Chapter 4.1
Dam Failure Hazard Risk Assessment

Introduction

A catastrophic dam failure would principally impact residents, businesses, property owners, and assets in unincorporated Thurston County, the Nisqually Indian Reservation, and the Town of Bucoda. However, impacts would be experienced regionally because flood damage and impacts to roads, power, and critical facilities would indirectly impact a larger portion of the population that lives in dam failure inundation areas.

Previous versions of this plan identified the risks of dam failure. However, a dam failure was not profiled in detail in the risk assessment. This plan update includes a new dam failure hazard profile, and this chapter describes the potential risks from catastrophic dam failure to people and community assets.

Climate change will produce warmer and wetter winters for Western Washington. The total days and quantity of rainfall is modeled to surpass the normal range of variation (see Chapter 4.5 Severe Weather Hazards Risk Assessment). There is a high likelihood for a single extreme atmospheric river or a series of heavy rainfall events to occur. More extreme precipitation

will increase the risks for landslides, glacial outbursts, and flood events that could adversely impact normal dam operations. There is great uncertainty how future climate conditions could achieve or surpass probable maximum flood conditions that older dams were designed to withstand. Profiling dam failure and its risks provides affected communities information to identify mitigation strategies to safeguard people, property, and the environment.

Definition

In the context of hazard mitigation planning, dam failure is a catastrophic type of failure characterized by the sudden, rapid, and uncontrolled release of impounded water which creates life and property threatening impacts downstream from the dam.

For dam operations, there are lesser degrees of failure. Any malfunction or abnormality outside the design assumptions and parameters that adversely affect a dam's primary function of impounding water is properly considered a failure. Lesser degrees of failure can progressively lead to or heighten the risk of a catastrophic failure. However, lesser degrees of failure, when detected early can normally be mitigated with immediate corrective action.

Causes of Dam Failure

There are several mechanisms that could be the driving force to cause a catastrophic failure. A review of local dams' Emergency Action Plans and federal dam regulatory agency resources identify possible sources of dam failure that could affect dams in Thurston County. These causes are described below. The US Corps of Engineers Hydraulic Reference Manual summarizes several possible failure modes based on the type of dam construction (Figure 4.1.1).[1]

Deferred Maintenance – Like any infrastructure, dams need to be maintained so that minor problems don't become major issues. Vegetation in Western Washington grows prolifically and quickly. Trees and brush, and burrowing animals increase the chances for internal erosion and surface slides of earthen dams. Debris can block spillways. Dams must be routinely monitored and maintained to prevent potential failures.

Earthquake – Major seismic events with sufficient violent ground shaking could compromise the structural integrity of an earthen or concrete dam or the ability of dam operations personnel to safely operate the dam.

Overtopping – Severe storms with excess rain or heavy snowpack, volcanic lahars, or mudflows can swell rivers, increase runoff, and create flood conditions that can exceed a spillway's operational capacity to maintain safe water levels below the crest of a dam structure. Malfunctioning spillway gates can also lead to overtopping. Overtopping is also caused by the action of high-speed wind driven waves that wash across the crest of a dam. Earth embankments are not designed to be overtopped and are vulnerable to the erosive action of excess water spilling over the embankment. According to the US Army Corps of Engineers, 30 percent of dam failures in the United States are attributed to overtopping.

Overturning – horizontal and vertical forces such as water pressure, silt pressure, and uplift pressure can act against a gravity dam, creating overturning force or rotation of the structure. The structure resists this rotation by having adequate weight. If the sum of all the forces acting on a dam surpasses its design threshold, either through or outside of the downstream toe of the dam, the dam will rotate and overturn.[2]

Piping – Most all dams experience some level of seepage. Earthen dams are vulnerable to internal erosion, a process called piping. Soil erosion can occur by flowing water if there are cavities, cracks in rock, or other openings large enough so that soil particles can be transported away by seeping water. This type of underground erosion, when not detected and corrected, can create an open path for flow and grow to breach that causes a dam failure and an uncontrolled release of impounded water.

Sabotage – an act of terrorism such as an explosive device could cause structural damage resulting in a major breach.

Sliding – When the dam slides over its foundation or one part of the dam slides over a part of itself, it is called a sliding failure. It occurs when the net horizontal forces acting on the gravity dam exceed the frictional resistance produced between the body of the dam and the foundation.

Figure 4.1.1 Possible Modes of Failure by Dam Type

Failure Mode	Earth Fill/Embankment	Concrete Gravity	Concrete Arch
Cracking	X	X	X
Equipment Failure	X	X	X
Foundation Defects	X	X	X
Overtopping	X	X	X
Overturning		X	X
Piping	X	X	X
Sliding	X	X	

Area of Impact

Thirty-eight 38 dams are located in or immediately adjacent to Thurston County. Eight of these are categorized as high hazard potential dams. This category is assigned to dams that have a potential to threaten life safety and property downstream in the event of their catastrophic failure. Thurston Regional Planning Council obtained copies of Emergency Action Plans for each of the high hazard potential dams from the Washington State Department of Ecology (WADOE) and the dam owners.

The dam failure hazard risk assessment only characterizes the community risk ratings for two dam project failure scenarios.

1. The Nisqually Hydroelectric Project, consisting of the Alder and La Grande dams; and
2. The Skookumchuck Dam

These scenarios were selected for Hazus modeling analysis because failures of these dams present the greatest risk to the region's population and assets. Future updates of the mitigation plan will attempt to perform additional exposure analysis for the other high hazard potential dams. See Map 4.1.2 for the dam failure inundation areas for these two scenarios. The results of these scenarios are presented in the Vulnerabilities and Impacts section and the community risk ratings are shown in the Risk Characterization section.

Table 4.1.1 lists the high hazard potential dams located in or immediately adjacent to Thurston County.[3] Figure 4.1.2 lists the categories of downstream hazard categories if a structure were to fail with an uncontrolled release of its reservoir. Information about each dam was gathered from the operator's Emergency Action Plan (EAP). The EAP describes the dam structures, identifies conditions that may endanger the dam, identifies actions to mitigate dam failures, and specifies protocols for notifying emergency personnel of an impending or actual dam failure. A summary of each dam and its downstream impacts is presented below.

LaGrande Dam. Photo courtesy Washington State Department of Transportation

Table 4.1.1 High Hazard Potential Dams and Impoundment Structures in or Near Thurston County

Dam	Owner	Year Built	Type	Height (Ft)	Length (Ft)	Storage (Acre Ft)	Purpose	Primary[1] Regulatory Agency	Hazard Category
Alder	Tacoma Public Utilities	1945	Concrete Single Arch	330	1,150	241,950	Hydroelectric & Recreation	FERC	1A
LaGrande	Tacoma Public Utilities	1944	Concrete Gravity	217	710	3,015	Hydroelectric	FERC	1B
Berger	Robert & Michelle Strawn	1970	Earth	11	500	128	Recreation	WADOE	1C
Kyte	Southwest Resources LLC, Jorgensen Timber	1966	Earth	20	265	27	Irrigation/ Recreation	WADOE	2D
Skookumchuck	TransAlta Centralia Generation	1970	Earth	195	1320	35,000	Water supply for Centralia Steam Plant	FERC	1A
SPSCC Stormwater Pond F	SPSCC	2005	Earth	10	680	12	Stormwater Conveyance	WADOE	1C
Rainier Lake Dam (Formerly Windsor Waterski Pond)	Windsor Estates Homeowners Association	1992	Earth	11	350	175	Recreation	WADOE	1C
Yelm Hydroelectric Project	City of Centralia	1929	Concrete and Earth	20	48,050	350	Hydroelectric	FERC	High

[1]FERC = Federal Energy Regulatory Commission; WADOE=Washington State Department of Ecology

Figure 4.1.2 Downstream Hazard Classification

Hazard Classification	Lives at Risk	Risk Level
1A	Greater than 300	High
1B	31 to 300	High
1C	7 to 30	High
2D	1 to 6	Significant

Nisqually Hydroelectric Project – the Alder and La Grande Dams

The Alder and LaGrande dams are located on the Nisqually River. The City of Centralia's Yelm Hydroelectric Plant is located about 15 miles downstream from the Nisqually Project at approximately River Mile (RM) 26.2. There are no recreation areas, water retention facilities, or residences immediately downstream of the dams that require individual notification. The town of McKenna (in Pierce County), with a population of 716 is located about 32 miles downstream of Alder Dam. State Route 507, which is approximately RM 22, crosses the Nisqually River, cuts through the center of McKenna, and continues into Yelm. Portions of McKenna would be affected, including the facilities adjacent to the river. The City of Yelm is located at approximately RM 14. Access to Yelm may be restricted, but facilities would not be affected. Nisqually Tribal Lands lie approximately between RMs 11 and 4.5. Facilities within the area which could be impacted include the fish hatcheries, the aqueduct pumping station, a school, and some residences (See Map 4.1.1).

The Tacoma Power Nisqually Hydroelectric Project EAP was last updated in December 2022 and identifies procedures and responsibilities for notifying local, state, and federal agencies of all types of dam failure that are categorized by Tacoma Power. Tacoma Power reports that they are presently performing a new flood inundation study that will include additional reservoir variable discharge scenarios. This study is expected to be completed within one to two years.

Berger Dam

The Berger Dam is located on a tributary of Scatter Creek approximately 1.4 miles northeast of the City of Tenino near Strawn Lane. The dam's EAP was last updated in May 2020. The Berger Dam EAP consists of two inundation maps that show dam break water flowing within Scatter Creek. Floodwater will drain and flood properties as far west near Old Hwy 99 SE in Tenino. The EAP is unclear about the number of residences at risk for dam floodwater inundation. It identifies at least five residences that are located in the inundation area. However, the inundation maps are annotated that the inundation area could impact 37 to 61 homes with major flooding but requires verification. The EAP reports the first residence would be inundated by over seven feet of floodwater in six minutes after a dam failure. Floodwater would reach Old Hwy 99 SE in approximately 95 minutes and reach a maximum depth of nearly seven feet.

Two flood simulation scenarios and reports were prepared using Decision Support System for Water Infrastructure Security (DSS-WISE) GIS modeling software in 2021. This analysis generated updated inundation area maps for a Berger Dam failure that is not cited in the EAP. A visual examination of the updated inundation area over arial photos shows properties along Strawn Lane, Valentine Road SE, and Old Military Road SE will most likely be impacted. A more thorough analysis of potential flood risks should be examined prior to the next hazard mitigation plan update.

Kyte Dam

The Kyte Dam is located in a remote area of south Thurston County on an unnamed tributary of Coffee Creek that flows into the Skookumchuck River. The dam's EAP was last updated in June 2022.

One residence and several greenhouses are located in the dam's inundation area. Slape/Mcelfresh and Boyd roads are also in the inundation area and would be affected. Floodwaters would reach the residence approximately 12 minutes after the dam failure.

Skookumchuck Dam

The Skookumchuck Dam is located on the Skookumchuck River in south Thurston County approximately 12 miles upstream from the Town of Bucoda. The area immediately downstream from the dam is rural. A Washington Department of Fish and Wildlife hatchery is located 0.6 RM below the dam. Properties in the Skookumchuck River Valley along Skookumchuck Road and its connecting local roads, Johnson Creek Road, Tono Road, 184th Avenue SE are in the inundation area. SR 507 would be flooded from 180th Avenue SE to the Lewis County border. The entire Town of Bucoda is in the dam breach inundation area and would be isolated due to all connecting roads being flooded. The EAP was last updated in July 2023. The EAP includes an inundation study for a probable maximum flood dam failure scenario. This scenario models a 16-foot surface water elevation above the 100-year flood for the Town of Bucoda.

This plan's risk assessment modeling analysis reveals that nearly 230 buildings in Bucoda are exposed to dam failure risks and 94 percent of the town's population would be impacted.

The dam floodwaters would drain into the Scatter Creek basin south into Lewis County and drain into the Chehalis River before re-entering Thurston County. North of the Lewis County border, floodwater would impact areas around Prather Road SE, James Road SE, Independence Road SE, Moon Rd SE, and US Highway 12 north to the Black River near the unincorporated area of Gate. 615 residences in unincorporated Thurston County would be affected.

SPSCC Stormwater Pond F

The South Puget Sound Community College (SPSCC) Stormwater Pond F straddles the border of Olympia and Tumwater City Limits. It sits immediately below the F parking lot on the south edge of the campus. It is a below grade stormwater retention pond for nearby residences on 29th Avenue SW and the F parking lot. There are no residents living downstream from the structure. The impoundment is above grade to the south end of the SPSCC campus.

The stormwater pond spillway will convey rising water to a surface drainage swale below the impoundment. SPSCC staff stated they have never seen water in the pond reach the elevation of the spillway. Spillway water will drain to an adjacent wetland. During wet year conditions, the wetland is designed to overflow via an engineered swale to an inlet that drains an underground stormwater bypass near the college's Technology Building. This drains into a stormwater pond between buildings 32 and 34. This pond then drains via a culvert directly to Percival Creek.

Page 13 of the EAP indicates that 29th Ave SW (Tumwater) is listed as a road at risk. However, the stormwater pond is below grade from 29th Ave is not vulnerable. There are no residences in the path of the flood zone below grade from the stormwater pond. The Technology Building on campus is also listed as a vulnerable asset. If a catastrophic failure of the embankment occurred, impacts would likely be minimal due to the open space and wetland that lies immediately below the pond. The second stormwater pond between the Technology Building and the Percival Creek outflow culvert would effectively mitigate any major flood damage.

The EAP was last updated in September 2016. This stormwater pond deserves reevaluation as a high hazard potential classification at the time the EAP is updated. The EAP should be updated to accurately report on dam failure vulnerabilities and its emergency contact information. At present, the college's ongoing security patrols, routine structural inspections, and maintenance activities are sufficiently maintaining the safe operation of this facility.

Rainier Lake Dam (Formerly Windsor Waterski Pond)

The Rainier Lake Dam is located at Morris Road SE and 127th Lane SE. It is a recreational impoundment that is owned by the Windsor Estates Homeowners Association. It was originally developed as a waterski pond in 1992. The EAP appears to have been last updated in 2016. The flood path in the

EAP was identified by WADOE in 1991. A downstream breach hazards map shows flow paths for a northeast breach and a southeast breach. In general, the flow paths drain toward Yelm Creek. The EAP is not clear about the number of downstream residents and properties that are potentially impacted. The EAP states five residences are located in the dam break floodplain. However, the EAP lists seven residences, two barns, and a few outbuildings on eight parcels that are at greatest risk. In addition, breach hazard maps that are not included in the EAP appear to show at least 17 residences and structures as at risk in the dam failure flow path in the vicinity of Morris Road SE and 123rd Avenue SE. The maps also show properties east of Morris Road SE near Harris Road SE as potentially at risk.

Yelm Hydroelectric Project

The Yelm Hydroelectric Project is a "run of the river dam" located near the communities of Yelm and McKenna. A diversion dam and intake structure are located at Nisqually RM 26.2, about 4 miles southeast of McKenna. The project's major structures include a concrete diversion dam, an intake structure, a 9.1-mile-long earthen canal, three spillways, forebay, gatehouse, two penstocks, powerhouse, and transmission lines. The diversion dam, constructed in 1985, is a concrete gravity dam. The dam has a structural height of 20 feet, but a hydraulic height of only four feet at low stages. During high stages, the dam is nearly submerged with a difference of less than one foot between the headwater and tailwater. The EAP states that this low hydraulic differential combined with the large-channel-capacity of the Nisqually River diminishes the risk of overflooding consequences from a structural failure of the diversion dam.

The Centralia power canal was first constructed in 1929. It conveys water to the powerhouse downstream from the dam. It has a maximum flow rate of 800 cubic feet per second. The normal average depth is nearly 12 feet, and the average velocity is 2.2 feet per second. The canal runs parallel to the Nisqually River and north of the City of Yelm. The distances between the canal and the river vary from about 100 feet at the diversion dam, to 500 feet near the McKenna Bridge on SR507, and up to 1.2 miles near the Yelm Creek Flume. The slope of the land between the canal and the river varies at average rates between one and four percent. The land is mostly forested with some single homes, residential developments, mobile home parks, and farmland. If the canal failed, residences and businesses within some areas of the inundation zone could see flood depths of two or more feet.

The EAP is concerned with the possible failure of the canal embankment. A series of flow and level sensors are located in high hazard areas to monitor the canal. Yelm Hydroelectric Project staff also inspect the canal and the diversion dam daily. The project does not sustain high flows within the canal; any cause for high flows would be the result of the Nisqually

River overtopping the canal embankment. The Nisqually Hydroelectric Project has a major impact on the elevation and flow of the Nisqually River. Unlike the other dam structures in Thurston County, the canal could be adversely impacted by vehicle accidents with vehicles entering the canal and creating an obstruction that could lead to failure.

A canal failure would likely be a progressive failure than an imminent failure. However, the EAP includes hypothetical canal breach scenarios that are instantaneous events. Inundation maps with flood arrival times, maximum depths, and maximum velocities are included in the plan to provide general guidance to the timing of events. In general, a canal failure flow from the canal to the river is estimated to be between one and twenty minutes, depending on the location of the breach. A failure of the canal would likely produce localized flooding at the site of the breach and flooding would occur along the down gradient route to the Nisqually River. The City of Centralia mails an annual letter to residents who live within the inundation zone. The letter describes the hydroelectric project, what warning signs to watch for, and how to report a canal failure. The EAP lists the mailing address for 115 property owners and residents within the inundation zone.

Extent

Actual dam failure is more likely to be progressive in nature than a catastrophic uncontrolled release of impounded water. For high hazard potential dams in Thurston County, the Emergency Action Plans are focused on worst-case scenarios. Tacoma Public Utilities and TransAlta have conducted flood inundation studies to determine flood routing and severity based on hydrologic modeling for two commonly used catastrophic dam failure planning scenarios:

1. **Fair Weather or "Sunny Day" Failure –** a scenario in which a dam breach occurs under normal operating conditions. A failure occurs with a reservoir at normal full pool elevation and with a normal stream flow prevailing. This scenario is generally considered to have the most potential for loss of human life due to a failure occurring when it is not expected.
2. **Probable Maximum Flood (PMF) –** a scenario based upon a hypothetical breach occurring during the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the drainage basin. PMF inundation reaches higher elevations resulting in more areas and additional populations being affected than the sunny day scenario.

The studies produce maps that show the modeled geographic extent of flooding for both Fair Weather and PMF scenarios. The maps areas are divided into sections. Each section is annotated with details for each scenario. This information includes the river mile, the flood wave or leading-edge arrival time, peak flow, and incremental rise or total rise in water surface. This information informs decisions about the types of warning systems that may be necessary to protect community members from

incoming flooding due to a dam breach. For example, the dam operators and emergency managers need to inform the population downstream when to expect flooding, when to evacuate, and how long the flooding may last after the arrival time. The maps can also be used for identifying road closures, evacuation routes, and identifying critical infrastructure vulnerabilities.

Copies of the inundation maps are not included in this plan at the request of the dam operators to limit the availability and distribution of sensitive information. Interested parties may request copies of EAPS and inundation maps from the dam owners. In lieu of the maps, the dam breach flood inundation level information is provided in tabular form. Table 4.1.2 shows Nisqually Hydroelectric Project Dam failure flood inundation levels for locations in Thurston County. Table 4.1.3 shows Skookumchuck Hydroelectric Project Dam failure inundation levels.

Key Terms for Flood Inundation Levels

Flood Arrival Time: The time that dam breach floodwater arrives at a river or basin cross-section and increases the elevation of the normal water level.

Time to Peak: The time for floodwater to reach its maximum elevation at a river or basin cross-section.

Peak Water Surface Elevation: In general, the maximum height above mean sea level that water in a reservoir, river, or flood plain has reached.

Peak Discharge: The maximum rate of discharge in cubic feet per second (cfs) – 1 cfs equals 7.48 gallons per second.

Table 4.1.2 Nisqually Dam Failure Inundation Levels in Thurston County[2]

Scenario	Flood Arrival Time (hr:min)	Time to Peak (hr:min)	Peak Water Surface Elevation (feet)	Peak Discharge (cubic feet per second, cfs)
RM 30 Near Hobson Road SE				
Sunny Day	0:55	1:13	424	2,117,762
PMF	0:42	1:00	431	2,732,420
RM 26.2 Yelm Hydroelectric Project Diversion Dam				
Sunny Day	1:34	2:19	38	872,796
PMF	1:09	1:54	394	1,295,659
RM 24 Vicinity of Crook Road and Arlene Lane SE				
Sunny Day	1:55	2:43	356	820,941
PMF	1:24	2:12	366	1,233,354
RM 22 Vicinity of SR507 Bridge near McKenna				
Sunny Day	2:15	3:07	334	772,350
PMF	1:42	2:33	343	1,199,754
RM 17 Two Miles Downstream from vicinity of Briar St SE and Heather Ln SE				
Sunny Day	2:55	4:13	243	673,880
PMF	2:18	3:30	254	1,063,493
RM 13.5 Vicinity of Yelm Hydroelectric Plant				
Sunny Day	3:31	4:37	170	656,619
PMF	2:42	4:00	183	1,040,331
RM 11 Vicinity of Peter Kalama Road SE on the Nisqually Indian Reservation				
Sunny Day	4:07	5:01	104	648,715
PMF	3:06	4:42	115	1,046,665
RM 5 Vicinity of Sportsman Lane SE				
Sunny Day	5:18	6:55	77	439,799
PMF	3:48	5:36	97	786,443
RM 3.5 Vicinity of Conine Street SE				
Sunny Day	5:31	7:07	41	438,775
PMF	4:00	5:54	48	783,885
0.6 miles below the dam, Washington Fish and Wildlife Hatchery				
Sunny Day	0:10	0:43	383	704,000
PMF	0:13	0:48	380	869,000
3.9 miles below the dam, Skookumchuck Road SE Bridge				
Sunny Day	0:36	0:59	334	551,000
PMF	0:32	1:00	333	764,000

[2]Note: Because of the method, procedures, and assumptions used to develop the flooded areas, the limits of flooding shown and flood wave travel on the inundation maps are approximate and should be used only as a guideline for planning purposes. Actual areas inundated will depend on actual failure or flooding conditions and may differ from what is shown.

Scenario	Flood Arrival Time (hr:min)	Time to Peak (hr:min)	Peak Water Surface Elevation (feet)	Peak Discharge (cubic feet per second, cfs)
10.4 miles below the dam, 184th Avenue SE and SR507				
Sunny Day	1:40	2:32	276	185,000
PMF	1:17	1:55	281	376,000
11.8 miles below the dam, Town of Bucoda				
Sunny Day	1:56	2:50	266	175,000
PMF	1:26	2:08	270	353,000
16.7 miles below the dam, Vicinity of Troy Street SE at the SR 507 Bridge				
Sunny Day	2:51	3:48	233	145,000
PMF	1:59	2:36	237	309,000
30.8 miles below the dam, Prather Road SE Bridge at the Chehalis River				
Sunny Day	7:50	10:42	148	61,000
PMF	4:59	6:24	151	190,000
36.7 miles below the dam, Independence Road SW Bridge at the Chehalis River				
Sunny Day	10:19	13:59	120	58,000
PMF	n/a	7:56	122	180,000

Previous Incidents

There are no documented incidents of dam failure in Thurston County.

Probability of Occurrence

The EAPs for the Nisqually Hydroelectric Project and the Skookumchuck Hydroelectric Project do not present information about the probabilities of the included sunny day and Probable Maximum Flood dam failure scenarios. For the dam failure hazard profile, no analysis was conducted to estimate the probability of dam failure. The probability of experiencing catastrophic dam failure is typically very low. For the risk assessment dam failure is categorized as low – a catastrophic dam failure is unlikely to occur within 100 years.

Vulnerabilities and Impacts

This risk assessment is based on catastrophic dam failures for the Nisqually Hydroelectric and the Skookumchuck Hydroelectric project dams. TRPC obtained copies of the dam inundation digital files from Tacoma Power and TransAlta Centralia Generation. A GIS exposure analysis was used to estimate the population within the dam inundation areas. A Level 2 user-defined analysis was performed for general building stock and critical facilities located in the dam failure hazard areas for the Probable Maximum Flood (PMF) scenarios. Depth grids were generated using the dam failure inundation areas and uploaded into the Hazus riverine flood model. By inputting depth data and known property replacement cost values, dollar-value estimates of damage were generated.

For the data tables in the sections that follow, only the jurisdictions with estimated impacts and vulnerabilities are shown, unless otherwise noted. For the Nisqually Hydroelectric Project dams, only unincorporated Thurston is affected. For the Skookumchuck Hydroelectric Project dams, only the Town of Bucoda and unincorporated Thurston County are affected.

Refer to Chapter 4.3 Flood Hazard Risk Assessment for a description of the types of direct impacts floodwaters would have on people, structures and systems, natural and cultural resources, and activities.

Impacts to People

Estimates of People Exposed to Dam Failure Flood Inundation

An estimated 4,406 people in unincorporated Thurston County and the Town of Bucoda reside in the combined Alder, LaGrande, and Skookumchuck PMF dam failure inundation areas (Table 4.1.4)

Bucoda residents are most at risk from a catastrophic dam failure from the Skookumchuck Dam. An estimated 94 percent of the community's population would be threatened by floodwater (Table 4.1.5). The community would be inundated with peak flood floodwater elevation within two hours. Warning notification time and evacuation orders are time-critical for such a scenario.

An estimated 1,719 unincorporated Thurston County residents also face Skookumchuck dam failure hazards, especially those residents who live in the Skookumchuck River Valley near and along Skookumchuck Road SE.

Table 4.1.4 Thurston County Population Residing in the Dam Failure Inundation Areas

Jurisdiction	Population	Nisqually Dams		Skookumchuck Dam		Combined Inundation Areas
		Population Exposed	%Population Exposed	Population Exposed	%Population Exposed	Population Exposed
Bucoda	610	0	0	571	94.1%	571
Unincorporated Thurston County	143,760	2,116	1.5%	1,719	1.2%	3,835
Total Planning Area	**300,500**	**2,116**	**0.7%**	**2,291**	**0.8%**	**4,406**

Estimates of People Displaced or Requiring Shelter

Table 4.1.5 shows estimates of the number of individuals who could be displaced or require short-term sheltering for dam failure.

Table 4.1.5 Number of Individuals Displaced and Needing Shelter for the Dam Failure Scenarios

Jurisdiction	Nisqually Dam Failure		Skookumchuck Dam Failure	
	Displaced Individuals	Individuals Needing Shelter	Displaced Individuals	Individuals Needing Shelter
Bucoda	0	0	169	12
Unincorporated Thurston County	31	2	20	0
Total Planning Area	31	2	199	12

Impacts to Structures and Systems

Estimates of Structures in Dam Inundation Areas

An estimated 1,594 total residences are located in the region's combined dam failure inundation areas. There are an estimated total 1,662 structures countywide that are potentially vulnerable to dam failure flooding (Tables 4.1.6 and 4.1.7)

Table 4.1.6 Number of Structures in the Nisqually Dam Failure Inundation Area

Jurisdiction	Number of Structures in Nisqually Dam Failure Inundation Areas							
	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	Total
Unincorporated Thurston County	757	34	1	0	0	0	4	**796**
Tota Planning Areal	757	34	1	0	0	0	4	**796**

Table 4.1.7 Number of Structures in the Skookumchuck Dam Failure Inundation Area

Jurisdiction	Number of Structures in Skookumchuck Dam Failure Inundation Areas							
	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	Total
Bucoda	222	6	0	0	0	2	0	**230**
Unincorporated Thurston County	615	15	3	0	1	2	0	**636**
Tota Planning Areal	837	21	3	0	1	4	0	**866**

Estimates of Structural and Content Damage in Dam Inundation Areas

Hazus modeling for dam failure scenarios estimates there would be an estimated 567 buildings impacted resulting in nearly $143 million in combined structural and content losses countywide for a catastrophic failure of the Nisqually Alder and LaGrande dams (Table 4.1.8). There would be an estimated 796 buildings impacted resulting in over $131 million in combined structural and content losses countywide for a catastrophic Skookumchuck Dam failure (Table 4.1.9)

Table 4.1.8 Estimated Value of Structural and Content Damage for the Nisqually Dam Failure Scenario

Jurisdiction	Buildings Impacted	Total Value of Structural and Content Damage	% of Total Value Damage
Unincorporated Thurston County	567	$142,932,250	0.6%
Total Planning Area	567	$142,932,250	$0.2%

Table 4.1.9 Estimated Value of Structural and Content Damage for the Skookumchuck Dam Failure Scenario

Jurisdiction	Buildings Impacted	Total Value of Structural and Content Damage	% of Total Value Damage
Bucoda	230	$46,409,627	72.8%
Unincorporated Thurston County	566	$84,646,048	0.3%
Total Planning Area	796	$131,055,675	0.2%

Estimates of Structural Damage Debris

Flood Hazus modeling estimates the tons of structural debris that will be generated by major flood events. Countywide, the Nisqually dam failure scenario would produce an estimated 33,155 tons of structural damage debris and the Skookumchuck Dam failure scenario would generate an estimated 21,610 tons of debris. Table 4.1.10 shows estimates of debris generation for each dam failure scenario.

Table 4.1.10 Estimates of Structural Debris for the Nisqually and Skookumchuck Dam Failure Scenarios

	Structure Debris (tons)	
Jurisdiction	Nisqually Dam Failure	Skookumchuck Dam Failure
Bucoda	0	7,248
Unincorporated Thurston County	33,115	14,362
Total Planning Area	33,115	21,610

Estimates of Lifeline Asset Exposure

There are an estimated 13 community lifeline assets located in the Nisqually dams' inundation area (Table 4.1.11). Exposed assets include an electric substation, a City of Lacey water treatment facility, three wells – two owned by Lacey and one by the Thurston PUD, the Wa He Lut Indian School, and seven state highway bridges. Table 4.1.13 shows the percent average value damage to structures by lifeline. While not included in the tabulations, the Yelm Hydroelectric Project owned by the City of Centralia would be adversely impacted by Nisqually River flooding.

There are an estimated 20 lifeline assets located in the Skookumchuck Dam inundation area (Table 4.1.12). Lifeline assets include an electric substation, a water pump station, three wells owned by Thurston PUD, two park shelter facilities, four fire stations owned by Bucoda and South Thurston Fire and EMS, four Bucoda government buildings, and five state highway bridges. Table 4.1.14 shows the percent average value damage to structures by lifeline.

Table 4.1.11 Community Lifelines located in the Nisqually Dam Failure Scenario

Location in Planning Area	Comm-unications	Energy	Food, Water, Shelter	Hazardous Material	Health & Medical	Safety & Security	Trans-portation	Total
Unincorporated Thurston County	0	1	4	0	0	1	7	13
Total Planning Area	0	1	4	0	0	1	7	13

Table 4.1.12 Community Lifelines located in the Skookumchuck Dam Failure Scenario

Location in Planning Area	Comm-unications	Energy	Food, Water, Shelter	Hazardous Material	Health & Medical	Safety & Security	Trans-portation	Total
Bucoda	0	0	3	0	0	5	0	8
Unincorporated Thurston County	0	1	3	0	0	3	5	12
Total Planning Area	0	1	6	0	0	8	5	20

Table 4.1.13 Estimates of Damage to Community Lifelines in the Nisqually Dam Failure Scenario

Lifelines	Number of Facilities Affected	% Average of Total Value Damaged	
		Structure	Content
Safety and Security	1	86%	100%
Food, Water and Sheltering	4	65%	81%
Health and Medical	0	N/A	N/A
Energy	1	65%	81%
Communications	0	N/A	N/A
Transportation	7	1%	N/A
Hazardous Material	0	N/A	N/A
Total/Average	13	54%	87%

Table 4.1.14 Estimates of Damage to Community Lifelines in the Skookumchuck Dam Failure Scenario

Lifelines	Number of Facilities Affected	% Average of Total Value Damaged	
		Structure	Content
Safety and Security	7	62%	99
Food, Water and Sheltering	6	42%	91
Health and Medical	0	N/A	N/A
Energy	1	65%	81
Communications	0	N/A	N/A
Transportation	5	3%	N/A
Hazardous Material	0	N/A	N/A
Total/Average	19	43%	90%

Impacts to Natural, Cultural, and Historic Resources

A catastrophic dam failure would have major impacts on the environment due to contamination of water resources and agricultural lands from hazardous materials released during the flood event. The sudden release of impounded water would scour gravel from river and stream beds and destroy vital fish habitat including fish hatcheries on the Nisqually and Skookumchuck Rivers. Rising floodwaters would also destroy surrounding riparian and portions of upland habitat impacting terrestrial species. The loss of such habitat would adversely impact traditional fishing, hunting, and foraging areas for the Nisqually and Chehalis tribes.

Dam floodwater would destroy culturally significant structures such as the Wa He Lut Indian School, the Bucoda Gym, and the Bucoda City Hall historic Oddfellows Building.

Impacts to Activities

A dam failure disaster would disrupt travel for people, goods, and services to and from Thurston County due to impacts to bridges over the Nisqually and Skookumchuck Rivers.

Risk Ratings

Social Vulnerability Rating and National Risk Index

Social vulnerability is the susceptibility of social groups to the adverse impacts of natural hazards, including disproportionate death, injury, loss, or disruption of livelihood. As a consequence enhancing risk component of the National Risk Index, a Social Vulnerability score and rating represent the relative level of a community's social vulnerability compared to all other communities at the same level. A community's Social Vulnerability score measures its national rank or percentile. A higher Social Vulnerability score results in a higher Risk Index score. Map 4.1.2 shows assets and structures in Thurston County that are located in the dam failure inundation areas by census tract social vulnerability ratings. Most areas affected by dam failure have a social vulnerability rating that ranges from relatively moderate to relatively high.

The Federal Emergency Management Agency does not include a dam failure hazard in its National Risk Index.

Community Hazard Risk Ratings for Dam Failure

The Town of Bucoda's dam failure risk rating is based solely on the Skookumchuck probable maximum flood dam failure scenario. Dam failure is a low probability high consequence event for Bucoda. As such, the risk rating model produces a risk ranking score of 18 or a medium risk rating, principally because the probability of a failure is low.

The unincorporated Thurston County and countywide dam failure risk rating process combines the dam failure scenarios for both the Nisqually and Skookumchuck dams. As such, the unincorporated county and countywide risk ranking scores are each 6, resulting in a low-risk rating.

Only four special purpose districts have critical facilities located in the dam failure inundation areas. All four have a low-risk rating. Table 4.1.16 shows special purpose district dam failure hazard risk ratings. The details of the dam failure hazard risk assessment calculations are shown in Appendix X.

Table 4.1.15 Community Dam Failure Hazard Risk Ratings

Municipal Plan Participants	Dam Failure Hazard	
	Risk Ranking Score	Risk Rating
Bucoda	18	Medium
Unincorporated Thurston County	6	Low
Total Planning Area	6	Low

Table 4.1.16 Special Purpose District Dam Failure Hazard Risk Ratings

Special Purpose District Plan Participants	Dam Failure Hazard	
	Risk Ranking Score	Risk Rating
Lacey Fire District	3	Low
SE Thurston Fire Authority	3	Low
Thurston PUD	6	Low
West Thurston Regional Fire Authority	3	Low

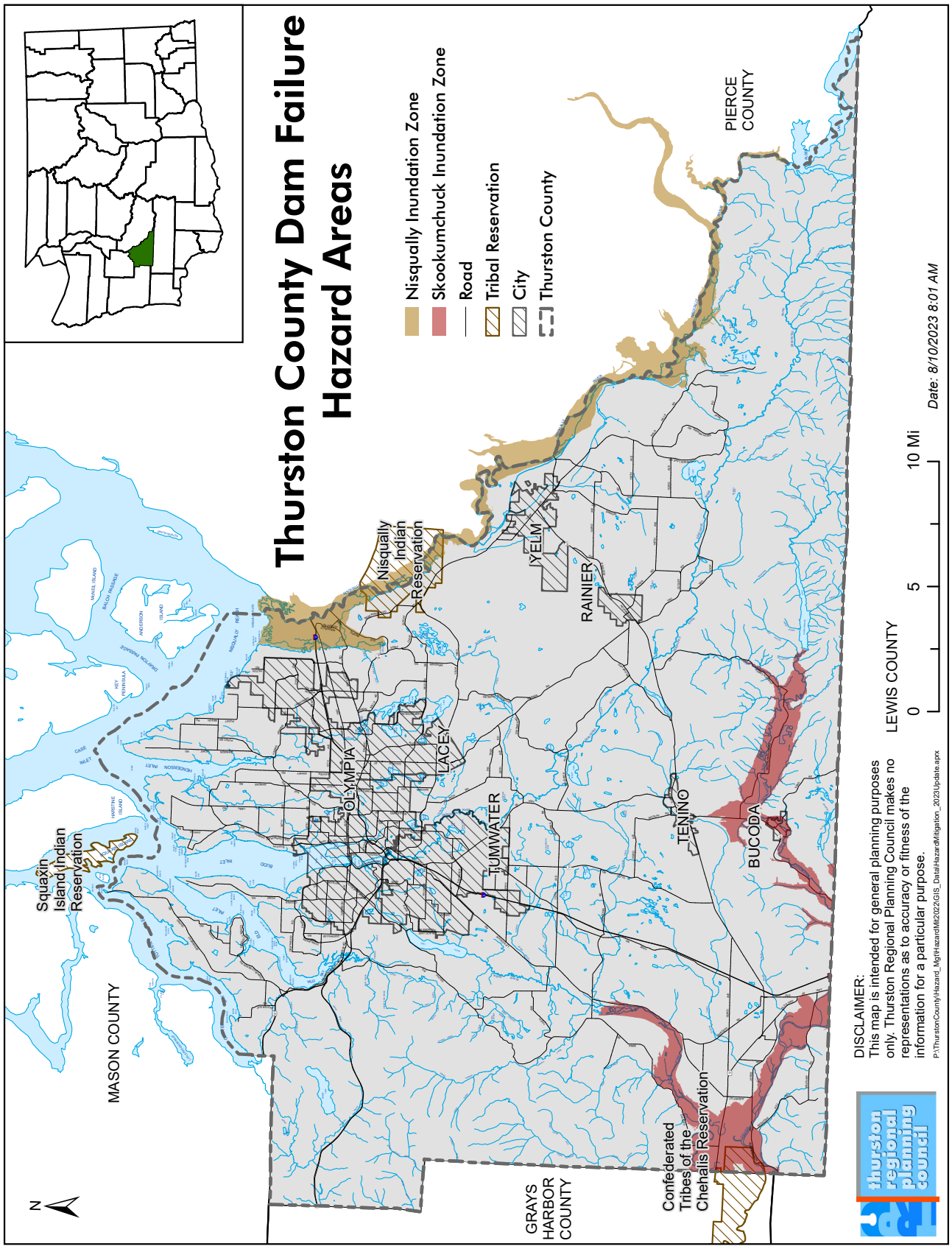
Changes in Dam Failure Hazard Risks Since Last Plan Update

This plan presents the region's first ever countywide dam failure risk assessment. This hazard profile provides a baseline assessment for future evaluation of the region's dam failure hazard vulnerabilities and risks.

Connection to the Regional Mitigation Strategy

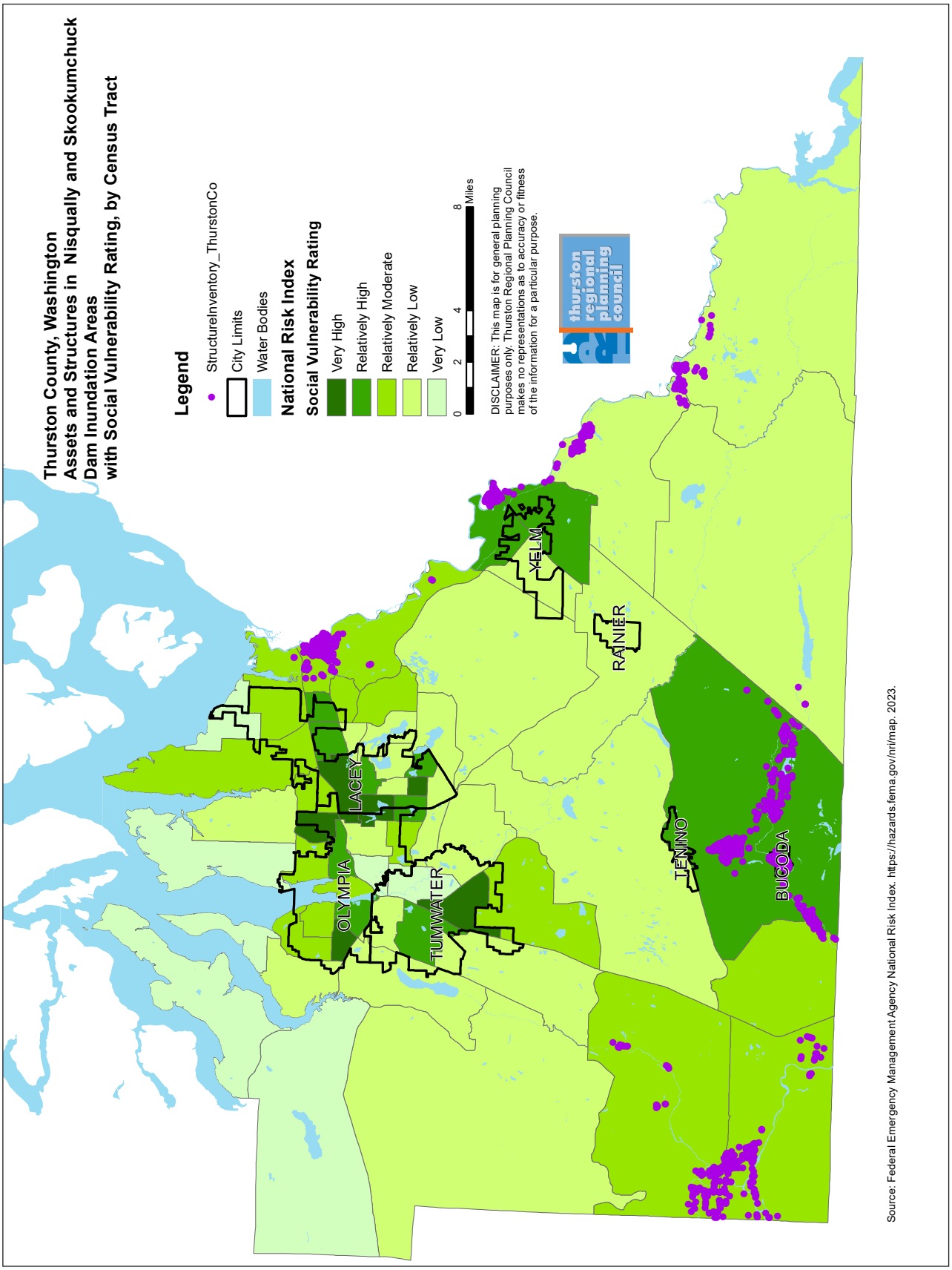
Dam Failure hazard information will be included through the Regional Hazard Mitigation Public Outreach Strategy initiative. The Hazard Modeling and Loss Estimation Capacity Building initiative will build local knowledge and technical skills to develop, operate, and maintain community-specific GIS-based hazard modeling tools that include local data such as data for other dam inundation areas not included in this hazard profile. Local modeling tools can inform planning and decision making for hazard mitigation, emergency management, disaster recovery, and training. The Lifeline Transportation Resiliency Plan will identify priority transportation projects to strengthen bridges, roads, and other multimodal transportation assets so they are less prone to floodwater inundation and closures.

The Hazard Mitigation Planning Workgroup identified a regional initiative, Evacuation Route Planning for Catastrophic Dam Failure and Volcanic Lahar. This initiative will develop an evacuation plan for potential dam failure and lahar hazards in coordination with residents, businesses, and other stakeholders. The plan will include routes, alert notification protocols, signs, staging areas, public education, emergency sheltering needs, operational plans, and training for organizations and personnel who would be involved in evacuation operations.



Map 4.1.1 Nisqually and Skookumchuck River Dam Failure Inundation Areas of Thurston County

Map 4.1.2 Exposed Assets and Structures in the Nisqually and Skookumchuck Dam Inundation Areas with Social Vulnerability Index Rating by Census Tract



Endnotes

[1]US Corps of Engineers. 2023. Hydrologic Engineering Center. Hydraulic Reference Manual: https://www.hec.usace.army.mil/confluence/rasdocs/ras1dtechref/6.3/performing-a-dam-break-study-with-hec-ras/estimating-dam-breach-parameters/causes-and-types-of-dam-failures.

[2]Association of State Dam Safety Officials. 2023. Gravity Dam Failure Modes:

https://damsafety.org/dam-owners/concrete-gravity-dam-failures.

[3]Inventory of Dams Report for Selected Washington Counties and Selected Dam Hazard Categories. 2020. Washington State Department of Ecology, Water Resources Program, Dam Safety Office. 200 pages.