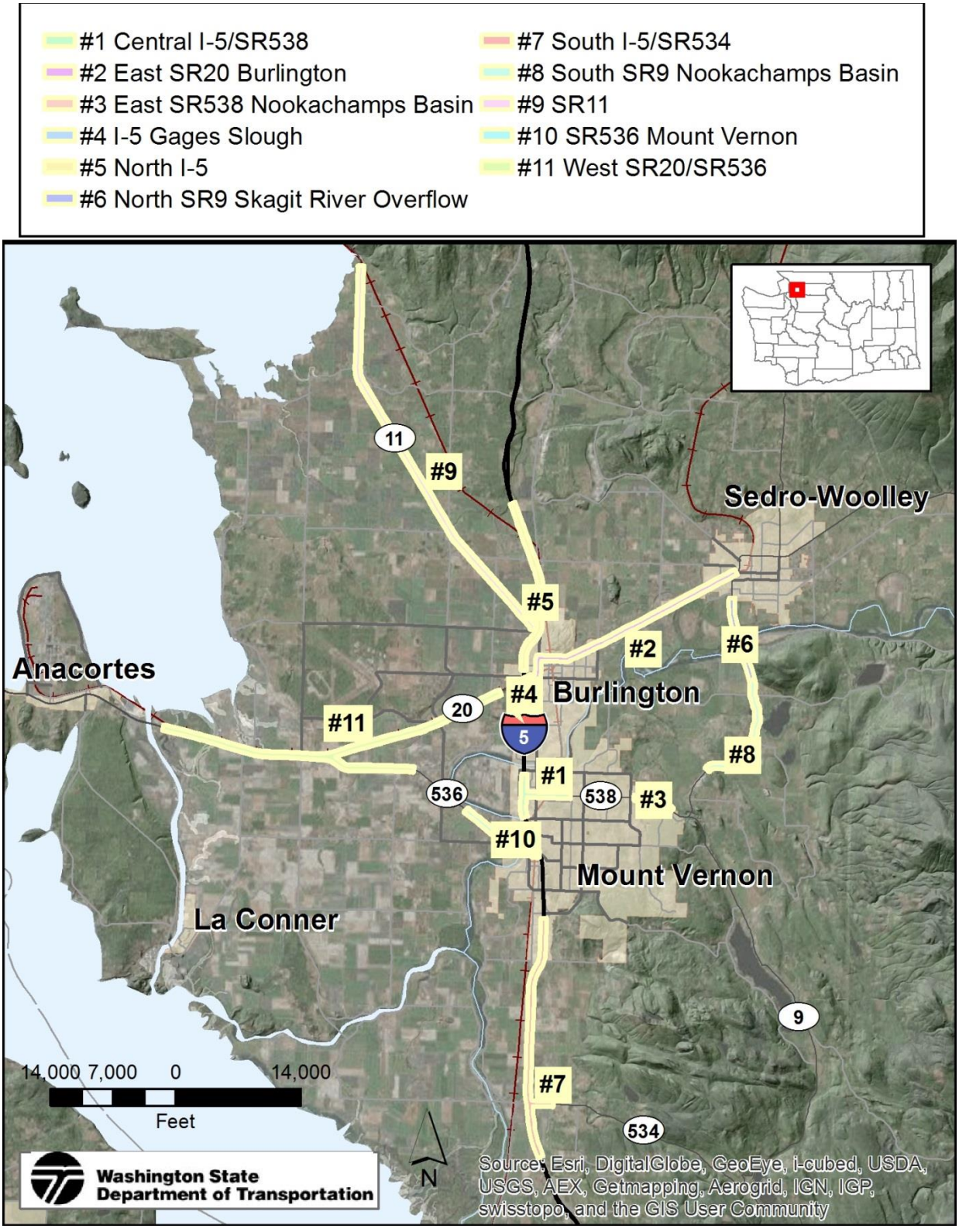


Figure 3-1 Skagit Segment Index

Table 3-1 Conceptual Strategies Identified for the 11 Vulnerable Highway Segments

Highway Segments – The Project Team Brainstormed the Following Options (see Figure 3-1)	Strategies		
	Future without Corps' Project	Tentatively Selected Plan	No Regrets
Segment 1: Central I-5 Anderson Road to George Hopper Road			
▪ Work with local agencies and the Corps to purchase additional storage capacity behind the dams run by Puget Sound Energy (PSE) and Seattle City Light.	x	x	x
▪ Work with the City of Mount Vernon to extend the floodwall to protect state highways.	x		x
▪ Raise I-5 above the flood elevation.	x		
Segment 2: SR 20 East of Burlington to Sedro-Woolley			
▪ Reroute traffic onto Cook Road or F&S Grade Road.	?[15]	x	x
▪ Raise the road (or portions) through this segment and install sufficient culverts or bridges to allow the water to pass from the Skagit River over to Joe Leary Slough.	x	x	?
▪ A high number of culvert ends are identified in this segment; it is possible that the other end may be buried or obstructed and not operating properly. If those culverts are not functioning properly now, fixing them might relieve flooding issues in smaller floods.			x
Segment 3: SR 538 Nookachamps Basin – SR 9 to I-5			
▪ Raise the road (or portions). It appears that this could be done to alleviate flooding for the more frequent flood events but may be difficult for the 2% and 1% ACE flood.	x	x	x
Segment 4: I-5 at – George Hopper to Chuckanut (SR 11)			
▪ Raise I-5 above the flood elevation.	x		
▪ Make SR 9 less vulnerable to flooding (see Segments 6 & 8) to serve as an alternate route if I-5 is closed for any reason.	x	x	x
Segment 5: North I-5 – Chuckanut (SR 11) to Samish River			
▪ Raise I-5 above the flood elevation. Raise the road (existing). The TSP sends more water to this segment of roadway, so the road would have to be raised to get above the higher flows as compared to existing flood elevations.	x	x	
▪ Work with other agencies to secure additional water storage. (The Corps includes this strategy in the TSP.)	x	x	x
Segment 6: North SR 9 Skagit River Overflow – Sedro-Woolley to Francis Rd./Old Day Creek Rd.			
▪ Explore options for a new alignment out of the floodway.	x	x	x
▪ Raise the road in the existing alignment.	x	x	x
Note: Either option would eliminate flooding concerns for this segment and add resilience to north-south travel. SR 9 is an alternate route for I-5. Making this route less likely to flood will improve the resilience of the transportation infrastructure and provide an alternate route that would allow limited north-south traffic flow and access for County residents who would otherwise be stranded or face long detours.			
Segment 7: South I-5 Fisher Creek to Anderson Road			
▪ Support the Corps' TSP. Implementing the TSP alleviates flooding in the segment.		x	
▪ Work with the City of Mount Vernon to extend its floodwall to the south to protect I-5. Further study is needed to determine if this option would protect I-5.	x		
▪ Raise I-5 above the flood elevation.	x		

[15] A "?" indicates that more information or analysis of potential benefits is needed.

Table 3-1 Conceptual Strategies Identified for the 11 Vulnerable Highway Segments (continued)

Highway Segments – The Project Team Brainstormed the Following Options (see Figure 3-1)	Strategies		
	Future without Corps' Project	Tentatively Selected Plan	No Regrets
Segment 8: South SR 9 Nookachamps Basin – Francis Rd./Old Day Creek Rd. to Turner Creek			
▪ Raise road above the flood elevation. Further evaluation is needed to determine if raising the roadway is feasible in the flood-prone areas near Clear Lake.	x	x	x
▪ Realign the highway.	x	x	x
Segment 9: SR 11 – I-5 to Blanchard Rd.			
▪ Raise road above the flood elevation.	x	x	
Segment 10: SR 536 Mount Vernon – I-5 to Avon Allen Rd.			
▪ Find alternate routes for local traffic and work with the local governments to make those routes more resilient during flood events.	x	x	x
Segment 11: West SR 20 and SR 536 – I-5 to Swinomish Channel			
▪ Find alternate routes for local traffic and work with the local governments to make those routes more resilient during flood events.	x	x	x
▪ Note: Allow the road to be brought back into service after a flood since the flood depths are so deep on SR 20. The following alternatives would allow the road to be destroyed by the flood, but in doing so, save other sections of the road. Both of these strategies might allow the road to be opened sooner after a flood event.			
□ Harden the road prism to allow the water to flow over it with minimal damage.	x	x	x
□ Make portions of the road sacrificial.	x	x	x
▪ Raise road above the flood elevation.	x	x	

3.2.1 What are our "no regrets" strategies?

We concluded that our path may change depending on whether the Corps builds or doesn't build the TSP. With that in mind, we developed "no regrets" strategies that would improve transportation infrastructure resilience regardless of future work by the Corps.

We recommend five primary "no regrets" strategies given what we know at this time:

- SR 20 (east of I-5): Raise the road at the low spot that floods at the 10 % ACE event.
- SR 9: Build a new alignment out of the floodplain or raise the road on a causeway in the existing alignment.
- SR 538 (east end): Raise the road to alleviate flooding for the more frequent flood events.
- Improve the intersection of SR 534/SR 9 to facilitate truck traffic.
- Coordinate with local agencies to identify and improve local routes that provide transportation redundancy.

We will continue to work with the Corps and the County to provide input to the TSP analysis. Once the TSP analysis is complete and the Corps and County make final recommendations, we will be able to create a longer-term plan of action for WSDOT facilities in Skagit County for flooding and weather-related closures that considers future climate impacts.

As a result of this pilot, we conclude that adaptation planning must have an iterative, integrated, multisystem approach. It is essential that WSDOT's plans and actions complement and actively work with federal and local flood protection efforts.

4 Lessons Learned:

4.1 What lessons did we learn during this process?

We learned several lessons during the pilot in relation to our goals and outcomes.

4.1.1 FHWA Framework

We relied on other studies and the FHWA Framework to guide our efforts. FHWA's Framework for adaptation planning and strategy identification was very useful and helped us tie our first vulnerability assessment to the more detailed Skagit River Basin study. In Figure 4-1, we show, via the callout boxes, where our data and other inputs fit into the Framework.

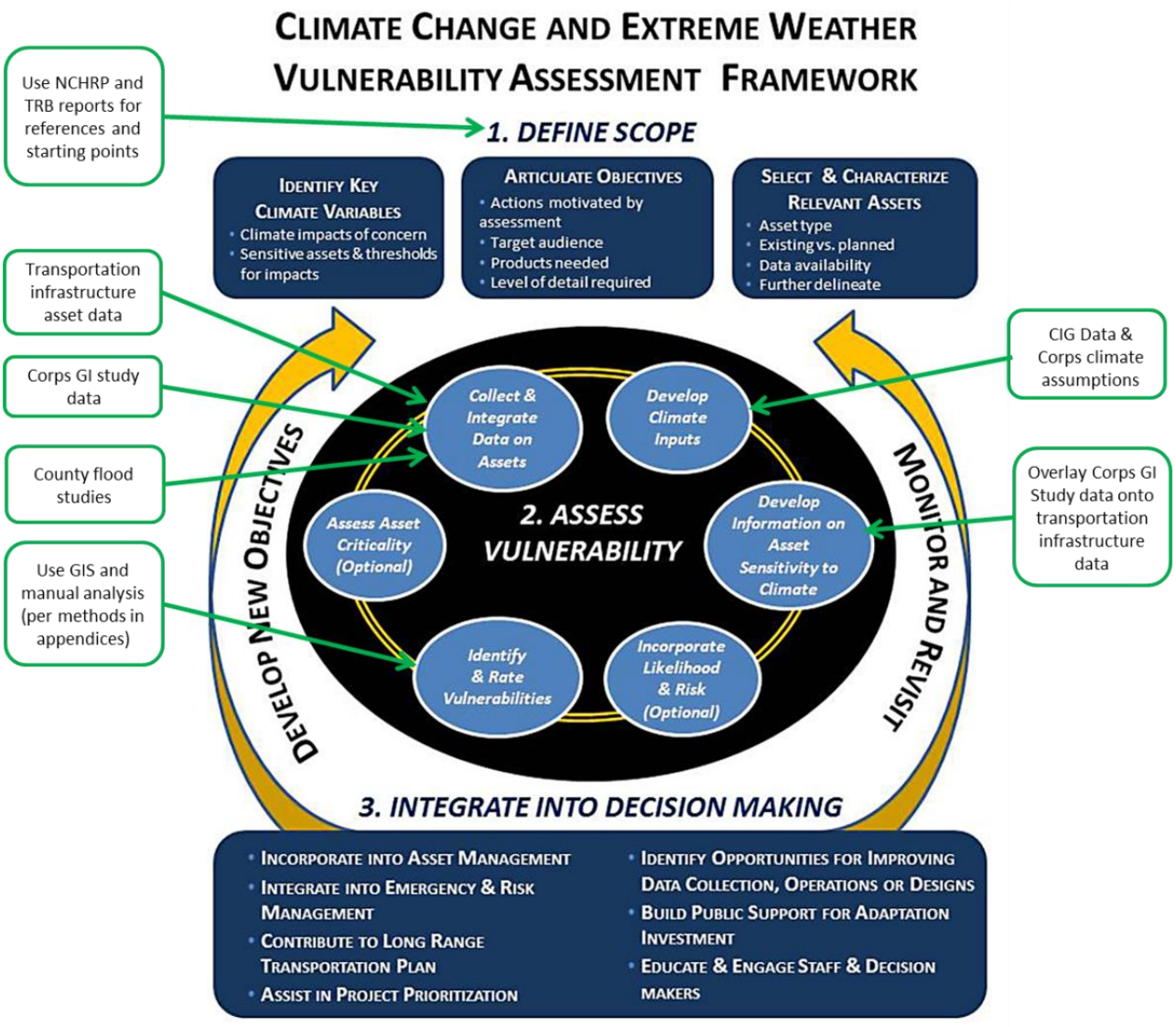


Figure 4-1 FHWA Vulnerability Assessment Framework: Elements of the Study

4.1.2 Corps flood modeling data

The flood modeling data provides another tool to analyze flood impacts and levee breech scenarios under existing and changing climate conditions. We can use that data to overlay our transportation asset data to determine if there is a risk to our system, and if there is, what adaptation strategies we should explore.

We found that our transportation system relies on flood protection that consists of the levee and dam system. So far, the system has worked. The maps show us the possibilities if the flood protection system fails. They also remind us that just because something hasn't happened in our memory doesn't mean it can't happen in the future or hasn't happened in the distant past (see Figure 1-4).

Predictions from the Climate Impacts Group (CIG) state that, by the end of the century, the current 1% ACE storm event will become the 4% ACE storm event and the 0.4% ACE storm event will become the 1% ACE storm event. The U.S. Army Corps of Engineers (Corps) used this guidance in its GI study and recommended that the tentatively selected Plan (TSP) build the levees to contain the 0.4% ACE storm event.

Corps flood modeling and flood hazard reduction proposals should inform our planning efforts so that our projects do not conflict with Corps or other flood-reduction projects.

4.1.3 Engaging with federal and local entities

Before you begin: For those of you hoping to work with Corps data, it will simplify the process if the Corps study is completed and all data is available before you begin your analysis. That way you will know what is available and what you need to produce for yourself, and your timeline won't be dependent on another's process.

Leverage available data sources: We started with our 2011 vulnerability assessment and added more depth and information to it. As noted above, we now have a greater appreciation of the value contained in completed flood studies. Transportation agencies don't need to wait for a new flood study to be undertaken; they can look at past studies and augment the prior work with climate change data from other sources.

Don't make assumptions: We assumed that we would have access to hydraulic modeling data that hadn't been done yet. It's important not to assume that what is needed for a transportation agency can be provided by another agency with a different definition of "infrastructure." The Corps' focus was homes and businesses (the National Flood Insurance Program rate payers), not highways, in their initial report.

4.1.4 Building the team

You need staff on your team who know both the local area and the people involved in climate adaptation work so that local responses and statewide policy can be considered in your study.

Make sure you have staff available with the expertise and time to carry the brunt of the workload. We needed staff with flood data analysis and GIS skills as primary team members.

During hydraulics analyses, use staff with resource-specific understanding and local familiarity. Without staff that has at least a basic understanding of how the data were created and the geography of the area, the data gaps may underestimate potential flood hazards, provide false positives, and/or overestimate the depth of flooding.

4.1.5 Overcoming challenges

Our greatest challenge was in linking our timeline to the Corps' GI study release. We were very focused on showing how to work with external data. When the Corps' timing was different than we expected, analyzing hydraulic data within the pilot schedule was difficult. This is a lesson in managing expectations. We will continue our analysis of hydraulic data and develop response strategies after this pilot is completed.

When faced with challenges, we stayed focused on our goal to use the FHWA model and the NCHRP 750 Framework[16] to create a replicable process. We also adjusted the scope of our effort to use the valuable information that was available. The conceptual nature of the TSP and our strategies were not sufficient for a detailed cost/benefit analysis.

4.2 Recommendations

As we come to the close of this phase of our work, we look back to see what we would do if we had it to do all over again. Some things we did well, other things could have gone more smoothly. Following is a list of considerations for other DOTs that are interested in replicating our approach.

4.2.1 What recommendations do we have for other to do this type of work?

1. **Partner with federal and local hazard reduction projects**: Transportation planners and asset managers need to reach out to the Corps in your region and to local flood managers. Find ways to advocate that transportation infrastructure be analyzed in the flood studies.

[16] http://www.camsys.com/pubs/nchrp_rpt_750.pdf

Keep in mind two things: (1) make sure impacts to the transportation system are considered, and (2) promote your DOT as a partner in the solutions (e.g., we should be partners, because what one agency does affects the other).

2. **Use existing studies:** Use completed GI studies or other flood hazard-reduction studies. Work with cities, counties, and the local Corps office or other cooperating agencies to get hydraulic modeling and GIS data.
3. **Use local knowledge to identify where problems areas lie:** Our interview process (Appendix A) worked well for past and existing locations with a history of flooding, sea level rise, river meander changes, and/or landslides. This was especially important since the data collection effort and analysis validated the anecdotal information.
4. **Coordinate:** It would be helpful to coordinate with cooperating agencies early in the process to ensure special data or model outputs are selected to avoid having to backtrack, redo, or rerun models to get that data.
5. **Look at how anticipated extreme weather events may impact problem areas you defined using the interview process:** Future conditions will be different than those you experienced in the past. Stay connected to university climate research centers and your state climatologist.
6. **Model where future changes will impact transportation infrastructure and what those changes might be:** This is where hydraulic data from the Corps is essential. Have specific data on your facilities, such as elevation, for flood impact analysis. For example, be cognizant that the existing 1% ACE might become the 4% ACE when planning future projects, especially those with a long life cycle.

4.2.2 What are some tips for using floodplain and hydraulic data from a similar flood study?

We learned a lot about what data the Corps uses. As noted above, the Corps study was still in the early stages, and we anticipate we'll get more information about the plan as it is finalized. Not all Corps studies are conducted the same way, so your experience may differ. Below are some tips associated with using floodplain and hydraulic data from the Corps or local flood managers, and potential issues you should consider:

1. Use the flood study to identify areas subject to inundation (you may have to overlay your own asset inventory). Expect detailed hydraulic analyses of the main channel, especially where there are bridges across the channel.

2. The Corps is likely to focus its cost/benefit analyses on the reduction of inundation of structures related to the National Flood Insurance Program (you may want to highlight costs of replacement or repair of transportation assets).
3. Expect that different hydraulic modeling studies will use different tools. The specific modeling tools will be selected by the hydraulic engineering team to best meet the conditions at the study or project site.
4. Do not expect detailed hydraulic modeling of overbank flows. With the exception of alluvial fans, flood hazards in the overbanks are typically from inundation of slow-moving water. In this case, we were fortunate to have the results of a sophisticated 2D floodplain hydraulics model. This is why we used our data analysis process (see Section 2.4).
5. Do not expect detailed analyses of flood impacts to the structural highway system. Impacts will typically be discussed in general terms of inundation of the highway and the costs of diverting around the inundated segment of highway.

4.2.3 What kind of data should you gather?

We learned to pull from our own data sets to augment what we got from interviews and the Corps study. We recommend other state DOTs and MPOs consider pulling data that tells the story about how your assets fit into the community and the region. Show the transportation network in context with other flood or disaster-planning efforts or studies.

Some things we did that helped us create a solid context and broaden our adaptation approach are listed below.

1. We characterized the transportation functions of our current assets, such as ADT, Truck %, and Fed. Functional Classification.
2. We included drainage management infrastructure and topographic conditions that influence drainage.
3. We mapped other hazards like geologic/soils stability issues and tsunami or volcanic hazard zones.
4. We identified community resources (such as hospitals) that need access protection in an emergency event, or natural resources (such as wetlands) that need to be protected or avoided in an adaptation response.

5 Conclusions and Next Steps

This study builds on WSDOT's earlier pilot to examine adaptation options in an identified highly vulnerable area: the Skagit River Basin (Basin). Our pilot team collaborated with Skagit County and the U.S. Army Corps of Engineers (Corps). We examined information from local experts and from the Corps' Skagit River Flood Risk Management General Investigation Study (GI study). We achieved our goal of advancing the Federal Highway Administration (FHWA) Framework and integrating the state DOT adaptation strategy with a major flood study.

In our proposal to FHWA, we anticipated that our study would include the following outcomes:

- A set of site-specific adaptation strategies for the state-owned and state-managed transportation infrastructure.
- A replicable evaluation process, including a life cycle cost analysis of multiple engineering and nonstructural adaptation options to reduce risk to infrastructure.
- A plan of action for flooding and weather-related closures to improve public safety and enhance continuity of international freight flow along this corridor that considers future climate impacts.

As we complete this report to FHWA, we recognize that we delivered approximately half of the anticipated outcomes. We focused on processes to analyze flood study data in the context of DOT data availability and to develop "no regrets" adaptation strategies. We took a qualitative look at continuity of operations during weather-related closures based on lessons learned in the Skagit River Bridge collapse and for our "no regrets" strategies.

We have further work to do in the area of life cycle cost analysis. We set forth next steps to more fully scope adaptation options and deliver a plan of action.

5.1 What were our key accomplishments?

The key conclusion from our pilot study is that transportation agencies must engage with local and federal flood hazard mitigation project planning efforts.

We created a process for bringing flood studies, such as the Corps' GI study, into state DOT vulnerability assessment and adaptation strategy development. There is a synergy that comes from combining our efforts. When we work together, we can find solutions that might not be possible, and avoid problems that might occur.

We developed a list of "no regrets" strategies that will benefit the area whether or not the Corps' projects are built or there are more extreme weather events.

"Here's what I would like to tell the partners when I next see them. We listened, we understand, and we want to work with you on the next steps."

Team member comment

5.2 How do we summarize our work?

WSDOT's pilot project demonstrates the tremendous value that can be achieved by partnering with the Corps, flood managers, and county public works departments. As a result of this pilot, we started a conversation in the Basin that engaged a variety of partners. We leveraged the good work of Skagit County and the Corps. We can inform each other's work and reduce potential future conflicts by working together.

We developed a replicable process for state DOTs to use federal or other local flood studies in climate adaptation strategy development. Building on the process we used for our qualitative vulnerability assessment, we followed the process in Figure 2-11.

We show what DOTs can to with hydraulic information that is created for another purpose. We explain how we can work to better connect highway-related data to inform federal and local adaptation planning and investment decision-making. We all benefit by working together.

Recent Encouragement from All Levels of Government:

- President Obama's EO 13653 "Preparing the United States for the Impacts of Climate Change" (November 2013)
- Washington Governor Inslee's EO 14-04 "Washington Carbon Pollution Reduction and Clean Energy Action" (April 2014)
- Recommendations of the President's State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience (November 2014)
- FHWA Order 5520, "Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events" (December 2014)

5.2.1 Integration (we can't do it alone)

We believe that, in order to be successful, adaptation strategies have to be integrated. The public sector (at all levels) must work with community groups and the private sector. Transportation managers need to coordinate solutions with public works and utilities. Drainage districts and flood protection managers need to work with tribes and cities.

Our pilot demonstrates the value of integration. We found locations where WSDOT—if unaware of the Corps' tentatively selected plan or local flood improvements—could invest in the wrong place and inadvertently block the flow of water that the Corps assumed would occur.

Our team's engagement with the Corps and the County on the Skagit GI study helps us do more than just react to their proposed solution: it makes WSDOT a willing partner in finding long-term solutions.

5.2.2 What recommendations do we have for the Corps and USDOT?

We recommend that the Corps and USDOT:

- Work together to develop a strategy for integrating agency-sponsored planning efforts, to eliminate the potential for disconnects.
- Strive to reduce regulatory barriers between their two agencies— especially in the way that roads and highways are considered in the Corps' economic analysis (see the Letter to the Corps in Appendix A). We discovered that not all of the Corps' GI studies analyze roads the same way. The Chehalis Basin GI did analyze the impacts to roads, but the Skagit GI has not yet done so.
- Invite FHWA Division offices or the state DOTs to be cooperating agencies in major flood studies.

We recommend that FHWA and the Federal Transit Administration encourage transportation agencies (at all levels) to seek out flood risk-reduction strategies proposed by others— especially when undertaking regional and corridor-level studies. This study points out the advantages to DOTs of using federal flood studies.

5.2.3 What ideas do we have for further study?

More research and demonstration pilots are needed to identify and remove administrative, regulatory, and policy barriers that discourage preparedness (FHWA Order 5520[17]). We recommend that USDOT and the Corps conduct a coordinated research project to delve deeper into their current processes and agency missions to see where connections can be improved.

Local agencies are the unifying force bringing federal, state, and tribal policy goals together. There are many recommendations within the report[18] of the President's Task Force that should be mined for further study.

5.3 What next steps do we anticipate?

On December 15, 2014, FHWA issued Order 5520, *Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events*. This order states that it is FHWA policy to integrate consideration of climate and extreme weather risks into its planning, operations, policies, and programs.

[17] http://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm
[18] http://www.whitehouse.gov/administration/eop/ceq/initiatives/resilience/taskforce

As a state agency, we work with both federal and local agencies. We are working with the state departments of Commerce and Ecology to develop guidance for local vulnerability assessments. We hope to coordinate with local governments on adding climate considerations into their Growth Management Act compliance and long-range planning efforts.

Internal to WSDOT, we will continue our work to integrate climate into decisions, including capital program investments and planning studies. Following are a few specific tasks we plan to work on in the future.

5.3.1 Within the Skagit River Basin

WSDOT will continue to work with the community on integrated long-range transportation/land use and emergency planning in Skagit County. WSDOT will monitor progress of the Corps' TSP and local investments, and continue to assess partnering opportunities.

- Members of the pilot team will continue to provide planning and technical support to evaluate and inform the TSP and other local proposals. Team members will conduct additional hydraulic analyses in the Basin using a variety of methods (see Appendix D, Hydrology and Hydraulics Methodology).

WSDOT will refine our plan of action for flooding and weather-related closures to consider future climate impacts and flood hazard-reduction changes in the Basin.

5.3.2 Statewide

As a result of this pilot project, WSDOT will integrate what we have learned into corridor planning and transportation studies. We will examine other flood hazard-reduction efforts (especially the Puyallup and Chehalis basins) to identify "no regrets" strategies in those basins.

WSDOT's Climate Change Evaluation guidance and our 2014–2017 agency strategic plan require consideration of climate impacts and discussion of resiliency. (See Goal 3 (environmental stewardship) from WSDOT's strategic plan at: http://www.wsdot.wa.gov/secretary/resultswsdot.htm)

We will also look for funding to further our adaptation efforts. For example, WSDOT is on the team applying for the 2015 National Disaster Resilience Competition grant. The grant requirements illustrate the strong direction to create and sustain multisector, multijurisdictional, community-based resilience. We are observing that the potential for significant funding and the very detailed grant requirements constitute a strong incentive to work together.

> WSDOT plans and those major capital projects undergoing environmental review (at the NEPA EIS and EA level) in the 2013–15 Biennium will document how climate change and extreme weather vulnerability are considered, and propose ways to improve resilience. –
>
> *Results WSDOT (2014–2017 Strategic Plan)*

The department is committed to preparing WSDOT's Climate-Ready Action Plan for the 2015–2017 Biennium, to focus department efforts, including decision support (asset management and practical guidance), leading by example (best practices), and capacity building for WSDOT staff and our partners.

We look forward to more demonstration pilots and to working with FHWA in interpreting federal direction and new guidance emerging on the consideration of climate change impacts. Most of all, we are excited to work together to leverage federal, state, tribal, and local resiliency opportunities.

Mount Vernon flood wall