PIERCE COUNTY
HAZARD IDENTIFICATION & RISK ASSESSMENT
DAM FAILURE HAZARD

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Identification Description

Definition

A dam is any "barrier built across a watercourse for impounding water.[1]" Dam failures are catastrophic events "characterized by the sudden, rapid, and uncontrolled release of impounded water.[2]

Types

Dam failures may be caused by structural deficiencies in the dam itself. These may come from poor initial design or construction, lack of maintenance and repair, or the gradual weakening of the dam through the normal aging processes. However, they can also be caused by other factors including but not limited to debris blocking the spillway, flooding, earthquakes, lahars, landslides, improper operation, vandalism, cyber-attack or terrorism.

Profile

Location and Extent[3]

The Washington Department of Ecology's inventory of dams, lists 58 dams or retention facilities either totally in Pierce County or shared jointly with another county. Of these, 46 have a peak storage capacity of 10 or more acre-feet. Of the 58 dams, 29 of them are listed as being of either high or significant hazard (see Table D-1 Pierce County Dams that Pose a High or Significant Risk to the Public).[5] The current count by classification are eight – 1A, seven – 1B, seven – 1C, seven – 2D and 2E. Since the last HIRA update in 2015, 13 dams have an increase in hazard class (10 of them are dikes at Lake Tapps).

Figure D-1 Reasons for Dam Failures Nationally[4]

OVERTOPPING – 34% of all failures
- Inadequate Spillway Design
- Debris Blockage of Spillway
- Settlement of Dam Crest

FOUNDATION DEFECTS – 30% of all failures
- Differential Settlement
- Sliding and Slope Instability
- High Uplift Pressures
- Uncontrolled Foundation Seepage

PIPING AND SEEPAGE – 20% of all failures
- Internal Erosion Through Dam Caused by Seepage– "Piping"
- Seepage and Erosion Along Hydraulic Structures Such as Outlet
- Conduits or Spillways, or Leakage Through Animal Burrows
- Cracks in Dam

CONDUITS AND VALVES – 10% of all failures
- Piping of Embankment Material Into Conduit Through Joints or Cracks

OTHER - 6% of all failures

Many of these, even though they are located in portions of the county with a low population base are a hazard because of the quantity of water they impound (see Table D-1 Pierce County High and Significant Risk Dams). This is the case with Alder, La Grande, and Mud Mountain Dams. A catastrophic failure of any of these dams could impact communities miles downstream. Others are listed as hazardous not because of the quantity of water they could

release, but rather because of their proximity to the public. There could be tens to hundreds of people or businesses located in a close proximity to the flow from a failure. It should be noted that a dam failure can happen at any time and be caused by anything. Map D-1 Pierce County High and Significant Risk Dams illustrates the locations of all the dams in the county.

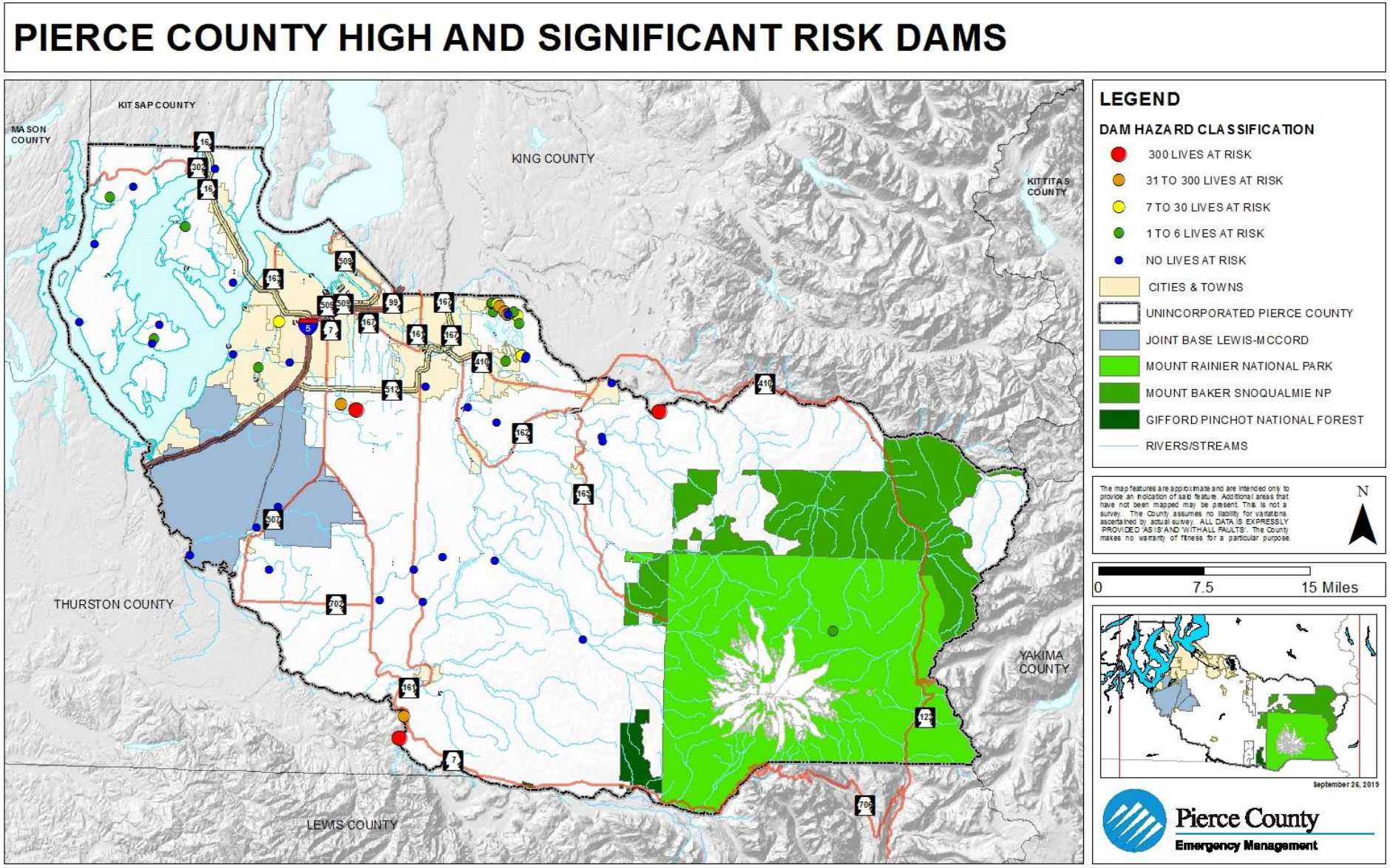
Table D-1 Pierce County Dams that Pose a High or Significant Risk to the Public.

Name	Hazard Class*	Owner	River or Stream	TWN RNGE SEC	Type**	Purpose†	Crest	Height	Normal Storage‡	Max Storage‡	Max Discharge
Alder Dam	1A	Tacoma. P. U.	Nisqually R.	T15 NR04 ES09	VA	H, R	1550 ft	330 ft	231,936	241,950	85,000 cfs
Bonney Lake WSU Infiltration Pond	2D	Weyerhauser Inc.	Offstream	T19 NR05 ES03	RE	C	1000 ft	5 ft	30	35	0 cfs
Butterworth Dam	2E	WA DFW Eng.	Eden Creek	T15 NR04 ES20	RE	I, S	300 ft	61 ft	2050	2450	25 cfs
Frozen Lake Dam	1B	US DOI NPS	Tributary – White R.	T17 NR09 ES33	RE	R, S	215 ft	19 ft	64	76	0 cfs
Harbor Hill North Pond	1B	Opg Properties LLC	Unnamed	T22 NR02 ES31	RE	C	900 ft	20.5 ft	17	51	unmarked
La Grande Dam	1B	Tacoma P. U.	Nisqually R	T16 NR04 ES04	PG	H, R	710 ft	217 ft	2676	3015	88,000 cfs
Leach Creek Stormwater Detention Dam	1B	Tacoma P. W.	Leach Creek	T20 NR02 ES14	RE	C	1000 ft	10 ft	1	110	280 cfs
McMillin Reservoir No.1 N. Dam	1C	Tacoma P. U.	Tributary - Puyallup R.-Offstream	T19 NR04 ES14	RE	S	2200 ft	30 ft	165	165	0 cfs
McMillin Reservoir No.1 S. Dam	1C	Tacoma P. U.	Tributary - Puyallup R.-Offstream	T19 NR04 ES14	RE	S	2200 ft	30 ft	166	166	0 cfs
Mud Mountain Dam	1A	US ACE	White R.	T19 NR07 ES17	ER	C	700 ft	425 ft	106,000	156,000	245,000 cfs
North Fork Clover Creek E1 Detention Basin	1A	Pierce Co.	N Fork Clover Creek	T19 NR03 ES14	RE	C, Q	850 ft	10 ft	1	135	749 cfs
North Fork Clover Creek E1 Detention Facility	1B	Pierce Co.	N Fork Clover Creek, W Branch	T19 NR03 ES10	RE	C	1090 ft	10 ft	85	104	1260 cfs
Slavic Lake Dam	2D	Slavic Christian Center	Offstream	T22 NR01 WS35	RE	R	40 ft	8 ft	8	10	30 cfs
Steilacoom Lake Dam	1B	City of Lakewood	Steilacoom Lake	T20 NR02 ES34	PG	F, R	120 ft	28 ft	2640	6970	1980 cfs
Sylvia Lake Dam PC	2D	Sylvia Lake. Country Club	Tributary - Puget Sound	T21 NR01 ES11	RE	R	387 ft	25 ft	67	124	160 cfs
Tapps Lake Backflow Prevention Structure	1C	Cascade Water Alliance (CWA)	Tapps Lake	T20 NR05 ES26	PG	R, S	73 ft	21.5 ft	55,500	46,655	1000 cfs
Tapps Lake Dike No. 1	1A	CWA	Diversion from White R.	T20 NR05 ES09	RE	H, R	200 ft	18 ft	19,000	22,000	0 cfs

Tapps Lake Dike No.11	1A	CWA	Diversion from White R.	T20 NR05 ES10	RE	H, R	1600 ft	23 ft	36,000	38,000	0 cfs
Tapps Lake Dike No.12	1C	CWA	Diversion from White R.	T20 NR05 ES10	RE	H, R	1250 ft	14 ft	23,000	25,000	0 cfs
Tapps Lake Dike No.2A	1C	CWA	Diversion from White R.	T20 NR05 ES05	RE	H, R	350 ft	9 ft	18,000	20,000	0 cfs
Tapps Lake Dike No.2B	1C	CWA	Diversion from White R.	T20 NR05 ES04	RE	H, R	300 ft	16 ft	26,000	28,000	0 cfs
Tapps Lake Dike No.3	1B	CWA	Diversion from White R.	T20 NR05 ES04	RE	H, R	600 ft	15 ft	26,000	28,000	0 cfs
Tapps Lake Dike No.4	1A	CWA	Diversion from White R.	T20 NR05 ES09	RE	H, R	4000 ft	45 ft	56,000	58,340	0 cfs
Tapps Lake Dike No.5	1A	CWA	Diversion from White R.	T20 NR05 ES09	RE	H, R	500 ft	24 ft	38,000	40,000	0 cfs
Tapps Lake Dike No.6	1A	CWA	Diversion from White R.	T20 NR05 ES10	RE	H, R	600 ft	26 ft	41,000	43,000	0 cfs
Tapps Lake Dike No.8	2D	CWA	Diversion from White R.	T20 NR05 ES10	RE	H, R	350 ft	20 ft	32,000	34,000	0 cfs
Tapps Lake Dike No.9	2D	CWA	Diversion from White R.	T20 NR05 ES10	RE	H, R	250 ft	15 ft	24,000	26,000	0 cfs
Tapps Lake Dike No.10	1C	CWA	Diversion from White R.	T20 NR05 ES10	RE	H, R	700 ft	19 ft	30,000	32,000	0 cfs
Tapps Lake Dike No.13	2D	CWA	Diversion from White R.	T20 NR05 ES27	RE	H, R	350 ft	6 ft	8000	10,000	0 cfs

*Hazard Classes: 1 – High Hazard, 1A – greater than 300 lives at risk, 1B – 31 to 300 lives at risk, 1C – 7 to 30 lives at risk, 2D – 1 to 6 lives at risk, 2E – 0 population at risk but significant economic and/or environmental effects.
**Type: ER – Rock Fill Dam, PG – Concrete Gravity Dam, RE – Earth Fill Dam, VA – Concrete Single Arch Dam.
†Purpose: C – Flood Control & Storm Water Management, F – Fish & Wildlife, H – Hydroelectric, I – Irrigation, Q – Water Quality, R – Recreation, S – Water Supply
‡All dam storage numbers are in acre-feet. One acre-foot is the quantity needed to cover one acre to the depth of one foot or 43,560 cubic feet, or 325,851 gallons.

Map D-1 Pierce County High and Significant Risk Dams



Others are listed as hazardous not because of the quantity of water they could release, but rather because of their proximity to the public. There could be tens to hundreds of people or businesses located in a close proximity to the flow from a dam failure. It should be noted that a dam failure can happen at any time and be caused by anything. Map D-1 Pierce County High and Significant Risk Dams illustrates the locations of all the dams in the county.

Occurrences

There have been a number of dam failures in Washington State over the past 100 years, some of which are shown in Table D-2. A review of the literature has not turned up any dam failures within Pierce County.

Table D-2 Select Dam Failures in Washington State[6,7]

Dam	Location	Failure Date	Nature of the Failure and Damage
Masonry Dam (Boxley Burst)	Near North Bend	12/23/1918	Excessive seepage through the glacial moraine abutment caused mud flow about one mi. from reservoir. It destroyed a RR line and village of Eastwick.
Eastwick Railroad Fill Dam	Near North Bend	02/1932	A landslide blocking a culvert caused a RR fill dam to fail destroying a portion of the RR tracks, the village of Eastwick and killing seven residents.
Loup Loup Dam	Near Malott	April 1938	A 50 foot high hydraulic fill dam failed when emergency spillway was undercut during a flood. It destroyed ½ mile of state highway, 25 homes and left 75 people homeless.
Lake Dawn Dam	Port Angeles	February 1950	Heavy Rains caused overtopping and failure of the earthen dam. one home destroyed and $4000 damage.
North Star Sand & Gravel Dams	Everett	December 1967	A 40 foot high dam washed out by overtopping due to lack of spillway. 25 foot high dam rebuilt, also failed, washed out Great Northern RR tracks and derailed a passing train.
Pillar Rock Dam	Wahkiakum Co.	January 1970	A logging road fill culver was blocked by debris. It overtopped and failed. That caused a 25 foot high concrete gravity dam to fail. three homes and a fish cannery were destroyed.
Sid White Dam	Near Omak	May 1971	Earthen dam failed due to seepage through animal burrows. Caused a second dam to fail and dumped debris into the town of Riverside.
Alexander Lake Dam	Near Bremerton	December 1982	Spillway undermined and failed during heavy rains. Caused damage at fish hatchery and homes in Gorst.
Upriver Dam	Spokane	May 20, 1986	Hydropower facility failed by overtopping. Lightning struck the system causing the turbines to shut down. Water rose behind the dam while they were trying to restart the turbines. Backup power systems failed and the spillway gated could not be raised in time. Caused $11 million in damage to the facility.
Chinook Dam	Pacific County	Thanksgiving Weekend 1990	Heavy rains overtopped the embankment and undermined the spillway, leading to failure of the dam. Approximately $100,000 damage to the facility.
Seminary Hill Reservoir	Centralia	October 05 1991	Failure along weak rock zone in a hillside caused a massive slide which breached the reservoir. three million gallons of water drained from the reservoir in three minutes. two homes were destroyed, many homes damaged, $3 million in damage.
Iowa Beef Processors Waste Pond Dam No. 1	Wallula near Richland	January 25, 1993	Failure of 15 foot high embankment released 300 acre-feet of waste water. Failure attributed to high reservoir levels due to snowmelt, entering animal burrows near the embankment crest, and eroding the dam. Washed out the Union Pacific RR tracks, derailed five locomotives and caused $5 million in damage.
Mill Creek Dam	Cosmopolis and Aberdeen	November 12, 2008	Pedestrian bridge washed out; residential areas flooded; ~12 homes received flood damages.

Recurrence Rate

Failure is a possibility for any dam. While there have been occasional failures across the state, their lack in Pierce County over the past one hundred years would indicate a recurrence rate of fifty or more years.

Impacts

Figure D-2 Mud Mt. Dam Intake[8]

The impact from any individual dam failure depends on a number of factors:

- What is the maximum amount of water the dam can contain?
- What is the maximum amount of water the dam contains when it fails?
- Is the failure immediate and total or only partial and slowly developing allowing the water to gradually build in volume and power?
- Is the dam located in a populated area or is it removed from developed areas and critical infrastructure?
- Are there any other contributing factors that might limit the evacuation from a threatened area or the emergency response to the incident?
- Is there a warning?

Health and Safety of Persons in the Affected Area at the Time of the Incident

Any individual dam has a very specific area that will be impacted by a catastrophic failure. The dams listed above in Table D1, will be a direct threat to the lives of individuals living in the inundation zone below the dam. Currently, populations who work in the inundation zone below the dam are not considered in the hazard classification process. Locals with data on businesses' number of employees and daily average customers can work with the Department of Ecology Dam Safety Office to identify hazard classification changes for weekdays.

The impact from any catastrophic failure would be similar to that of a flash flood. Just six inches of moving water can knock you down and one foot of moving water can sweep your vehicle away.[9] Lives can be lost. The water and landscape can be contaminated with hazardous materials such as sharp debris, pesticides, fuel and untreated sewage.[10] There could be injuries from impacts with debris being carried by the flood. With the cold water and cold air temperature for much of the year, hypothermia could exacerbate many of the problems for those rescued and contribute to the number of drowning deaths. Water may also be electrically charged from underground or downed power lines.[11] For more information see Flood chapter.

Because of their small size, or their location in uninhabited areas, thirty dams in Pierce County are not shown on Table D1. While it cannot be precluded, these dams are not expected to cause death or injury to individuals. However, it is possible that an individual or group of individuals could be in the wrong place at the wrong time and become a casualty of one of them failing.

Health and Safety of Personnel Responding to the Incident[12]

Response to a dam failure is a response to a hazardous situation. Swift-water rescue of individuals trapped by the water puts the immediate responders at risk for their own lives. Later, after the water has receded, those involved in the cleanup may be at risk of contamination if not wearing proper personal protective gear from the debris left behind.

Continuity of Operations and Delivery of Services

Continuity of operations for any jurisdiction outside the direct impact area could be very limited. Unlike most flood situations, a dam failure's impact will be constrained to an area within a single watercourse. In addition, the failure, while sending a surge of water down the individual watercourse will not usually continue to send water down over an extended period of time. There will be a surge of water and then with most dams the quantity will taper off relatively quickly.

Exceptions would include the partial failure of one of the large dams in the County, or the failure of a major dam during a major rain, or rain on snow event. In either of these cases, there could be a flood hazard already in existence when the dam fails.

Having the damage located within a single watercourse, while limiting the area directly impacted, could still cause major disruption of operations and the delivery of services. The heavy onrush of water associated with an event of this type could, through the destruction of infrastructure in the impacted area, put a total halt in a jurisdiction's ability to respond to many of the day-to-day needs of its citizens.

Property, Facilities, and Infrastructure

No matter the size of the dam, the large quantity of water associated with the failure of a dam creates a scouring force in the area immediately below it. For small dams this might only cover a few dozen to hundreds of yards not impacting much if any infrastructure. For large dams, like Alder, La Grande and Mud Mountain scouring could go for miles and damaged infrastructure may be found all the way to Puget Sound.

Depending on the quantity of water, the force caused by its onrush can take out buildings, power lines, sewage systems and roads. Damaged sewage systems are serious health hazards and need to be assessed as soon as possible. A large dam with a high head of water could effectively scour the terrain below it for miles, taking out all buildings and other infrastructure. This scouring force could also erode soil and any buried pipelines in the steeper portions of the valleys. Where the slope moderates and the rivers enter a wider plain the water would slow down and while still damaging the infrastructure it would act more like a very high, flood or small tsunami. There would still be some scouring in certain areas, but some other areas along the edges of the inundation zone might have a lot of debris deposition.

Failure of one of the major dams on the White or Nisqually Rivers when full could damage highways as far as I-5. Smaller roads and bridges closer to the actual failure could be totally removed due to the force of the water. Roads may have weakened and could collapse under the weight of a car. Floods in Washington damage bridges on a regular basis without anywhere near the quantity of water that could be released by a catastrophic dam failure on one of the County's major rivers.

Environment

Any dam that fails has a detrimental impact on the environment. Of the 58 dams in Pierce County, seven are classified a significant risk to the environment only. The degree of the impact will vary depending on the size of the failure. Small dams will probably only impact a very small portion of the environment downstream. In the other extreme, the scouring action of a large quantity of water will destroy all vegetation in its path. A very large dam could hypothetically take out forested areas. Like any flash flood, this will destroy any wildlife caught in the flow. Fish habitats, including spawning beds, could be destroyed. Unlike most floods, the force of the water from a large dam failure will have a major scouring impact on portions of the valley. In some areas it will take off most if not all topsoil, limiting the ability of the environment to return to normal. It could take years for the natural restorative processes to bring back an ecosystem similar to what was there beforehand.

A large dam that fails, depending on the quantity of water released, could have an impact far beyond what is normally expected from a flood on its watercourse. Part of this is due to the volume of water that at peak may have a flow many times that of even a record flood. Added to this is the large quantity of material, both natural, like logs and other vegetation, and human related, like fertilizer, sewage, livestock, vehicles, and other hazardous materials. This material as it is deposited, may cause further pollution of not just the areas normally flooded, but also land that lies far above or away from the normal flood plain.

Economic and Financial Condition

The economic impact from the failure of many of the smaller dams in the County is negligible. Impacts would be to the owner of the dam and potentially to a small local group, probably geographically located directly downstream from the dam. The area they impact would be so small and, in most cases isolated, that a failure of one would go almost unnoticed by the rest of the County.

As the size of the dam increases and the proximity to the public and/or critical infrastructure increases, the severity of the impact to our economy increases. Any of the dams listed in Table D-1 could have an impact on either the overall economy or on the financial condition of many of the businesses or homeowners located in the inundation zones from those dams.

A couple of the worst-case scenarios include a failure of Mud Mountain Dam or Alder Dam during peak storage. Either of these could not only kill many people but could irrevocably damage the infrastructure. The supply chain would be disrupted as roads and bridges would be lost. This includes damage to the main north-south corridor of Interstate 5. Businesses would be damaged or in many cases destroyed, and municipalities in the inundation zones would have a

long-term process of rebuilding and reopening. Not all businesses will reopen, and some may choose to relocate. All of this would not only impact those areas in the inundation zone, but any area relying on either the infrastructure or businesses located in that zone.

Public Confidence in the Jurisdiction's Governance

For many of the small dams located in the County whose failure would have no impact on the general public there would be little change in the public's confidence in local governments or any agency overseeing their safety or operation.

The failure of any dam that does considerable damage to the community, will have a lot of scrutiny by the press and the public. The organizations most in the line of fire will be those responsible for the dam and those responsible for overseeing its licensing and safety. When the ownership of the dam is a public agency the confidence in that agency will be adversely affected. Dam safety inspections fall to the Dam Safety Office in the Washington State Department of Ecology.

When a dam fails that directly impacts the public, especially if there are deaths associated with it, there will be considerable scrutiny of why it happened. The next point will be to ask the date of the last inspection and what were its results. If an inspection was conducted multiple years ago questions will arise concerning why it was not done more recently. This will be especially critical if it is shown that the dam in question was not inspected at the rate recommended by FEMA.[13] This is summarized by the State of Washington:

> Guidelines for dam safety prepared by the Federal Emergency Management Agency recommend annual inspections of high hazard dams (3 or more homes at risk), a 2-year interval for significant hazard dams (1 or 2 homes at risk), and a 5-year interval for low hazard dams (no homes at risk).[14]

Current inspection requirements as listed in the Washington Administrative Code [15] are:

> (1) As authorized by RCW 43.21A.064, the department has the authority to conduct routine periodic inspections of all existing dams with high and significant downstream hazard classifications to reasonably secure safety to life and property.
> • Dams with high downstream hazard classifications will be inspected every five years.
> • Dams with significant downstream hazard classifications will be inspected every five years, or ten years if workload or staffing necessitates a longer cycle between inspections.
> • Dams classified as low hazard are not included in the periodic inspection program.

A dam failure of a class one or two dam, especially when there are injuries or fatalities, combined with lengthy periods between inspections will bring unwanted scrutiny on the State of Washington. This will lead to a decrease in the public's confidence in the State's governance.

Resource Directory

Regional

- **Pierce County Department of Emergency Management**
  https://www.piercecountywa.gov/6481/Know-Your-Hazards
- **US Army Corps of Engineers North Western Division**
  http://www.nwd.usace.army.mil/
- **Washington State Department of Ecology, Dam Safety Office**
  http://www.ecy.wa.gov/programs/wr/dams/dss.html

National

- **FEMA National Dam Safety Program**
  https://www.fema.gov/national-dam-safety-program
  https://Ready.gov/floods
- **Association of Dam Safety Officials (ASDSO)**
  https://damsafety.org/
- **Centers for Disease Control and Prevention**
  https://www.cdc.gov/niosh/topics/emres/sitemgt.html
- **National Geographic**
  https://www.nationalgeographic.com/environment/natural-disasters/flood-safety-tips/
  https://Ready.gov/floods

Endnotes

[1] Dam, Washington Department of Ecology, Glossary at http://www.ecy.wa.gov/programs/wr/cwp/images/pdf/legsrpt/chptr7_glossry_111506.pdf
[2] Dam Failure, NOAA, National Weather Service, Glossary at http://www.nws.noaa.gov/glossary/index.php?letter=d
[3] Inventory of Dams Report June 11, 2019, Washington Department of Ecology, Water Resources Program, Dam Safety Office Revised Edition June 2018 Publication #94-16
[4] Notable Dam Failures, Washington State Department of Ecology, http://www.ecy.wa.gov/PROGRAMS/wr/dams/failure.html
[5] Legacy classifications are used to measure the hazard downstream impacts. 1A = Greater than 300 lives at risk 1B = From 31-300 lives at risk 1C = From 7-30 lives at risk. These are all considered in the high category. https://fortress.wa.gov/ecy/publications/publications/94016.pdf
[6] Notable Dam Failures and Incidents in Washington State, Department of Ecology http://www.ecy.wa.gov/programs/wr/dams/Reports/damfailure_ws.pdf
[7] Information on the Mill Creek Dam failure came from Dam Failures, Dam Incidents (Near Failures), Association of State Dam Safety Officials, http://www.damsafety.org/media/Documents/PRESS/US_FailuresIncidents.pdf
[8] Mud Mountain Dam and intake structure showing the dam in its normal empty state. Photo from the Army Corps of Engineers – Seattle District.
[9] FEMA. Accessed February 2020 from https://Ready.gov/floods
[10] Floods 101, Christina Nunez, National Geographic access August 13, 2019 at https://www.nationalgeographic.com/environment/natural-disasters/floods/
[11] Ibid.
[12] Natural Disasters and Severe Weather: Response Worker Health and Safety, Centers for Disease Control, accessed August 12, 2019 at https://www.cdc.gov/disasters/workers.html
[13] Federal Guidelines for Dam Safety, prepared by the Interagency Committee on Dam Safety, Federal Emergency Management Agency, June 1979, reprinted April 2004, pp. 39-42.
[14] Water Resources Program Policy 5404, Washington State Department of Ecology, Dam Safety Office as shown at http://www.ecy.wa.gov/programs/wr/rules/images/pdf/pol5404.pdf
[15] WAC 173-175-705 Periodic inspection by the department, as shown at http://apps.leg.wa.gov/wac/default.aspx?cite=173-175-705