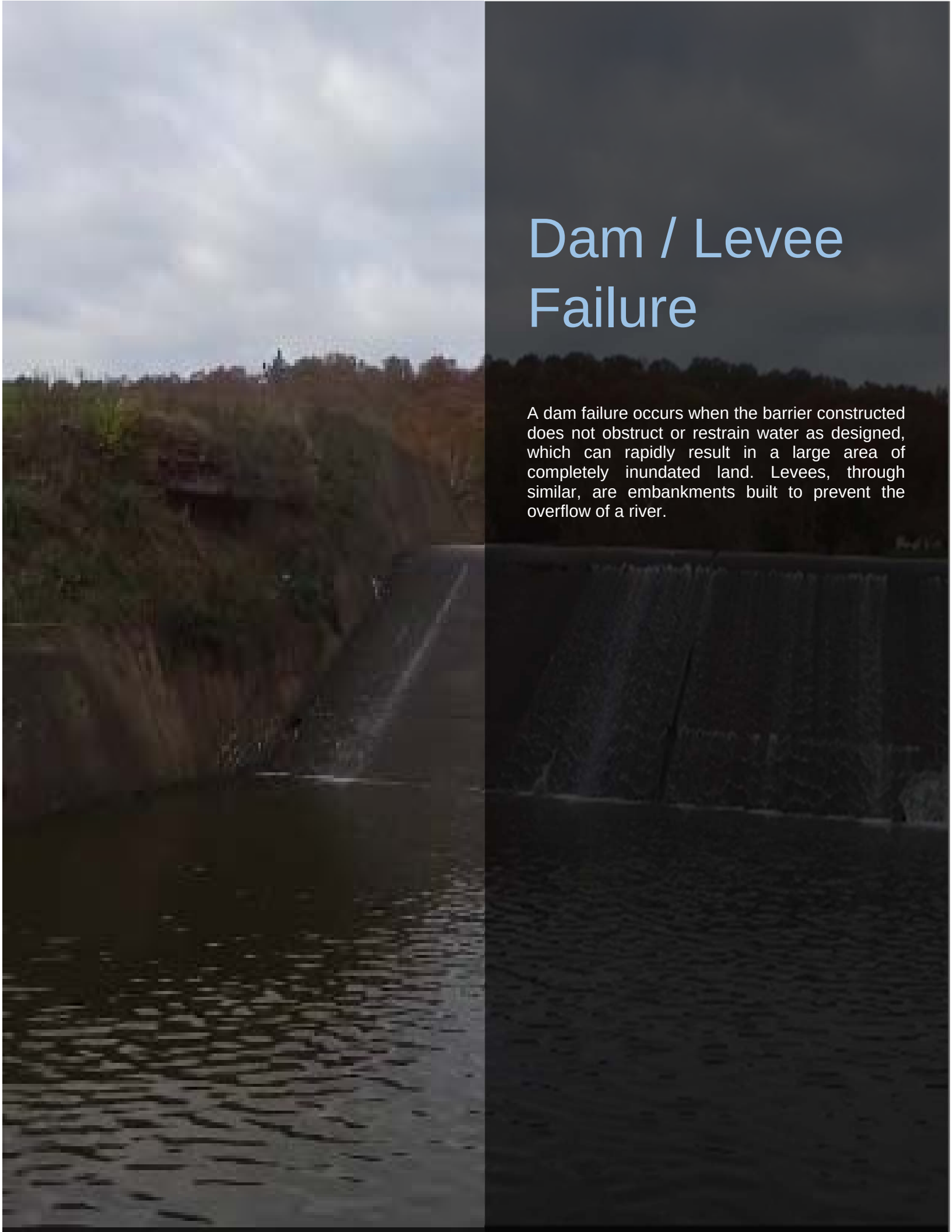


Dam / Levee Failure

A dam failure occurs when the barrier constructed does not obstruct or restrain water as designed, which can rapidly result in a large area of completely inundated land. Levees, through similar, are embankments built to prevent the overflow of a river.

2.0 RISK ASSESSMENT

2.2.1 Dam and Levee Failure

A dam is a barrier built across a waterway to control the flow or raise the water level. A dam failure occurs when the barrier constructed does not obstruct or restrain water as designed, which can rapidly result in a large area of completely inundated land. Levees, though similar, are embankments built to prevent the overflow of a river.				
Vulnerability HIGHEST HIGH MEDIUM LOW LOWEST	Period of Occurrence:	Dam failure can occur at any time, typically following a period of prolonged precipitation.	Hazard Index Ranking:	Lowest
	Warning Time:	Over 24 hours	State Risk Ranking:	7
	Probability:	Remote (unlikely to occur on an annual basis)	Severity:	Minor (localized, less than 10% of land area affected)
	Type of Hazard:	Technological	Disaster Declarations:	None

Hazard Introduction and Overview

Dams are man-made structures generally made with concrete or earthen materials built across a stream or river to hold water for storage, flood control, or electricity generation (National Geographic, n.d.). There are 91,457 dams in the United States, the average age of which is 57 years old (NID, 2020). The majority of these dams are privately owned. State and local authorities, public utilities, and federal agencies own others. Most of the dams in Ohio were constructed by farmers and other individuals and are small dams. The State of Ohio operates more than 100 dams in the state, while the federal government operates over 30. As populations grow and development continues, the overall number of high-hazard potential dams is increasing. The number of high-hazard potential dams with noted deficiencies has also increased, with an estimated 2,330 in 2020 (Association of State Dam Safety Officials).

Dams are an integral component of infrastructure in the United States, the benefits of dams are numerous: they provide drinking water supplies, navigation and recreation opportunities, renewable energy through hydropower, agricultural irrigation, and save lives by preventing or reducing floods.

The failure of a large dam, although a man-made structure, may result in the natural event of flooding. A dam failure is defined as any malfunction or abnormality outside the design assumptions and parameters that adversely affect a dam's primary function of impounding water (FEMA, 2017).

Typically, dam failures are most likely to happen due to one of the following reasons:

- **Overtopping** occurs when water spills over the top of the dam. Overtopping failures result from the erosive action of water on the embankment. Erosion is due to uncontrolled flow of water over, around, and adjacent to the dam. Earthen embankments are not designed to be overtopped and therefore are particularly susceptible to erosion. Once erosion has begun during overtopping, it is almost impossible to stop. Overtopping due to inadequate spillway design, debris blockage of spillways, or settlement of the dam crest account for approximately 34% of all dam failures in the U.S.
- **Foundation Defects, Slope Instability, and Structural Failures** can occur in either the embankment or the appurtenances. Structural failure of a spillway, lake drain, or other appurtenance may lead to failure of the embankment. Cracking, settlement, and slides are the more common signs of embankment structural failure. Large cracks in either an appurtenance or the embankment, major settlement, and major slides will require emergency measures to ensure safety, especially if the problems occur suddenly. These types of failures cause approximately 30% of all dam failures.
- **Piping** is the internal erosion caused by seepage. Seepage occurs around hydraulic structures, such as pipes and spillways, through animal burrows, around roots of vegetation, and through cracks in the dam. All earthen dams have seepage resulting from water percolating slowly through the dam and its foundation. Seepage must, however, be controlled in both velocity and quantity. If uncontrolled, it can progressively erode soil from the embankment, resulting in the rapid failure of the dam. Erosion of the soil begins at the downstream side of the embankment, either in the dam proper or the foundation, progressively works toward the reservoir, and eventually develops a “pipe” or direct conduit into the reservoir. Seepage can cause slope failure by creating high pressures in the soil pores or by saturating the slope. Piping accounts for another 20% of dam failures in the U.S.

The three (3) types of failures described above are often interrelated in a complex manner. For example, uncontrolled seepage may weaken the soil and lead to a structural failure. A structural failure may shorten the seepage path and lead to a piping failure. Surface erosion may result in structural failure, and so on. Minor defects such as cracks in the embankment may be the first visual sign of a major problem, which could lead to failure of the structure. Someone experienced in dam design and construction should evaluate the seriousness of all deficiencies as soon as they are detected.

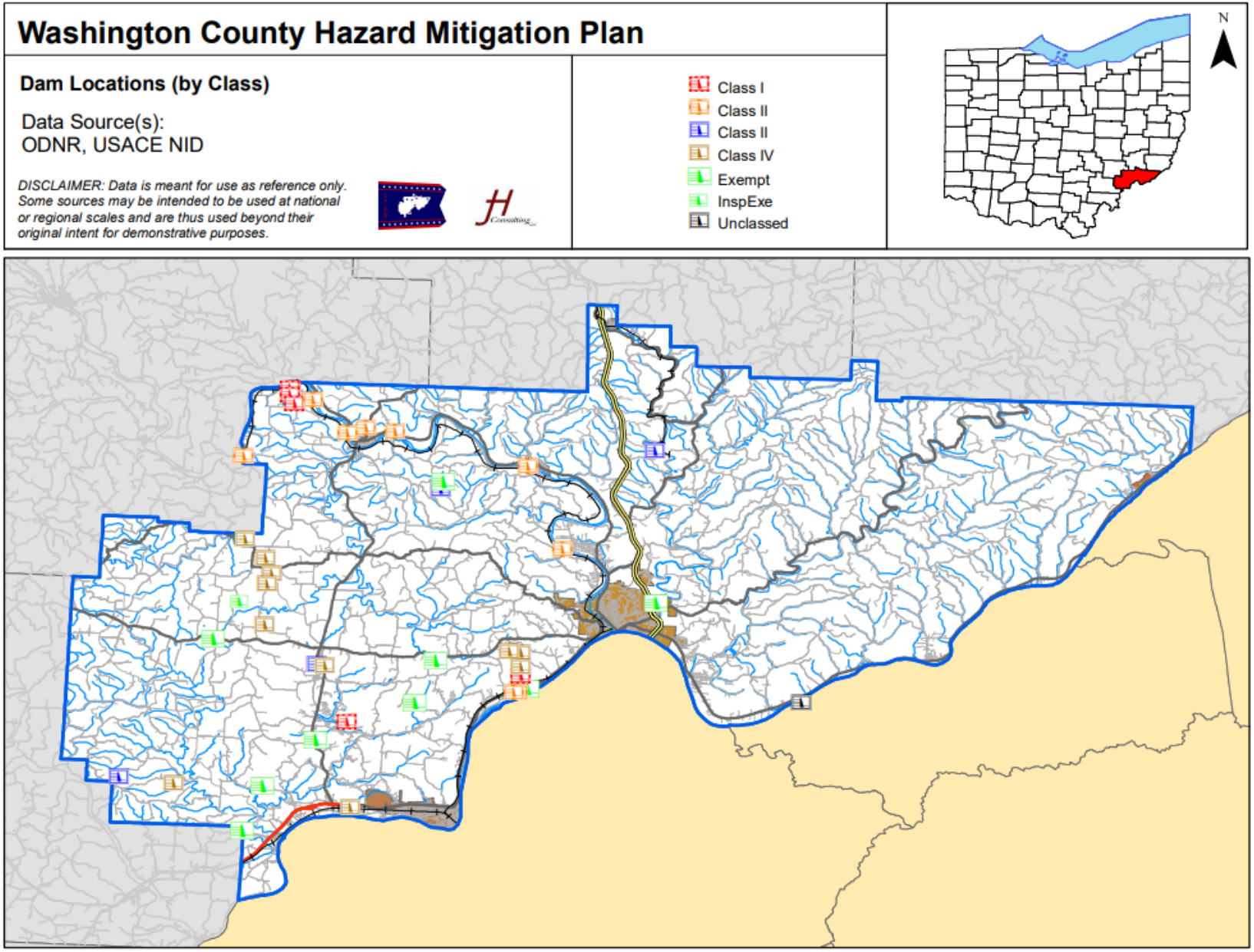
Additionally, the Ohio Department of Natural Resources (ODNR), Division of Water Resources – Dam Safety Program classifies dam failures as either "sunny day" failures or "rainy day" failures. "Sunny day" failures are those that occur during non-flooding conditions, in which the reservoir is at or near a normal level. "Rainy day" failures are those that involve periods of flooding or rainfall and can exacerbate inadequate spillway capacity. It can be assumed that sunny day failures are more catastrophic due to their unpredictable nature.

Dams are not the only structures that can fail. Levees, barriers, and other structures that retain water can fail and cause flood damage and loss of life. The ODNR is the agency responsible for the regulation of levees in Ohio. According to the ODNR, "a levee is any artificial barrier together with appurtenant works that will divert or restrain the flow of a stream of other body of water for the purpose of protection an area from inundation by flood water" (ODNR, 2016). While dams constantly control the flow of water, most levees are built purely for flood control and protection.

Though levees are designed to a certain level of potential flood, the U.S. Army Corps of Engineers (USACE) notes that levees are not subject to consistent design, construction, operations, and maintenance standards. Those under the auspices of the USACE receive regular inspections, but this represents an estimated 15% of the levees in the country (USACE, n.d.). Levees function as part of a system. In other words, a levee in one area may overtop by design to protect larger populations downstream (USACE, n.d.). "'Levee failure' implies that something about the levee failed to prevent flooding on the land side of the levee" (USACE, n.d.). Levee failures can result from overtopping, water flow through or under a levee, erosion, by an object hitting the levee, or by an object on the levee (e.g., tree or building) falling and taking a portion of the structure with it (USACE, n.d.). The USACE also maintains the National Levee Database (NLD).

Location and Extent

The (ODNR), Division of Water Resources – Dam Safety Program provides a map of all dams in Washington County. According to ODNR, there are dams in 12 Washington County townships: Aurelius, Salem, Marietta, Muskingum, Adams, Warren, Belpre, Dunham, Barlow, Palmer, Fairfield, and Decatur. The following map depicts the locations of dams throughout the county. As can been seen, these dams extend over much of the western portion of Washington County, with Salem Township being the farthest east location. The National Levee Database indicates that there are no levees or floodwalls located in or near Washington County.


Washington County Hazard Mitigation Plan
Dam Locations (by Class)
Data Source(s):
ODNR, USACE NID
DISCLAIMER: Data is meant for use as reference only. Some sources may be intended to be used at national or regional scales and are thus used beyond their original intent for demonstrative purposes.
Class I
Class II
Class II
Class IV
Exempt
InspExe
Unclassed
N
WASHINGTON

The National Performance of Dams Program (NPDP) was founded in 1994 at Stanford University to collect current and historical information on the performance of dams in the United States. The NPDP also maintains a catalog of all dams in the United States, as well as information regarding past incidents with dams. The following table presents the NPDP, NID, and ODNR dams in Washington County, in total there are 40 dams located in the county.

Dam Name	*Dam Type*	*Hazard Class*	*Main Purpose*	*Dam Height (ft)*
Eramet Waste Retention	Earthfill, Zoned	I	Waste Retention	117.5
Muskingum River Lower Fly Ash Dam	Earthfill, Zoned	I	Waste Retention	75
Muskingum River Middle Fly Ash Dam	Earthfill	I	Waste Retention	100
Muskingum River Upper Fly Ash Dam	Earthfill, Zoned	I	Waste Retention	135
Veto Lake Dam	Earthfill	I	Recreation, Public	38
Carman Lake Dam	Earthfill	II	Recreation, Private	18.5
Chopper's Lake Dam	Earthfill	II	Recreation, Private	22.8
Eramet Fluid Waste Pond 1A	Earthfill, Homogeneous	II	Waste Retention	35
Eramet Slag Tailings Pond	Earthfill	II	Waste Retention	25
Muskingum River Lock & Dam No. 2	Timber Crib / Concrete	II	Recreation, Public	17.5
Muskingum River Lock & Dam No. 3	Timber Crib / Concrete	II	Recreation, Public	17.6
Muskingum River Lock & Dam No. 4	Timber Crib / Concrete	II	Recreation, Public	17
Muskingum River Lock & Dam No. 5	Timber Crib / Concrete	II	Recreation, Public	19.7
Units 1-4 Bottom Ash Pond Dam	Earthfill	II	Waste Retention	33
Badger Pond Dam	Earthfill	III	Recreation, Private	33.4
Davlin Lynch, LLC Dam	Earthfill	III	Recreation, Private	23
Strahler's Lake Dam	Earthfill	III	Recreation, Private	28.8
Washington Co. Fish & Game Club Lake	Earthfill	III	Recreation, Private	17.8
Bogard's Pond Dam	Earthfill	IV	Recreation, Private	13.6
Elkem Leachate Retention Dam	Earthfill, Zoned	IV	Leachate Retention	29
Lee Pond Dam	--	IV	Recreation, Private	15
Pinkerton Lake Dam	Earthfill	IV	Recreation, Private	22
Shaffer Lake Dam	Earthfill	IV	Recreation, Private	12.2
Shaffer Lake No 1 Dam	Earthfill	IV	Recreation, Private	16.7
Shell Chemical Slag Pond Dam	Earthfill	IV	Waste Retention	16.5
Warren Local School District Dam	Earthfill	IV	Recreation, Private	18.5
Windland Pond Dam	Earthfill	IV	Recreation, Private	13.5
Woodruff Lake Dam	Earthfill	IV	Recreation, Private	17.6
Wynn Pond Dam	--	IV	Recreation, Private	15
Barnes Pond Dam	Earthfill	Exempt	Recreation, Private	10
Cyanamid Corp. Pond Dam	--	Exempt	Water Supply, Ind.	43
Dexter Lake Dam	Earthfill	Exempt	Recreation, Private	18.2
Goodfellows Park Lake Dam	Earthfill	Exempt	Recreation, Private	9.6
Gorsuch Bottom Ash Impoundment Dam	Earthfill	Exempt	Waste Retention	8
Gribble's Pond Dam	--	Exempt	Recreation, Private	12
Pitts Pond Dam	--	Exempt	Recreation, Private	10
Ramsey Pond Dam	Earthfill	Exempt	Recreation, Private	23
Shupola Lake Dam	Earthfill	Exempt	Recreation, Private	16
Wagner's Pond Dam	Earthfill	Unclassed	Water Supply, Agr.	26.8
Willow Island Locks and Dam	Concrete, Gravity	Unclassed	Recreation, Public	--

Source: National Inventory of Dams / Ohio Department of Natural Resources

Hazard Impacts

Uncontrolled floodwaters are one of the most powerful and destructive forces in nature. Dams that are not designed to withstand major storms may be destroyed, increasing flood damage downstream. Dams may also be destroyed as a cascading effect of an earthquake.

The potential for damage due to dam failure is increasing along with the increased number of residential and commercial development located within the hydrological shadow of dams. In many cases, existing dams will need to be modified to keep downstream areas safe from catastrophic flooding. Washington County contains dams that could present the possibility of significant flood damage to the residents and businesses located near or downstream from the dams. In many cases the dams are less than five miles away from the nearest community.

The NPDP defines "incident" as any event that provides insight to the structural and operational integrity of a dam", thus incidents can be either positive (such as implementation of emergency action plans) or negative (dam failure). The following table presents potential incidents defined by the NPDP.

DAM INCIDENTS	
Event	*Description*
Inspection Findings	The findings of a dam safety inspection that identify unsatisfactory or unsafe conditions at a dam. These might include observations of deterioration, signs of distress or instability of a dam or appurtenant structures.
Dam Failure	Any event resulting in the breach of a dam (partial or complete) and the uncontrolled release of the reservoir.
Controlled Breach	A planned (non-emergency, non-incident initiated) breach of a dam; possibly carried out to remove the dam from service or to make major repairs.
Downstream Release-Controlled or Uncontrolled	Uncontrolled release of the reservoir (e.g., appurtenant structure misoperation), or controlled release with damage.
Inflow Floods, Earthquakes	The performance of a dam (satisfactory or unsatisfactory; anticipated or unanticipated) generated by a nearby seismic event or inflow flood.
Misopertation, Operator Error	Misoperation of appurtenant structures such as failing to comply with the project rule curve.
Equipment Failure	Failure of mechanical or electrical equipment to perform the functions for which they were intended.
Deterioration	Deterioration of concrete, steel, or timber structures that jeopardizes the structural/functional integrity of a dam or appurtenant structures.
Dam Safety Modification	Modifications to improve the safety of a dam or appurtenant structures such as might be required due to changes in design criteria. Note, repairs following an incident are reported as part of a follow-up to an incident.
Reservoir Incidents	Events that occur in the reservoir (e.g., landslides, waves) that may impact the safety of the dam.
Emergency Action Plans	Implementation of an Emergency Action Plan (or emergency actions) in part or whole.
Regulatory Action	The regulator has determined an unsafe condition exists, or the dam does not meet applicable design criteria (e.g., inadequate spillway capacity), and requires action to be taken by the owner (e.g., reservoir restriction, safety modification).

Source: National Performance of Dams Program

In addition to national classifications, states can implement custom classification systems for dams. According to Ohio Administrative Code Rule 1501:21-13-01, dams fall under one of four classes, which are described below. The four classes are based on height, storage capacity, and downstream hazard potential. The height of a dam is defined as the vertical dimension measured from the natural streambed at the downstream toe of a dam to the low point along the top of the dam. The storage volume of a dam is defined as the total volume impounded when the pool level is at the top of the dam immediately before it is overtopped. According to the Ohio Department of Natural Resources (ODNR), the damage predicted by a dam failure coincides with the class of the dam. The potential downstream hazard is defined as the resultant downstream damage should the dam fail, including probable future development.

- **Class I:** Dams having a storage volume greater than 5,000 acre-feet or height greater than 60 feet. Probable loss of life and structural damage to high value property (i.e., homes, industries, major public utilities) would occur in the event of complete failure.
- **Class II:** Dams having a total storage volume greater than 500 acre-feet or height of greater than 40 feet. Failure of this class would cause high-value property damage to businesses, other dams, homes, state and interstate highways, railroads, water/wastewater/industrial impoundments, and only assess routes to residential areas.
- **Class III:** Dams having a total storage volume greater than 50 acre-feet or height greater than 25 feet. Failure of this class of dam would cause loss of property, particularly agricultural structures, garages, exempt dams, and county, township, and city roads, crops and livestock.
- **Class IV:** Dams having a total storage volume of 50 acre-feet or less and a height of 25 feet or less. Class IV dams are exempt from permit requirements. Failure of this class of dam would not cause downstream hazard impacts to structures, losses would be confined mainly to the dam itself.

The impacts of a dam failure are contingent on many factors and, therefore, cannot be concisely described. The following is an estimate of the downstream impacts of a dam failure of the Eramet Waste Retention Dam, which is a Class I dam that has an estimated Sunny Day Population At-Risk (PAR) greater than 50. Because of the uncertainty of determining precisely who and what will be impacted by a failure of this dam, a scale was developed by the ODNR – Dam Safety Program (DSP) to categorize dams based on their estimated impact to lives and structures downstream. The “Very High, High, Medium, and Low” scale is based on the PAR

and was developed using experience with flood modeling, aerial photographs, field observations, and engineering judgement.

Class I Dams – Estimated Downstream Damage Level & Estimated Population At-Risk (PAR)					
County	*Dam*	*Sunny Day Damage Level*	*Sunny Day PAR Level*	*Rainy Day Damage Level*	*Rainy Day PAR Level*
Washington	Eramet Waste Retention Dam	High	Medium	High	Medium

Source: ODNR – Dam Safety Program, "Population at Risk" Evaluation, 2019

The ODNR classifies levies in much the same way, however only the effects of a levee failing are considered for Classes I-III. Only Class IV has a height definition, which is not more than 3 feet.

The U.S. Army Corps of Engineers' National Inventory of Dams (NID) maintains a database of maps in the United States that meet one of the following criteria:

1. High hazard potential classification – loss of human life is likely if the dam fails
2. Significant hazard potential classification – no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or impact other concerns
3. Equal or exceed 25 feet in height and exceed 15 acre-feet in storage
4. Equal or exceed 50 acre-feet storage and six feet in height.

The NID's goal is to include all dams in the U.S. that meet those criteria, and reconciles conflicting and duplicative data from 68 data sources. Historically, the NID was published every two years, but in 2019 began updating the database yearly. According to the NID, there are 19 dams in Washington County. Of those 19, five are high hazard potential, eight are significant hazard potential, and six are low hazard potential.

Historical Occurrences

No one knows exactly how many dam failures have occurred in the U.S., but they have been documented in every state. From 2005-2013, there were 173 dam failures and 587 incidents nationwide. The Stanford National Performance of Dams Program (NPDP) tracks dam incidents that occur around the world and collects data related to these incidents. According to the NPDP there have been two incidents within Washington County in the last 20 years. Neither of these incidents resulted in damage to any property other than the dam.

HISTORICAL DAM FAILURE OCCURRENCES – WASHINGTON COUNTY			
Dam Name	*Incident Type*	*Incident Date*	*Purpose*
Chopper S Lake Dam	Inflow Flood-Hydrologic Event	4/10/1994	Recreation
Wagner S Pond Dam	Inadequate Spillway Capacity	2/9/1996	Water Supply

Source: National Performance of Dams Program

Waterford Township – April, 1994

The first of these events occurred on April of 1994 when heavy rainfall resulted in the failure of the Choppers Lake Dam in Waterford Township. A breach approximately eight feet deep appeared after earth adjacent to the spillway eroded, causing the spillway discharge chute to collapse. The breach sent water from the dam into the Muskingum River. There was no downstream damage reported and it is unknown if an EAP was in place or implemented (Stanford NPDP).

Palmer Township – February, 1996

The second dam failure in Washington County listed in the NPDP database occurred less than two years later, in February of 1996. This incident occurred at the Wagner S Pond Dam in Palmer Township and was reported to be an incident of inadequate spillway capacity. The record shows that there was no uncontrolled release of the reservoir and there were no documented consequences. It is unknown if an EAP existed or was implemented (Stanford NPDP).

Loss and Damages

Losses from a dam failure are dependent on the size, purpose, and inundation area of the dam. Loss estimates and vulnerable structures for a dam incident were generated using a multistep analysis. The total number of structures estimated by HAZUS-MH as moderately damaged by the 100-year flood was identified as 451. The number of total structures identified in this manor was then divided by the number of Class I, II, and III dams present in the county

(18) to estimate the number of vulnerable structures for any one dam failure. This figure was then multiplied by the percentage of each structure type found in the county as generated by the Ohio EMA's HAZUS-MH loss estimate workbook. Average structural value for each type was also obtained from the loss estimate workbook, generating the figures in the table below.

DAM & LEVEE FAILURE EXPOSURE ESTIMATE – MIP DATA ENTRY		
Structure Type	*Number*	*Loss Estimate*
Residential	18	$2,482,275.34
Non-Residential	6	$838,681.71
Critical Facilities	1	$127,605.64
TOTALS	25	$3,495,562.68

Source: Ohio EMA HAZUS-MH Loss Estimate Workbook Calculation

Vulnerability Assessment

This section summarizes the vulnerability to Washington County from dam and levee failures. Dam failure results in consequences such as damages to existing buildings, damage to infrastructure, loss of services form utilities, loss of government services (including fire and police), loss of business income, displacement of individuals and businesses, loss of crops and livestock, and loss of life (FEMA, n.d.).

Because dam failures have the potential to result in loss of life and severe economic loss, the American Society of Civil Engineers (ASCE) recommends that all high hazard dams have any emergency action plan in the event of an impending failure (ASCE, 2013). An emergency action plan, or EAP, is "an essential plan used in the event of a dam failure to identify and notify people residing below the dam, and to coordinate their evacuation" (ASCE, 2013). The Ohio HMP states that "all classes are required to have EAPs and Class I's are required to include dam failure inundation mapping" (2019).

Washington County conducted an online survey for the public to share its thoughts on hazard vulnerabilities. The following table presents the results of that survey regarding dam and levee failure.

PUBLIC SENTIMENT, DAM & LEVEE FAILURE – WASHINGTON COUNTY					
	Level of Concern				
Hazard	*Not at All*	*Somewhat*	*Concerned*	*Very*	*Total Responses*
Dam Failure	17 (47.22%)	16 (44.44%)	1 (2.78%)	2 (5.56%)	36
In the past ten years, do you remember this hazard occurring in your community?				1 (2.78%)	36
Have you noticed an increase in the occurrences or intensity of this hazard?				1 (2.78%)	36
Have you noticed a decrease in the occurrences or intensity of this hazard?				0 (0.00%)	36

Source: Online Public Survey Results

The following table assigns point totals based on the research presented in this profile for each category that appears in Ohio EMA's Mitigation Information Portal (MIP) tool.

DAM & LEVEE VULNERABILITY SUMMARY			
Category	*Points*	*Description*	*Notes*
Frequency	2	Low	There have been two dam incidents and zero levee failures in Washington County since 1994 (for an average of 0.1 incidents per annum).
Response	2	One day	Due to frequent inspections of dams in Washington County and minimal recorded historical damage downstream, the response to an event would be expected to be minimal.
Onset	1	Over 24 hours	Because officials frequently inspect dams and their inundation can be predicted based on weather, warning of a critical failure is expected.
Magnitude	1	Localized (< 10% land area affected)	Most dams are in rural areas.
Business	1	Less than 24 hours	Most dams are in rural areas. The county's economy should not be disrupted by either failure.
Human	2	Low (some injuries)	Most dams in the county are Class IV or unclassified. Failure would not cause significant human harm.
Property	1	< 10% property affected	Most dams in the county are Class IV or unclassified, suggesting that property loss would be primarily from the loss of the dam itself and the owner's property.
Total	10	Lowest