SUMMARY:

Mitigation is defined in 44 CFR 201.2 as any sustained action taken to reduce or eliminate long-term risk to human life and property from hazards. The Federal Emergency Management Agency (FEMA) provides States, local communities, tribes, and private non-profits with financial assistance for plans and projects that will reduce or eliminate risks from natural hazards through Hazard Mitigation Assistance (HMA) grants. The HMA grants include post-disaster grants under the Hazard Mitigation Grant Program and pre-disaster grants under the Pre-Disaster Mitigation Program (PDM), the Flood Mitigation Assistance Program, the Repetitive Flood Claims Program, and the Severe Repetitive Loss Program.

FEMA awards mitigation grants based on whether proposed projects are determined to be cost-effective, environmentally sound and technically feasible. With these significant investments being made in mitigation, the need to demonstrate the cost-effectiveness of the funded projects is crucial for continued support. FEMA has traditionally determined the cost-effectiveness of proposed mitigation projects by estimating the damage that would occur in probabilistic hazard events.

Since 1956, Washington State has received 45 major disaster or emergency declarations. Most of these declarations involve flooding, the last occurring in January 2009. In addition, our region is also known for its vulnerability to earthquakes, ranked second only behind California with respect to the potential impacts from one of the three types of earthquakes to which our region is prone. Our most recent major disaster declaration related to earthquake was for the 2001 Nisqually Earthquake.

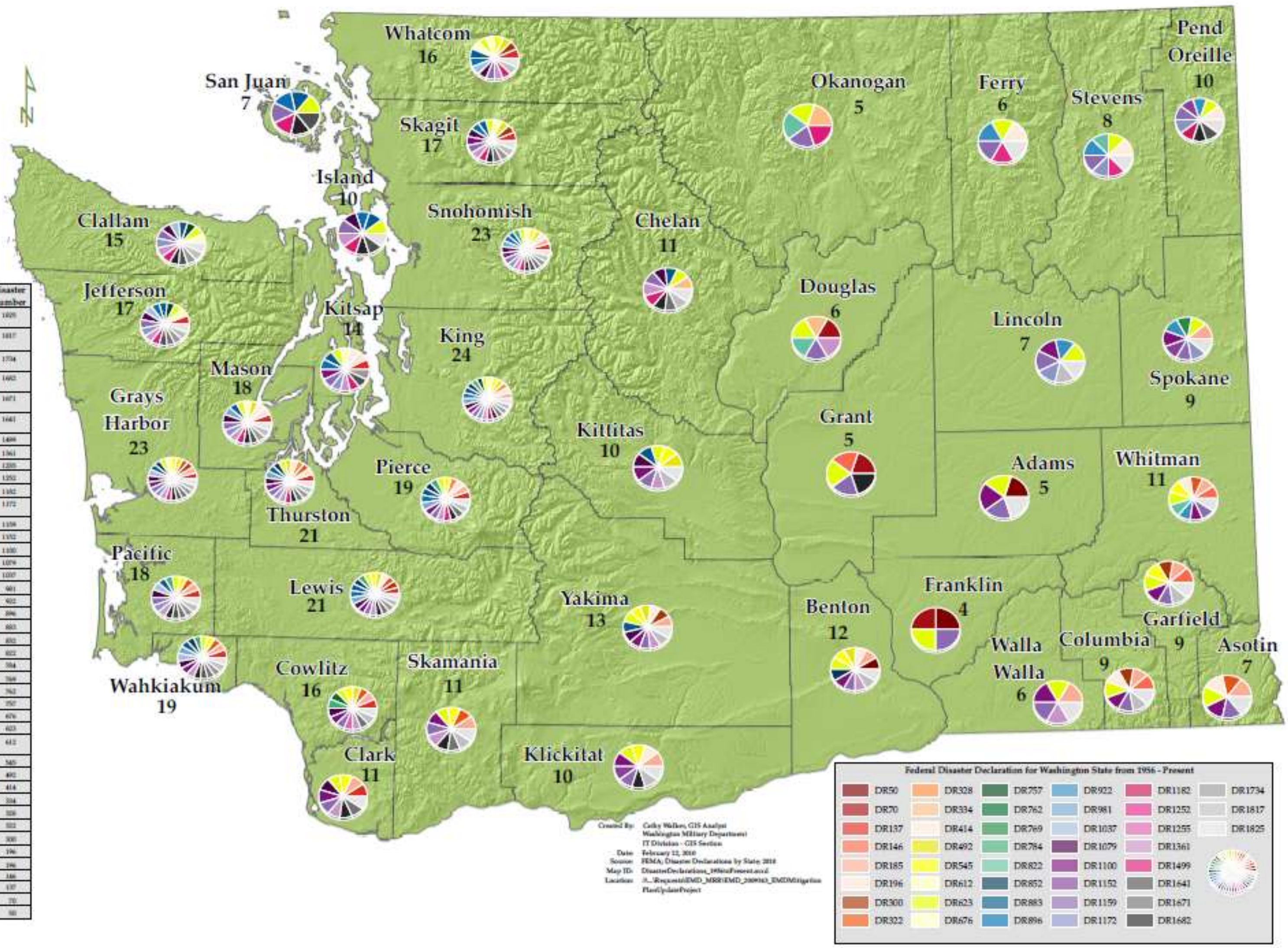
Washington State has been very proactive in seeking funding from the various grant sources to help reduce or eliminate the long-term risk to people and property from the hazards within our region.

1. INTRODUCTION

Washington State currently lists nine natural hazards to which the region is most vulnerable: avalanche, drought, earthquake, flood, landslide, severe storm, tsunami, volcano and wildland fire (EMD, 2008). While most of the 45 declarations within Washington State involved flooding, a mix of hazards are involved, including two declarations (1965 and 2001) for earthquakes; several landslides, and the eruption of Mt. St Helens. Since late 1995, every county in the state has been included in at least two major disasters; Grays Harbor, Snohomish, King, Lewis, and Thurston Counties have each been listed in disaster declarations in excess of 17 times for flood events since 1956, with several counties being included in excess of 20 disasters or emergency declarations as demonstrated on the following map.

Washington State Federal Disaster Declarations - 1956 to 2009

Date	Disaster Type	Disaster Number
3/2009	Severe Winter Storm and Record & Near Record Snow	1825
1/2009	Severe Winter Storm, Landslides, Mudslides, and Flooding	1817
12/2007	Severe Storms, Flooding, Landslides, and Mudslides	1734
2/2007	Severe Winter Storm, Landslides, and Mudslides	1682
12/2006	Severe Winter Storm, Landslides, and Mudslides	1671
5/2006	Severe Storms, Flooding, Tidal Surge, Landslides, and Mudslides	1641
11/2003	Severe Storms and Flooding	1499
3/2001	Earthquake	1361
10/1998	Landslide: City Of Kelso	1255
10/1998	Flooding	1252
7/1997	Snowmelt/Flooding	1182
4/1997	Severe Storms, Flooding, Landslides, and Mudslides	1172
1/1997	Severe Winter Storms/Flooding	1159
1/1997	Ice and Snow Storms	1152
2/1996	Severe Storms/Flooding	1100
1/1996	Storms, High Winds, Flooding	1079
8/1994	El Nino Effects (the Salmon Industry)	1037
3/1993	Severe Storm, High Winds	981
11/1991	Fires	922
3/1991	High Tides, Severe Storm	896
11/1990	Flooding, Severe Storm	883
1/1990	Flooding, Severe Storm	852
4/1989	Heavy Rains, Flooding, Mudslides	822
12/1986	Severe Storms, Flooding	784
7/1986	Severe Storms, Flooding	769
3/1986	Heavy Rains, Flooding, Landslides	762
2/1986	Severe Storms, Flooding	757
1/1983	Severe Storms, High Tides, Flooding	676
5/1980	Volcanic Eruption, Mt. St. Helens	623
12/1979	Storms, High Tides, Mudslides, Flooding	612
12/1977	Severe Storms, Mudslides, Flooding	545
12/1975	Severe Storms, Flooding	492
1/1974	Severe Storms, Snowmelt, Flooding	414
6/1972	Severe Storms, Flooding	334
3/1972	Heavy Rains, Flooding	328
2/1972	Severe Storms, Flooding	322
2/1971	Heavy Rains, Melting Snow, Flooding	300
5/1965	Earthquake	196
12/1964	Heavy Rains & Flooding	185
3/1963	Floods	146
10/1962	Severe Storms	137
3/1957	Floods	70
2/1956	Floods	50



In an effort to mitigate the impact of the state's hazards, Washington State jurisdictions have been very proactive in their mitigation initiatives, and have sought grant funding to assist in completion of their various projects. Since 2002, Washington jurisdictions have been the recipient of 144 HMGP and PDM grants, which have included elevation, acquisition and seismic retrofit projects, as well as mitigation planning grants.

In addition to hazard mitigation grant programs, the State's jurisdictions also receive grants from programs such as: FCAAP, HUD, Homeland Security, National Earthquake Hazards Reductions Program (NEHRP), the United States Army Corps of Engineers (USACE), and various state and federal fire reduction and planning programs through the U.S. Department of Natural Resources, and the Washington State Department of Natural Resources. A more thorough list of mitigation-funding programs is available in Tab 7 of the HMP. All of these programs and funding opportunities contribute to enhancing the state's ability to mitigate the impact of hazards.

Beyond funding sources, the state has also been proactive in mitigation efforts through the establishment of regulatory authority to mitigate damages and enhance life safety. This has been accomplished through the establishment of statewide laws, local policies, and procedures, all of which have had an impact on the extent of damages sustained from hazards. A few of these examples are included in this report within Section 6 - *Additional Mitigation Efforts*. A more comprehensive list of regulatory efforts can also be viewed within Tab 7 of the HMP, within the *Capabilities* portion.

For all of these mitigation efforts, whether structural, procedural or process, the question remains as to the effectiveness of those projects. FEMA reports indicate that for every $1 spent on mitigation activities, $4 is saved. This Losses Avoided Study will review and discuss a number of efforts recently completed within Washington. We will review projects funded through various disaster events, include a recap of the findings of three of FEMA's LAS for DR-1100-WA, DR-1079-WA, DR-1159-WA, and conduct a study on 24 projects funded through disasters DR-1671-WA, DR-1682-WA, DR-1641-WA, and DR-1734-WA.

Historically, the State has relied upon FEMA to provide LAS for projects, and FEMA has provided a number of such studies, including, but not limited to:

- "Evaluating Losses Avoided Through Hazard Mitigation." *City of Centralia, Washington.* (2008)
- "Measuring Success Hazard Mitigation." *Rainier Manor Mobile Home Park, Sumner, Washington*. (2007)
- "Evaluating Losses Avoided Through Hazard Mitigation." *City of Snoqualmie, Washington.* (2007)

As indicated, these reports will be reviewed for effectiveness with information incorporated into Section 5 of this study.

While FEMA has provided these initial studies, the state has been very proactive in its mitigation efforts. There are currently numerous projects which have either been completed, or are underway, many of which have been funded by either PDM or HMGP funds. However, as indicated, there are other mitigation initiatives also in place beyond the PDM and HMGP.

In an effort to determine the level of effectiveness of all of these various activities, the state is embarking upon its own LAS to determine effectiveness of not only structural projects, but also regulatory actions and other mitigation efforts. While not all of these elements are included in the initial LAS, ultimately the intent is to include the various other grant-funded mitigation projects, as well as other state and federally funded programs and initiatives. This initial Loss Avoidance Study will review various PDM and HMGP projects to determine their level of success in a quantitative method, as well as review various other programs, policies and procedures to determine their qualitative success.

2. Purpose

Currently Washington State has an Enhanced Hazard Mitigation Plan. The State has historically demonstrated its ability to meet the criteria for this Enhanced status through various means, including the ability to monitor the requirements of the various FEMA grants indicated above. An additional requirement to maintain the Enhanced status is the ability to track the effectiveness of the grants funded by FEMA. In accordance with 44 CFR 201.5(2) (ii), the State of Washington initiated this study to determine the cost-effectiveness of the various mitigation projects. This the first endeavor at this type of study, and due to time constraints, the volume of work required to conduct such a study, and available manpower, an analysis of every FEMA-funded project was not possible. However, this study included as many projects as possible from those disasters referenced in Section 1 above. The intent from the completion of this initial study is to continue to enhance and capture data from past grant projects during the next plan update cycle. This will be accomplished by continuing to populate the mitigation grants data analysis database developed for this loss avoidance study. .

3. Methodology Overview

FEMA has developed a Loss Avoidance Study (LAS) methodology to evaluate the cost-effectiveness of mitigation projects. The methodology used within the FEMA studies are based on the analysis of actual natural hazard events that have occurred in the project study area since completion of the mitigation project. Using a similar methodology, a project sponsor can assess the benefits of a mitigation project in terms of its actual performance (FEMA, Loss Avoidance Study: Washington Flood Reduction, 2009). Washington State will closely mirror FEMA's LAS approach in the development of this study.

It is important to note that this study does not include loss avoidance calculations associated with social impacts, which can be both positive and negative. Not calculated in this study are elements such as: economic impact; loss of use; displacement; employment impacts; environmental degradation or revitalization; increased employment opportunities associated with rebuilding; gentrification, and medical/health issues, etc. While these elements contribute to the overall estimate of avoided losses for a mitigation project, the software used to conduct this study does not allow for inclusion of social impacts as part of its calculation of avoided loss. Therefore, the State's study will only be looking at the structural recovery/loss aspect of a loss avoidance study, as well as a qualitative review of the regulatory authority in place to strengthen mitigation initiatives.

Loss avoidance methodology can be applied to mitigation of any hazard (e.g., flood, wildfire, seismic, wind). Mitigation projects themselves vary in nature with some projects mitigating several hazards. The projects can be structural or non-structural in nature, and include the development of a procedure or a process. The losses avoided (also referred to in this report as damage prevented or benefits derived) by the implementation of the mitigation projects were quantified depending on the event type. In this study, the focus was on seismic retrofit to mitigate damages sustained as a result of earthquakes; elevation projects which mitigation flood events, and property acquisitions, which have the potential to mitigate flood and landslide/erosion events.

Flood hazard mitigation projects can be classified as either building modification or flood reduction projects. Building modification projects mitigate damage by modifying a building to reduce the risk of damage from flooding and include elevation, acquisition, relocation, and floodproofing. Flood reduction projects mitigate damage by reducing the hazard itself, and include stormwater drainage system improvements, channel modifications, flood walls/barriers, and other hydraulic structures that reduce the severity of flooding (FEMA, Loss Avoidance Study: Washington Flood Reduction, 2009).

Seismic retrofits can be classified as structural and non-structural in nature. While current practice of seismic retrofitting is predominantly concerned with structural improvements to reduce the seismic hazard of using the structures, it is similarly essential to reduce the hazards and losses from non-structural elements.

For purposes of this study, the sample size is relatively small: 24 projects total. The small sample size is based on the number of completed mitigation projects for which all data needed to conduct the modeling and analysis was available. Of these 24 projects, 20 are flood projects; the state's number one hazard of concern during the 2010 Risk Assessment. The four remaining projects are representative of the state's second hazard of greatest concern: earthquake. Of the various grants funded by FEMA, the majority are for flood related mitigation efforts.

Two different methodologies were utilized to conduct the modeling for the flood hazard projects. One of the sample sets, encompassing 11 projects, was conducted by Ed Whitford, GIS Analyst for Tetra-Tech, Inc. An additional nine flood projects were modeled by Cathy Walker, GIS Analyst for the Washington State Military Dept. Emergency Management Division.

In addition to the 20 flood projects, four seismic retrofit projects were also reviewed for the purpose of this study. The modeling for those projects was also conducted by the Washington State Military Department (Cathy Walker).

4. Phase Development Process:

Losses avoided studies consist of three phases. Although Phases 1 and 3 are similar regardless of the type of hazard or mitigation project being evaluated, Phase 2 varies dependent upon the type of hazard and project. This phased approach was created and utilized by FEMA in the most recent 2009 study titled "Loss Avoidance Study: Washington Flood Reduction." While the basic Phase approach is utilized and reference is made throughout FEMA's study, certain elements have been modified to meet the needs of this study specifically as they relate to the seismic study. For exact language on FEMA's phased approach, the actual study should be reviewed: "Loss Avoidance Study: Washington Flood Reduction" (August, 2009).

Assumptions:

The following assumptions were used for the Losses Avoided calculations:

- A building damage of 50 percent or more would result in demolition
- HAZUS-MH4 default depth-damage relationships for residential structures, contents and displacement costs were used in the analysis.
- HAZUS-MH4 default Percent Ground Acceleration was not utilized. PGA was supplied by USGS ShakeMaps.
- Damage relationships for residential structures, contents and displacement costs were used in the analysis.
- A content value of either 50 or 70 percent of the building replacement value was used. The variations in these amounts are dependent upon analyst who conducted analysis as defined in individual reports attached.
- Building replacement costs was captured via the grant application submitted by jurisdiction.
- Where available, Flood Discharge Values were provided by the flood information studies for each jurisdiction within which each structure was located. Digital DFIRM data as well as the FIT tool was utilized to determine depth grids for the Snoqualmie projects.

Phase One

For all projects, Phase 1 consists of the development of the initial project list. Projects are selected based on criteria determined by the sponsoring agency. The initial list of projects is screened based on the availability of data required for completion of all phases of the study. Projects with adequate data advance to Phase 2.

To capture the project list, the first phase of the project included the development of a database which would hold all of the necessary data. The database was developed in a method which would allow the exporting and importing of the data into HAZUS-MH Version 4, the analysis tool utilized to run scenario events. The data needed to populate the database was gathered, in part, from the application submitted by the jurisdiction. Eventually, it is intended that as the grant applications are received, the information would be populated into this database, which will elevate the need to populate the data source to conduct the studies in the future. Historically, the state utilized a spreadsheet to capture the data. Due to this factor, this was the most time consuming portion of the study as the information had to be manually captured and entered into the database. This involved retrieving files from archives for those projects completed. As a result of this factor, it was determined that this initial study would be most effective if it focused on projects meeting one of the following criteria: 1) those projects completed most recently, and 2) those projects which included *groups* versus *individual* projects, where possible. Additional projects will be added during the next plan update cycle.

PHASE TWO

Phase 2 is composed of a Physical Parameter Analysis. The elements thereof, again, are dependent upon the hazard. For purposes of this LAS, two types of hazards were included: earthquake and flood. The physical parameter analysis includes data collection, hydrologic analysis, and hydraulic analysis.

During the development phase of this LAS, Tetra-Tech, Inc., was in the process of completing a local Hazard Mitigation Plan for the City of Snoqualmie, one of the recipients of FEMA HMGP funds for elevation of 11 residences. As a course of plan development, Tetra-Tech gathered extensive information concerning localized flood events, and agreed to conduct a LAS for the 11 residences utilizing that information.

General information for those 11 Snoqualmie projects are depicted below.

BCR VALUES

ID	Award Amount	Bldg Replacement Value	Content Cost (70% of Bldg)	Rep. Loss Yes/No / #/RL	RL Amount Paid in Claims	Severe Rep. Loss / #/SRL	Severe RL Amount Claims	GMA Compliant	BCR	NFIP Compliant
1	$78,738	$79,540	$55,678	Y / 2	$56,077	N		Yes	2.92	Yes
2	$138,538	$139,680	$97,776	Y / 5	$48,904	N		Yes	7.18	Yes
3	$125,887	$83,420	$58,394	Y / 4	$22,419	N		Yes	3.34	Yes
4	$125,976	$88,270	$61,789	Y / 5	$25,825	N		Yes	11.18	Yes
5	$149,400	$387,450	$271,215	Y / 5	$198,553	N		Yes	5.7	Yes
6	$151,459	$273,540	$191,478	Y / 4	$261,976	Y / 4	$261,976	Yes	.66	Yes
7	$102,767	$124,160	$86,912	N		N		Yes	1.81	Yes
8	$96,908	$130,950	$91,665	N		N		Yes	1.35	Yes
9	$102,767	$121,250	$84,875	N		N		Yes	.45	Yes
10	$108,763	$135,800	$95,060	N		N		Yes	3.81	Yes
11	$121,056	$156,013	$109,209	N		N		Yes	1.04	Yes
T	$1,302,259.00	$1,720,073	$1,204,051							

Flood:

For the flood portion of the study, we examined both elevations and acquisitions. The following charts illustrate the physical parameters associated with the Snoqualmie modeling conducted by Tetra-Tech, Inc.

Attribute	Source	Definition
Occupancy	HAZUS/KCA	HAZUS Occupancy Type (i.e. Residential)
Name	EC/KCA	Owner Name
Address	EC/KCA	
City	EC/KCA	
Year Built	EC/KCA	
Number of Stories	EC/KCA	
Building Cost	KCA	Building Replacement Cost
Content Cost	KCA	70% of Building Replacement Cost
Area	KCA	Building Square Feet
Building Type	Assumption	All Structures Assumed to be Wood Construction
Design Level	KCA	Based off of Year Constructed Using HAZUS Defenitions
Foundation Type	EC	
First Floor Height Pre-Mitigation	EC	Height of First Floor above Lowest Adjacent Grade, Pre-Mitigation
First Floor Height Post-Mitigation		Height of First Floor above Lowest Adjacent Grade, Post-Mitigation
EC = FEMA Elevation Certificate		*KCA = King County Assessor*

Table 1 – Information Gathered

Table 2 – Populated Spreadsheet with relevant information

Property	City	Year Built	Building Value	Content Value	Flood Building Type	Flood Design Level	Flood Foundation Type	First Floor Height Pre-Mitigation	First Floor Height Post Mitigation
1	Snoqualmie	1939	$79,540	$55,678	WOOD	1	5	-0.1	11.4
2	Snoqualmie	1923	$139,680	$97,776	WOOD	1	4	-3	10.8
3	Snoqualmie	1923	$83,420	$58,394	WOOD	1	4	-3.9	9.8
4	Snoqualmie	1924	$88,270	$61,789	WOOD	1	4	-3.1	UNKNOWN*
5	Snoqualmie	1976	$387,450	$271,215	WOOD	3	5	-1.4	7.6
6	Snoqualmie	1965	$273,540	$191,478	WOOD	2	5	0	5.5
7	Snoqualmie	1948	$124,160	$86,912	WOOD	1	5	-2.1	7.9
8	Snoqualmie	1964	$130,950	$91,665	WOOD	2	5	-0.8	9.8
9	Snoqualmie	1947	$121,250	$84,875	WOOD	1	5	-0.9	6.7
10	Snoqualmie	1920	$135,800	$95,060	WOOD	1	5	-0.6	12
11	Snoqualmie	1919	$156,013	$109,209	WOOD	1	5	-0.6	7.4

*Construction not completed

Legend:

Flood Design Level		*Flood Foundation Type*			
0	*Unknown*	*1*	*Pile*	*5*	*Crawl Space*
1	*Prior to 1950*	*2*	*Pier*	*6*	*Fill*
2	*1950-1970*	*3*	*Solid Wall*	*7*	*Slab on Grade*
3	*Post 1970*	*4*	*Basement/Yard*		

The pre-mitigation and the post-mitigation first floor height attributes were calculated by subtracting the Lowest Adjacent Grade from the First Floor Elevations. An accurate First Floor Height is critical when trying to accurately calculate flood damage losses.

The HAZUS FIT (Flood Information Tool) extension was used to develop a 100YR depth grid using King County LiDAR data along with the King County DFIRM. 100 year water surface elevations were extracted from DFIRM cross sections and the 100 year flood hazard area was used as the extent and location boundary. The FIT generated depth grid was loaded into the HAZUS project as a User Data Depth Grid.

For perspective purposes, the following represents actual historic flood discharge rates for recorded events occurring within Snoqualmie:

- Jan 2009 cfs: 55,000 (10 year flood)
- Nov 2009 cfs: 78,800 (>100 year flood)
- Nov 2008 cfs: 45,200
- Nov 2006 cfs: 50,500 (10-25 year flood)
- Jan 2005 cfs: 37,100
- Oct 2003 cfs: 29,200
- Feb 1996 cfs: 51,700
- Nov 1995 cfs: 50,200
- Nov 1990 cfs: 78, 800

The DFIRM 100 year discharge at the Snoqualmie Falls (close proximity to location of properties) is 78,500 cfs. The 50 year discharge = 71,000 cfs, and the 10 year = 52,000 cfs.

Two UDF records for each property were loaded into HAZUS (22 total), one record with the pre-mitigation first floor height, and the second with the post mitigation first floor height. The 100 year flood analysis was run on all 22 points.

The following tables and information represent the physical parameters for the modeling conducted by the Washington State Military Department, Emergency Management Division.

Table 3 – Populated Spreadsheet with relevant information – State Run Models

Project Type/Title	Applicant	Disaster Number	Project Year	Grant Type	Final Project Cost	Award Amount	Building Name	Yr Built	# Stories	Sq Ft	Bldg Replacement Value
Acquisition	City of Sultan	1641	2006	HMGP	$258,179	$278,400	Owner 1	1950	1	1,656	$158,893
Acquisition	Pierce County	1671	2007	HMGP	in progress	$361,414	Owner 2	1987	1	2,717	$255,561
Acquisition	Pierce County	1671	2007	HMGP	in progress	$198,738	Owner 3	1987	1	1,628	$153,130
Acquisition	Pierce County	1671	2007	HMGP	in progress	$353,765	Owner 4	1990	1	2,400	$316,136
Acquisition	Pierce County	1671	2007	HMGP	in progress	$287,991	Owner 5	1998	1	2,371	$223,016
Acquisition	Pierce County	1671	2007	HMGP	in progress	$308,693	Owner 6	1988	1	2,187	$205,709
Acquisition	Pierce County	1671	2007	HMGP	in progress	$115,538	Owner 7	1981	1	192	$18,060
Acquisition	Pierce County	1682	2006	HMGP	in progress	$328,969	Owner 8	1992	1	1,909	$179,561
Acquisition	King County	1671	2007	HMGP	$455,914	$500,355	Owner 9	1992	1	2,770	$255,948

Project Type/Title	Applicant	FL_BldgType	Flood Design Level	Flood Foundation Type	First Floor BFE (ft)	Ground BFE (ft)	FirstFloorHeight (ft)	Proj. Complete	BCR
Acquisition	Owner 1	WOOD	2	5	111.7	106.68	5.02	Yes	5.23
Acquisition	Owner 2	MH	3	1	356.9	352.49	4.41	No	10.6
Acquisition	Owner 3	MH	3	6	304	308.46	-4.46 (3.0)	No	4.91
Acquisition	Owner 4	WOOD	3	5	300.8	305.48	-4.68 (3.0)	No	12
Acquisition	Owner 5	WOOD	3	5	359.9	356.53	3.37	No	7.98
Acquisition	Owner 6	WOOD	3	5	359.8	354.49	5.31	No	0.51
Acquisition	Owner 7	WOOD	3	7	356.3	352.84	3.46	No	1.35
Acquisition	Owner 8	WOOD	3	5	412.1	411.48	0.62	No	0.63
Acquisition	Owner 9	WOOD	3	7	Not Provided	469.35	Not Provided (3.0)	Yes	0.22

Ground BFE Obtained from USGS Seamless Server (1/3 Arc Second Resolution)
Default first floor heights in red were used where First Floor BFE minus Ground BFE were negative or not provided

The first floor height of each structure was imputed into the HAZUS-MH model to determine flood damages. For these projects, this data was not captured during the grant application process. Instead, a first floor base flood elevation (BFE) which designates the height of the first floor of a structure above sea level was captured. To determine the height of the first floor from the ground for each structure in this study, ground elevation data for each location was gathered from the USGS Seamless Server website at 1/3 Arc Second (~10 meter) resolution and then used to subtract the first floor BFE from the ground elevation to get a first floor height of each structure. Due to the resolution of the available elevation data, two structures were calculated as having negative first floor heights (Owner 3 and 4, Table 3), while one other structure didn't have first floor elevation data available (Owner 9, Table 3). For these three structures, a first floor elevation of 3 feet was used as a default first floor height in this analysis.

Elevation data needed for each study region was downloaded directly within the HAZUS-MH User Data window from the USGS Seamless Server website at the 1'Arc Second resolution. Streams were delineated using a 5 square mile radius, so as to capture the most accurate path of the streams and tributaries located within each study region. Streams delineated nearest the location of each property acquisition were examined against a river GIS data layer downloaded from the Washington State Department of Ecology to determine the name of the streams nearest each property. Flood Insurance Studies for King, Pierce, and Snohomish Counties were downloaded from the FEMA Map Service Center *(http://msc.fema.gov)* to determine flood discharge values for the 1% annual chance (or 100 year flood event) and 0.2% chance flood events for each stream nearest the flood acquisition properties. What is plotted on the floodplain map is the extent of the 1 percent annual chance flood inundation no matter when it occurs during the design storm event.

The Owner 1 property located in Sultan, WA in Snohomish County was located at the confluence of the Sultan River and the Skykomish River. According to the FEMA Flood Insurance Study conducted for Snohomish County in 2005, flood discharge values for the 1% annual chance flood event on the Sultan River were 44,500 cubic feet per second (cfs) and 56,400 cfs for the 0.2% annual chance flood event (FEMA, Sept. 2005, p. 47). The flood insurance study for the Skykomish River indicated eight different discharge values for the 1% and 0.2% annual chance events, depending on the location on the river. Since the Owner 1 property was located just below the intersection of Wallace River with the Skykomish River the discharges values from this study for the "below Wallace River" location were used. The 1% annual chance discharge value at this location was 129,500cfs and the 0.2% annual chance value was 170,200cfs (FEMA, Sept. 2005, p. 46). To determine losses avoided to the Owner 1 property a floodplain was delineated in HAZUS-MH for both the 100-year flood event and the 500-year flood event using the corresponding flood discharge values for the Skykomish and Sultan Rivers indicated in the Flood Insurance Study for Snohomish County, WA.

Property acquisitions for Owners 2 through 8 were all located in Pierce County, WA in the Town of Orting. Owners 2 through 7 were located along the Carbon River at its intersection with South Prairie Creek, while the Owner 8 property was located on the Puyallup River just south of the river's confluence with Kapowsin Creek. According to the FEMA Flood Insurance Study completed for Pierce County in 1987, flood discharge values for the Puyallup River at the confluence with Kapowsin Creek for the 1% annual flood event were 17,300cfs and were 22,400cfs for the 0.2% annual chance flood event (FEMA, 1987, p. 72). For the Carbon River at the confluence with South Prairie Creek, 14,500cfs was the discharge value indicated for the 1% annual chance event and a discharge value of 19,500cfs was indicated for the 0.2% annual chance event (FEMA, 1987, p. 69). South Prairie Creek at its confluence with the Carbon River was also included in this analysis. Flood discharge values for the 1% annual chance flood event were 8,700cfs and were 10,900cfs for the 0.2% annual chance flood event, according to the

Flood Insurance Study for Pierce County, WA (FEMA, 1987, pp. 68,72-73). To determine losses avoided to the properties for the Owner 2 through 8 locations, a floodplain was delineated in HAZUS-MH for both the 100-year flood event and the 500-year flood event using the corresponding flood discharge values for the Carbon and Puyallup Rivers and the South Prairie Creek as indicated in the Flood Insurance Study for Pierce County, WA.

The last property (Owner 9) included in this study was located in King County, WA near in the City of Issaquah. The Owner 9 property was located near the Raging River near Interstate 90. According to the Flood Insurance Study completed for King County in 2005, the Raging River has five different discharge values depending on the location of the river (FEMA, April 2005, p. 45). The location of the Owner 9 property was at the confluence of the Raging River with Lake Creek. While no location listed in the flood insurance study corresponded to the location of the Owner 9 property, the discharge values for the 1% and 0.2% annual chance events for the Raging River for the "at mouth" location were used in this analysis. These discharges values of 7,413cfs and 10,465cfs for the 1% and 0.2% annual chance events are higher than the other locations, therefore large losses for this property will be more scrutinized then others due to the uncertainty in the discharge values for these events (FEMA, April 2005, p. 45). To determine losses avoided for the Owner 9 location, a floodplain was delineated in HAZUS-MH for both the 100-year and 500-year flood event using the corresponding flood discharge values for the Raging River as indicated in the Flood Insurance Study for King County, WA.

Earthquake:

For the seismic portion of this study, we reviewed four grant-funded projects for seismic retrofitting of structures. Two of these grants were HMPG grants awarded in 2008 to Pacific Lutheran University (PLU) located in Parkland, WA near Tacoma. These two grants were for seismic retrofitting of two student dormitory buildings: Hong Hall and Hinderlie Hall. The other two grants included in this analysis were PDM grants. One of these grants was awarded in 2005 to the City of Edmonds for the seismic retrofit of the City's community center, the Anderson Cultural Center. The other PDM grant was awarded to the University of Washington (Seattle Campus) in 2008 for the seismic retrofitting of the Padelford Parking Garage.

Determining the physical parameter analysis is much more difficult for seismic studies within the state because of the stochastic variations in the physical properties associated with the various types of earthquakes to which the region is susceptible. Because of this, earthquakes used in this study were selected based on the magnitude of the scenario earthquake, the location of the scenario epicenter, and the proximity of this epicenter to the location of the seismic project. In addition, the building type was entered *prior to* project completion and *after* project completion.

For the Pacific Lutheran University seismic projects for Hinderlie Hall and Hong Hall residence buildings, the USGS ShakeMaps for the M7.1 Tacoma Fault Earthquake Scenario, the M7.2 SeaTac Earthquake Scenario, and the M7.2 Nisqually Earthquake scenario were chosen.

For the seismic projects located at the University of Washington and the City of Edmonds, three different scenario earthquakes were selected for this study. These three scenarios included the M7.4 Southern Whidbey Island Fault Scenario, the M7.2 Large Seattle Fault Scenario, and the M6.8 Shallow Seattle Fault Scenario.

In order to increase the accuracy of the damage estimates for the earthquake scenarios modeled, hazard data maps of liquefaction susceptibility were also included in each analysis. The building types were also incorporated into the model. This allowed for the use of HAZUS' Advanced Engineering Building Module (AEBM).

Once the damage level was determined for the various scenarios, the projects advanced to Phase 3 for Loss Estimation Analysis.

PHASE THREE

In Phase 3, damages are calculated for the various scenarios. Once the damages are calculated, losses avoided were determined by comparing damage that *would likely have been caused* by the same magnitude quake or flood event without the project with *damage that could occur* with the project in place completed. The difference between the scenarios determines the losses avoided. The Return on Investment (ROI) is calculated by comparing the losses avoided to the project investment.

The losses avoided and return on investment calculations are contained within Section 7 below.

5. FEMA REPORTS:

As indicated, the State has historically relied upon FEMA to provide LAS for projects during various disaster events while in the Joint Field Office, and FEMA has provided a number of such studies, including, but not limited to:

- "Evaluating Losses Avoided Through Hazard Mitigation." *City of Centralia, Washington.* (2008)
- "Measuring Success Hazard Mitigation." *Rainier Manor Mobile Home Park, Sumner, Washington*. (2007)
- "Evaluating Losses Avoided Through Hazard Mitigation." *City of Snoqualmie, Washington.* (2007)

Review of the studies has also demonstrated a positive return on investment. A brief recap of the project listed above follows. More detailed information concerning each study can be obtained from the specific report indicated.

The Centralia project was an elevation project funded by HMGP after the 1996 and 1997 flooding events: DR #1100-WA and DR-1159-WA, respectively. The study sample included 35 of the original 116 elevated homes, these selected because all necessary information to conduct the LAS was available. The report indicates that: "the flood damages prevented from this single event likely exceeded the original project cost by almost two to one" when referring to a flood event occurring after the elevation project had been completed (FEMA 2008, 5).

For Rainier Manor Mobile Home Park, FEMA's arrival could not have come at a better time. Many of these homes in the area are located in a Special Flood Hazard Area of the Puyallup River, with a nearby levee providing low-level flood protection. The November 1995 Disaster (Major #1079) flooded half of the 77 homes in the area, with 35 completely destroyed or substantially damaged by FEMA's standards. After the 1995 flood, all of the substantially damaged units were replaced with new units which were elevated to at least the base flood level. It should be noted that the local ordinance at that time required replacement structures to be elevated only to the base flood level, rather than the NFIP requirement of one foot above.

When reviewing FEMA's report for the Rainier Manor Mobile Home Park, the Summary recap, states:

> All of the 14 homes in our study would have had inundation damage from the November 2006 flood event had they not been elevated. Seven of the structures would have experienced less than 2 feet of water and the remaining seven would have been flooded between 2.20 and 4.06 feet, and would have been considered a total loss. It is important to note that manufactured homes are unique in terms of the high degree of damages associated with relatively low levels of inundation. Flood depths as flow as two feet above FFE will result in 100 percent loss of structure….. For the homes analyzed in this study, flood looses from the November 2006 flood [estimated to be a 20-25 year event at Rainier Manor] would have ranged $5,218 to $99,416…..The total losses avoided from this event were estimated to be $906,482.

The City of Snoqualmie, King County, State and FEMA, during the last 25-30 years, have committed millions of dollars to either relocating or elevating more than 100 residential properties within the Snoqualmie River floodplain. Also impacted by the 1996 and 1997 flooding events, DR #1100-WA and DR-1159-WA, respectively, FEMA provided funding to elevate or acquire many of these structures. Because data was not available for all mitigated residences, especially acquired properties, the study sample included only 28 residential structures for which all necessary data was available. In attempting to determine the losses avoided, FEMA noted that the numbers would likely have been greater had the US Army Corps of Engineers not completed the removal of a constriction in the Snoqualmie River downstream of the City, as the construction had previously caused backwater in the study region during previous flood events. FEMA indicated, at page six, that by applying "an average elevation project cost of $46,959 to all 28 structures" which resulted in a "total mitigation cost of $1,314,852," the "estimated total losses avoided were $1,624,700," demonstrating that the "flood damages prevented in the November 2006 event alone likely exceeded the original project cost" (FEMA, 2007).

6. Additional Mitigation Efforts

In addition to the customary "project" type mitigation efforts, the Washington State currently has several mitigation initiatives underway which are regulatory in nature. The true cost benefit derived from these undertakings cannot be determined at this point in time, but the projects themselves have the potential to carry a high rate of return based on the potential impact to specific hazards. Some of these programs are still in the feasibility or study stage, but have reached some level of recognition statewide as to the potential for imminent change in the way we, as a state, conduct business. In this plan edition, only two such undertakings will be reviewed: Climate Change and Wildland-Urban Interface Fire. Information on these two initiatives are attached as appendices at the end of this document: Appendix 1 – Climate Change; Appendix 2 – Wildland-Urban Interface Fire.

7. Losses Avoided

The following tables describe the pre and post mitigation loss estimates for the Snoqualmie flood elevation projects, funded under DR 1682 in 2006. The owner(s) names and addresses have been removed to maintain confidentiality. It should be noted that after HMGP application, but prior to completion of elevation projects, the 11 residences were impacted in both 2006 and 2009 by significant flood events.

The 2006 flood on the Snoqualmie River at Snoqualmie had a discharge of 60,500 cfs and was considered to be a 10 to 25 year flood. The 2009 flood at Snoqualmie had a discharge of 55,000 cfs, and was considered to be a 10-year flood. The record flood on the Snoqualmie River at Snoqualmie was the November 25, 1990 flood, which had a discharge of 78,800 cfs (78,500 is the 100-year discharge).

For comparison, the 2006 flood on the Snoqualmie River at Carnation had a discharge of 71,800 and was considered to be a 30 year flood. In 2009, it had a discharge of 84,100 at Carnation, which was considered to be just under a 100-year flood (the 100-year discharge is now 91,800 cfs). The 2009 flood was the flood of record on the Lower Snoqualmie.

The actual dollars paid for the 2006 and 2009 are reflected in the Table 2 below (shaded in blue tones). The Tetra-Tech's model estimations are defined in Tables 4 and 5 below.

Table 4 - HAZUS Model Projections

Property	Pre Mitigation Building Loss	Pre Mitigation Content Loss	Post Mitigation Building Loss	Post Mitigation Content Loss
1	$32,780	$18,700	$0	$0
2	$72,990	$36,890	$9,780	$0
3	$45,881	$25,026	$5,839	$0
4	$47,060	$23,890	UNKNOWN*	UNKNOWN*
5	$110,780	$70,890	$0	$0
6	$79,250	$50,560	$0	$0
7	$39,660	$25,710	$0	$0
8	$52,540	$29,600	$0	$0
9	$37,150	$24,210	$0	$0
10	$55,560	$31,590	$0	$0
11	$51,830	$32,750	$0	$0

**Construction not completed*

Loss estimates were then validated using recent actual loss claims from the 2006 and 2009 Snoqualmie River floods. Even though these floods were not considered 100 year events, they were still assumed to be best available data for validating the HAZUS outputs. The following table represents a comparison of the HAZUS output to the 2006 and 2009 actual losses incurred.

Table 5 – Actual Losses (2006 and 2009 Flood Events) Compared to HAZUS-Model Estimations

ID	Actual Losses 2006 Flood		Actual Losses 2009 Flood		Total Bldg Loss 06 + 09	Total Losses Bldg. & Content 06 & 09	TETRA-TECH, INC. HAZUS-MODELING ESTIMATIONS (100 YEAR EVENT)			
	Actual Bldg Loss 2006	Actual Content Loss 2006	Actual Bldg Loss 2009	Actual Content Loss 2009	Actual Bldg Losses 2006 + 2009	Actual Content Losses 2006 + 2009	PRE Bldg Loss	PRE Content Loss	POST Bldg Loss	POST Content Loss
1	$23,417.67	$0.00	$22,659.72	$10,000.00	$46,077.39	$10,000.00	$32,780	$18,700	$0	$0
2	$20,353.80	$0.00	$13,846.90	$1,324.11	$34,200.70	$1,324.11	$72,990	$36,890	$9,780	$0
3	$13,507.04	$2,009.67	$2,820.71	$240.25	$16,327.75	$2,249.92	$45,881	$25,026	$5,839	$0
4	$2,561.52	$0.00	$14,433.89	$0.00	$16,995.41	$0.00	$47,060	$23,890	$0	$0
5	$66,341.43	$0.00	$79,986.71	$319.98	$146,328.14	$319.98	$110,780	$70,890	$0	$0
6	$66,629.21	$15,000.00	$86,205.23	$13,106.23	$152,834.44	$28,106.23	$79,250	$50,560	$0	$0
7	$36,050	$0.00	Not on Rep Loss List		Not on Rep Loss List		$39,660	$25,710	$0	$0
8	$78,185.06	$21,000.00	$107,465.03	$21,000.00	$185,650.09	$42,000.00	$52,540	$29,600	$0	$0
9	$95,300.79	$17,456.21	$49,372.22	$4,476.06	$144,673.01	$21,932.27	$37,150	$24,210	$0	$0
10	$89,232.64	$13,915.09	$79,046.77	$23,612.89	$168,279.41	$37,527.98	$55,560	$31,590	$0	$0
11	$43,286.52	$0.00	$69,990.00	$0.00	$113,276.52	$0.00	$51,830	$32,750	$0	$0
TOTALS	$534,865.68	$69,380.97	$525,827.18	$74,079.52	$1,060,692.86	$143,460.49	$625,481	$369,816	$15,619	$0

Utilizing FEMA's method to determine Return on Investment [ROI= Losses Avoided/ Project Investment (* 100 to gain percentage figure)] the Return on Investments for the Snoqualmie projects are represented as follows:

Table 6 – Return on Investments – Snoqualmie Projects

	Return on Investments		
Property ID	ROI Based on HAZUS-MH Model 100-Year event	ROI Based on 2006 Flood Event Type	ROI Based on 2009 Flood Event Type
1	65.38%	29.74%	41.48%
2	79.31%	14.69%	10.95%
3	56.33%	12.33%	2.43%
4	56.32%	2.03%	11.46%
5	121.60%	44.41%	53.75%
6	85.71%	53.90%	65.57%
7	63.61%	35.08%	
8	84.76%	102.35%	132.56%
9	59.71%	109.72%	52.40%
10	80.13%	94.84%	94.39%
11	69.87%	35.76%	57.82%

With respect to the remaining nine flood projects, which analysis was conducted by the Washington State Military Department, Emergency Management Division, the following analysis also demonstrates a positive return on investment.

The Owner 1 property near the town of Sultan, WA was located near the confluence of the Sultan and Skykomish Rivers. A flood depth grid for the 1% and 0.2% annual chance flood events for these streams was generated in HAZUS-MH and an analysis was ran to determine estimated damages to this structure. HAZUS-MH estimated damages for this property for the 100-year at $37,289 or 23.5% (Table 7.). Content loss for this event was estimated at $23,917 or 30.1%. For the 500-year annual flood event (0.2% annual chance), building damage estimates for the Owner 1 property were $43,547 or 27.4%. Content loss for the 500-year event was estimated at $28,444 or 35.8%. Total losses for the 100-year and 500-year flood events were 50.7% and

63.2% for the Owner 1 property. Total losses avoided for the Owner 1 property were $238,430 after a single flood event of the 1% annual chance or greater magnitude. According to the grant application for the Owner 1 property, final project mitigation costs were $258,179, resulting in a ROI of 92.3% after a single flood event.

City of Sultan Property Acquisition - 1% Annual Chance Event						
Name	Occupancy Class	% Bldg Damage	Bldg Loss	% Content Damage	Content Loss $	% Total Loss
Owner 1	RES1	23.5%	$37,389	30.1%	$23,917	50.7%
City of Sultan Property Acquisition - 0.2% Annual Chance Event						
Name	Occupancy Class	% Bldg Damage	Bldg Loss	% Content Damage	Content Loss $	% Total Loss
Owner 1	RES1	27.4%	$43,547	35.8%	$28,444	63.2%

Table 7. Estimated Damages for Owner 1 for the 1% and 0.2% Annual Chance Flood Events

The property acquisition projects located in Pierce County were for Owners 2 through 8. These properties were located near the Carbon River and its confluence with South Prairie Creek and one property was located near the Puyallup River near this river's confluence with Kapowsin Creek. Flood depth grids for the 1% and 0.2% annual chance flood events for these streams were generated in HAZUS-MH and an analysis was ran to determine the estimated damage to these structures.

For the 1% annual chance event HAZUS-MH estimated damages for only 4 of the 7 structures (Owners 2, 5-7) (Table 8.). This is likely due to the simplicity of the hydrology model within the HAZUS-MH software used to generate flood depth grids for estimating flood damage. With a more sophisticated flood modeling software program and greater resolution elevation data for the study area, a flood depth grid encompassing all 7 structures for the 1% and 0.2% annual chance flood events is considered probable. For the 1% annual chance event, the Owner 2 property experienced a building loss estimate of $58.415 or 22.9% and a building content loss of $35,597 or 27.9%. Total loss for the Owner 2 property in this event was 50.8%. The Owner 5 property experienced the greatest overall loss in this event at $60,223 building loss and $39,773 estimated content loss for a total loss of $99,996 or 62.7%. The Owner 6 property experienced the least amount of building and content loss at $16, 201 or 9.8%. The Owner 7 property had an estimate building loss of $3,988 or 22.1% and an estimated content loss of $2,282 or 25.3% for a total loss of $6,270 or 47.5%. The total loss avoided for the Owner 2 through Owner 8 properties was estimated at $740,337 for the 100-year flood event.

Pierce County Property Acquisitions - 1% Annual Chance Event						
Name	**Total Loss (%)**	**Total Damages ($)**	**Total Replacement Cost**	**Project Cost**	**ROI**	**Average ROI**
Owner 2	50.8%	$94,012	$383,342	$361,414	106%	**106%**
Owner 5	62.7%	$99,996	$334,524	$287,991	116%	**116%**
Owner 6	9.8%	$16,201	$308,564	$308,693	5%	**12%**
Owner 7	47.4%	$6,270	$27,090	$115,538	5%	**14%**

Pierce County Property Acquisitions - 0.2% Annual Chance Event					
Name	**Total Loss (%)**	**Total Damages ($)**	**Total Replacement Cost**	**Project Cost**	**ROI**
Owner 2	61.7%	$112,554	$383,342	$361,414	106%
Owner 5	62.1%	$98,968	$334,524	$287,991	116%
Owner 6	38.1%	$59,678	$308,564	$308,693	19%
Owner 7	61.1%	$7,836	$27,090	$115,538	23%

Table 8. Estimated Damages for Owner 2-8 Properties for the 1% and 0.2% Annual Chance Flood Events

The 500-year flood event had greater losses experienced by the project properties, even though the previously excluded properties remained outside of the flood boundary for this event. The Owner 2 property had an estimated building loss of $67,268 or 26.3% and a building content loss of $45,286 or 35.4% for a total loss estimate of 61.7% for this property. The Owner 6 property had a building loss estimate of $59,342 and a content loss of $39,626 for a total loss of $98,968 or 62.1%. The Owner 6 property remained the property with the least amount of damage with a total loss estimate of $59,678 or 38.1%, while the Owner 7 property had a total loss estimate of $7,836 or 61.1%. The total loss avoided for the Owner 2 through 8 properties was estimated at $804,634 for a 500-year flood event.

Average losses avoided for the 100-year and 500-year flood events for the properties acquired in Pierce County (Owners 2-8) were estimated at $772,486. The final project costs for these mitigation projects were not available at the time of this study, since these projects have not yet been completed. Therefore, to determine the ROI for these six mitigation projects the award amount for each grant was used. The total award amounts for the grants provided to acquire the six flood mitigation properties in Pierce County was $1,955,108, this results in an ROI of 39.5% after a single flood event of 1% annual chance or greater magnitude. However, since damage estimates were only calculated for four of the seven properties it seems reasonable to determine the average ROI for only those properties which were able to be analyzed in this study. The average ROI for the Owner 2 and Owners 5-7 properties within this study was 62% after a single flood event of 1% annual chance or greater. With the removal of these properties from the flood inundation area, the ROI will continue to increase after each subsequent flood events, resulting in a positive return on investment after two or more floods.

The final flood mitigation property analyzed in this study was located in the City of Issaquah near the Raging River. Flood depth grids for the 1% and 0.2% annual chance flood events for this stream were generated in HAZUS-MH and an analysis was ran to determine the estimated damage to the Owner 9 structure. Both the 1% annual chance and 0.2% annual chance flood depth grids generated in HAZUS-MH failed to include the Owner 9 property. This resulted in no damage calculations for the 1% or 0.2% annual chance flood events for the Owner 9 property. This result further proves how the simplicity of the hydrology model in HAZUS-MH can fail to produce areas of known flooding in an analysis. With greater resolution elevation data in the form of LiDAR (Light Detection and Ranging) data and a more sophisticated flood modeling software package, a flood depth grid for the 100-yaer and 500-year flood event that includes the Owner 9 property is highly likely.

Overall the total losses avoided for the 100-year (1% annual chance) and 500-year (0.2% annual chance) flood events for the flood mitigation properties included in this study was $1,010,916 with a total mitigation costs of $2,669,201 for a ROI of 37.9% after a single flood event. The average ROI for those properties in which HAZUS-MH was able to calculate damages was much higher at 68.1%. Due to the fact that these properties no longer are located in the flood inundation area and that the HAZUS-MH model was unable to calculate damages for four of the nine properties, the losses avoided through the mitigation of these properties is believed to be higher than estimated. Although losses avoided are believed to be higher than calculated, from these results the public can expect to see a positive return on investment for the flood mitigation properties in this study after two or more floods.

Earthquake Results

The seismic retrofit projects included in this study were analyzed in the HAZUS-MH Advanced Engineering Building Module (AEBM) at both the pre-and post-mitigation states for each building using three scenario earthquakes that are deemed probable earthquake scenarios for the given location of each project.

The seismic projects completed at PLU were for the seismic retrofitting of two student residence halls, Hinderlie Hall and Hong Hall. These residence halls were seismically mitigated from the pre-seismic building code (PC) to the low-seismic building code (LC) as a result of the mitigation grant received by Pacific Lutheran University in 2008. Both of these residence halls were modeled in HAZUS-MH using the AEBM model at both the pre-and post-mitigation states for the Tacoma Fault M7.1, SeaTac M7.2, and the

Scenario EQs / Mitigation Projects	M7.2 Nisqually	M7.2 SeaTac	M7.1 Tacoma Fault
PLU - Hinderlie Hall (Pre-Retrofit)	$396,000	$396,000	$226,000
PLU - Hinderlie Hall (Post-Retrofit)	$248,000	$248,000	$139,000
Post Mitigation Damage Savings =	**$148,000**	**$148,000**	**$87,000**
PLU - Hong Hall (Pre-Retrofit)	$355,000	$355,000	$203,000
PLU - Hong Hall (Post-Retrofit)	$223,000	$223,000	$125,000
Post Mitigation Damage Savings =	**$132,000**	**$132,000**	**$78,000**

Table 9. Damage Estimates for Hinderlie Hall and Hong Hall

Nisqually M7.2 earthquake scenarios to determine the losses avoided to these structures as a result of the mitigation efforts.

For the Nisqually earthquake scenario, HAZUS-MH calculated pre-mitigation damages for Hinderlie Hall at approximately $396,000 and post-mitigation damages at $248,000, resulting in a savings of $148,000 as a result of the mitigation project (Table 9). HAZUS-MH calculated the same pre-and post-mitigation damages for Hinderlie Hall for the SeaTac M7.2 scenario, also resulting in a savings of $148,000 due to the mitigation efforts.

For the Tacoma fault scenario HAZUS-MH calculated a lower pre-mitigation damage for Hinderlie Hall at approximately $226,000 and post-mitigation damages at $139,000, resulting in a savings of $87,000 as a result of the mitigation efforts for Hinderlie Hall. These three scenarios resulted in an average post-mitigation loss avoidance of approximately $127,700. According to the grant application for this project, final costs for the seismic retrofit for Hinderlie Hall was $1,112,248, this results in only a 11.5% return on investment (ROI) for this project should one of these scenario earthquakes occur in the future.

For the Nisqually earthquake scenario, HAZUS-MH calculated pre-mitigation damages for Hong Hall at approximately $355,000 and post-mitigation damages at $223,000, resulting in a savings of $132,000 as a result of the seismic retrofit project. HAZUS-MH calculated the same pre-and post-mitigation damages for Hong Hall for the SeaTac M7.2 scenario, also resulting in a savings of $132,000 due to the mitigation efforts. For the Tacoma fault scenario HAZUS-MH calculated a lower pre-mitigation damage then the first two scenarios at approximately $203,000 and post-mitigation damages at $125,000, resulting in a savings of $87,000 as a result of the mitigation project for Hong Hall. These three scenarios resulted in an average post-mitigation loss avoidance of approximately $114,000. The grant application for Hong Hall indicates the final cost of the seismic retrofit project for Hong Hall was $994,470, this result in only an 11.5% ROI for this project should one of these scenario earthquakes occur in the near future.

Mitigation projects located at the University of Washington and at the City of Edmonds were also modeled in HAZUS-MH using the AEBM model at both the pre- and post-mitigation states for the Southern Whidbey Island Fault (SWIF) M7.4, Seattle Fault M7.2, and the Seattle Fault M6.8 earthquake scenarios to determine the losses avoided to these structures as a result of the mitigation projects.

The Anderson Cultural Center located in the City of Edmonds serves as the city's recreation facility for youth athletic leagues, fitness classes, and cultural and art classes for children and adults. The City of Edmonds received a PDM grant to seismically retrofit this building in 2005. As a result of this grant, the Anderson Cultural Center was seismically mitigated from a pre-seismic building code (PC) to the low-seismic building code (LC).

For the SWIF and Seattle M7.2 earthquake scenarios, HAZUS-MH calculated pre-mitigation damages for the Anderson Center at $1,263,000 and post-mitigation damages at $780,000, resulting in a savings of $483,000 as a result of the mitigation project (Table 10.). For the Seattle Fault M6.8 scenario, HAZUS-MH calculated pre-mitigation damages at $1,257,000 and post-mitigation damages at $773,000, resulting in a savings of $484,000 for this scenario. These three scenarios resulted in an average loss avoidance of approximately $483,300. The grant application for the City of Edmonds indicates that the total cost for the project was $1,912,032; this resulted in an average ROI of 25.3% for these scenario earthquakes. This project ran into cost overruns over the original award amount of $1,042,920. If this project were to have been completed with the original funds awarded, an ROI of 46.3% would have been realized after one of the event scenarios.

The University of Washington received a PDM grant in 2007 to seismically retrofit the Padelford Parking Garage located on the Seattle Campus. This parking garage is used to house student and faculty vehicles during the academic term and is also used for event parking during sporting events in nearby Husky Stadium. As a result of the PDM grant this parking facility was seismically retrofitted from a low seismic building code (LC) to a high seismic building code (HC).

Scenario EQs / Mitigation Projects	M7.4 South Whidbey Island Fault	M7.2 Seattle Fault	M6.8 Seattle Fault
City of Edmonds – Anderson Center (Pre-Retrofit)	$1,263,000	$1,263,000	$1,257,000
City of Edmonds – Anderson Center (Post-Retrofit)	$780,000	$780,000	$773,000
Post Mitigation Damage Savings =	$483,000	$483,000	$484,000
UW – Padelford Parking Garage (Pre-Retrofit)	$1,252,000	$1,689,000	$1,689,000
UW – Padelford Parking Garage (Post-Retrofit)	$365,000	$460,000	$460,000
Post Mitigation Damage Savings =	$887,000	$1,229,000	$1,229,000

Table 10. Damage Estimates for the Anderson Cultural Center and the UW- Padelford Parking Garage

HAZUS-MH calculated pre-mitigation damages for the Padelford Parking garage at $1,252,000 for the SWIF M7.4 earthquake scenario and post-mitigation damages at $365,000, resulting in a savings of $887,000 as a result of the mitigation project. For the Seattle M7.2 and M6.8 scenarios, HAZUS-MH calculated pre-mitigation damages at $1,689,000 and post-mitigation damages at $460,000, resulting in a savings of $1,229,000 for each scenario. The three earthquake scenarios analyzed in HAZUS-MH for the Padelford Parking Garage had an average loss avoidance of approximately $1,115,000. The grant application for the University of Washington indicates that the total cost of the mitigation project was $697,153, this resulted in a ROI of 159.9% should one of these scenario earthquakes occur in the future.

8. Summary

During the next three year update cycle, the State will continue to capture data to provide additional studies such as the one conducted herein. In conducting this Loss Avoidance Study, it was determined that statewide LiDAR data would dramatically enhance not only the ability to conduct a more viable Hazus-MH Model to determine losses avoided, but would also enhance information needed for a more robust flood mitigation effort. It was determined that the state will continue in its efforts to enhance the LiDAR data in order to not only better assist jurisdictions in their quest to mitigate flood, but also to allow for a greater level of accuracy for hazard analysis and determining losses avoided.

Review of the calculations for the various projects which were the topic of this analysis effectively demonstrates a positive Return on Investment for each of the projects based solely on the comparison of award to losses. Once the various other elements of loss are included, such as the social impact, displacement of residents, potential impact to the environment, etc., the return on investment has a much greater benefit ratio. Further, if one were to include calculations for injuries and/or death, which are presently calculated by FEMA as: minor injury: $12,000, major injury: $1,483,750 and death: $5,800,000 (Benefit-Cost Analysis Course Student Manual, March 2009), the return on investment would increase exponentially.

It is evident that the state has been proactive in its attempts to mitigate the various hazards to which we are prone. Effective use of our various grant programs such as demonstrated within this study, as well as the state's own efforts towards mitigation will continue to make our state more resilient to disasters. These efforts will not only protect our residents from harm and economic losses, but will continue to allow our state to grow within the global market.

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APPENDIX 1

CLIMATE CHANGE:

Claim change is something which has been on the radar of all governments worldwide. Whether you believe it to be cyclic in nature, or as a result of CO^2 emissions, the fact remains that states, Washington included, are moving forward in a proactive manner.

In Washington, the impact of climate change is far-reaching. From rising sea-levels to shrinking glaciers, drought to insect infestation in our forests, all of these potential impacts were reviewed in the Climate Impacts Group study.

The goals of Executive Order 07-02 were legislated during the 2007 Legislative Session with the passage of Substitute Senate Bill (ESSB) 6001 and E2SHB 2815. On May 3, 2007 Governor Gregoire signed this landmark legislation which established in statute the statewide Greenhouse Gas (GHG) emissions reduction goals and imposed an emissions performance standard on baseload electric generation.

With the passage of these Bills, Governor Gregoire declared Washington's commitment to address climate change on February 7, 2007. At that time, she signed Executive Order No. 07-02, which directed the Washington Department of Ecology (Ecology) and Department of Community, Trade and Economic Development (now Department of Commerce) to lead the Washington Climate Challenge. The Directors of Ecology and Commerce formed the Climate Action Team (CAT) to advise on the full range of policies and strategies to be considered in order to achieve the goals specified in the Executive Order to reduce emissions, create clean energy jobs, and reduce expenditures on imported fuels. Business, academic, tribal, government, religious and environmental leaders were convened to form the CAT in March 2007, and remain in place as of 2010.

The purpose of Substitute Senate Bill 6001 (ESSB 6001) was to create "AN Act relating to mitigating the impacts of climate change" as defined within ESSB 6001, available at: http://apps.leg.wa.gov/documents/billdocs/2007-08/Pdf/Bills/Senate%20Passed%20Legislature/6001-S.PL.pdf

In coordination and support of mitigation efforts to control climate change and its impacts, during the 2009 Legislative Session, the following Bills were presented which provided support to various elements involved in climate change.

Climate Change:

- Responding to Climate Change**:** E2SSB 5560 directed Ecology and other agencies to develop a response strategy to assist the state and local governments in preparing for and adapting to impacts from climate change.

Greenhouse Gas Emissions:

- Reducing Greenhouse Gas Pollution in Buildings: The Legislature approved E2SSB 5854, which requires:
- A strategic plan for enhancing energy efficiency and reducing greenhouse gas emissions from homes and buildings.
- Performance standards, benchmarking and other reporting requirements for public buildings.
- The State Energy Code to move toward a 70 percent reduction in annual energy consumption for new buildings by 2031.

Clean Energy

- Expanding the Energy Freedom Program: ESHB 2289 expands the Energy Freedom July 2009 Program to encourage energy efficiency, renewable energy and innovative energy technology markets in Washington.
- Creation of a Sustainable Energy Trust**:** E2SHB 1007 removes barriers in financing the upfront costs of renewable energy and energy-efficiency improvement projects. July 2009
- Clean Energy Leadership Initiative: SSB 5921 enables the Governor to create a clean energy leadership council in collaboration with a private-public alliance focusing on growing Washington's clean technology sector.
- Enhancing Energy Efficiency: The Legislature approved E2SSB 5649, which:
- Implements community-wide energy efficiency upgrades.
- Enhances the low-income residential weatherization program.
- Assesses the energy efficiency of properties in the Housing Trust Fund.

Economic

- Evergreen Jobs Initiative**:** E2SHB 2227 establishes the Evergreen Jobs Initiative to create 15,000 new green economy jobs by 2020 and to prioritize programs to train workers in green economy job sectors.

Land-Use Planning and Permitting

- Reducing Climate Pollution through Land-Use Planning**:** 2SHB 1172 requires implementation of a transfer of development rights program to encourage new development in high-density areas. (See Growth Management Services, Regional Transfer of Development Rights at the Department of Commerce.)
- Permitting Anaerobic Digesters from Solid Waste**:** SB 5797 streamlines permitting requirements to spur renewable energy development from agricultural waste and livestock manure.

Transportation/Vehicles

- Reducing High Global Warming Potential Vehicle Refrigerants**:** SHB 1984 approves the use of substitutes for ozone-depleting and high-global warming potential refrigerants.

Government

- State Agency Leadership: The Legislature passed three bills that require state agencies to lead by example:
- E2SSB 5560 holds state agencies accountable for reducing their carbon footprint and requires them to reduce fuel consumption and increase fuel efficiency.
- SHB 2287 requires agencies to reduce current paper use, increase paper recycling and purchase 100 percent recycled content paper.
- SSB 6088 requires the Department of Transportation to develop a joint comprehensive commute trip reduction plan for all state agencies located in the Olympia, Lacey and Tumwater urban growth area.

Washington's endeavors toward climate change are very progressive. The Governor has instructed state agencies to change their course of business to guarantee some level of efficiency with respect to their daily operations. The benefits of these changes remain to be seen as we are only in the early stages of the directive, but there are continuing studies be conducted which will, ultimately, demonstrate their level of effectiveness.

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APPENDIX 2

WILDLAND-URBAN INTERFACE FIRE:

Each year, countless fires erupt as a result of nature, or manmade. Within Washington, the Department of Natural Resource (DNR) is the responsible agency tasked with managing our natural resources, and the Wildfire Protection Program. In an effort to mitigate the impacts of fires upon our forestlands, the 2007 Washington Legislature directed DNR to examine issues in the context of its mission to prevent, prepare for and suppress forest fires in Washington State. A budget proviso directed DNR to:

- Create a broad-based, multi-stakeholder group to examine previous studies of DNR Fire Programs (e.g., Tridata 1997, JLARC Suppression Study 2005, DNR Fire Strategic Plan for 2020 of 2006, Forest Health Plan of 2004, et al);
- Examine the current funding mechanisms of fire programs for appropriateness and adequacy; and
- Look at future challenges and opportunities and what makes sense for the future of the fire program.

DNR conducted a study to determine what proactive measures could be undertaken to help diminish the potential for and impact from fires. In this study, five potential initiatives were reviewed. The below recommends are an excerpt from the 2008 DNR report:

Recommendation 1: The Forest Fire Prevention and Protection Work Group recommends elimination of the Forest Fire Protection Assessment (FFPA) refund while simultaneously reducing the amount paid by the owners of unimproved parcels but adding a surcharge to those parcels that contain improvements like homes and other structures.

Costs and Benefits

- Following implementation, the agency will realize an increase in funding through the reduction in administrative costs associated with the refunds. This translates to more funding available for prevention and presuppression activities.
- A fully funded wildland fire program will also assist with several other policy options including the Work Group policy recommendation to adopt the 2006 ICC WUI Code as an amendment to the State Building Code (Recommendation 2) and the Work Group's recommendations regarding property owner responsibility (Recommendation 3). These policies will move Washington State closer to the objective of having a complete, coordinated, and comprehensive fire protection program.
- The range of options provides decision makers a great deal of flexibility.
- Counties should not see an increase in costs to administer the change in the assessments. Currently they collect a small fee ($0.50 per parcel) to process the assessments. This is anticipated to continue and cover the costs of the new process.

Recommendation 2: The Forest Fire Prevention and Protection Work Group recommends that the State begin a formal process of evaluating the International Code Council Wildland Urban Interface Code (ICC WUI Code) for statewide adoption. This Code would establish a minimum standard for how homes and structures are built and maintained in natural areas rated as having a moderate or higher hazard for wildfire.

Costs and Benefits of Adopting ICC WUC Code Statewide

- Costs and benefits are difficult to determine at this juncture and estimates would not be accurate enough to be useful. There would be a cost to the state for processing the building code change, and to each of the jurisdictions for the adoption process.

Recommendation 3: The Forest Fire Prevention and Protection Work Group recommends the State encourage owners of homes and structures situated on forested land without the protection of a fire district to take action and provide incentives to do so.

Costs and Benefits

- The main benefits of Recommendation 3 will be improved public/firefighter safety, reduced losses of natural resources and improved property from wildfire, and reduced direct fire suppression expenses borne by DNR and other fire protection agencies. The latter will come in two ways:
  1. Where property owners take appropriate action, agency fire suppression tactics will not need to be altered to ensure that approaching forest wildfires do not destroy unprotected improvements.
  2. If property owners fail to take appropriate action, DNR will have authority to recover from them suppression costs expended to ensure that approaching forest wildfires do not destroy unprotected improvements.

Recommendation 4: The Forest Fire Prevention and Protection Work Group recommends that the Legislature fund and direct DNR to assemble a work group consisting of the members of the Work Group and other interested stakeholders to study and recommend to the Legislature actions needed to increase the use of biomass and prescribed fire to reduce forest fire hazards.

Costs and Benefits

- Costs will be to assemble and support a work group to develop the policy recommendations. The benefit will be that a group oriented specifically toward prescribed fire will have the time and focus to develop a detailed set of consensus based recommendations on the issue.

Recommendation 5: The Forest Fire Prevention and Protection Work Group recommends that the Legislature direct and provide funding for DNR to form a blue ribbon advisory panel that would examine the costs and benefits that could result from more effective fire prevention activities, including forest management, specifically as they relate to forest health issues.

Costs and Benefits

- As a consequence of large intense forest fires in the inland west over recent years, considerable public attention is being directed at the question of how to reduce hazardous fuel loads from the overly dense forests that characterize the region.

  Removal of the many small trees that make up these fuel loads is known to be costly. While large trees can be removed for lumber and other product values as reflected in the market, the market value for the smaller logs may be less than the harvest and hauling charges, resulting in a net cost for thinning operations that are needed to lower fire risk. However, failure to remove these small logs results in the retention of ladder fuels that support the transfer of ground fire to a crown fire with destructive impacts to the forest landscape.

  Many non-market benefits or avoided costs are not being considered in the market computation that only considers the market value for the log relative to the cost of delivering the logs to market. A first attempt at estimating these costs and benefits appears to show that the benefits will likely exceed the costs as justification for more aggressive treatments to reduce fire risk. There are however many different beneficiaries complicating the issue of who should pay. (Extracted from the report: *Investigation of Alternative Strategies for Design, Layout, and Administration of Fuel Removal Projects. 'Market and Non-Market Values.'* College of Forest Resources, Rural Technology Initiative, University of Washington, July 2003, at www.ruraltech.org).

  It is hoped that this group may also be able to expand the dialogue on the utilization of forest biomass for the reduction of carbon dioxide emissions. The Governor's Climate Action Team has identified forest biomass as one of the most promising untapped pools that may be utilized for energy production.

  Establishing a panel can build on previous work, defining the potential opportunities and barriers to considering non-market costs of forest management treatments for forest health and fire risk reduction and crafting solutions oriented to successful implementation in Washington State.