ATKINS

State of Washington Military Department - Emergency Management Division,
Lewis County, Washington

Loss Avoidance Study

Homes Elevated after the December 2007 Flood Event

December 2007 Flood Event in Centralia and the unincorporated areas surrounding Centralia, Washington
Photo credit: WSDOT

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Plan Design Enable

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Introduction

The City of Centralia, Washington is a small city with a population of 16,336 (2010 Census) and an area of about 7.5 square miles. Centralia, which is located along Interstate 5 about 25 miles south of Olympia, was incorporated in 1886. Centralia and the surrounding unincorporated areas of Lewis County have experienced numerous floods throughout its recorded history.

Figure 1 – General location map of project area

Major flood events in Centralia typically occur during the winter season, generally from November through February. The principal flood sources are the Chehalis River and its tributary the Skookumchuck River, along with their tributaries Coffee Creek, China Creek and Salzer Creek. The worst flooding occurs when the Chehalis River and its tributaries reach flood stage at approximately the same time. This type of flooding occurs when only minor snowmelt contributes to flows in the Chehalis River and its tributaries with flooding being governed primarily by rainfall within the Chehalis River Basin. Furthermore, flooding in Centralia is frequently exacerbated by backwater flooding from the Chehalis River into the Skookumchuck River and the smaller tributaries, along with ponding on the east side of Interstate 5.

Table 1 – Presidential disaster declarations for flooding in Lewis County

Presidential disaster declarations for flooding in Lewis County	
Disaster Number	**Date**
DR-4056	March 2012
DR-1963	March 2011
DR-1817	Jan 2009
DR-1734	Dec 2007
DR-1671	Nov 2006
DR-1159	Dec 1996
DR-1100	Feb 1996
DR-883	Nov 1990
DR-852	Jan 1990
DR-784	Nov 1986
DR-414	Jan 1974
DR-322	Jan 1972
DR-300	Jan 1971

Source: FEMA

Table 1 shows that significant flood events on the Chehalis River occurred in 1934, 1938, 1971, 1972, 1976, 1987, 1990, 1991, 1996, 2008 and 2009, along with numerous smaller flood events.

Table 2 – Peak flood discharges in the Chehalis River at Ground Mound

Peak flood discharges in the Chehalis River at Ground Mound	
Date	**Peak Discharge (cfs[1])**
December 4, 2007	79,100
February 9, 1996	74,800
January 10, 1990	68,700
November 25, 1986	51,600
January 8, 2009	50,700

[1] Cubic feet per second

The United States Geological Survey (USGS) stream gage on the Chehalis River at Grand Mound, about 7 miles downstream from Centralia, has been in operation since 1928. Over this time period, 9 of the 11 largest flood events have occurred since 1971. The 5 largest recorded floods all occurred between 1986 and 2009, including the December 2007 flood of record, as shown in Table 2.

Total damages in the 2007 flood event for the Chehalis River Basin were estimated to be approximately $500 million. Total damages in the 1996 flood were estimated to be approximately $150 million, which corresponds to about $220 million in 2013 dollars. The severity of the flood risk in Centralia is further illustrated by the number of FEMA-listed repetitive loss properties in Centralia. The July 2012 FEMA Repetitive Loss list includes 78 homes with Centralia postal addresses, which includes homes in the City of Centralia and adjacent portions of Lewis County. The FEMA list includes only homes with flood insurance that meet FEMA's repetitive loss criteria. Given Centralia's long history of flooding, with 5 major floods since 1986, there are undoubtedly many other homes in Centralia with a history of repetitive damages.

Flood mitigation planning and measures

Formal flood mitigation measures for the City of Centralia and Lewis County date from 1982 when the first FEMA Flood Insurance Rate Maps (FIRM) were adopted. The adoption of the FEMA FIRMs and participation in the National Flood Insurance Program (NFIP) requires communities to comply with NFIP floodplain regulations, including restrictions on development within mapped Special Flood Hazard Areas (SFHA)—the 100-year floodplain.

Centralia's 2008 Comprehensive Flood Management and Natural Hazards Mitigation Plan include numerous flood mitigation objectives, as follows:

- Planning and zoning, open space preservation and stormwater management.
- Property protection on a building by building basis, including relocations and elevations.
- Hazard warning, hazard response and critical facilities protection.
- Structural projects such as levees or reservoirs, diversion methods and storm sewers.
- Public information activities to advise property owners about flood hazards and how to protect themselves.

Lewis County's 2009 Multi-Jurisdictional Hazard Mitigation Plan also includes numerous flood mitigation objectives along the same lines as Centralia's. In addition, both of these plans include more detailed strategies and action items intended to reduce flood risks as mitigation measures are implemented.

For existing homes at flood risk, there are three common mitigation measures:

- **Elevation.** Raise a home to at least the Base Flood Elevation (100-year flood elevation) or higher to substantially reduce the future risk of flood damage,
- **Relocation.** Move a home from the floodplain to outside the floodplain
- **Acquisition.** Acquire and demolish a home at very high flood risk and assure that the vacant land is held in perpetuity as open space through ordinance or by conveyance of the vacated land into a trust with the deed indicating that the land remain as open space.

For the City of Centralia and adjacent unincorporated areas of Lewis County, elevation is often the preferred flood mitigation measure for homes because many of the flood-prone neighborhoods are long-established communities. The average age of the 24 homes elevated after the 2007 flooding is 59 years.

The losses avoided reported in the 2008 and 2013 loss avoidance studies include avoided building damages, contents damages and displacement costs for temporary housing while flood damage is being repaired for the elevated homes. There are additional benefits to the community from elevating homes, including reduced debris removal and disposal costs, reduced environmental impacts from downstream debris which may include hazardous materials, and reduced emergency management and response costs. These benefits were not included in the loss avoidance study data.

2008 FEMA Loss Avoidance Study

The City of Centralia and vicinity suffered widespread flooding in February 1996 and January 1997. Both of these events were presidentially-declared disasters: 1996 (DR-1100-WA) and 1997 (DR-1159). After these events, FEMA's Hazard Mitigation Grant Program (HMGP) funding was provided to elevate 116 homes in Centralia.

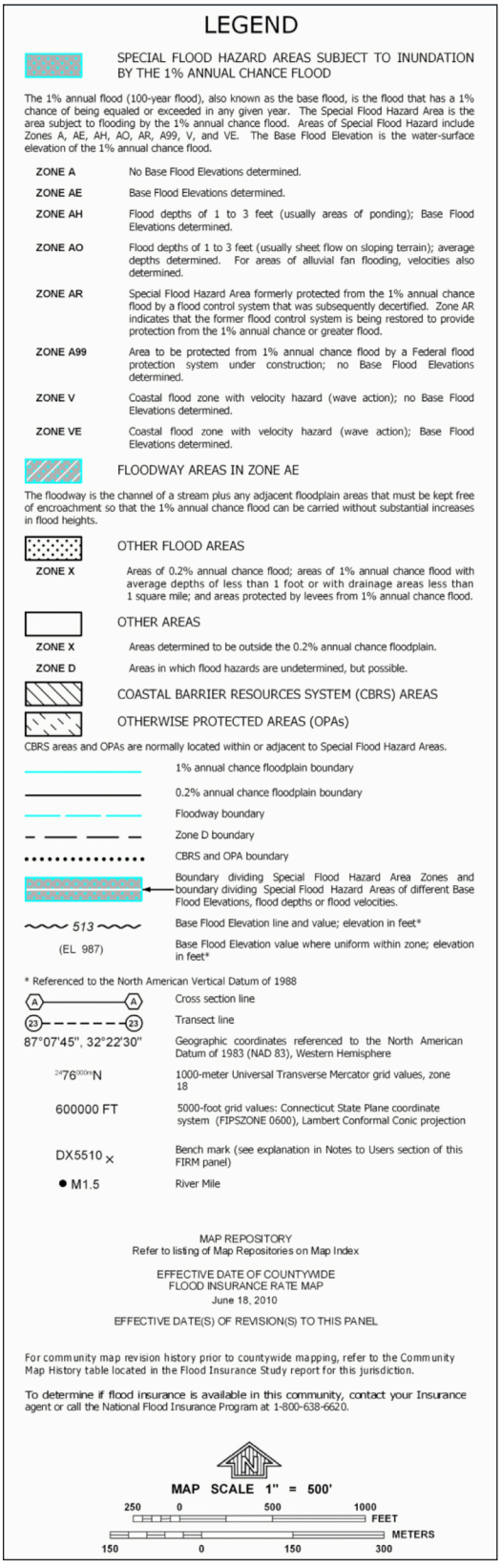
In 2008, FEMA's loss avoidance study (Evaluating Losses Avoided Through Hazard Mitigation) documented the damages avoided in the December 2007 flood event for 35 of the elevated homes for which detailed data was available. The estimated total cost for these elevations was $1,017,415 (an average cost of $29,069 per home). The losses avoided for the 2007 flood event were estimated to total $1,905,760, including avoided building damages, avoided contents damages and avoided displacement costs for temporary housing. **Thus, for this one event, the losses avoided were nearly twice the cost to elevate these 35 homes.**

These 35 homes were elevated from 2.1 to 9.6 feet. Most of the homes (25) had no damage in the December 2007 flood event. However, 2 homes had water slightly above the first floor, and 8 others had water within 1 foot of the first floor and thus suffered minor flood damages. The December 2007 flood is the flood of record for the Chehalis River, and the flood elevations were significantly above the 100-year flood level, which is why some of the houses suffered minor flood damages even after being elevated. For the homes that did suffer minor damages in the 2007 flood, the losses avoided total of $1,905,760 takes these minor damages into account.

2013 Loss Avoidance Study

The present loss avoidance study focuses on an additional 24 homes that were elevated in Centralia and vicinity after the December 2007 flood event. As previously noted, this flood was the flood of record on the Chehalis River, on reaches of the tributaries where flood elevations are governed by backflows from the Chehalis River, and in ponding areas (FEMA Flood Zone AH) east of Interstate 5. For an explanation of Flood Zones see Figure 2. FEMA HMGP funding was provided for these elevations from the presidentially-declared December 2007 flood event (DR-1734-WA).

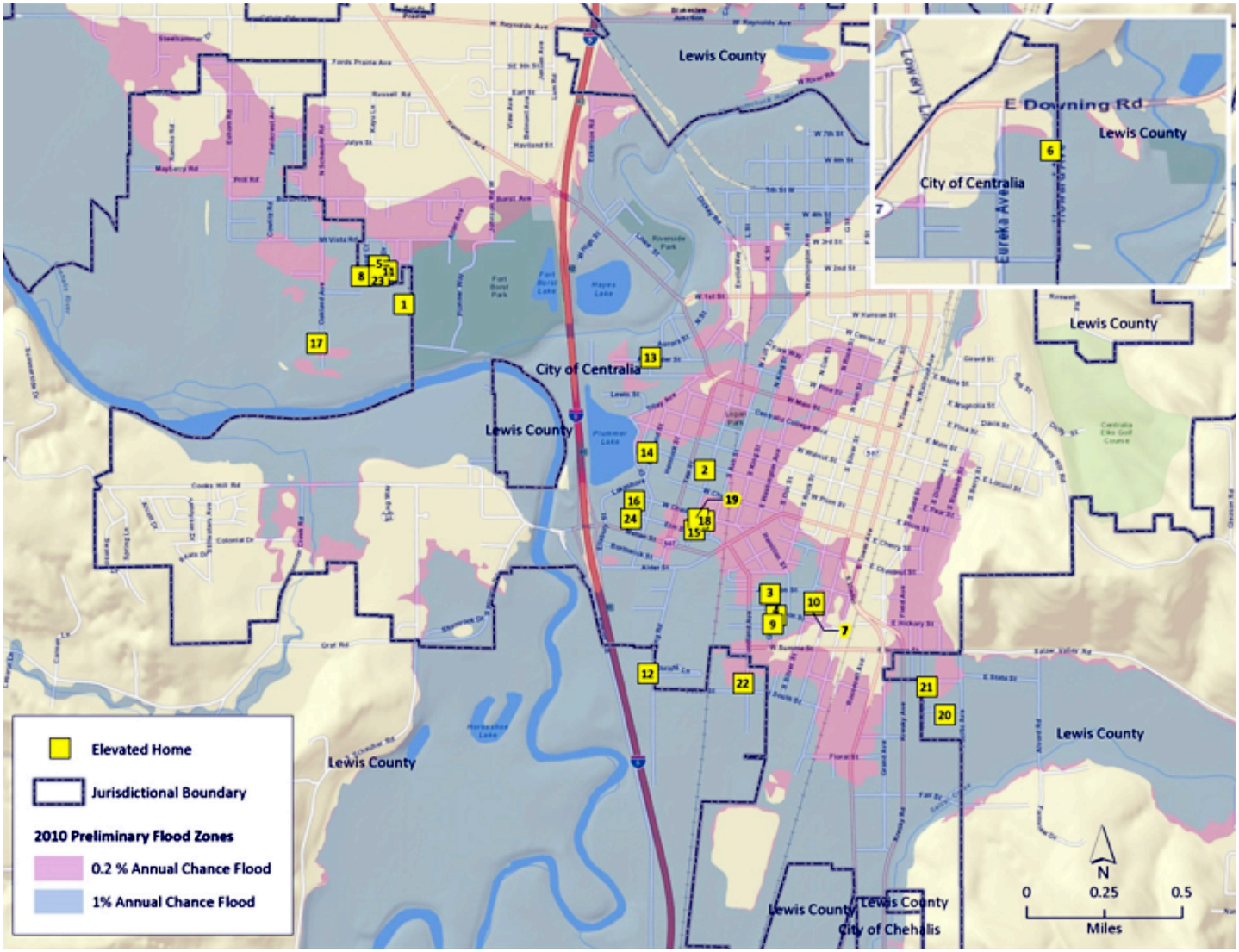
Figure 2 – Digital Flood Insurance Rate Map (DFIRM) Legend



Source: FEMA

Information about the 24 elevated homes is summarized in Table 3, with addresses and other information omitted for privacy reasons.

Figure 3 – General locations of elevated structures for Table 3



Map created by Atkins

Table 3 – Home elevations statistics

Prop. #[1]	Const. Date	Square Feet	BRV/SF BNI 2013[2]	Building Replacement Value	Number of Stories	Pre-Elevation FFE[3]	Post-Elevation FFE[3]	Number of Feet Raised
1	1989	3,521	$138.99	$489,384	2	166.6	174.2	7.6
2	1969	2,225	$173.58	$386,216	1	171.1	177.1	6.0
3	1976	1,686	$177.50	$299,265	1	171.0	178.2	7.2
4	1935	1,183	$180.82	$213,910	1	171.5	178.7	7.2
5	1978	1,764	$177.50	$313,110	1	168.4	174.2	5.8
6	1920	1,718	$151.73	$260,672	2	197.0	203.8	6.8
7	1920	842	$180.82	$152,250	1	172.8	178.9	6.1
8	1977	2,088	$173.58	$362,435	1	169.7	173.4	3.7
9	1930	2,340	$147.86	$345,992	2	173.4	182.2	8.8
10	1959	1,593	$180.82	$288,046	1	173.7	176.5	2.8
11	1978	2,084	$173.58	$361,741	1	170.4	174.2	3.8
12	1958	1,370	$180.82	$247,723	1	173.7	181.1	7.4
13	1930	1,504	$154.83	$232,864	2	175.0	178.8	3.8
14	1907	1,109	$180.82	$200,529	1	175.0	177.0	2.0
15	1956	3,121	$162.32	$506,601	1	174.1	177.0	2.9
16	1970	960	$154.48	$148,301	2	174.0	176.0	2.0
17	1984	2,076	$180.82	$375,382	1	170.0	172.8	2.8
18	1969	1,456	$180.82	$263,274	1	175.2	178.0	2.8
19	1965	3,009	$162.32	$488,421	1	175.5	177.5	2.0
20	1920	1,752	$151.73	$265,831	2	176.1	180.1	4.0
21	1960	990	$180.82	$179,012	1	177.3	182.7	5.4
22	1925	799	$180.82	$144,475	1	176.9	180.9	4.0
23	1980	2,088	$173.58	$362,435	1	167.5	173.7	6.2
24	1952	1,622	$180.82	$293,290	1	174.3	176.8	2.5

Source: WA EMD

[1] Property number for identification purposes, for losses avoided calculations only.

[2] BRV is building replacement value. BRV/SF values taken from the BNI Building News Home Builders Costbook 2013. BRV estimates from various sources differ. BNI values were used because these are used by Washington Emergency Management Division and FEMA Region X for evaluation of FEMA mitigation projects. Values are the medium price for "average" one-story and two-story homes. BRV/SF varies with the size of the home with smaller homes having higher costs/SF. Building costs in Centralia and vicinity are lower than those in the Puget Sound area; therefore, the national values were used without applying a location cost factor, per Washington Emergency Management Division guidance.

[3] First floor elevation – the top of the lowest finished floor.

As shown above, the homes were raised between 2.0 and 8.8 feet. The total cost of the 24 elevations was $1,451,365, an average of $60,474 per home, which corresponds to $33.83/square foot. The cost of elevations varies with the size of the home, the type of foundation, construction details of each home, site conditions and other factors. Photographs for representative elevated homes are shown on the following pages.

All building photos are courtesy of WA EMD

Figure 4 – Completed elevation shows home now sitting on top of concrete block

Figure 5 – Completed elevation shows home now sitting on top of concrete block

Figure 6 – Rear view of home being elevated

Figure 7 – Side view of home in Figure 6

2013 Loss Avoidance Study: Approach, methods and issues

Loss avoidance studies are typically done when a major flood event occurs after homes have been elevated. For the present study, this is not the case. The most recent significant flood event in Centralia was the January 2009 flood, which was a much smaller event than the December 2007 event. Furthermore, the elevations of many of the homes elevated after the December 2007 event were completed after the January 2009 flood. Therefore, for the present study, we consider flood "scenarios"—specific flood events such as a 100-year event and the December 2007 event. This loss avoidance study compares the estimated damages for the 24 homes at the pre-elevation first floor elevations to those at the post-elevation first floor elevations.

The 2013 loss avoidance study is complicated by the fact that FEMA's flood hazard analysis and floodplain mapping was revised in 2010, with substantial changes. FEMA's November 11, 2010 Flood Insurance Study (FIS) for Lewis County, Washington and Incorporated Areas and the associated FIRMs are "preliminary," which means they are not yet final or adopted by local jurisdictions. Nevertheless, this data represents the latest and most accurate flood hazard data available for Centralia and vicinity.

The FIS and associated FIRMs effective at the time of the December 2007 flood event were:

- The FIS for Lewis County Washington Unincorporated Areas (July 17, 2006), and
- The FIS for City of Centralia, Washington, Lewis County (December 1, 1981).

The flood hazard data in the 2006 and 1981 studies, including the stream discharge tables and the flood profile graphs (which show the elevations of 10-, 50-, 100- and 500-year floods along the reaches of each river or stream) were essentially identical.

However, the 2010 study has substantially higher stream discharges and correspondingly higher flood elevations for the 10-, 50-, 100- and 500-year flood events than the 2006 and 1981 studies.

These changes are very important, not only for the present loss avoidance study, but also for flood mitigation planning and implementation of flood mitigation measures in Centralia and vicinity. The 24 homes elevated after the December 2007 flood were elevated to at least 2.0 feet above the then-current 100-year flood levels, based on the FEMA 1981 or 2006 flood data. Based on the 2010 FEMA flood data, the 100-year flood elevation and other flood elevations are substantially higher. The result is that the elevated homes have higher residual flood risk after elevation than previously thought to be the case, based on the FEMA 1981 or 2006 flood data.

The substantial changes in FEMA flood hazard data between the 2010 data and previous data are summarized in tables 4, 5, and 6.

Table 4 – Stream discharges: Chehalis River

Stream Discharges (Cubic Feet Per Second)				
Flood Return Period (Years)	**2010 FIS Table 13[1]**	**2006 FIS Table 11[2]**	**2006 FIS Table 8[2]**	**1981 FIS Table 4[3]**
500	100,333	100,200	70,000	70,000
100	75,084	74,300	56,000	55,760
50	65,410	64,300	51,600	51,600
10	45,084	43,800	38,700	38,600

Data Sources

[1] FEMA Flood Insurance Study for Lewis County (Preliminary), November 11, 2010, at the USGS Ground Mound Gaging Station.

[2] FEMA Flood Insurance Study for Lewis County, July 17, 2006 at the USGS Grand Mound Gaging Station. The values in Table 8 were used to calculate the flood profiles, which are essentially identical to those in the 1981 Flood Insurance Study for Centralia.

[3] FEMA Flood Insurance Study for City of Centralia, December 1, 1981, downstream from confluence with Snookumchuck River. Data apparently for the USGS Grand Mound Gaging Station (by comparison with 2006 FIS Table 8).

Table 5 – Flood elevations: Chehalis River

Flood Elevations: Chehalis River Confluence with Snookumchuck River				
Flood Return Period (Years)	2010 (NAVD 1988)[1]	Increase from 2006 to 2010 (Feet)	2006 (NAVD 1988)[2]	2006 (NAVD 1988)[3, 4]
500	179.5	3.3	176.2	172.8
100	176.3	1.9	174.4	171.0
50	175.0	1.2	173.8	170.4
10	172.8	1.2	171.6	168.2

Data Sources

[1] FEMA Flood Insurance Study for Lewis County (Preliminary), November 11, 2010.

[2] Elevations in NAVD 1988 datum are 3.4 feet higher than those in NGVD 1929 datum, per FEMA Flood Insurance Study for Lewis County (Preliminary), November 11, 2010.

[3] FEMA Flood Insurance Study for Lewis County, July 17, 2006.

[4] Same values as FEMA Flood Insurance Study for City of Centralia, December 1, 1981.

There are two common vertical elevation datums: 1929 National Geodetic Vertical Datum (NGVD) and 1988 North American Vertical Datum (NAVD). In Centralia, elevations measured using NAVD 1988 are 3.4 feet higher than those measured using NGVD 1929.

The 1981 and 2006 FEMA FISs and the corresponding FIRMs used the 1929 NGVD datum, while the 2010 FIS and the corresponding FIRMs used the 1988 NAVD data.

Flood elevation certificates may use either datum. When comparing first floor elevations and flood elevations, one must always confirm that the reference datums are the same, or correct the data to a consistent reference datum.

For the present loss avoidance studies, we evaluate the losses avoided for three flood scenarios as summarized in Table 6:

- 100-year flood event per data in the 1981/2006 FEMA Flood Insurance Studies – Flood Scenario 1.
- 100-year flood event per data in the 2010 FEMA Flood Insurance Study – Flood Scenario 2.
- December 2007 flood event – Flood Scenario 3.

Table 6 – Scenario Flood Events for Loss Avoidance Study

Scenario Flood Events: Chehalis River Data[1]				
Event	Discharge (cfs)[2]	Flood Elevation 2010 FEMA Data	Flood Return Period (Years)	
			2010 FEMA Data	2006/1981 FEMA Data
December 2007	79,100	176.8	116	>500
100-Year Flood (2010 FEMA Data)	75,084	176.3	100	>500
100-year Flood (2006/1981 FEMA Data)	56,000	174.0	19	100

[1] At confluence with Skookumchuck River

[2] Cubic feet per second, the volume of water flowing in the river.

As shown in Table 6, the changes between the 2006/1981 FEMA data and the 2010 FEMA data are profound. For example, a flood event on the Chehalis River with a discharge of 56,000 cfs was estimated to be a 100-year event per the 2006/1981 FEMA studies. However, the 2010 FEMA FIS estimates that this level of flood has a return period only about 19 years.

This change may appear drastic, but the credibility and reasonableness of the 2010 data is substantiated by the historical flood data as shown in Table 2. In the 23 years since 1990, there have been three flood events with discharges above 68,000 cfs—well above the 2006/1981 100-year flood event. Thus, the 2010 data is the most current, best available and most accurate data for evaluating flood risk in Centralia and vicinity.

For the 24 elevated homes (see Table 3), flood damages and losses are evaluated for three scenario flood events as stated previously. The damages and losses considered include: building damages, contents damages, and displacement costs (cost for temporary housing when a home must be vacated for flood repairs). The building and contents damages are estimated using FEMA depth-damage functions for one- and two-story homes without basements. These depth-damage functions provide estimated building and contents damages, expressed as a percentage of building replacement value in one foot increments of flood depth relative to the first floor. Displacement times are also estimated in one foot increments of flood depth. Building replacement values were estimated from the BNI Building News Home Builder's 2013 Costbook. Displacement costs were estimated as $1.44/SF per month, the FEMA standard value, plus $500 for one-time costs. FEMA depth damage functions for one- and two-story homes without basements are shown in Table 7.

Table 7 – FEMA Depth-damage functions

Flood Depth Feet[1]	One-Story w/o Basement			Two-Story w/o Basement		
	Building Damage Percent[2]	Content Damage Percent[2]	Displacement Time (Days)	Building Damage Percent[2]	Content Damage Percent[2]	Displacement Time (Days)
-2	0.0%	0.0%	0	0.0%	0.0%	0
-1	2.5%	2.4%	0	3.0%	1.0%	0
0	13.4%	8.1%	0	9.3%	5.0%	0
1	23.3%	13.3%	45	15.2%	8.7%	45
2	32.1%	17.9%	90	20.9%	12.2%	90
3	40.1%	22.0%	135	26.3%	15.5%	135
4	47.1%	25.7%	180	31.4%	18.5%	180
5	53.2%	28.8%	225	36.2%	21.3%	225
6	58.6%	31.5%	270	40.7%	23.9%	270
7	63.2%	33.8%	315	44.9%	26.3%	315
8	67.2%	35.7%	360	48.8%	28.4%	360

[1] Relative to first floor elevation. For example, a 1-foot flood means water depth from 0.5 to 1.5 feet above the first floor.

[2] Building and contents damages expressed as a percentage of building replacement value.

Flood Scenario #1: Chehalis River Discharge of 56,000 cfs – 100-Year Flood per FEMA 2006/1981 Flood Insurance Studies

Prop. #	Number of Stories	2006 FEMA 100-Year Flood: Before Elevation							
		Depth Above First Floor (Feet)	Building Damage Percent	Contents Damage Percent	Displace. Days	Bldg. Dollar Damage	Contents Dollar Damage	Displace. Costs	Total Damage & Losses
1	2	5.5	40.7%	23.9%	270	$199,179	$116,963	$46,132	$362,274
2	1	2.9	40.1%	22.0%	135	$154,872	$84,967	$14,918	$254,758
3	1	5.0	53.2%	28.8%	225	$159,209	$86,188	$18,709	$264,106
4	1	4.5	53.2%	28.8%	225	$113,800	$61,606	$13,276	$188,683
5	1	3.6	47.1%	25.7%	180	$147,475	$80,469	$15,741	$243,685
6	2	2.3	20.9%	12.2%	90	$54,480	$31,802	$7,922	$94,204
7	1	2.7	40.1%	22.0%	135	$61,052	$33,495	$5,956	$100,504
8	1	1.3	23.2%	13.3%	45	$84,085	$48,204	$5,010	$137,299
9	2	3.2	26.3%	15.5%	135	$90,996	$53,629	$15,663	$160,288
10	1	0.3	13.4%	8.1%	0	$38,598	$23,332	$500	$62,430
11	1	1.6	32.1%	17.9%	90	$116,119	$64,752	$9,503	$190,373
12	1	2.3	32.1%	17.9%	90	$79,519	$44,342	$6,418	$130,280
13	2	1.0	15.2%	8.7%	45	$35,395	$20,259	$3,749	$59,403
14	1	-2.0	0.0%	0.0%	0	$0	$0	$0	$0
15	1	-0.1	13.4%	8.1%	0	$67,884	$41,035	$0	$108,919
16	2	-1.0	3.0%	1.0%	0	$4,449	$1,483	$0	$5,932
17	1	-1.0	2.5%	2.4%	0	$9,385	$9,009	$0	$18,394
18	1	-1.2	2.5%	2.4%	0	$6,687	$6,319	$0	$13,006
19	1	-1.5	2.5%	2.4%	0	$12,211	$11,722	$0	$23,933
20	2	1.1	15.2%	8.7%	45	$40,406	$23,127	$4,284	$67,818
21	1	0.7	23.3%	13.3%	45	$41,710	$23,809	$2,638	$68,157
22	1	1.1	23.3%	13.3%	45	$33,663	$19,215	$2,226	$55,104
23	1	4.0	47.1%	25.7%	180	$170,707	$93,146	$18,540	$282,393
24	1	0.0	13.4%	8.1%	0	$39,301	$23,756	$0	$63,057
					Totals:	**$1,761,183**	**$1,002,630**	**$191,186**	**$2,954,999**

Flood Scenario #1: Chehalis River Discharge of 56,000 cfs – 100-Year Flood per FEMA 2006/1981 Flood Insurance Studies

Prop. #	Number of Stories	2006 FEMA 100-Year Flood: After Elevation							
		Depth Above First Floor (Feet)	Building Damage Percent	Contents Damage Percent	Displace. Days	Bldg. Dollar Damage	Contents Dollar Damage	Displace. Costs	Total Damage & Losses
1	2	-2.1	0.0%	0.0%	$0	$0	$0	$0	$0
2	1	-3.1	0.0%	0.0%	$0	$0	$0	$0	$0
3	1	-2.2	0.0%	0.0%	$0	$0	$0	$0	$0
4	1	-2.7	0.0%	0.0%	$0	$0	$0	$0	$0
5	1	-2.2	0.0%	0.0%	$0	$0	$0	$0	$0
6	2	-4.5	0.0%	0.0%	$0	$0	$0	$0	$0
7	1	-3.4	0.0%	0.0%	$0	$0	$0	$0	$0
8	1	-2.4	0.0%	0.0%	$0	$0	$0	$0	$0
9	2	-5.7	0.0%	0.0%	$0	$0	$0	$0	$0
10	1	-2.5	0.0%	0.0%	$0	$0	$0	$0	$0
11	1	-2.2	0.0%	0.0%	$0	$0	$0	$0	$0
12	1	-5.1	0.0%	0.0%	$0	$0	$0	$0	$0
13	2	-2.8	0.0%	0.0%	$0	$0	$0	$0	$0
14	1	-4.0	0.0%	0.0%	$0	$0	$0	$0	$0
15	1	-3.0	0.0%	0.0%	$0	$0	$0	$0	$0
16	2	-3.0	0.0%	0.0%	$0	$0	$0	$0	$0
17	1	-3.8	0.0%	0.0%	$0	$0	$0	$0	$0
18	1	-4.0	0.0%	0.0%	$0	$0	$0	$0	$0
19	1	-3.5	0.0%	0.0%	$0	$0	$0	$0	$0
20	2	-3.0	0.0%	0.0%	$0	$0	$0	$0	$0
21	1	-4.7	0.0%	0.0%	$0	$0	$0	$0	$0
22	1	-2.9	0.0%	0.0%	$0	$0	$0	$0	$0
23	1	-2.2	0.0%	0.0%	$0	$0	$0	$0	$0
24	1	-2.5	0.0%	0.0%	$0	$0	$0	$0	$0
					Totals:	**$0**	**$0**	**$0**	**$0**

2006 FEMA 100-Year Flood Total Damages and Losses	
Before Elevation	$2,954,999
After Elevation	$0
Avoided	$2,954,999
Percent Reduction	100%

For this flood scenario, the 2006 FEMA 100-Year Flood event, there are no damages after elevation because all 24 homes were elevated at least 2 feet above this flood level.

Flood Scenario #2: Chehalis River Discharge of 75,084 cfs – 100-Year Flood per FEMA 2010 Flood Insurance Study

Prop. #	Number of Stories	2010 FEMA 100-Year Flood: Before Elevation							
		Depth Above First Floor (Feet)	Building Damage Percent	Contents Damage Percent	Displace. Days	Bldg. Dollar Damage	Contents Dollar Damage	Displace. Costs	Total Damage & Losses
1	2	8.0	48.8%	28.4%	360	$238,819	$138,985	$61,343	$439,147
2	1	5.8	58.6%	31.5%	270	$226,322	$121,658	$29,336	$377,316
3	1	5.9	58.6%	31.5%	270	$175,369	$94,268	$22,351	$291,988
4	1	5.4	53.2%	28.8%	225	$113,800	$61,606	$13,276	$188,683
5	1	8.6	58.6%	31.5%	270	$183,482	$98,630	$23,361	$305,474
6	2	-20.2	36.2%	21.3%	225	$94,363	$55,523	$19,054	$168,941
7	1	4.2	47.1%	25.7%	180	$71,710	$39,128	$7,775	$118,613
8	1	4.1	47.1%	25.7%	180	$170,707	$93,146	$18,540	$282,393
9	2	3.6	31.4%	18.5%	180	$108,642	$64,009	$20,718	$193,368
10	1	3.2	40.1%	22.0%	135	$115,507	$63,370	$10,823	$189,699
11	1	3.6	47.1%	25.7%	180	$170,380	$92,967	$18,506	$281,853
12	1	3.9	47.1%	25.7%	180	$116,678	$63,665	$12,337	$192,679
13	2	2.8	26.3%	15.5%	135	$61,243	$36,094	$10,246	$107,583
14	1	1.8	32.1%	17.9%	90	$64,370	$35,895	$5,291	$105,556
15	1	2.8	40.1%	22.0%	135	$203,147	$111,452	$20,724	$335,323
16	2	2.9	26.3%	15.5%	135	$39,003	$22,987	$6,721	$68,711
17	1	2.7	40.1%	22.0%	135	$150,528	$82,584	$13,952	$247,065
18	1	1.7	32.1%	17.9%	90	$84,511	$47,126	$6,790	$138,427
19	1	1.4	32.1%	17.9%	90	$156,783	$87,427	$13,499	$257,709
20	2	5.1	53.2%	21.3%	225	$141,422	$56,622	$19,422	$217,466
21	1	3.9	47.1%	25.7%	180	$84,315	$46,006	$9,054	$139,374
22	1	4.3	47.1%	25.7%	180	$68,048	$37,130	$7,403	$112,581
23	1	10.3	63.2%	33.8%	315	$229,059	$122,503	$32,071	$383,633
24	1	2.6	40.1%	22.0%	135	$117,609	$64,524	$11,011	$193,144
					Totals:	**$3,185,818**	**$1,737,305**	**$413,602**	**$5,336,725**

For this scenario, the 2010 FEMA 100-Year Flood, the total damages and losses are about 80% higher than in the previous scenario, the 2006 FEMA 100-Year Flood, because the 2010 FEMA 100-Year Flood elevations are significantly higher than the 2006 FEMA 100-Year Flood elevations.

Flood Scenario #2: Chehalis River Discharge of 75,084 cfs – 100-Year Flood per FEMA 2010 Flood Insurance Study

Prop. #	Number of Stories	2010 FEMA 100-Year Flood: After Elevation							
		Depth Above First Floor (Feet)	Building Damage Percent	Contents Damage Percent	Displace. Days	Bldg. Dollar Damage	Contents Dollar Damage	Displace. Costs	Total Damage & Losses
1	2	0.4	9.3%	5.0%	0	$45,513	$24,469	$0	$69,982
2	1	-0.2	13.4%	8.1%	0	$51,753	$31,283	$0	$83,036
3	1	-1.3	2.5%	2.4%	0	$7,482	$7,182	$0	$14,664
4	1	-1.8	0.0%	0.0%	0	$0	$0	$0	$0
5	1	2.9	13.4%	8.1%	0	$41,957	$25,362	$0	$67,319
6	2	-27.0	0.0%	0.0%	0	$0	$0	$0	$0
7	1	-1.9	0.0%	0.0%	0	$0	$0	$0	$0
8	1	0.4	13.4%	8.1%	0	$48,566	$29,357	$0	$77,924
9	2	-5.3	0.0%	0.0%	0	$0	$0	$0	$0
10	1	0.4	13.4%	8.1%	0	$38,598	$23,332	$0	$61,930
11	1	-0.2	13.4%	8.1%	0	$48,473	$29,301	$0	$77,774
12	1	-3.5	0.0%	0.0%	0	$0	$0	$0	$0
13	2	-1.0	3.0%	1.0%	0	$6,986	$2,329	$0	$9,315
14	1	-0.2	13.4%	8.1%	0	$26,871	$16,243	$0	$43,114
15	1	-0.1	13.4%	8.1%	0	$67,884	$41,035	$0	$108,919
16	2	0.9	15.2%	8.7%	45	$22,542	$12,902	$2,574	$38,017
17	1	-0.1	13.4%	8.1%	0	$50,301	$30,406	$0	$80,707
18	1	-1.1	2.5%	2.4%	0	$6,582	$6,319	$0	$12,900
19	1	-0.6	2.5%	2.4%	0	$12,211	$11,722	$0	$23,933
20	2	1.1	15.2%	8.7%	45	$40,406	$23,127	$4,284	$67,818
21	1	-1.5	2.5%	2.4%	0	$4,475	$4,296	$0	$8,772
22	1	0.3	13.4%	8.1%	0	$19,360	$11,702	$0	$31,062
23	1	4.1	13.4%	8.1%	0	$48,566	$29,357	$0	$77,924
24	1	0.1	13.4%	8.1%	0	$39,301	$23,756	$0	$63,057
					Totals:	**$627,827**	**$383,482**	**$6,858**	**$1,018,166**

2010 FEMA 100-Year Flood Total Damages and Losses	
Before Elevation	$5,336,725
After Elevation	$1,018,166
Avoided	$4,318,559
Percent Reduction	81%

The losses avoided for this scenario are higher than those for the previous scenario because the losses for before elevation are 80% higher. Even though 19 of the 24 elevated homes would have shallow flooding in this scenario, the total damages and losses are reduced by 81%.

Flood Scenario #3: Chehalis River Discharge of 79,100 cfs – December 2007 Flood Event

Prop. #	Number of Stories	Flood of Record (December 2007): Before Elevation							
		Depth Above First Floor (Feet)	Building Damage Percent	Contents Damage Percent	Displace. Days	Bldg. Dollar Damage	Contents Dollar Damage	Displace. Costs	Total Damage & Losses
1	2	11.2	52.4%	30.3%	405	$256,437	$148,283	$68,948	$473,669
2	1	6.7	63.2%	33.8%	315	$244,088	$130,541	$34,142	$408,771
3	1	6.8	63.2%	33.8%	315	$189,135	$101,152	$25,992	$316,279
4	1	2.9	58.6%	31.5%	270	$125,351	$67,382	$15,832	$208,565
5	1	9.4	58.6%	31.5%	270	$183,482	$98,630	$23,361	$305,474
6	2	-22.7	36.2%	21.3%	225	$94,363	$55,523	$19,054	$168,941
7	1	5.1	53.2%	28.8%	225	$80,997	$43,848	$9,594	$134,439
8	1	4.8	53.2%	28.8%	225	$192,815	$104,381	$23,050	$320,247
9	2	5.1	36.2%	21.3%	225	$125,249	$73,696	$25,772	$224,718
10	1	4.0	47.1%	25.7%	180	$135,670	$74,028	$14,264	$223,961
11	1	7.4	47.1%	25.7%	180	$170,380	$92,967	$18,506	$281,853
12	1	-0.5	53.2%	28.8%	225	$131,789	$71,344	$15,296	$218,429
13	2	2.8	31.4%	18.5%	180	$73,119	$43,080	$13,495	$129,694
14	1	2.8	40.1%	22.0%	135	$80,412	$44,116	$7,686	$132,215
15	1	7.5	47.1%	25.7%	180	$238,609	$130,196	$27,465	$396,271
16	2	7.6	31.4%	18.5%	180	$46,566	$27,436	$8,794	$82,796
17	1	4.5	40.1%	22.0%	135	$150,528	$82,584	$13,952	$247,065
18	1	2.6	40.1%	22.0%	135	$105,573	$57,920	$9,935	$173,428
19	1	-0.4	32.1%	17.9%	90	$156,783	$87,427	$13,499	$257,709
20	2	25.7	40.7%	23.9%	270	$108,193	$63,534	$23,206	$194,933
21	1	0.5	47.1%	25.7%	180	$84,315	$46,006	$9,054	$139,374
22	1	1.6	53.2%	28.8%	225	$76,861	$41,609	$9,129	$127,599
23	1	10.3	63.2%	33.8%	315	$229,059	$122,503	$32,071	$383,633
24	1	7.3	47.1%	25.7%	180	$138,140	$75,376	$14,514	$228,029
					Totals:	**$3,417,917**	**$1,883,563**	**$476,612**	**$5,778,091**

The total damages and losses before elevation for the December 2007 flood of record are about 8% higher than those for the 2010 FEMA 100-Year flood event because the average flood depth is about 0.69 foot higher.

Flood Scenario #3: Chehalis River Discharge of 79,100 cfs – December 2007 Flood Event

Prop. #	Number of Stories	Flood of Record (December 2007): Before Elevation							
		Depth Above First Floor (Feet)	Building Damage Percent	Contents Damage Percent	Displace. Days	Bldg. Dollar Damage	Contents Dollar Damage	Displace. Costs	Total Damage & Losses
1	2	0.4	9.3%	5.0%	0	$45,513	$24,469	$0	$69,982
2	1	-0.2	13.4%	8.1%	0	$51,753	$31,283	$0	$83,036
3	1	-1.3	2.5%	2.4%	0	$7,482	$7,182	$0	$14,664
4	1	-1.8	0.0%	0.0%	0	$0	$0	$0	$0
5	1	2.9	13.4%	8.1%	0	$41,957	$25,362	$0	$67,319
6	2	-27.0	0.0%	0.0%	0	$0	$0	$0	$0
7	1	-1.9	0.0%	0.0%	0	$0	$0	$0	$0
8	1	0.4	13.4%	8.1%	0	$48,566	$29,357	$0	$77,924
9	2	-5.3	0.0%	0.0%	0	$0	$0	$0	$0
10	1	0.4	13.4%	8.1%	0	$38,598	$23,332	$0	$61,930
11	1	-0.2	13.4%	8.1%	0	$48,473	$29,301	$0	$77,774
12	1	-3.5	0.0%	0.0%	0	$0	$0	$0	$0
13	2	-1.0	3.0%	1.0%	0	$6,986	$2,329	$0	$9,315
14	1	-0.2	13.4%	8.1%	0	$26,871	$16,243	$0	$43,114
15	1	-0.1	13.4%	8.1%	0	$67,884	$41,035	$0	$108,919
16	2	0.9	15.2%	8.7%	45	$22,542	$12,902	$2,574	$38,017
17	1	-0.1	13.4%	8.1%	0	$50,301	$30,406	$0	$80,707
18	1	-1.1	2.5%	2.4%	0	$6,582	$6,319	$0	$12,900
19	1	-0.6	2.5%	2.4%	0	$12,211	$11,722	$0	$23,933
20	2	1.1	15.2%	8.7%	45	$40,406	$23,127	$4,284	$67,818
21	1	-1.5	2.5%	2.4%	0	$4,475	$4,296	$0	$8,772
22	1	0.3	13.4%	8.1%	0	$19,360	$11,702	$0	$31,062
23	1	4.1	13.4%	8.1%	0	$48,566	$29,357	$0	$77,924
24	1	0.1	13.4%	8.1%	0	$39,301	$23,756	$0	$63,057
					Totals:	**$627,827**	**$383,482**	**$6,858**	**$1,018,166**

Flood of Record (December 2007) Total Damages and Losses	
Before Elevation	$5,778,091
After Elevation	$1,745,273
Avoided	$4,032,818
Percent Reduction	70%

The losses avoided for the Flood of Record (December 2007) are lower than those for the FEMA 2010 100-Year Flood, even though the losses before mitigation are 8% higher, because after elevation, more homes flood and the after elevation homes have higher losses. Nevertheless, even in this Flood of Record scenario, the elevations reduce the damages and losses by 70%.

Conclusions and lessons learned

The losses avoided results for the three flood scenarios evaluated yield the following conclusions:

- Elevating homes is highly effective in eliminating or reducing damages from flooding, but not 100% effective for floods larger than anticipated at the time of the elevation project.
- Homes that are elevated at least 2 feet above the 100-year flood elevation will have no flood damages during a future flood event at this level, based on FEMA depth damage functions.
- Floods greater than the 100-year flood, such as the December 2007 flood of record, can and do occur. In events larger than the 100-year flood, some elevated homes may still have damages, although water depths and damages will be much lower than if the homes had not been elevated.
- Determinations of flood risk, such as the estimated discharge and flood elevation for a 100-year flood on the Chehalis River at a given location, have uncertainties, and estimates often change over time as rivers are re-evaluated with updated data. Absent major flood control projects, updated estimates generally result in higher flood estimates because of increasing development in watersheds and other factors. There are also other factors such as channel migration and sedimentation in the channel which may increase flood depths and/or flood velocities at some locations.
- In some cases, as for Centralia, updated flood estimates may substantially raise the level of flood risk, with substantial increases in the elevations of the 100-year and other flood events.

Recomendations

Given the above considerations, elevation to the 100-year flood elevation plus 2 feet should be considered the minimum acceptable elevation. Safer, more-effective elevation strategies with a higher likelihood of avoiding residual risk damages in future flood events include:

- Elevating more than 2 feet above the 100-year flood elevation.
- Elevating to the higher of: a) the 100-year flood level plus 2 or more feet; or,
  b) the flood of record, plus 1 or more feet, whichever is higher.
- Once an elevation is undertaken, the incremental cost of going up another foot or two or three is relatively small in most instances. The additional increase in elevation can significantly reduce residual risk damages such as wave action from wind, passing vehicles, or rescue boats during high water.
- Some residual risk is unavoidable, such as mold and silt.

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