Earthquake Study

Four Vashon-Specific Scenarios

Vashon Disaster Preparedness Coalition

July 2005

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Key Findings: Four Vashon Scenarios

The Vashon Earthquake Study evaluates four possible earthquake scenarios at locations ranging from Bellevue (the much-publicized Seattle Fault Scenario) to three Vashon-specific events. The studied earthquakes range between 6.7 and 7.0 magnitude. Computer modeling for each of the scenarios utilized HAZUS software, the national standard software produced by the Federal Emergency Management Agency.

Casualty Estimates

As many as 70 people on Vashon would require some degree of medical treatment, with as many as ten people critically injured or killed by the most severe of the four studied earthquake scenarios.

- Time of day has a major effect on the number of casualties. For example, a mid-afternoon or commuter hour earthquake would be the most devastating.
    - At least two people and as many as ten would be critically injured or killed depending on which of the four scenario earthquakes took place.
    - A total of between five and as many as 24 people would suffer major, critical or fatal injuries. At least 18 people and as many as 70 would be injured, requiring at least basic medical care (beyond minor first aid).
- However, if any of the four studied scenarios takes place in the middle-of-the night HAZUS projects a sharply reduced injury rate and no loss of life on Vashon.
    - During a middle-of-the-night earthquake people would be in their homes, generally in wood frame structures. Unlike masonry buildings, wood frame structures flex during a seismic event. Although they may sustain heavy damage, their flexibility decreases their chances of total collapse and resulting catastrophic injury to the occupants.
    - By contrast, casualties rise sharply in daytime - when people are concentrated in large numbers at jobs, stores and schools, buildings that are often of masonry construction.
- The Seattle Fault Scenario, with its more distant Bellevue focus, would have serious consequences but would have the least effect on the people of Vashon. HAZUS projects that this scenario would not cause any deaths. Total injuries would range from 8 to a total of 20 people depending on time of day.

Building Damage Estimates

- About 100 to as many as 250 Vashon buildings would be so severely damaged that they would be uninhabitable. That represents between 2% and 5% of all Vashon building stock.
- In all, between 600 and 1,100 Vashon buildings would be moderately damaged or worse, meaning they would require extensive repairs or be rendered uninhabitable.
    - This total represents at least 12% and as much as 22% of all Vashon buildings.

- These buildings would be most susceptible to post-earthquake fires from damaged electrical wiring or natural gas pipes.

- Cumulatively, a total of 1,400 to 1,700 Vashon buildings would be at least slightly damaged by the four studied scenario earthquakes.
  - Two scenarios would be most damaging. More than one-fifth of Vashon structures would be damaged by either Scenario 3 (Mid-Island) or Scenario 4 (South of Vashon).
  - At least one-tenth of all Vashon buildings would be damaged to some extent by the other two scenarios.

Emergency Shelter & Food Requirements

- In the immediate aftermath of a daytime earthquake the Island would need to find shelter for a total of 640 to 1,300 people, including those rendered homeless by destruction of their homes and those mainland residents stranded on the Island by loss of ferry service.
- These sheltered people would require between 1,920 and 3,900 meals per day, a total of between 13,00 and 27,000 meals during the first week after the earthquake.
- If ferry service was out for more than a week, food needs would quickly soar as grocery stores and home pantries were depleted. Assuming a two week ferry service outage the Island could require as many as 235,000 emergency meals to feed those in shelters as well as the Island's own population once food supplies had been depleted.

Direct Economic Losses

- Depending on the scenario, direct economic losses from structure damage would be at least $41.2 million. Potentially, losses could reach nearly $83 million.
- As with casualties, two of the four scenarios have the most significant economic impacts, Scenario 3 (Mid-Island) or Scenario 4 (South of Vashon).

Why a Vashon Study?

The Seattle Fault Scenario

In early 2005 a working group published the Seattle Fault Scenario, a study of the casualties, damage and economic losses that would result from a magnitude 6.7 shallow earthquake centered on Bellevue. The results were shocking for the Puget Sound region.

- 1,600 deaths.
- 24,200 injuries.
- Most hospital facilities heavily damaged, severely reduced capacity to cope with the massive casualties.
- 9,700 buildings destroyed and another 29,000 severely damaged.
- 154,500 buildings moderately damaged.
- Collapsed bridges cutting all six major highways in the Seattle metropolitan area.
- Downtown and Fauntleroy ferry terminals damaged.
- Port facilities badly damaged.
- Utilities and other lifeline facilities cut in poor soil areas.

The Seattle Fault Scenario paints an authoritative picture. It was based on months of data gathering by a team of geologists, engineers, planners and disaster response experts. The team utilized the nationally accepted HAZUS computer modeling software to run projections. More details of this important baseline study for the Puget Sound region can be found at http://seattlescenario.eeri.org/index.php.

Vashon Stands Alone

The Seattle Fault Scenario study, adopted by reference in this study, confirmed a key planning assumption of the Vashon Disaster Planning Coalition (VDPC). The devastation and chaos of such a regional disaster would consume virtually all the resources of the mainland agencies that might ordinarily be expected to come to Vashon's aid in a more limited on-Island emergency such as a wildfire, airplane crash or terrorist attack.

Thus, Vashon would be virtually on its own in the immediate aftermath of the quake, left to deal with perhaps dozens of casualties and support of hundreds of homeless for days or even several weeks.

This Vashon-stands-alone planning assumption also holds true for the disaster recovery phase in the weeks following a regional disaster earthquake. Extreme damage to mainland transportation and the high demand for construction resources would strain resources to the limit and prevent major reconstruction help reaching the Island for weeks or possibly even a few months following the event.

What About Vashon Impacts?

Ironically, the Seattle Fault Scenario amplified the VDPC planning assumptions that the mainland would need to focus on its own enormous needs during a major earthquake event. The study contained almost no specific results for Vashon.

Therefore, the projected very serious earthquake effects on the mainland begged the questions: What conditions might Vashon be forced to face virtually alone? How many injuries? Would there be fatalities? How many homeless would require food and shelter?

Since the mainland earthquake study contained no answers to these questions for Vashon, it was clear that the Vashon Disaster Planning Coalition needed a Vashon-specific study that began where the Seattle Fault Scenario study left off.

Study Goals and Methodology

Three Goals

1. Provide a scientific and Vashon-specific estimate of earthquake casualties and damage to help Vashon agencies plan and prepare for disaster response and recovery.
2. Help the residents of Vashon understand the importance of home- and business-level disaster preparedness for their own comfort and survival.
3. Since Vashon will stand nearly alone in a regional earthquake disaster, give mainland agencies the information they need to help Vashon get ready before disaster strikes.

Methodology

- This study adopts by reference the Seattle Fault Scenario (February, 2005) study as a baseline for mainland conditions following a significant earthquake event.
- The study estimates impacts from four earthquake scenarios that create a logical bracketing pattern around and on Vashon.
    - The four scenarios test effects from the baseline Seattle Fault Scenario study, plus three more locations to the north of Vashon, the middle of Vashon, and the south of Vashon.
    - Each scenario earthquake would be severe enough to have a major impact on the mainland resources normally available to Vashon following a disaster, in keeping with the planning basis for the Vashon Disaster Preparedness Coalition.
- The same HAZUS computer modeling software utilized in the Seattle Fault Scenario study has also been used to estimate Vashon-specific casualties and damage.
    - Data gathering and HAZUS computer runs have been carried out by Vashon Disaster Planning Coalition volunteers.
    - Volunteer efforts have been overseen by expert disaster planners and geologists who volunteered their personal time to aid the effort. (Special thanks from VDPC to Dr. Greg Wessel, an Environmental Scientist/Geologist for King County who lives on Vashon, and Ed Quarles, a HAZUS expert and All-Hazard Plan Coordinator in the Washington State Emergency Management Division.
- The four scenarios fall with a range of historic intensities recorded on multiple occasions in the last century and thus represent most likely cases. The impact of a "monster" seismic event has not been estimated in this study.

Note: The HAZUS modeling software provides aggregate estimates of earthquake effects for the two census blocks on Vashon Island. The model does take into account some data on some types of critical facilities such as highways, bridges, fire stations and schools. However, building-by-building earthquake damage assessments can only be provided by qualified civil engineers following detailed site inspections. The HAZUS software does not provide facility-specific damage estimates.

Vashon-Specific Scenarios

Scenario Design Criteria

- A baseline scenario was developed around the Seattle Fault Scenario that was the nexus for creating this Vashon-specific study.
- In addition to the baseline scenario, the other three scenarios geographically bracketed the island since ground shaking varies with distance from the epicenter.
- All scenarios were designed with intensities that would absorb mainland resources in order to fit the "Vashon stands alone" worst case planning basis.

Four Earthquake Scenarios

Scenario 1 (Baseline)
Seattle Fault, Bellevue, Magnitude 6.7
The same shallow earthquake postulated in the Seattle Fault Scenario study but with Vashon-specific data and a Vashon-specific computer modeling run.

Scenario 2 (North of Vashon)
Seattle Fault, South Bainbridge, Magnitude 7.0
Identical to the Seattle Fault Scenario, except moved west on the fault to the location of a suspected historic quake of magnitude 7.3 that took place prior to the arrival of European settlers and recorded history.

Scenario 3 (Mid-Island)
Seattle Fault, Center of Vashon Island, Magnitude 7.2
Based on the suggestion of a United States Geologic Survey scientist who pointed out the potential for a "Benioff Zone" deep quake that could be located (as was the Point Robinson earthquake of 1995) on the southern edge of the Seattle Fault zone. This scenario postulates a deep earthquake 50 kilometers below the surface.

Scenario 4 (South of Vashon)
Tacoma Fault, Dalco Passage, Magnitude 6.7
A seismic event on the postulated but not yet well-studied Tacoma Fault at a relatively shallow depth of 15 kilometers under the water passage between Point Defiance and the southern tip of Vashon Island.

In order to study the effects of these four earthquake scenarios, the HAZUS computer modeling program was loaded with Vashon-specific soil, liquefaction, and landslide data in consultation with an expert geologist with detailed knowledge of Vashon conditions. The national default data included in the federal database was enhanced by a team that collected additional detail on various critical facilities on the Island. It should be reiterated that HAZUS does not provide fine-grained estimates of damage for specific sites. It analyzes by census block. There are two census blocks on Vashon: 1) the north half of Vashon Island, and 2) the south half of Vashon Island plus Maury Island.

Ground Shaking & Soil Condition Analysis

Calculations of ground shaking form the foundation of the HAZUS computer projections of casualties and damage. In general, the greater the ground shaking, the greater the casualties and building damage.

Seismologists measure ground shaking in terms of peak ground acceleration (PGA). The four earthquake scenarios postulated in this study would generate peak ground accelerations in the two Vashon census blocks in the range of .22 to .35g. That means the back and forth horizontal shaking would equal 22% to 35% of the force of gravity.

Ground Shaking Projections for Vashon

Scenario	North Vashon	South Vashon/Maury
1. Baseline	.283g	.219g
2. North of Vashon	.346g	.248g
3. Mid-Island	.305g	.293g
4. South of Vashon	.281g	.349g

As points of reference, here are some ground shaking estimates for other projected and historic earthquakes.

- .10g to .12g on Vashon during the 1995 Nisqualy earthquake.
- .65g near the Bellevue epicenter of the Seattle Fault Scenario compared to approximately .22g to .28g on Vashon (Scenario 1 of this study).
- .65g at the epicenter of the 1994 Northridge earthquake compared to .25g to .30g in downtown Los Angeles.

Ground shaking generally decreases with distance from the epicenter. Therefore, as the study shows, a northern earthquake would have greater effects on the north end of the Island. A mid-Island earthquake would cause more evenly distributed ground shaking. A southern earthquake would cause more ground shaking in the south Island areas.

Certain types of soils amplify the energy from an earthquake and thus result in more ground shaking for a given magnitude of earthquake. This variable was taken into account in the study. For Vashon, the participating experts recommended assuming a default soil type found in most of the western United States. Additional factors were also applied to account for the potential landslide and liquefaction hazards around Vashon's coastline, including the ancient land slump along the east shore of Maury Island and the gravel soils left by the last glacial age at the southern tips of Vashon and Maury Islands.

It should be noted that perhaps 40% of Vashon housing has been built in areas described as landslide prone areas in the King County hazard maps. However, these maps do not predict landslides. Instead, they suggest a heightened risk at any given location within the hazard area. Experience tells us that landslides would be an intermittent effect of seismic activity within the designated hazard area. Depending on the severity of the event, road closures and home collapses would be likely at some locations but would not be a universal or even widespread result of the four scenario earthquakes. In addition, homes built since the Seventies generally conform to modern building codes that increase the survivability of residents caught inside them during an earthquake.

Building Damage Estimates

Based on ground shaking estimates, the HAZUS computer model calculates the aggregate damage to various types of homes, businesses, and other structures in the study area. Information about buildings and population in the HAZUS database comes from the 2000 census. Two important points must be repeated for those studying this section:

- Building damage estimates do not refer to any specific buildings or geographic group of buildings. Rather, the computer model computes damages based on the aggregate building stock, assuming average construction.
- Rounding errors for different types of calculations of building damage counts result in minor differences in category and scenario totals between the various tables.

Summary of Building Damage Estimates

- About 100 to as many as 250 Vashon buildings would be so severely damaged that they would be uninhabitable. That represents between 2% and 5% of all Vashon building stock.
- In all, between 600 and 1,100 Vashon buildings would be moderately damaged or worse, meaning they would require extensive repairs or be rendered uninhabitable.
    - This total represents at least 12% and as much as 22% of all Vashon buildings.
    - These buildings would be most susceptible to post-earthquake fires from damaged electrical wiring or natural gas pipes.
- Cumulatively, a total of 1,400 to 1,700 Vashon buildings would be at least slightly damaged by the four studied scenario earthquakes.
    - Two scenarios would be most damaging. More than one-fifth of Vashon structures would be damaged by either Scenario 3 (Mid-Island) or Scenario 4 (South of Vashon).
    - At least one-tenth of all Vashon buildings would be damaged to some extent by the other two scenarios.

Building Damage Count by Scenario

Extent of Damage	Scenario 1 Baseline	Scenario 2 North of Vashon	Scenario 3 Mid-Island	Scenario 4 South of Vashon
Slight	1,368	1,524	1,729	1,717
Moderate	495	628	819	891
Extensive	82	118	185	175
Complete	14	26	67	48
Total Moderate to Complete Damage	591	772	1,071	1,114
% of All Vashon Buildings	*12%*	*15%*	*21%*	*22%*
Total Uninhabitable (Extensive or Complete Damage)	96	144	252	223
% of All Vashon Buildings	*2%*	*3%*	*5%*	*4%*

Count of Uninhabitable or Unusable Buildings by Type & Scenario
(Buildings Extensively Damaged or Completely Destroyed)

Type of Building	Scenario 1 Baseline	Scenario 2 North of Vashon	Scenario 3 Mid-Island	Scenario 4 South of Vashon
Single Family	24	40	66	86
Other Residential	68	97	174	128
Commercial	4	5	9	7
Industrial	1	1	1	1
Education	0	0	0	0
Agriculture	0	0	0	0
Government	0	0	0	0
Religion	0	0	0	0
Total	97	143	250	222
% of All Vashon Buildings	*2%*	*3%*	*5%*	*4%*

Casualty Estimates

Based on ground shaking estimates, and the resulting estimated building damage, HAZUS can predict potential casualties from an earthquake event.

Time of day makes a major difference in casualty counts. Earthquakes injure far fewer people if they happen in the middle of the night, as opposed to the middle of the business day or during commuting hours. A range of factors explains this effect. For example:

- In the middle of the night most people are in their homes. Wood frame homes resist total collapse in earthquakes surprisingly well since they flex with the shaking. Survivability increases further if the dwelling was built since modern building codes were enacted.
- During daytime, more people are shopping, working or in school. Commercial dwellings built of masonry are more brittle and the collapse of a given building will cause incrementally more injuries because people are concentrated in one spot.

HAZUS classifies injuries into four severity categories, which this study characterizes as minor, major, critical and fatal injuries for brevity in the following tables.

- Severity 1 *(Minor)* injuries require basic medical aid but not hospitalization.
- Severity 2 *(Major)* injuries require a greater medical care and hospitalization, but are not life threatening if treated.
- Severity 3*(Critical)* injuries pose an immediate threat to life if not treated adequately and expeditiously.
- Severity 4 *(Fatal)* means the victims were instantaneously killed or mortally injured.

Summary of Casualty Estimates

- By far, the on-Island earthquake scenario (Scenario 3, Mid-Island) presents the worst case of the four studied scenarios with between 20 and 70 total injuries, and as many as 10 people critically or fatally injured depending on the time of day.
- The Seattle Fault Scenario, with its more distant Bellevue focus, would have serious consequences but would have the least effect on the people of Vashon.
    - HAZUS projects that this scenario would not cause any fatal injuries.
    - Total injuries would range from 8 to a total of 20 people with most injuries being cause by a daytime earthquake.
- A middle of the night event would be the least serious of the three studied times of day. If one of the four scenario earthquakes hit at 2:00am:
    - No lives would be lost and there would be no critical injuries according to HAZUS projections.
    - Between one and three people would suffer major injuries requiring hospitalization. At least eight people and as many as 20 would be injured, requiring at least basic medical care.

- A mid-afternoon earthquake would cause the most total injuries of the studied times of day, but would not be the worst case for critical and fatal injuries.
  - At least two people and as many as six would be critically injured or killed.
  - A total of between five and as many as 20 people would suffer major, critical or fatal injuries. At least 20 people and as many as 70 would be injured, requiring at least basic medical care.
- A commuter hour earthquake would kill the most people and cause the highest number of severe injuries, although total injuries would be slightly fewer than a mid-afternoon earthquake.
  - At least two people and as many as 10 people would be critically injured or killed.
  - The number of major, critical or fatal casualties would total at least five and as many as 24 people. Total injuries from a commuter hour earthquake would range from 18 to 65 people.

VDPC recognizes the sensitivity of the casualty projections in this study and emphasizes again that HAZUS estimates casualties and damages in the aggregate and not a fine-grained manner. Findings are not linked to any specific buildings or neighborhoods.

Middle of Night (2:00am) Casualty Count by Severity & Scenario

Severity	Scenario 1 Baseline	Scenario 2 North of Vashon	Scenario 3 Mid-Island	Scenario 4 South of Vashon
1. Minor	7	10	17	14
2. Major	1	2	3	2
3. Critical	0	0	0	0
4. Fatal	0	0	0	0
Total Injuries	8	12	20	16
Total Major, Critical & Fatal	1	2	3	2
Total Critical & Fatal	0	0	0	0

Work Day (2:00pm) Casualty Count by Severity & Scenario

Severity Levels	Scenario 1 Baseline	Scenario 2 North of Vashon	Scenario 3 Mid-Island	Scenario 4 South of Vashon
1. Minor	15	25	50	35
2. Major	3	6	14	9
3. Critical	1	1	2	2
4. Fatal	1	2	4	3
Total Injuries	20	34	70	49
Total Major, Critical & Fatal	5	9	20	14
Total Critical & Fatal	2	3	6	5

Commuter Hours (5:00pm) Casualty Count by Severity & Scenario

Severity Levels	Scenario 1 Baseline	Scenario 2 North of Vashon	Scenario 3 Mid-Island	Scenario 4 South of Vashon
1. Minor	13	21	41	30
2. Major	3	7	14	9
3. Critical	1	3	6	5
4. Fatal	1	2	4	3
Total Injuries	18	33	65	47
Total Major, Critical & Fatal	5	12	24	17
Total Critical & Fatal	2	5	10	8

Emergency Shelter & Food Requirements

Based on the HAZUS results and some additional data gathering, we have been able to estimate Vashon's requirements for shelter and food following the four scenario earthquakes. Three circumstances drive post-earthquake requirements for temporary housing and food distribution.

- The number of Islanders left homeless because their dwellings have been damaged to the point that they would be uninhabitable.
- The number of mainland residents who might be stranded on the Island by a daytime earthquake (teachers, business employees, etc.).
- The length of time before ferry service could be restored to supply food, to remove stranded mainlanders to their homes, and to Vashon residents stranded on the mainland.

Summary of Emergency Shelter & Food Requirements

- In the immediate aftermath of a daytime earthquake the Island would need to find shelter for a total of 640 to 1,300 people, including those rendered homeless by destruction of their homes and those mainland residents stranded on the Island by loss of ferry service.
- During the first week after the earthquake these sheltered people would require between 1,920 and 3,900 meals per day, a total of between 13,00 and 27,000 total meals.
- If ferry service was out for more than a week, food needs would quickly soar as grocery stores and home pantries were depleted. Assuming a two week ferry service outage the Island could require as many as 235,000 emergency meals to feed those in shelters as well as the Island's own population once food supplies had been depleted.

Emergency Shelter

- The building damage section of this study provides the baseline for estimating the number of people left homeless on the Island by one of the four studied scenario earthquakes.
    - About 100 to as many as 250 Vashon buildings would be so severely damaged that they would be uninhabitable.
    - At the Census estimate of 2.4 residents per household, at least 240 people and as many as 600 people would need to be housed in emergency shelters.
- A daytime ferry census conducted for emergency planning purposes shows that 400 to 700 mainland residents commute to the Island each day. This number could be stranded on the Island by a daytime earthquake event and would require emergency shelter.
- Many variables could affect the number of people who would require shelter following an earthquake.

- A middle-of-the-night earthquake would have a significant positive impact on emergency requirements since mainland commuters would not be stranded on the Island.
- Some homeless would be taken in by neighbors and some would find lodging in the Island's small number of bed and breakfast establishments rather than avail themselves of emergency shelter.
- A seismic event during summer could significantly increase the number of people requiring shelter. For example, summer camps attract an estimated 500 to 750 attendees. The camps have detailed disaster plans and we have assumed for this study that this population will be sheltered on site, although earthquake damage could impinge capacity.
- A seismic event on a holiday or summer weekend could find many people enjoying their vacation homes on the Island. There are more than 500 such dwellings on Vashon and Maury Islands. At an average of 2.4 per household this could swell shelter requirements by more than 1,000 beds.

Shelter Requirements by Scenario (Daytime Event – 2.4 Residents/Household)

	Scenario 1 Baseline	Scenario 2 North of Vashon	Scenario 3 Mid-Island	Scenario 4 South of Vashon
Homeless	240	345	600	530
Stranded	400 to 700	400 to 700	400 to 700	400 to 700
Total Beds	640 to 940	745 to 1,045	1,000 to 1,300	930 to 1,230

Emergency Food

- Estimates of emergency food requirements depend heavily on when the Island's sole means of supply - the ferry system - could be restored following a seismic event.
  - The Seattle Fault Scenario predicts damage to the mainland ferry facilities in downtown Seattle and at Fauntleroy, and extensive damage to the region's freeway system due to collapsed bridges. Together, these circumstances suggest major delays in supplying food to the Island.
  - In the absence of a working highway system, emergency response planners on the mainland have run scenarios that assume the ferry system would be commandeered as an emergency transport link to help deal with the massive mainland needs predicted by the Seattle Fault Scenario.
- The most immediate needs for food would be to care for the homeless and stranded mainlanders housed in emergency shelters. For a daytime event, at three meals per day, Vashon would immediately need to supply between 1,920 and 3,900 meals per day to those in shelters. That amounts to 13,000 to 27,000 meals in the first week after the earthquake.
- We estimate that Island residents still in their homes would run out of food within one week. Island grocery stores would quickly deplete reserve supplies with no hope of

replenishment until restoration of the ferry system. Most residents probably do not stock more than one week's worth of food.

- The 2000 census recorded roughly 10,000 permanent Island residents. Food requirements from week two onward would be very severe, especially for a middle-of-the-night event that would see nearly all the Island's residents at home.
  - For a daytime event, we have estimated that 2,500 residents could be off-Island for work, school and shopping during a daytime summer event. That leaves 7,500 residents to be fed once supplies run out.
  - The number of people requiring meals during the second week following an earthquake could be as high as 10,000 for a middle-of-the-night event.
- If the ferry service was out for two weeks, the Island might need to supply as many as 215,000 to 235,000 in order to feed the homeless and the Island's own population once food supplies had been depleted.

Meal Requirements by Week (Daytime Event)

	Week 1	Week 2	Two Week Total
Homeless	5,040 to 12,600	5,040 to 12,600	10,080 to 25,200
Stranded	8,400 to 14,700	8,400 to 14,700	16,800 to 29,400
Residents	0	157,500	157,500
Total Meals	13,440 to 27,300	170,900 to 184,800	184,380 to 212,100

Meal Requirements by Week (Middle-of-the-Night Event)

	Week 1	Week 2	Two Week Total
Homeless	5,040 to 12,600	5,040 to 12,600	10,080 to 25,200
Stranded	0	0	0
Residents	0	210,000	210,000
Total Meals	5,040 to 12,600	215,040 to 222,600	220,080 to 235,200

Direct Economic Loss Estimates

The HAZUS computer model calculates two kinds of direct economic losses that relate to structure damage.

- Capital stock losses include structure, contents and business inventory damages.
- Income losses include relocation, capital, wages, and rental losses.

These estimates do not include indirect or "multiplier effect" economic losses that are more diffuse. These long term effects are difficult to calculate in cases of major disaster since reconstruction, however much a hardship it might present, generates countervailing economic activity by such businesses as building contracting and retail household goods stores, as well as wages for workers in the building trades.

Summary of Direct Economic Losses

- Depending on the scenario, direct economic losses from structure damage would be at least $41.2 million. Potentially, losses could reach nearly $83 million.
- Two scenarios, Mid-Island and South of Vashon, have the worst effects and economic damages from the four scenarios track closely with the degree of structural damage projected by HAZUS.

Direct Economic Losses from Structure Damage by Scenario (In Rounded Millions of Dollars)

Type of Loss	Scenario 1 Baseline	Scenario 2 North of Vashon	Scenario 3 Mid-Island	Scenario 4 South of Vashon
Capital	36.3	51.1	72.0	65.2
Income	4.9	7.0	10.9	8.6
Total	$41.2	$58.1	$82.9	$73.8

Not Covered in This Analysis

Resource limitations have prevented analysis of a number of earthquake effects that could have serious consequences on Vashon. In a future update to this study the authors hope to incorporate planning estimates of:

- Potential secondary damage from tsunami or seiching wave action following a severe earthquake.
- Potential secondary damage from fires following an earthquake as a result of damage to natural gas and electrical power lines.
- Sanitation problems caused by cuts of electrical power to the Island's sewer district and to septic system pumps.
- Water supply problems caused by breaks in service lines or loss of electrical power involving the Island's dozens of large and small water services.
- Earthquake susceptibility of Vashon's two ferry terminals, given that the Seattle Fault Scenario estimates damage to both the downtown Seattle and Fauntleroy terminals.
- Earthquake susceptibility of Vashon's electrical and natural gas utility service through information sharing and collaboration with Puget Sound Energy.
- Earthquake susceptibility of Vashon's telecommunications utility service, including land line and cellular telephones, and television cable service through information sharing and collaboration with CenturyTel and Comcast.

It should be noted, for planning purposes, that VDPC has identified four communications resources that have been incorporated into the Island's disaster planning.

- A primary emergency two-way radio service will be the Vashon Island Fire and Rescue system. The system links with the Valley Comm dispatch center and King County Emergency Coordination Center via the county-wide 800 Mhz system. The fire department's original VHF radio system and dispatch console have also been retained and will serve as backup.
- An extensive Island Backbone two-way radio-based system of emergency communications, with several redundant frequencies and systems, has been established through collaboration between local Amateur Radio operators and VDPC.
- CenturyTel has indicated that the Island's telephone service was originally operated as a self-contained Island phone company. This design history, along with service redundancy required by federal law, suggests that the Island has a good chance of having intra-Island phone service within a few hours of an earthquake event.
- The Island's Internet-based radio station, Voice of Vashon, has developed and tested an emergency broadcast system that will allow short range live broadcasting on the FM band in the event of a disaster.

The Lessons of History

History teaches us that the four earthquake scenarios in this study are well within the range of probability. Some would contend that earthquakes of this severity are fundamental to the natural history of the Puget Sound region. The Mount Saint Helens eruption of 1980 demonstrated powerfully that Puget Sound residents share the Pacific "Ring of Fire" with such seismically volatile locations as Alaska, Japan, Hawaii and Indonesia.

The Seattle Fault dominates the Puget Sound seismological landscape. The centerline of the east-west fault starts under Issaquah on the east, runs south of downtown Seattle and on out to the Hood Canal in the west. Since the cross section of the fault slants down and to the south, the fault zone includes a wide band of sub-faults that extend deep beneath the surface under Vashon Island.

Geologists believe that earthquakes of magnitude 7.6 to 7.7 are very possible on the Seattle Fault and that major events of that magnitude take place every 500 to 1,500 years. Evidence indicates the last such Seattle Fault event took place around 900 AD.

A number of more moderate but still severe seismic events have been recorded just in the last 55 years, many of them on the Seattle Fault.

April 13, 1949, Between Olympia and Tacoma, Magnitude 7.1: This earthquake killed eight people and seriously injured dozens. On Vashon there was slight to moderate damage to well-built structures and considerable damage to poorly built buildings. Chimneys broke and fell. No deaths or injuries were recorded on Vashon.

April 29, 1965, South Seattle, Magnitude 6.5: The shaking affected an area over 130,000 square miles and killed three people, all in Seattle.

- On Maury Island, the earthquake was sharply felt with rapid motion and loud earth noises but damage was slight. Chimneys twisted and fell. Plaster, windows, walls, chimneys, and ground cracked. Dishes and windows broke. Knickknacks, books, pictures, and plaster fell. Small objects and furnishings shifted; vases and small objects overturned.
- On Vashon Island the quake was also sharply felt. There was considerable chimney loss. Wall cracks and fallen plaster were reported from practically all parts of Vashon with the southern and western sections reporting most severe damage. The Burton-Tahlequah Road settled. Stock was thrown from shelves in markets and bottles broke.

January 29, 1995, Point Robinson on Maury Island, Magnitude 5.0: This shallow quake was attributed to one of the north-trending thrust faults of the Seattle fault zone. While it was widely felt by Island residents, no structural damage was noted and little personal property was affected.

February 28, 2001, Nisqually Delta between Olympia and Tacoma, Magnitude 6.8: The Nisqually quake has become the most studied and analyzed Pacific Northwest seismic event in history. On Vashon and Maury Islands, damage was light and limited to cracked and toppled chimneys, ruptured natural gas lines and several minor landslides. Three small slides accompanied by associated fissures rendered access roads to residential areas impassable to heavy vehicles such as fire engines and water tenders. One person was killed in West Seattle. There were no injuries or major damage on Vashon.