4.3.1 Dam Failure

Hazard Profile

The following section provides the hazard profile (hazard description, location, extent, previous occurrences and losses, probability of future occurrences, and impact of climate change) and vulnerability assessment for the dam failure hazard in Rockland County.

Hazard Description

A dam is an artificial barrier allowing storage of water, wastewater, or liquid-borne materials for many reasons (flood control, human water supply, irrigation, livestock water supply, energy generation, containment of mine tailings, recreation, or pollution control). Many dams fulfill a combination of these stated functions (Association of State Dam Safety Officials 2023). Dam failure is any malfunction or abnormality outside of the design that adversely affects a dam's primary function of impounding water and potentially leads to a sudden, rapid, and uncontrolled release of water (USSD 2023). The risks that are associated with dams must always be minimized and maintained properly, including safety inspections, technical review of a proposed new dam, monitoring and enforcement of dam safety criteria and emergency preparedness (NYS DEC n.d.).

Man-made dams can be classified by the type of construction material used, methods applied in construction, slope, or cross-section of the dam, how a dam resists forces of water pressure behind it, means used to control seepage, and occasionally, purpose of the dam. Materials used for construction of dams include earth, rock, tailings from mining or milling, concrete, masonry, steel, timber, miscellaneous materials (plastic or rubber), and any combination of these materials (Association of State Dam Safety Officials 2023). Dams are built for the purpose of power production, agriculture, water supply, recreation, and flood protection.

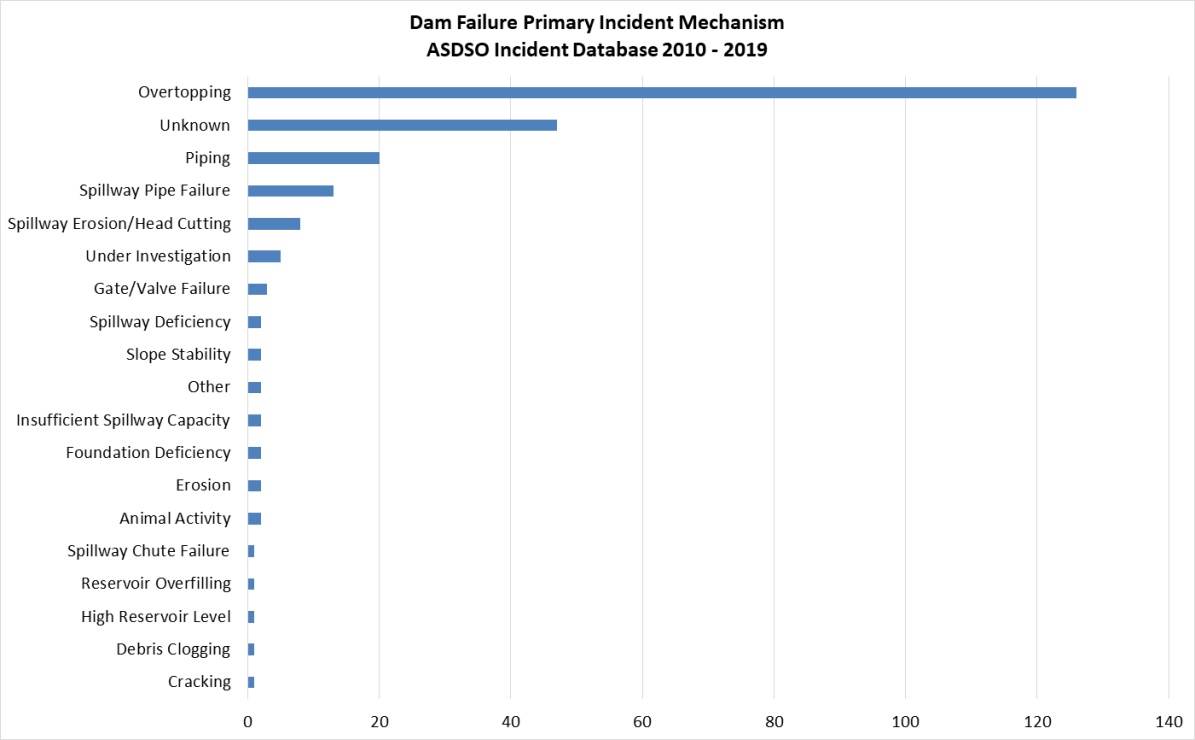
More than a third of the nation's dams are at least 50 years old. Approximately 15,000 of those dams pose a significant hazard to life and property if failure occurs. About 2,000 unsafe dams are dispersed throughout the United States in almost every state.

Dams typically fail when spillway capacity is inadequate and excess flow overtops the dam or when internal erosion (piping) through the dam or foundation occurs. Complete failure occurs if internal erosion or overtopping results in a complete structural breach, releasing a high-velocity wall of debris-filled water that rushes downstream, damaging or destroying anything in its path (FEMA 2016).

Figure 4.3.1-1 visualizes the primary causes of dam failures, nationally. Dam failures can result from one or a combination of the following (ASDSO n.d.):

- Overtopping caused by floods that exceed capacity of the dam
- Deliberate acts of sabotage
- Structural failure of materials used in dam construction
- Movement or failure of the foundation supporting the dam
- Settling and cracking of concrete or embankment dams
- Piping and internal erosion of soil in embankment dams
- Inadequate maintenance and upkeep

Figure 4.3.1-1. Dam Failure Causes



Source: ASDSO n.d.

Regulatory Oversight of Dams

Potential for catastrophic flooding caused by dam failures led to passage of the NDSP (Public Law 92-367). For 30 years, the NDSP has protected Americans from dam failure. NDSP is a partnership among the states, federal agencies, and other stakeholders that encourages individual and community responsibility for dam safety. Under FEMA's leadership, state assistance funds have allowed all participating states to improve their programs through increased inspections, emergency action planning, and purchase of needed equipment. FEMA has also expanded existing training programs and initiated new training programs (FEMA 2022). Grant assistance from FEMA provides support for improvement of dam safety programs that regulate most dams in the United States (FEMA 2023).

The State of New York has a comprehensive dam safety program through which three governmental authorities regulate dam safety throughout the state:

- NYSDEC – Environmental Conservation Law (ECL) Article 15, Part 673
- FERC – 18 *Code of Federal Regulations* (CFR) 12.22-24
- USACE – EP 1110-2-13, Dam Safety Preparedness

Dam safety EAPs are formal dam failure procedures written by the dam owner/operator. EAPs are site-specific plans and relate only to the facility's procedures to prevent/mitigate occurrence of a catastrophic dam failure. USACE is responsible for submitting an EAP for each dam it owns, operates, and maintains. EAPs for hydroelectric dams fall under the purview of FERC, and NYSDEC regulates dam safety and EAPs for all dams in New York.

New York State Department of Environmental Conservation

The New York State Department of Environmental Conservation's (NYSDEC) Dam Safety Section is responsible for safety inspection of dams, technical review of proposed dam construction or modification, monitoring of remedial work for compliance with dam safety criteria, and emergency preparedness for all dams in the state. NYSDEC is responsible for more than 100 flood control projects throughout the state, most of which were constructed by US Army Corps of Engineers (USACE) and are operated and maintained by NYSDEC (in some cases with local municipal partners) (NYSDEC 2014).

The State inspects high hazard dams every two years and moderate hazard dams every four years. To support emergency planning efforts and raise awareness among local officials and emergency managers, a copy of each inspection report is sent to the chief executive of the community in which the dam is located. Municipal officials or emergency managers from any municipality in the dam's inundation area may receive a copy of the inspection report upon request (NYSDEC 2023).

US Army Corps of Engineers Dam Safety Program

USACE is responsible for safety inspections of some federal and non-federal dams in the United States that meet size and storage limitations specified in the National Dam Safety Act, including the 80 dams identified in the USACE National Inventory of Dams (NID). USACE has inventoried dams and has surveyed each state and federal agency's capabilities, practices, and regulations regarding design, construction, operation, and maintenance of dams. USACE has also developed guidelines for inspection and evaluation of dam safety (USACE 2014).

Federal Energy Regulatory Commission Dam Safety Program

The Federal Energy Regulatory Commission (FERC) has the largest dam safety program in the United States. FERC cooperates with many federal and state agencies to ensure and promote dam safety and, more recently, homeland security. FERC staff inspect hydroelectric projects on an unscheduled basis to investigate the following (FERC 2020):

- Potential dam safety problems
- Complaints about constructing and operating a project
- Safety concerns related to natural disasters
- Issues concerning compliance with terms and conditions of a license

Every five years, an independent FERC-approved consulting engineer must inspect and evaluate projects with dams higher than 32.8 feet (10 meters) or with total storage capacity of more than 2,000 acre-feet (FERC 2020).

FERC monitors and evaluates seismic research in geographic areas where seismic activity is a concern. This information is applied to investigate and analyze structures of hydroelectric projects within these areas. FERC staff also evaluates effects of potential and actual large floods on safety of dams. FERC staff visit dams and licensed projects during and after floods, assess extents of damage, and direct any studies or remedial measures the licensee must undertake. FERC's *Engineering Guidelines for the Evaluation of Hydropower Projects* guides its engineering staff and licensees in evaluations of dam safety. The publication is frequently revised to reflect current information and methodologies (FERC 2020).

FERC requires licensees to prepare Emergency Action Plans (EAP) and conducts training sessions on developing and testing these plans. The plans outline an early warning system in the event of an actual or potential sudden release of water from a dam failure. The plans include operational procedures that may be implemented during

regulatory measures, such as reducing reservoir levels and downstream flows, as well as procedures for notifying affected residents and agencies responsible for emergency management. These plans are frequently updated and tested to ensure that all applicable parties are informed of the proper procedures in emergencies (FERC 2020).

Location

In the State of New York, there are 400 high hazard dams and 700 moderate hazard dams that pose a threat to jurisdictions in the event of a dam failure. 32 dams are present throughout Rockland County. Most of these dams pose little risk; however, there are 13 high hazard dams. Table 4.3.1-1 is a complete list of the high hazard dams in Rockland County (NYS DHSES n.d.). Figure 4.3.1-2 shows the locations of dam inundation areas in Rockland County.

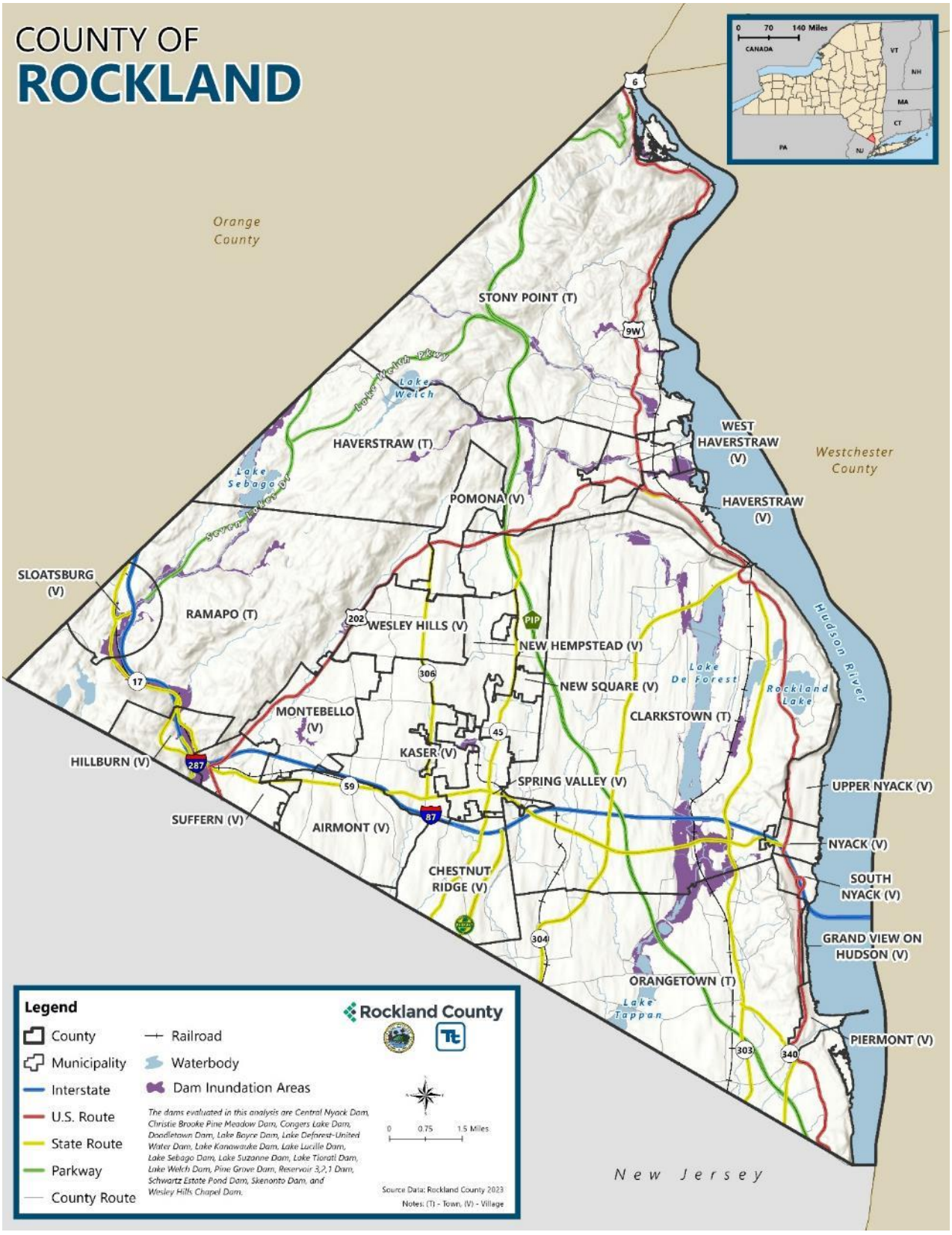
According to the NID, all dams in Rockland County are state regulated. All 13 high hazard dams eight additional dams also have EAPs. In addition, there are dams located in neighboring counties near the County border that may impact parts of the County (USACE 2023).

Table 4.3.1-1. High Hazard Dams in Rockland County (via NID)

Dam Name	Municipality	Stream	Class
First Reservoir Dam	Thiells	Horse Chock Brook	High
Lake Deforest Dam	West Nyack	Hackensack River	High
Lake Welch Dam	Willow Grove	Minisceongo Creek	High
Lake Sebago Dam	Sloatsburg	Stony Brook Creek	High
Garnerville Dam	West Haverstraw	Minisceongo Creek	High
Tivoli Dam	Sloatsburg	Ramapo River Tributary	High
Potake Lake Dam	Sloatsburg	Ramapo River Tributary	High
Lake Kanawauke Dam	New Sebago Beach	Stony Brook	High
Lake Suzanne Dam	Spring Valley	Pascack Brook	High
Lake Lucille Dam	Lake Lucille	Hackensack River	High
Central Nyack Dam	Clarkstown	Hackensack River Tributary	High
Pine Grove Lake Dam	Sloatsburg	Ramapo River Tributary	High
Congers Lake Dam	Congers	E. Branch Hackensack River	High

Source: USACE 2023

Figure 4.3.1-2. Dam Inundation in Rockland County



Extent

Dam failures can occur suddenly, without warning, and may occur during normal operating conditions. This is referred to as a "sunny day" failure. Dam failures may also occur during a large storm event. Significant rainfall can quickly inundate an area and cause floodwaters to overwhelm a reservoir. If the spillway of the dam cannot safely pass the resulting flows, water will begin flowing in areas not designed for such flows, and a failure may occur. New York has seen significant property damage including damage or loss of dams, bridges, roads, and buildings because of storm events and dam failures.

According to the NYSDEC Division of Water Bureau of Flood Protection and Dam Safety, the hazard classification of a dam is assigned according to the potential impacts of a dam failure pursuant to 6 New York Codes Rules and Regulations (NYCRR) Part 673.3 (NYSDEC date unknown) (N.Y. Comp. Codes R. & Regs. Tit. 6 § 673.3 - General provisions n.d.). Dams are classified in terms of potential for downstream damage if the dam were to fail. These hazard classifications are identified and defined below (NYS DEC n.d.):

- *Low Hazard (Class A)* is a dam located in an area where failure will damage nothing more than isolated buildings, undeveloped lands, or township or county roads; and/or will cause no significant economic loss or serious environmental damage. Failure or mis-operation would result in no probable loss of human life. Losses are principally limited to the owner's property.
- *Intermediate Hazard (Class B)* is a dam located in an area where failure may damage isolated homes, main highways, and minor railroads; interrupt the use of relatively important public utilities; and/or cause significant economic loss or serious environmental damage. Failure or mis-operation would result in no probable loss of human life, but may cause economic loss, environment damage, disruption of lifeline facilities, or impact other concerns. Dams classified as intermediate hazard dams are often located in predominantly rural or agricultural areas but could be in areas with population and significant infrastructure.
- *High Hazard (Class C)* is a dam located in an area where failure may cause loss of human life, serious damage to homes, industrial or commercial buildings, important public utilities, main highways, or railroads, and/or will cause extensive economic loss. This hazard classification is for dams in which excessive economic loss (urban area including extensive community, industry, agriculture, or outstanding natural resources) would occur as a direct result of dam failure.
- *Negligible or No Hazard (Class D)* is a dam that has been breached or removed, or has failed or otherwise no longer materially impounds waters, or a dam that was planned but never constructed. These dams are defunct dams posing negligible or no hazard to downstream areas. NYSDEC may retain pertinent records regarding such dams.

Previous Occurrences

FEMA Major Disaster and Emergency Declarations

Between 1954 and 2023, Rockland County was not included in any major disaster (DR) or emergency (EM) declarations for dam failure-related events (FEMA 2023). However, dam failures have occurred due to other precursor events, such as hurricanes, tropical storms, and severe storms. For declarations of events which have triggered dam failures that occurred between 2017 and 2023, refer to Table 4.3.1-2. Detailed information about the declared disasters since 1954 is provided in Section 3 (County Profile).

Table 4.3.1-2. FEMA Declarations for Dam Failure Precursor Events in Rockland County (2017 to 2023)

Date(s) of Event	Event Type	FEMA and/or USDA Declaration Number (if applicable)	Rockland County included in declaration?	Location Impacted	Description
August 21-24, 2021	Hurricane	EM-3565-NY	Yes	Countywide	New York Hurricane Henri

Sources: FEMA 2023

USDA Declarations

The Secretary of Agriculture from the U.S. Department of Agriculture (USDA) is authorized to designate counties as disaster areas to make emergency loans to producers suffering losses in those counties and in counties that are contiguous to a designated county. Between 2018 and 2023, Rockland County was not included in any dam failure-related agricultural disaster declarations.

Previous Events

For this 2024 HMP update, known hazard events that impacted Rockland County between January 2017 and December 2023 are discussed in Table 4.3.1-3. For events prior to 2017, refer to the 2018 Rockland County HMP.

Table 4.3.1-3. Hazard Events in Rockland County (2017 to 2023)

Date(s) of Event	Event Type	FEMA and/or USDA Declaration Number (if applicable)	Rockland County included in declaration?	Location Impacted	Description
August 4, 2020	Tropical Storm	N/A	N/A	Rockland County	the remnants of Tropical Storm Isaias brought high winds and heavy rain to Rockland County. High winds caused a tree to fall at the downstream edge of the Pine Grove Lake Dam crest. These conditions created a void in the embankment and a crack in the soil around the tree roots, but further examination concluded the cracking was due to earth being pulled away by the roots, not due to dam slope sliding.

Sources: ASDSO n.d.

Probability of Future Occurrences

For the 2024 HMP update, best available data was used to collect hazard event details. These details were used to calculate the probability of future occurrence of hazard events in the County. Information from the 2019 State of New York HMP, the 2018 Rockland County HMP, and FEMA were used to identify the number of events that occurred between 1999 and 2023. Table 4.3.1-4 provides the calculated probability of future dam failure events in Rockland County.

Table 4.3.1-4. Probability of Future Dam Failure Events in Rockland County

Hazard Type	Number of Occurrences Between 1999 and 2023	Percent Chance of Occurring in Any Given Year
Dam Failure	3	12.5%

Sources:
Notes: *Disaster occurrences include federally declared disasters since the 1950 Federal Disaster Relief Act, and selected dam failure events since 1968. Due to limitations in data, not all dam failure events occurring between 1954 and 1996 are accounted for in the tally of occurrences. As a result, the number of hazard occurrences is underestimated.*

In Section 4.4, the identified hazards of concern for Rockland County were ranted. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Partnership, the probability of occurrence for dam failure in the County is considered 'occasional'.

Climate Change Projections

Dams are designed partly based on assumptions about a river's flow behavior, expressed as hydrographs. Changes in weather patterns can have significant effects on the hydrograph used for the design of a dam. If the hygrograph changes, it is conceivable that the dam can lose some or its entire designed margin of safety, also known as freeboard. Loss of designed margin of safety may cause floodwaters more readily to overtop the dam or create unintended loads. Such situations could lead to a dam failure.

Warming atmospheric temperatures influence ocean temperatures. With the projected increase in temperature, it is anticipated that ocean waters will increase as well, causing ice sheets and glaciers to melt, increasing the level of the ocean's waters. Sea level rise can impact the amount of water in the tidal Hudson River, impacting not only bordering communities, but inland communities as well. With an increase in water, the inundation area of a dam failure may increase, causing damage further than originally anticipated.

Rockland County is part of Region 2, Catskill Mountains, and the West Hudson River Valley. In Region 2, it is estimated that temperatures will increase by 3.0 °F to 5.0 °F by the 2050s and 4.0 °F to 8.0 °F by the 2080s. Precipitation totals will increase between 0 and 10 percent by the 2050s and 5 to 10 percent by the 2080s. Table 4.3.1-5 displays the projected seasonal precipitation change for ClimAID Region 2 (NYSERDA 2014). Increases in precipitation can lead to dams becoming fuller, increasing the risk of overtopping during heavy rainfall events.

Table 4.3.1-5. Projected Seasonal Precipitation Percent Change in Region 2 from Present to 2050

Winter	Spring	Summer	Fall
0 to +15	0 to +10	-5 to +10	-5 to +10

Source: NYSERDA 2014

Climate change can impact stored water systems as increased rainfall accumulations can cause reservoirs to overtop. Dams are designed using a hydrograph to evaluate dam safety issues for situations where the reservoir inflow peak discharge is greater than the maximum spillway capacity, the reservoir has large surcharge storage, and/or the reservoir has dedicated flood control space. Increased precipitation may result in overtopping, as the hydrographs are based off historical events (USBR 2003). The overtopping of a dam can lead to areas downstream to become inundated with flood waters that would otherwise be safely stored.

Vulnerability Assessment

Dam failures are a hazard of concern for Rockland County because 32 dams are present across the County, 13 of which are identified as high hazard (Figure 4.3.1-2) (USACE 2023). Dam failure events are frequently triggered by other natural hazard events such as earthquakes, landslides, or severe weather, which limits their predictability and intensifies the risk for potential damage.

Dam failure inundation maps and downstream hazard areas are considered sensitive information and are not made available in the Rockland County Hazard Mitigation Plan. To assess the County's risk to dam failure, an exposure analysis was conducted for the County's assets (population, building stock, critical facilities, historic assets, and new development) using the Dam Inundation Areas provided by Rockland County. This analysis combined all available dam inundation areas to create an aggregate dam inundation area for the County. An asset is indicated as exposed if it is in at least one dam failure inundation area. Evaluated dams include Central Nyack Dam, Christie Brooke Pine Meadow Dam, Congers Lake Dam, Doodletown Dam, Lake Boyce Dam, Lake Deforest-United Water Dam, Lake Kanawauke Dam, Lake Lucille Dam, Lake Sebago Dam, Lake Suzanne Dam, Lake Tiorati Dam, Lake Welch Dam, Pine Grove Dam, Reservoir 3,2,1 Dam, Schwartz Estate Pond Dam, Skenonto Dam, and Wesley Hills Chapel Dam.

Impact on Life, Health, and Safety

The impact of dam failure on life, health, and safety depends on several factors such as the class of dam, the area being protected, the location, and the proximity of structures, infrastructure, and critical facilities to the dam. According to the State HMP, the level of impact due to a failure can be estimated using the United States Army Corps of Engineers's (USACE) hazard potential classification system (USACE 2014). Table 4.3.1-6 outlines these hazard classifications.

Table 4.3.1-6. United States Army Corps of Engineers Hazard Potential Classification

Hazard Category (a)	Direct Loss of Life (b)	Lifeline Losses (c)	Property Losses (d)	Environmental Losses (e)
Low	None (rural location, no permanent structures for human habitation)	No disruption of services (cosmetic or rapidly repairable damage)	Private agricultural lands, equipment, and isolated buildings	Minimal incremental damage
Significant	Rural location, only transient or day-use facilities	Disruption of essential facilities and access	Major public and private facilities	Major mitigation required
High	Certain (one or more) extensive residential, commercial, or industrial development	Disruption of essential facilities and access	Extensive public and private facilities	Extensive mitigation cost or impossible to mitigate

Source: USACE 2014

Note: a. Categories are assigned to overall projects, not individual structures at a project.
b. Loss-of-life potential is based on inundation mapping of area downstream of the project. Analyses of loss-of-life potential should consider the population at risk, time of flood wave travel, and warning time.
c. Lifeline losses include indirect threats to life caused by the interruption of lifeline services from project failure or operational disruption; for example, loss of critical medical facilities or access to them.
d. Property losses include damage to project facilities and downstream property and indirect impact from loss of project services, such as impact from loss of a dam and navigation pool, or impact from loss of water or power supply.
e. Environmental impact downstream caused by the incremental flood wave produced by the project failure, beyond what would normally be expected for the magnitude flood event under which the failure occurs.

Overall Population

The entire population residing within a dam failure inundation zone is considered exposed and vulnerable to an event. The potential for loss of life is affected by the capacity and number of evacuation routes available to populations living within these areas. As shown in Table 4.3.1-7, there are 5,437 persons located in the dam inundation area; the Village of Spring Valley has the greatest population in the dam inundation area with 1,689 persons.

Dam failure can displace persons in the area if flooding of structures occurs. Dam failure may mimic flood events, depending on the size of the dam reservoir and breach. Understanding potential outcomes of flooding for each dam in Rockland County would require intensive hydraulic modeling.

Table 4.3.1-7. Estimated Population Located in the Aggregate Dam Inundation Area

Jurisdiction	Total Population	Estimated Population Located in the Aggregate Dam Inundation Area	
		Number of People	Percent of Total
Airmont, Village of	9,964	0	0.0%
Chestnut Ridge, Village of	10,211	0	0.0%
Clarkstown, Town of	81,385	1,394	1.7%
Grand View on Hudson, Village of	241	0	0.0%
Haverstraw, Town of	14,028	392	2.8%
Haverstraw, Village of	12,292	417	3.4%
Hillburn, Village of	1,110	30	2.7%
Kaser, Village of	5,433	0	0.0%
Montebello, Village of	4,665	108	2.3%
New Hempstead, Village of	5,440	0	0.0%
New Square, Village of	9,433	0	0.0%
Nyack, Village of	7,303	0	0.0%
Orangetown, Town of	36,127	32	0.1%
Piermont, Village of	2,525	0	0.0%
Pomona, Village of	3,306	0	0.0%
Ramapo, Town of	48,846	245	0.5%
Sloatsburg, Village of	3,043	597	19.6%
South Nyack, Village of	2,803	0	0.0%
Spring Valley, Village of	32,953	1,689	5.1%
Stony Point, Town of	14,876	242	1.6%
Suffern, Village of	11,376	12	0.1%
Upper Nyack, Village of	2,355	0	0.0%
Wesley Hills, Village of	6,105	0	0.0%
West Haverstraw, Village of	10,665	280	2.6%
Rockland County (Total)	**336,485**	**5,437**	**1.6%**

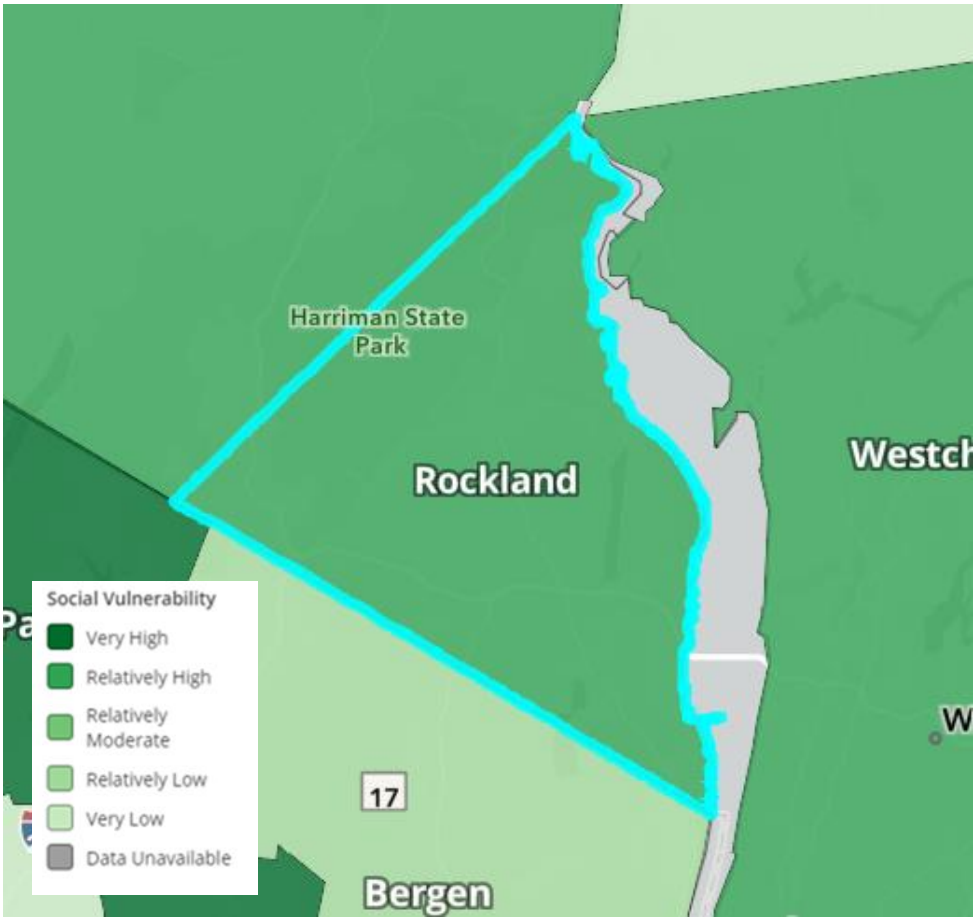
Source: U.S. Census Bureau, American Community Survey 5-year Estimates 2017-2021
Note: Values are rounded down.

Socially Vulnerable Populations

According to Census data, there are 49,451 total persons living below the poverty level, 52,060 persons over the age of 65 years, 27,605 persons under the age of 5 years, 26,990 non-English speakers, 29,008 persons with a disability, 49,451 living in poverty, and 109,704 living below ALICE in Rockland County. These populations are more at risk during a dam failure event because economically disadvantaged populations are more likely to make the decision to evacuate based upon the net economic impact to their family, while elderly populations are likely to seek or need medical attention. The availability of medical attention may be limited due to isolation during a flood event and other difficulties in evacuating. There is often limited warning time for a dam failure event. Populations without adequate warning of the event are highly vulnerable. Individuals who may not receive adequate warning

may include those that are lack internet connection, do not speak English proficiently, and/or do not regularly use the communication tool used for warnings, like a cellphone or social media account. Figure 4.3.1-3 displays the FEMA National Risk Inventory's Social Vulnerability Index for the County of Rockland, which is identified as 'relatively high'.

Figure 4.3.1-3. FEMA Social Vulnerability Index for Natural Hazards



Source: FEMA n.d.

As shown in Table 4.3.1-7, there are 5,437 persons located in the dam inundation area. Table 4.3.1-8 presents the estimated socially vulnerable populations located in the aggregate dam inundation area. Of the 5,437 persons located in the dam inundation area, there are 802 persons over the age of 65 years, 435 persons under the age of 5 years, 741 non-English speakers, 518 persons with a disability, 748 living in poverty, and 1,980 living below ALICE.

Table 4.3.1-8. Estimated Vulnerable Persons Located Within the Aggregated Dam Inundation Hazard Area

Jurisdiction	Vulnerable Population						Estimated Vulnerable Persons Located Within the Aggregated Dam Inundation Hazard Area											
	Over 65	Under 5	Non-English Speaking	Disability	Poverty Level	Living Below ALICE	Over 65	Percent of Total	Under 5	Percent of Total	Non-English Speaking	Percent of Total	Disability	Percent of Total	Poverty Level	Percent of Total	Living Below ALICE	Percent of Total
Airmont, Village of	1,487	660	355	727	1,067	2,616	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Chestnut Ridge, Village of	1,587	1,368	617	1,149	1,947	1,957	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Clarkstown, Town of	16,757	3,729	4,251	8,056	3,548	22,733	287	1.7%	64	1.7%	73	1.7%	138	1.7%	61	1.7%	390	1.7%
Grand View on Hudson, Village of	64	13	0	16	13	32	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Haverstraw, Town of	2,523	1,093	996	1,228	1,414	5,023	70	2.8%	31	2.8%	28	2.8%	34	2.8%	39	2.8%	140	2.8%
Haverstraw, Village of	1,624	882	2,045	1,500	1,796	4,671	55	3.4%	30	3.4%	69	3.4%	51	3.4%	61	3.4%	159	3.4%
Hillburn, Village of	161	114	48	145	154	362	4	2.7%	3	2.7%	1	2.7%	4	2.7%	4	2.7%	10	2.7%
Kaser, Village of	174	1,319	1,350	102	3,284	1,182	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Montebello, Village of	563	193	165	303	516	588	13	2.3%	4	2.3%	4	2.3%	7	2.3%	12	2.3%	14	2.3%
New Hempstead, Village of	816	259	65	383	121	439	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
New Square, Village of	201	1,523	1,651	319	5,699	1,586	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Nyack, Village of	1,521	347	265	862	286	3,653	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Orangetown, Town of	6,912	1,804	1,056	3,540	1,626	12,603	6	0.1%	2	0.1%	1	0.1%	3	0.1%	1	0.1%	11	0.1%
Piermont, Village of	539	141	142	181	48	1,214	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Pomona, Village of	613	246	116	293	111	520	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Ramapo, Town of	4,698	7,183	1,265	2,424	16,194	18,912	24	0.5%	36	0.5%	6	0.5%	12	0.5%	81	0.5%	95	0.5%
Sloatsburg, Village of	513	200	68	380	166	1,437	101	19.6%	39	19.6%	13	19.6%	74	19.6%	33	19.6%	282	19.6%
South Nyack, Village of	535	59	32	371	73	911	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Spring Valley, Village of	3,176	3,730	9,690	2,751	7,963	13,385	163	5.1%	191	5.1%	497	5.1%	141	5.1%	408	5.1%	686	5.1%
Stony Point, Town of	2,653	594	265	1,619	667	4,393	43	1.6%	10	1.6%	4	1.6%	26	1.6%	11	1.6%	71	1.6%

Jurisdiction	Vulnerable Population						Estimated Vulnerable Persons Located Within the Aggregated Dam Inundation Hazard Area											
	Over 65	Under 5	Non-English Speaking	Disability	Poverty Level	Living Below ALICE	Over 65	Percent of Total	Under 5	Percent of Total	Non-English Speaking	Percent of Total	Disability	Percent of Total	Poverty Level	Percent of Total	Living Below ALICE	Percent of Total
Suffern, Village of	2,316	490	866	1,101	706	5,449	2	0.1%	1	0.1%	1	0.1%	1	0.1%	1	0.1%	6	0.1%
Upper Nyack, Village of	479	88	19	161	170	539	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Wesley Hills, Village of	862	626	0	406	513	1,008	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
West Haverstraw, Village of	1,286	944	1,663	991	1,369	4,490	34	2.6%	25	2.6%	44	2.6%	26	2.6%	36	2.6%	118	2.6%
Rockland County (Total)	**52,060**	**27,605**	**26,990**	**29,008**	**49,451**	**109,704**	**802**	**1.5%**	**435**	**1.6%**	**741**	**2.7%**	**518**	**1.8%**	**748**	**1.5%**	**1,980**	**1.8%**

Source: U.S. Census Bureau, American Community Survey 5-year estimates 2017-2021; ALICE 2021
Note: Values are rounded down.

Impact on General Building Stock

Buildings located downstream of a dam are at risk to damages should there be a failure. Properties located closest to the dam inundation area have the greatest potential to experience the largest, most destructive surge of water. The overall impact of flooding damages caused by dam failure will vary depending on the depth of flooding and velocity of the surge.

The potential damage is the modeled loss that could occur to the exposed inventory measured by the structural and content replacement cost value. There are an estimated 1,926 buildings in the dam inundation area, representing approximately 2.7 percent of the County's total general building stock and 2.7 percent of the County's inventory replacement cost value. The Town of Clarkstown has the greatest number of its buildings located in the dam inundation area (665 buildings or 2 percent of its total building stock). Refer to Table 4.3.1-9 for the estimated exposure of the dam inundation area by jurisdiction.

Table 4.3.1-9. Estimated Number and Total Replacement Cost Value of Structures Located in the Aggregate Dam Inundation Area

Jurisdiction	Total Number of Buildings	Total Replacement Cost Value (RCV)	Estimated Number and Total Replacement Cost Value of Structures Located in the Aggregate Dam Inundation Area			
			Number of Buildings	Percent of Total	Total Replacement Cost Value of Buildings	Percent of Total
Airmont, Village of	4,324	$2,712,726,498	0	0.0%	$0	0.0%
Chestnut Ridge, Village of	3,996	$2,590,102,202	0	0.0%	$0	0.0%
Clarkstown, Town of	34,094	$22,578,694,610	665	2.0%	$509,009,033	2.3%
Grand View on Hudson, Village of	219	$123,746,894	0	0.0%	$0	0.0%
Haverstraw, Town of	5,157	$14,687,792,118	180	3.5%	$933,991,050	6.4%
Haverstraw, Village of	2,232	$1,373,775,543	81	3.6%	$164,215,430	12.0%
Hillburn, Village of	499	$340,797,550	30	6.0%	$120,050,659	35.2%
Kaser, Village of	197	$434,976,786	0	0.0%	$0	0.0%
Montebello, Village of	2,002	$1,957,771,278	45	2.2%	$23,605,206	1.2%
New Hempstead, Village of	2,074	$1,416,579,766	0	0.0%	$0	0.0%
New Square, Village of	455	$640,979,013	0	0.0%	$0	0.0%
Nyack, Village of	1,830	$1,930,474,072	0	0.0%	$0	0.0%
Orangetown, Town of	18,439	$19,240,363,073	26	0.1%	$97,151,228	0.5%
Piermont, Village of	841	$520,681,014	0	0.0%	$0	0.0%
Pomona, Village of	1,437	$947,429,629	0	0.0%	$0	0.0%
Ramapo, Town of	9,783	$7,401,302,608	75	0.8%	$207,213,312	2.8%
Sloatsburg, Village of	1,776	$780,218,848	367	20.7%	$150,283,766	19.3%
South Nyack, Village of	1,009	$628,994,780	0	0.0%	$0	0.0%
Spring Valley, Village of	3,468	$2,977,580,954	157	4.5%	$78,915,119	2.7%
Stony Point, Town of	8,819	$4,492,546,145	151	1.7%	$57,462,089	1.3%
Suffern, Village of	3,110	$2,011,976,760	44	1.4%	$35,851,085	1.8%
Upper Nyack, Village of	1,121	$714,087,836	0	0.0%	$0	0.0%
Wesley Hills, Village of	2,432	$1,597,464,375	0	0.0%	$0	0.0%
West Haverstraw, Village of	3,171	$1,575,031,545	105	3.3%	$108,232,036	6.9%
Rockland County (Total)	**112,485**	**$93,676,093,896**	**1,926**	**1.7%**	**$2,485,980,013**	**2.7%**

Source: Rockland County, NYS Office of Information Technology Services Geospatial Services and NYS Department of Taxation and Finance's Office of Real Property Tax Services (ORPTS) 2022; Center for International Earth Science Information Network, New York State Energy Research and Development Authority 2022; U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2022

Impact on Critical Facilities and Community Lifelines

Dam failures may also impact critical facilities and lifelines located in the downstream inundation zone. Consequentially, dam failure can cut evacuation routes, limit emergency access, and/or create isolation issues. Dam failure can cause severe downstream flooding and may transport large volumes of sediment and debris, depending on the magnitude of the event. Widespread damage to buildings and infrastructure affected by an event would result in large costs to repair these locations. In addition to physical damage costs, businesses can be closed while flood waters retreat, and utilities are returned to a functioning state. Further, utilities such as overhead power lines, cable and phone lines could also be vulnerable. Loss of these utilities could create additional isolation issues for the inundation areas.

Table 4.3.1-10 summarizes the number of community lifelines exposed to the dam inundation area. Of the 69 community lifelines located in the dam inundation area, Safety and Security has most facilities exposed (34). Refer to Section 3 (County Profile) for more information about the critical facilities and lifelines in Rockland County.

Table 4.3.1-10. Number of Lifelines Located in the Aggregate Dam Inundation Area

FEMA Lifeline Category	Number of Lifelines	Number of Lifelines Located in the Aggregate Dam Inundation Area
Communications	154	7
Energy	0	0
Food, Water, Shelter	71	2
Hazardous Materials	56	4
Health and Medical	195	8
Safety and Security	349	34
Water Systems	8	14
Transportation	148	0
Rockland County (Total)	**981**	**69**

Impact on the Economy

Severe flooding that follows an event like a dam failure can cause extensive structural damage and withhold essential services. The cost to recover from flood damages after a surge will vary depending on the hazard risk of each dam.

Severe flooding that follows an event like a dam failure can cause extensive damage to public utilities and disruptions to delivery of services. Loss of power and communications may occur and drinking water and wastewater treatment facilities can become temporarily out of operation. Debris from surrounding buildings can accumulate should the dam mimic major flood events, such as the 1-percent annual chance flood event that is discussed in Section 4.3.6 (Flood).

Impact on the Environment

The environmental impacts of a dam failure can include significant water-quality and debris-disposal issues or severe erosion that can impact local ecosystems. Floodwaters can back up sanitary sewer systems and inundate wastewater treatment plants, causing raw sewage to contaminate residential and commercial buildings and the

flooded waterway. The contents of unsecured containers of oil, fertilizers, pesticides, and other chemicals may get added to flood waters. Hazardous materials may be released and distributed widely across the floodplain. Water supply and wastewater treatment facilities could be offline for weeks. After the flood waters subside, contaminated and flood-damaged building materials and contents must be properly disposed of. Contaminated sediment must be removed from buildings, yards, and properties.

The total land area in the dam inundation area is summarized in Table 4.3.1-11 by jurisdiction. Overall, the County has 4,496 acres (4.1 percent of all County land) in the dam inundation area. Of those 4,496 acres, 992 acres lie in the Town of Clarkstown, 775 acres in the Town of Ramapo, and 704 acres in the Town of Haverstraw.

Table 4.3.1-11. Total Acres of Land Area (Excluding Waterbodies) Located in the Aggregate Dam Inundation Area

Jurisdiction	Total Acres of Land Area	Total Acres of Land Area (Excluding Waterbodies) Located in the Aggregate Dam Inundation Area	
		Total Acres Located in the Dam Inundation Area	Percent of Total
Airmont, Village of	2,844	0	0.0%
Chestnut Ridge, Village of	3,109	0	0.0%
Clarkstown, Town of	23,295	992	4.3%
Grand View on Hudson, Village of	106	0	0.0%
Haverstraw, Town of	11,066	704	6.4%
Haverstraw, Village of	1,254	105	8.4%
Hillburn, Village of	1,364	253	18.5%
Kaser, Village of	103	0	0.0%
Montebello, Village of	2,704	76	2.8%
New Hempstead, Village of	1,747	0	0.0%
New Square, Village of	220	0	0.0%
Nyack, Village of	492	0	0.0%
Orangetown, Town of	13,958	343	2.5%
Piermont, Village of	411	0	0.0%
Pomona, Village of	1,488	0	0.0%
Ramapo, Town of	19,415	775	4.0%
Sloatsburg, Village of	1,564	528	33.8%
South Nyack, Village of	389	0	0.0%
Spring Valley, Village of	1,285	69	5.4%
Stony Point, Town of	17,910	409	2.3%
Suffern, Village of	1,317	84	6.4%
Upper Nyack, Village of	738	0	0.0%
Wesley Hills, Village of	2,102	0	0.0%
West Haverstraw, Village of	988	156	15.8%
Rockland County (Total)	**109,869**	**4,496**	**4.1%**

Source: Rockland County 2020; USGS, NHD 2023
Note: 1) Excludes areas designated as water
2) Values are rounded to the nearest whole value
Abbreviation Notes:
1) USGS: United States Geological Survey
2) NHD: National Hydrography Dataset

Cascading Impacts on Other Hazards

Dam failure can cause severe downstream flooding, depending on the magnitude of the failure. Other potential secondary hazards of dam failure are landslides around the reservoir perimeter, bank erosion on the rivers, and destruction of downstream habitat. Dam failures can occur as a result of structural failures, such as progressive erosion of an embankment or overtopping and breaching by a severe flood. Earthquakes may weaken dams. Floods caused by dam failures have caused loss of life and property damage (FEMA 2013).

Future Changes That May Impact Vulnerability

Understanding future changes that affect vulnerability can assist in planning for future development and ensure establishment of appropriate mitigation, planning, and preparedness measures. The County considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in population
- Other identified conditions as relevant and appropriate, including the impacts of climate change

Potential or Projected Development

As discussed and illustrated in Section 3 (County Profile), areas targeted for future growth and development have been identified across the County. Any areas of growth could be potentially impacted by a dam failure event if the structures are located within the flood protection area and mitigation measures are not considered. Therefore, it is the intention of the County and all participating municipalities to discourage development in vulnerable areas or to encourage higher regulatory standards at the local level. Due to the sensitive nature of dam locations and downstream inundation zones, an assessment to determine the proximity of these new development sites to potential dam inundation cannot be performed at this time.

Projected Changes in Population

Rockland County has experienced an increase in its population since 2010. According to the U.S. Census Bureau, the County's population increased by approximately 8.5 percent between 2010 and 2020 (County of Rockland 2021). Cornell University's Program on Applied Demographics produced populations projections by County from 2016 to 2040. According to these projections, Rockland County is projected to have a population of 356,758 by 2030 and 372,432 by 2040 (Cornell University 2018).

As the population increases any changes in the density of population can impact the number of persons exposed to the probable maximum flood inundation hazard areas. Higher density can not only create issues for residents during evacuation of a dam failure event but can also have an effect on commuters that travel into and out of the County for work, particularly during a flood event that may impact transportation corridors, which are also major commuter roads. Refer to Section 3 (County Profile) for more information about population trends in the County.

Other Identified Conditions

Most studies project that the State of New York will see an increase in average annual precipitation. Annual precipitation amounts in the region are projected to increase, primarily in the form of heavy rainfalls, which have the potential to increase the risk to dam failures. Increases in precipitation may stress the structures (NYSERDA 2014). Further, existing flood control structures may not be able to retain and manage increases in water flow from more frequent, heavy rainfall events. Heavy rainfalls may result in more frequent overtopping of these dams

and flooding of the County's assets in adjacent inundation areas. However, the probable maximum flood used to design each dam may be able to accommodate changes in climate.

Change of Vulnerability Since 2018 HMP

Overall, the County's vulnerability has not changed, and the County will continue to be exposed and vulnerable to dam failure events, especially those located within or near downstream inundation zones. Because of the sensitive nature of the dam failure inundation zones, potential losses have not been quantified and presented in this plan. To estimate potential losses to population, buildings, critical facilities and infrastructure, dam inundation areas and depths of flooding may be used to generate depth grids. Hazus may be used to estimate potential losses for the County and participating municipalities.