



# REPORT

# Evaluating Losses Avoided Through Hazard Mitigation

City of Centralia, Washington



FEMA



# **Evaluating Losses Avoided Through Hazard Mitigation**

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City Of Centralia, Washington

February 2008



## Introduction



*Jim Smith (FEMA staff) visits one of the elevated homes in the City of Centralia.*

major floods in 1996 and 1997. HMGP is a part of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (The Stafford Act) and provides grants for states and communities to implement hazard mitigation measures after presidentially declared disasters.

Over the past 15 years, the Cities of Centralia and Chehalis, Lewis County, and individual homeowners, with the support of FEMA, Washington State Emergency Management Division, and the Small Business Administration have invested several million dollars to acquire or elevate many flood-prone residential structures in Lewis County. With the expenditure of these large amounts of public and private funds, the question is often asked: **How well are these mitigation initiatives working? Are we able to quantify the losses avoided as a direct result of implementing acquisition and elevation programs?**

In an attempt to answer these questions, this evaluation focused on a sample of 35 residential structures located in the City of Centralia that were elevated under FEMA's Hazard Mitigation Grant Program (HMGP) after

## Methodology

In order to calculate the flood losses that were avoided due to an elevation project, it is necessary to obtain the following pre-mitigation data on each residential structure to be evaluated:

- Location
- Structure type
- Structure square footage
- First floor elevation (before and after mitigation)
- Number of floors

FEMA was able to obtain *Elevation Certificates* from the City of Centralia's Building Department for 67 structures that were elevated under the HMGP after the 1996 and 1997 flooding. Detailed elevation information was obtained for 35 of the elevated homes that are located within the same area that was again flooded by the December 2007 event. Flood elevations for the December 2007 flood event were established from high water marks obtained for each structure. The *Elevation Certificates* provided the data required to develop pre-elevation, depth-damage relationships for each structure. With these relationships established, losses avoided from the December 2007 flood event were calculated for each building, contents, and displacement costs avoided. With the high quality of data obtained on these 35 structures, this analysis will begin to answer the questions posed in paragraph 1.

It is important to understand the difference between a benefit-cost analysis to assess cost effectiveness, which is performed for FEMA-funded mitigation projects, such as the HMGP, and the methodology that is used to assess losses avoided. A benefit-cost analysis identifies potential future losses that will be avoided over the life of mitigation projects by the use of a probability analysis. Measuring the losses avoided of past mitigation projects applies a methodology (stage-damage functions) that can be used after a flood event, to quantify the losses that would have occurred had the mitigation not been undertaken.

## Economic Assumptions

Assumptions used for the Losses Avoided calculations are:

- Building replacement costs of \$99.46/sq foot (2008 prices and conditions) were obtained from R. S. Means - CostWorks. Building costs were specific to the Centralia area.
- A content value of 40 percent of the building replacement value was used.
- The default depth-damage relationships for residential structures, contents, and displacement costs from the Riverine Full Data BCA Modules, were used in the analysis.
- A building damage of 50 percent or more would result in demolition (default value specified in FEMA's BCA Riverine Flood-Full Data Module).

## Computation of Losses Avoided

### Building Data

Table 1 provides building data by address and HMGP disaster number, for 35 homes that were elevated after the 1996 and 1997 FEMA flood disaster declarations. The elevation data came from *Elevation Certificates* provided by the Centralia Building Department and building data (structure type & square footage) were obtained from Lewis County Assessors records. The 2008 structure replacement value was based on \$99.46 per square foot, which was derived from R.S. Means CostWorks.



*Herman Huggins (FEMA staff) indicates the high water mark from the December 2007 floods.*

### Depth-Damage Functions

Data from Table 1 was entered into FEMA's Riverine Flood - Full Data BCA Module for each of the 35 structures being analyzed. Table 2 provides an example of the default, model generated building depth-percent damage function, content percent damage function, and displacement days for a 1-story structure with no basement (all but 6 of the homes fall into this category), for various flood depths.

FEMA's Riverine BCA Module was run for each elevated structure, and the resulting monetary depth-damage relationship output (for buildings, contents and displacement costs) was the basis for calculating the losses avoided from the December 2007 flood.

TABLE I - Building data for elevated structures in the City of Centralia.

Property ID	Base Flood Elevation	FFE (Before)	FFE (After)	Feet Raised	Structure Type	Square Footage	2008 Structure Replacement Value
<b>FEMA DISASTER DR-1100-WA</b>							
1	173.5	173.3	179.0	5.7	1 Story	1,398	\$ 139,045
2	173.0	173.2	175.9	2.7	1 Story	1,319	\$ 131,188
3	174.0	172.5	177.1	4.6	1 Story	1,656	\$ 164,706
4	174.7	174.8	177.6	2.8	1 Story	1,536	\$ 152,771
5	N/A	175.0	177.8	2.8	1 Story	872	\$ 86,729
6	174.1	172.1	177.6	5.5	1 Story	1,188	\$ 118,158
7	173.0	171.5	176.7	5.2	2 Story	1,380	\$ 137,255
8	174.3	174.4	177.9	3.5	1 Story	1,630	\$ 162,120
9	169.0	168.8	172.1	3.3	1 Story	1,452	\$ 144,416
10	173.0	170.6	176.7	6.1	1 Story	1,008	\$ 100,256
11	174.2	173.5	178.5	5.0	1 Story	1,344	\$ 133,674
12	174.7	168.3	177.9	9.6	1 Story	2,364	\$ 235,549
13	174.1	174.8	177.8	3.0	1 Story	1,250	\$ 124,325
14	173.0	173.1	176.4	3.3	2 Story	1,593	\$ 158,440
15	173.0	171.9	175.7	3.8	1 Story	1,628	\$ 161,921
16	173.0	172.1	176.1	4.0	2 Story	1,945	\$ 193,450
17	175.1	175.2	177.3	2.1	1 Story	1,775	\$ 176,542
18	173.0	173.3	176.2	2.9	1 Story	845	\$ 84,044
19	174.0	173.2	177.6	4.4	1 Story	1,857	\$ 184,697
20	173.0	171.5	176.8	5.3	1 Story	1,560	\$ 155,158
21	173.0	172.8	175.6	2.8	1 Story	1,284	\$ 127,707
22	173.5	173.5	178.0	4.5	2 Story	3,302	\$ 328,417
23	173.0	174.1	176.2	2.1	1 Story	1,692	\$ 168,286
24	173.0	171.1	177.9	6.8	1 Story	1,314	\$ 130,690
25	173.5	174.5	177.6	3.1	1 Story	1,356	\$ 134,868
26	173.0	171.7	175.8	4.1	1 Story	896	\$ 89,116
27	N/A	175.3	177.3	2.0	1 Story	918	\$ 91,304
28	173.0	172.6	175.3	2.7	1 Story	1,028	\$ 102,245
<b>FEMA DISASTER DR-1159-WA</b>							
29	174.0	173.5	175.1	1.6	1 Story	980	\$ 97,471
30	170.0	170.9	173.0	2.1	1 Story	1,578	\$ 156,948
31	176.0	174.9	178.4	3.5	1 Story	1,044	\$ 103,836
32	169.8	170.2	172.8	2.6	1 Story	1,490	\$ 148,195
33	173.5	174.6	177.4	2.8	1 Story	1,920	\$ 190,963
34	174.3	174.3	177.7	3.4	2 Story	1,798	\$ 178,829
35	170.0	170.5	173.5	3.0	2 Story	2,116	\$ 210,457

Notes: FFE designates First Floor Elevation  
Base Flood Elevation and FFE referenced to the National Geodetic Vertical Datum of 1929 (NGVD '29)



TABLE 2 - Relation of damage to flood depth for 1-story buildings (without basements) in City of Centralia.  
 [Flood depth in feet; values in building and content columns in percent]

Flood Depth	Building (DDF)	Contents (DDF)	Displacement (days)
-1	0	0	0
0	9%	14%	0
1	14%	21%	62
2	22%	33%	126
3	27%	41%	166
4	29%	44%	182
5	30%	45%	190
6	40%	60%	270
7	43%	65%	294
8	44%	66%	302
>8	45%	68%	310

#### Sample Calculation: ID 19

Flood Elevation	173.9 ft
First Floor Elevation	171.9 ft
Flood Depth	2 ft
Building DDF	22%
Contents DDF	33%
Displacement Period	126 days

Note: DDF designates Depth Damage Function

**Considering that the estimated total losses avoided were \$1,905,760, the flood damages prevented from this single event likely exceeded the original project cost by almost two to one.**





## Hydrologic Data

This losses avoided analysis was based solely on the December 2007 flood event which had peak discharges ranging from 63,100 cubic feet per second (cfs)<sup>1</sup> at the Chehalis River near Doty gage (upstream of Centralia) to 79,100 cfs<sup>2</sup> at the Chehalis River near Ground Mound gage, downstream of Centralia. These discharges equate to an approximate 500-year, and 200-year recurrence interval, respectively.

December 2007 Flood elevations shown on Table 3 were derived by comparing high water marks on each structure to the known first floor elevation of the raised home. This peak flood stage was then compared to pre-mitigation first floor elevations to derive the “avoided” water depth in each home. It should be noted that 2 of the elevated homes had water slightly above the first floor elevations (FFE’s) and eight others had water within 1 foot of the first floor, and thus sustained minor flood damage. Pre-mitigation water depths would have ranged from 0.7 feet below to 9.0 feet above the FFE’s.

## Losses Avoided

Losses Avoided, or flood damages prevented by these two past HMGP home elevation projects, were derived by taking the water depth relative to FFE’s from Table 3, and recording the corresponding damages for that water depth found in the *Riverine Flood – Full Data BCA Model’s* depth-damage output tables. Two homes had water slightly above the first floor during the December 2007 event, and eight others had water within 1 foot of the first floor. The observed damages associated with these flood levels have been netted out of the Losses Avoided for these structures. A summary of the Losses Avoided for each structure, and damage category, can be found in Table 4. The location of each structure within the study area, and the approximate depth of flooding are displayed on Plate 1.

## Cost-Effectiveness

The individual project cost for each structure elevated was unavailable, so a cost-effectiveness analysis for each home could not be accomplished. Good aggregate data was available however, for HMGP projects DR-1100-WA, and DR-1159-WA that elevated a total of 116 Centralia homes in 1996 and 1997 for a cost of \$3,371,969, or an average cost of \$29,069 per structure. Since all homes in this analysis were elevated in the same time period under these two disasters, and were randomly distributed throughout the floodplain, this average would be a fairly accurate estimate of the mitigation costs for all homes in our study. Applying an average elevation project cost of \$29,069 to all 35 structures, results in a total mitigation cost of \$1,017,415. Considering that the estimated total losses avoided were \$1,905,760, the flood damages prevented from this single event likely exceeded the original project cost by almost two to one.

<sup>1</sup> Provisional USGS Data

<sup>2</sup> *ibid*

TABLE 3 - Relation of damage to flood depth for I-story buildings (without basements) in City of Centralia.

Property ID	December 2007 Flood Elevation (NGVD '29)	FFE Before Elevation (NGVD '29)	Water Above FFE (feet)	FFE After Elevation (NGVD '29)	Water Below/Above FFE (feet)
<b>FEMA DISASTER DR-1100-WA</b>					
1	177.5	173.3	4.2	179.0	-1.5
2	173.1	173.2	-0.1	175.9	-2.8
3	174.3	172.5	1.8	177.1	-2.8
4	177.1	174.8	2.3	177.6	-0.5
5	176.4	175.0	1.4	177.8	-1.4
6	177.8	172.1	5.7	177.6	0.2
7	174.9	171.5	3.4	176.7	-1.8
8	177.7	174.4	3.3	177.9	-0.2
9	171.1	168.8	2.3	172.1	-1.0
10	174.9	170.6	4.3	176.7	-1.8
11	178.1	173.5	4.6	178.5	-0.4
12	177.3	168.3	9.0	177.9	-0.6
13	176.6	174.8	1.8	177.8	-1.2
14	175.2	173.1	2.1	176.4	-1.2
15	173.9	171.9	2.0	175.7	-1.8
16	175.1	172.1	3.0	176.1	-1.0
17	177.1	175.2	1.9	177.3	-0.2
18	175.2	173.3	1.9	176.2	-1.0
19	176.4	173.2	3.2	177.6	-1.2
20	174.8	171.5	3.3	176.8	-2.0
21	174.7	172.8	1.9	175.6	-0.9
22	177.0	173.5	3.5	178.0	-1.0
23	173.4	174.1	-0.7	176.2	-2.8
24	174.4	171.1	3.3	177.9	-3.5
25	176.8	174.5	2.3	177.6	-0.8
26	173.7	171.7	2.0	175.8	-2.1
27	174.8	175.3	-0.5	177.3	-2.5
28	174.1	172.6	1.5	175.3	-1.2
<b>FEMA DISASTER DR-1159-WA</b>					
29	175.5	173.5	2.0	175.1	0.4
30	171.9	170.9	1.0	173.0	-1.1
31	177.6	174.9	2.7	178.4	-0.8
32	170.6	170.2	0.4	172.8	-2.2
33	176.4	174.6	1.8	177.4	-1.0
34	174.7	174.3	0.4	177.7	-3.0
35	171.8	170.5	1.3	173.5	-1.7

Notes: FFE Designates First Floor Elevation  
 NGVD '29 Designates The National Geodetic Vertical Datum of 1929

TABLE 4 - Losses avoided as results of building elevations in City of Centralia, flood of December 2007.

Property ID	Water Depth above FFE Pre-Mitigation (feet)	Losses Avoided (2007 dollars)			
		Building Repair Costs	Content Losses	Displacement Costs	Total
<b>FEMA DISASTER DR-1100-WA</b>					
1	4.2	\$ 40,601	\$ 24,360	\$ 12,116	\$ 77,077
2	-0.1	\$ 10,626	\$ 6,376	\$ -	\$ 17,002
3	1.8	\$ 33,600	\$ 20,160	\$ 8,635	\$ 62,395
4	<u>1/</u> 2.3	\$ 29,026	\$ 17,416	\$ 9,866	\$ 56,308
5	1.4	\$ 14,917	\$ 8,950	\$ 4,506	\$ 28,373
6	<u>1/</u> 5.7	\$ 31,903	\$ 19,141	\$ 13,544	\$ 64,588
7	3.4	\$ 25,804	\$ 15,483	\$ 6,792	\$ 48,079
8	<u>1/</u> 3.3	\$ 33,072	\$ 19,844	\$ 12,627	\$ 65,543
9	2.3	\$ 33,938	\$ 20,363	\$ 9,479	\$ 63,780
10	4.3	\$ 29,375	\$ 17,625	\$ 9,770	\$ 56,770
11	<u>1/</u> 4.6	\$ 32,349	\$ 19,409	\$ 11,982	\$ 63,740
12	<u>1/</u> 9.0	\$ 97,517	\$ 58,510	\$ 30,095	\$ 186,122
13	1.8	\$ 25,363	\$ 15,217	\$ 7,103	\$ 47,683
14	2.1	\$ 21,389	\$ 12,833	\$ 4,546	\$ 38,768
15	2.0	\$ 35,623	\$ 21,374	\$ 9,438	\$ 66,435
16	3.0	\$ 34,821	\$ 20,893	\$ 8,161	\$ 63,875
17	<u>1/</u> 1.9	\$ 24,716	\$ 14,830	\$ 9,570	\$ 49,116
18	1.9	\$ 17,818	\$ 10,691	\$ 5,862	\$ 34,371
19	3.2	\$ 50,607	\$ 30,364	\$ 13,793	\$ 94,764
20	3.3	\$ 42,824	\$ 25,694	\$ 12,228	\$ 80,746
21	<u>1/</u> 1.9	\$ 25,924	\$ 15,554	\$ 7,612	\$ 49,090
22	3.5	\$ 62,399	\$ 37,440	\$ 13,427	\$ 113,266
23	-0.7	\$ 4,544	\$ 2,726	\$ -	\$ 7,270
24	3.3	\$ 36,070	\$ 21,642	\$ 10,827	\$ 68,539
25	<u>1/</u> 2.3	\$ 29,266	\$ 17,560	\$ 9,037	\$ 55,863
26	2.0	\$ 19,606	\$ 11,763	\$ 6,363	\$ 37,732
27	-0.5	\$ 4,109	\$ 2,465	\$ -	\$ 6,574
28	1.5	\$ 18,404	\$ 11,043	\$ 5,288	\$ 34,735
<b>FEMA DISASTER DR-1159-WA</b>					
29	<u>1/</u> 2.0	\$ 11,697	\$ 7,018	\$ 6,004	\$ 24,719
30	1.0	\$ 21,973	\$ 13,184	\$ 4,795	\$ 39,952
31	<u>1/</u> 2.7	\$ 24,609	\$ 14,766	\$ 8,426	\$ 47,801
32	0.4	\$ 16,302	\$ 9,781	\$ 1,845	\$ 27,928
33	1.8	\$ 38,957	\$ 23,374	\$ 9,631	\$ 71,962
34	0.4	\$ 11,803	\$ 7,082	\$ -	\$ 18,885
35	1.3	\$ 21,466	\$ 12,880	\$ 1,563	\$ 35,909
<b>TOTAL</b>		\$ 1,013,018	\$ 607,811	\$ 284,931	\$1,905,760

Note: FFE designates First Floor Elevation

1/ These structures sustained some building and content damage from the December event. These damages have been netted out of the Losses Avoided figures.

## Summary

Had they not been elevated, all of the 35 homes in our study would have had inundation damage, or significant incremental damage from the December 2007 flood event. Fifteen of the structures would have experienced less than 2 feet of water, 18 would have been flooded between 2 and 5 feet, and 2 would have had over 5 feet of water above pre-mitigation first floor elevations. One home would have had 9 feet of inundation. The extent of flood damage is related to the depth of the flood within the structure, and the value of both the structure and its contents. Had these 35 homes not been elevated, the December 2007 flood would have caused between \$6,574 and \$186,122 in flood losses for each home. For just these 35 elevated homes, the total losses avoided from the December 2007 flood are estimated to be \$1,905,760.

The cost-effectiveness of these Centralia elevation projects was clearly established for a single flood event. It can be expected that the payoff from mitigation expenditures will continue to increase over the effective life of the structures, as cumulative losses avoided grow with subsequent flood events.



## **Appendix**

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