4.14 Dam Failures

The Federal Emergency Management Agency (FEMA) defines a dam as "a barrier constructed across a watercourse for the purpose of storage, control, or diversion of water." Dams typically are constructed of earth, rock, concrete, or tailings (chaff) from mining operations. A dam failure is the collapse, breach, or other failure resulting in downstream flooding.

The amount of water impounded in the reservoir behind a dam is measured in acre-feet. An acre-foot is the volume of water that covers an acre of land to a depth of one foot, or approximately 325,000 gallons. As a function of upstream topography, even a very small dam may impound or detain many acre-feet or millions of gallons of water.

4.14.1 Hazard Profile

A break in a dam or levee produces an extremely dangerous flood situation because of the high velocities and large volumes of water. In the event of a dam or levee failure, the potential energy of the water stored behind even a small dam or levee can cause great property damage, as well as loss of life if there are people downstream from the dam or behind the levee.

The overtopping or forced release of a dam due to heavy rain is a threat to downstream properties

The extent of this inundation may be minimal to uninhabited farmland or catastrophic in an urban environment.

Dams: Dam failures are primarily caused by hydrologic or structural deficiencies. A hydrologic deficiency is inadequate spillway capacity caused by excessive runoff from heavy precipitation. Structural deficiencies include seepage, erosion, cracking, sliding, and overturning, mainly caused by the age of a dam and lack of maintenance. The operation of a reservoir can also influence the safety of the structure.

There can be varying levels of dam failure. Partial dam failures include inadequate spillway capacity that causes excess flow to overtop the dam; and internal erosion through the dam or foundation.

Complete failure occurs if internal erosion or overtopping results in a total structural breach, releasing a high-velocity wall of debris-laden water rushing downstream, damaging or destroying everything in its path.

Flooding can occur downstream from a dam without the structure being breached. Sometimes, to prevent overtopping and catastrophic failure, dams are forced to make emergency releases of large amounts of water, which can cause downstream flooding.

Levees. Levee failures or damages behind levees can be caused by several occurrences:

- overtopping due to flood heights exceeding the levee design-protection elevation;

- flooding from upstream sources internal to the levee;
- erosion caused by embankment leaking or "piping" or excessive saturation of a sand levee. "Piping" is internal erosion caused by seepage, and can occur around pipes, through animal burrows, around roots of trees, and other weaknesses.
- improper operation and maintenance, including failure to inspect and repair seepage problems or manage vegetation.

The failures of levees along the Mississippi River in 1993 and in New Orleans after Hurricane Katrina in 2005 have focused new attention on the inherent hazards of levees.

Levee failures can cause catastrophic floods, releasing sudden walls of water that can sweep across lands thought to be protected by the structure. Thus, levees and dams may create a false sense of security, increasing the amount of property at risk of flooding as people and businesses locate behind levees and floodwalls, believing they are totally safe. In addition, levees, dams, and other structural measures are extremely costly and can disrupt or destroy the natural environment.

In the event of a dam failure, the potential energy of the water stored behind even a small dam can cause great property damage and, if there are people downstream, loss of life. The following factors influence the impact of a dam failure:

- level of failure (partial or complete);
- rapidity of failure (sudden or gradual);
- amount of water released;
- nature of the development and infrastructure located downstream.

A break in a dam produces an extremely dangerous flood situation because of the high velocities and large volumes of water. The severity of impact on areas downstream and the height to which waters will rise are largely functions of valley topography and the volume of water released.

Besides dam failures, there are hazardous actions that have to be taken to prevent dam failures, such as sudden releases of water when the dam is threatened with overtopping. In this case, a dam may have failed in its purpose to protect downstream people and property, without physically failing.

Location

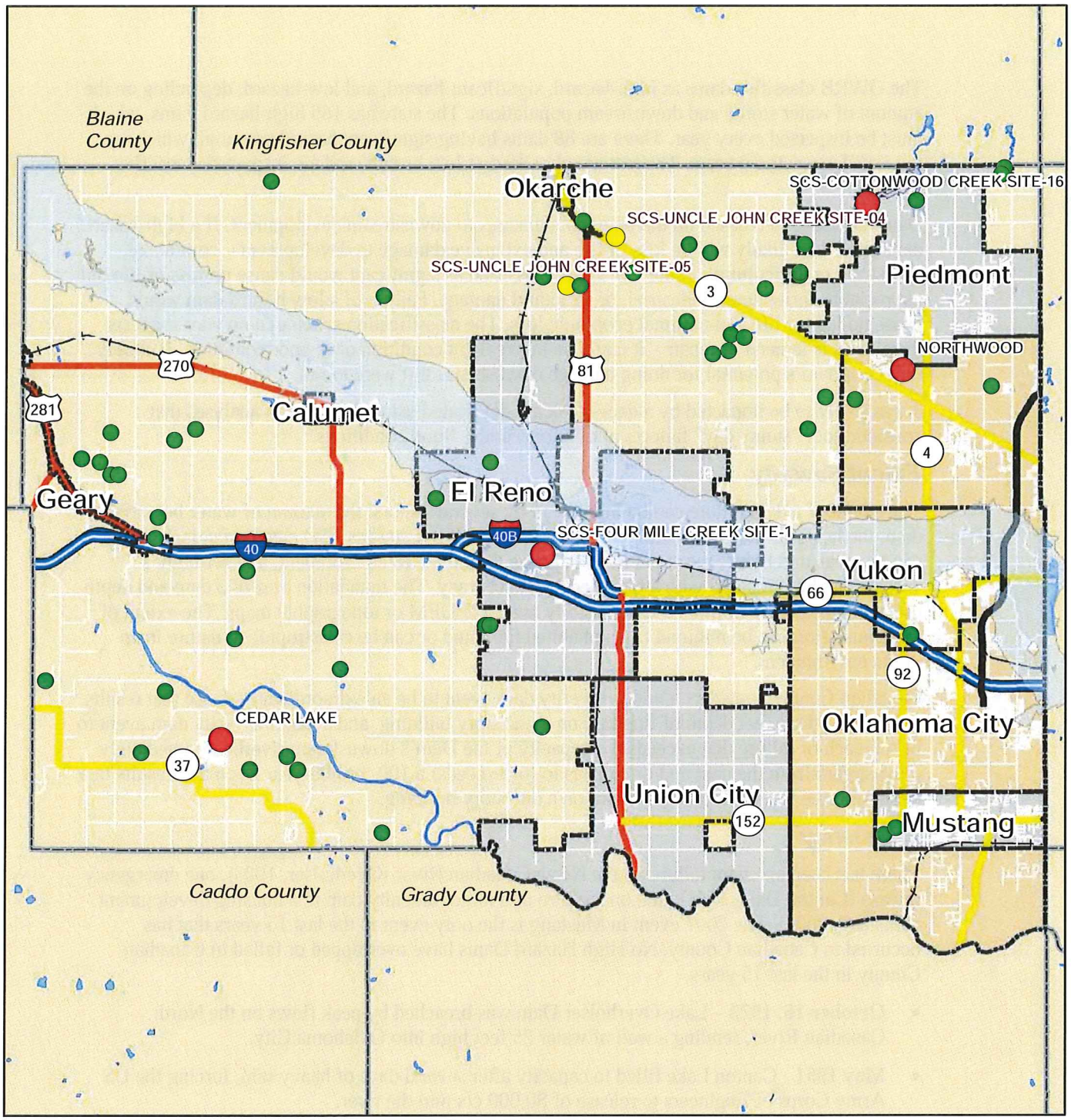
There are four high-hazard dams located in Canadian County: Northwoods Dam, Cottonwood Creek Dam Site 16, El Reno Lake Dam, and Cedar Lake Dam. The locations of these dams are shown in Figure 4-33.

Measurement

The amount of water impounded in the reservoir behind a dam is measured in acre-feet. An acre-foot is the volume of water that covers an acre of land to a depth of one foot, or approximately 325,000 gallons. As a function of upstream topography, even a very small dam may impound or detain many acre-feet or millions of gallons of water.

Any artificial water barrier structure that has a height of 25 feet or more from the natural streambed and 50 acre feet or more of storage capacity qualifies as a dam and is under the jurisdiction of the Oklahoma Water Resources Board (OWRB).

There are 4,524 dams in Oklahoma (including private structures), with approximately half (2,300) operated by the National Resources Conservation Service (NRCS). Emergency Action Plans have been filed for 160 of the most important dams in the state.



LEGEND

- Interstate
- US Highway
- State Highway
- Turnpike
- Railroads
- Not in Plan
- City Limits

HAZARD

- High
- Sig.
- Low
- Dam Failure

0 2 4 Miles

N W E S

CANADIAN COUNTY 1890 OK

Flanagan & Associates, LLC
Planning Consultants

Figure 4-33

Canadian County

Dams

The OWRB classifies dams as high-hazard, significant-hazard, and low-hazard, depending on the amount of water stored and downstream populations. The state has 165 high-hazard dams, which must be inspected every year. There are 88 dams having significant hazard potential, which are inspected every three years. The rest are classified as low hazard, and are inspected every five years.

Dams are classified based on the potential damages to downstream development. If a high-hazard dam fails, there likely will be loss of life and extensive damage to development – communal, industrial, or agricultural. Failure of a dam classified as significant would cause no loss of life but appreciable agricultural, industrial, or structural damage. Failure of a low hazard dam would cause no loss of life and minimal economic loss. The classification scheme in no way suggests that a dam is in need of repair – it could be in excellent condition or in poor condition. It simply reflects a dam's potential for doing damage downstream if it were to fail.

Areas likely to be impacted by a dam break are delineated using dam breach analyses that consider both "sunny day" failures and failures under flood conditions.

Extent/Severity

The extent of a dam failure can be influenced by several factors: the amount of water behind the dam, the height of the dam itself, and the way in which a dam fails. The extent of a dam failure can be measured before the event itself happens. Using a GIS environment, a water body's volume can be measured with a high degree of accuracy. The inundation area of a dam and depth of flooding can be determined using readily available DEM or topographic maps. The extent of this inundation can be minimal to uninhabited farmland or can be catastrophic in nature in an urban environment.

Canadian County considers a minor severity dam event to be an extraordinary release that results in less than three feet depth of flooding on a one story building, and a major severity dam event to be a breach or failure that exceeds the capacity of the Dam's downstream riverbed immediately downstream from the dam and/or equates to (or exceeds) a 100- or 500-year flood and results in a depth of three feet of flooding or more on a one story building.

Frequency

There has been one dam failure on the North Canadian River (Overholser, 1923), one emergency release (Canton Dam, 1951), and one failure of a minor amenity dam in a housing development (Mustang, 2007). The 2007 event in Mustang is the only event in the last 15 years that has occurred in Canadian County. No High Hazard Dams have overtopped or failed in Canadian County in the last 15 years.

- **October 16, 1923** – Lake Overholser Dam was breached by peak flows on the North Canadian River, sending a wall of water 25 feet high into Oklahoma City.
- **May 1951** - Canton Lake filled to capacity after several days of heavy rain, forcing the US Army Corps of Engineers to release of 80,000 cfs into the river.
- **May 2007** – Spitler Lake Dam in the Quail Lake Estates in Mustang, an amenity impoundment, failed during very heavy rains. Damage was $20,000

These failures and emergency releases do not support generalizations about dam failure frequency, other than the obvious relationship between very heavy rainfall, peak flooding events, and the increased likelihood of dams being overwhelmed.

Impact

The impact of this hazard can affect homes, business, agriculture, and infrastructure that are located downstream from the dam. Dam failure can occur over prolonged periods of time, giving people downstream time to prepare for the flood surge, or can be sudden with little to no warning time. Emergency releases from a dam, to avoid the imminent failure of the structure can also cause catastrophic downstream flooding.

4.14.2 History/Previous Occurrences

In Oklahoma, there have been three significant, documented dam failures. As stated above, Lake Overholser Dam failed in October 1923, displacing 15,000 residents. Cleveland, in Pawnee County, suffered losses in the half-million dollar range when the town was inundated by the Cleveland Dam break of September 4, 1940. Both the Overholser and Cleveland failures resulted from sudden and heavy rainfall. After 14.6 inches of rain fell in the Wewoka area on the night of April 13-14, 1945, heavy flows on Coon Creek overtopped and breached the earth-filled Wewoka Dam, sending a wall of water into Wewoka Creek. Eight people in the path of the deluge were killed and the town of Wewoka was under four feet of water near the train depot. Eighty people were forced from their homes. Locally, $20,000 in damages were incurred when Spitler Lake Dam in the Quail Lake Estates in Mustang, an amenity impoundment, failed during very heavy rains.

Dams can "fail" in ways other than being breached. Sometimes, in order to prevent overtopping and catastrophic failure, dams are forced to make emergency releases of huge amounts of water. In late September and early October, 1986, nearly 2 feet of rain fell northwest of Tulsa, causing the Arkansas, Caney, and Neosho Rivers to flood. To prevent the Arkansas River from overtopping the Keystone Dam, the Corps of Engineers had to open the floodgates and release 310,000 cfs of water through Sand Springs, Tulsa, Jenks and Bixby. No one knew if the World War II era sand levees would hold, and a catastrophic failure of the levee system was widely feared. In fact, the Sand Springs levee was breached, but volunteers plugged it with sandbags. On the west bank, the river swamped Garden City up to the rooftops. More than 1,800 Tulsa-area homes and businesses were inundated by the flood. Tulsa County's damages were estimated at $63.5 million (in '86 dollars), Sand Springs' at $32.5 million, and Bixby's at $13.4 million.

Bixby home during flood of October 1986, when Keystone Dam was forced to release 310,000 cfs

A similar emergency release from Copan and Hulah Lakes during the same storm resulted in the worst flood in Bartlesville's history. The Caney River rose to 30 feet above normal, which was 17 feet above flood stage, inundating half of the city, including the downtown area. Damage was so extensive that the region was declared a Presidential Disaster Area.

Canton Lake Dam

Probability/Future Events

As there have been no High hazard dam failures that have impacted Canadian County, its communities, or

schools it is not anticipated an event will happen within the next 15 years, as indicated in Table 4-2. Canadian County, its Communities and Public School systems have a Low probability of a future dam failure event unless otherwise specified in Appendix F or Appendix G.

4.14.3 Vulnerability

This section summarizes information about Canadian County's vulnerability to dam failures, including the impact on people, structures and buildings, critical facilities, and infrastructure. This information, as well as information provided by the County, incorporated communities and public schools, was used to determine the Vulnerability Criteria identified in Tables 4-2 and 4-3. Canadian County was determined to be at Low risk to the Dam Failure hazard. (See Table 4-2 Hazard Risk Analysis, and Table 4-3, Summary of Hazard risk Analysis Ranking Criteria for an explanation of how the rankings were derived.) Appendices F and G identify where the incorporated communities and public school systems differ from the county.

Canadian County High Hazard Dams

Of the 58 dams in Canadian County, the OWRB has classified four as High Hazard, two as Significant Hazard, and 52 as low hazard. The High Hazard dams are El Reno Lake Dam in El Reno, Northwood Lake Dam and Cottonwood Creek Site 16 Dam, both in the northeast quadrant of the county in the vicinity of Piedmont, and Cedar Lake Dam in the extreme southwest near Niles. To this list must be added Canton Lake Dam in Blaine County, and Sanford Dam at Lake Meredith on the Canadian River in the Texas panhandle. Information about the dams and the potential impacts of each are summarized in the following tables.

Table 4–45: Canadian County High Hazard Dams

Canton Lake Dam	Description
Location:	Canton, OK
Sources:	North Canadian River
Flows into:	North Canadian River
Drainage Area:	12,483 sq. mi.
Owner/operator:	US Army Corps of Engineers
Year built:	1948
Length:	15,140 feet
Height:	68 feet
Lake size	1,500 acres
Capacity	208,664 acre-feet
Construction material:	Rolled earth and Masonry
Use of Dam:	Water supply, Flood Control, Recreation
Result of failure:	Potential inundation of Calumet and El Reno
Sanford Dam	**Description**
Location:	Borger, TX
Sources:	Canadian River
Flows into:	Canadian River
Drainage Area:	20,220 sq. mi. total drainage (9,090 sq. mi. actual drainage)
Owner/operator:	Canadian River Municipal Water Authority
Year built:	1965
Length:	6,380 feet
Height:	228 feet (198 ft. above streambed)
Lake size	21,640 acres
Capacity	1,382,500 acre-feet
Construction material:	Rolled earth and Masonry
Use of Dam:	Water Supply, Flood Control, Recreation
Result of failure:	Potential inundation of Canadian River floodplain.
Failures to date:	None

El Reno Lake Dam (Fourmile Creek Site 1)	Description
Location:	West of El Reno on Lake El Reno
Source:	Fourmile Creek
Flows into:	Fourmile Creek and North Canadian River
Owner/operator:	City of El Reno, Canadian County Conservation District
Year built:	1966
Length:	2,223 feet
Height:	40 feet
Construction material:	Earth-fill and Masonry
Use of dam:	Water storage, flood control and recreation
Capacity:	2,865 acre feet
Land area:	170 surface acres of water
Flood damage history:	Several flood events in El Reno prior to construction
Results of failure:	Inundation of El Reno along Four Mile Creek
Failures to date:	None

Cottonwood Creek Site 16 Dam	Description
Location:	1 mile west of the City of Piedmont, on NW 234th St. and Frisco Rd.
Sources:	Cottonwood Creek
Flows into:	Cimarron River drainage basin
Owner/operator:	Canadian County Conservation District
Year built:	1965
Length:	3,600 feet
Height:	56 feet
Lake size	608 acres
Capacity	4,147 acre-feet
Construction material:	Earth fill
Use of Dam:	Water storage, flood control
Result of failure:	Inundation in rural Piedmont and unincorporated Canadian County.
Failures to date:	None

Northwood Lake Dam	Description
Location:	Between Piedmont City Limits and the NW Expressway on Cemetery Road
Source:	Deer Creek
Flows into:	Deer Creek, Cottonwood Creek, Cimarron R.
Owner/operator:	Northwood Lake Homeowners Association
Year built:	1961
Length:	2,665 feet
Height:	42 feet
Construction material:	Earth-fill
Use of dam:	Recreation, water storage and flood control
Capacity:	2,700 acre feet
Land area:	190 surface acres of water
Flood damage history:	None to date
Results of failure:	Inundation of parts of south Piedmont
Failures to date:	None

Cedar Lake Dam	Description
Location:	Cedar Road, N. of State Hwy 37
Source:	Tributary to Canadian River
Flows into:	Canadian River
Owner/Operator:	Western Sportsman Club
Year built:	1959
Length:	1025 feet
Height:	45 feet
Construction material:	Earth-fill
Use of Dam:	Recreation, water storage and flood control
Capacity:	1543 acre feet of water
Land Area:	62 surface acres of water
Flood damage history:	None to date
Results of failure:	Inundation of downstream property, transportation routes and Unincorporated Canadian County
Failures to date:	None

Canadian County Significant Hazard Dams

There are two Significant Hazard Dams that would impact populations and infrastructure in Canadian County, both on tributaries to Uncle John's Creek: Uncle John's Creek Site 5 Reservoir and Uncle John's Creek Site 7 Reservoir. Both have structures, roads and farms that could be potentially impacted, depending on stream and weather conditions at the time of failure.

Data Limitations

It is not possible to accurately assess the ultimate threat these High and Significant Hazard dams present without detailed hydrological and hydraulic studies of each site.

Population

The populations most at risk of a dam failure would be those living, working, and attending school in the inundation area. Impacts on Canadian County populations would depend on the magnitude of the failure, the time of day when the failure occurs, and the amount of warning provided. Emergency releases from either Canton Dam or Sanford Dam would provide at least 48 hours' warning to residents of Canadian County. Injuries and casualties are more likely from a failure of one of Canadian County's four High Hazard dams, since there would be less warning time, particularly if a failure were to occur at night, during peak flows, as occurred when Wewoka Dam failed (see above). Vulnerable populations, including public schools, should have evacuation plans in place.

Buildings

Residences and outbuildings in the floodplains of the Canadian and North Canadian rivers would be most at risk from failures or emergency releases from either Canton or Sanford dams. If failures were to occur during peak flows on the rivers, it is likely that the floodplains would be completely filled, as has occurred in past peak floods in 1923 and 1904. As the floodplains of both rivers are fairly well defined, the number of residences and outbuildings at risk can be estimated through analysis of aerial maps and prior studies by the US Army Corps of Engineers and FEMA.

Critical Facilities

There are two critical facilities in Canadian County that would be impacted by failures or emergency releases, primarily from Canton Dam, but also from El Reno Dam. These are the Federal Correctional Institution and Darlington Public School. A dam failure could render either

of these facilities to be non-operational and, depending on the level of damages, may require complete replacement of the facility.

Tier II Sites

There are no Tier II sites in Canadian County that would be impacted by a dam failure.

Infrastructure

Several Canadian County roads and bridges are vulnerable to a breach of one of the four High Hazard and three Significant Hazard dams. To what degree these would be impacted can only be determined by a detailed hydrological study.

4.14.4 Dam Failure Scenario

During the October 1923 flood on the North Canadian, the highest documented flood event at El Reno, the estimated flow at the future Canton Lake Dam site was 87,800 cfs. At El Reno the river reached 31 feet—six feet higher than the current flood of record of 2007. Under conditions of a clear day failure, a Canton Dam release would be absorbed into the floodplain or otherwise dissipated before reaching the city. However, under peak flood conditions, the surge from a failure could push the river to 32 feet and inundate much of the floodplain, low-lying neighborhoods and railroad facilities near El Reno. An emergency release of this magnitude is not unprecedented. In May 1951 the US Army Corps of Engineers was forced to release 80,000 cfs into the North Canadian from Canton Lake. If the river were already in flood downstream, the surge at Calumet, El Reno and Yukon would rival the 1923 flood. A detailed hydrological study would be required to determine the precise impacts of such an event for the farms, schools and communities in Canadian County. A release of this size would take 83 hours to reach the communities, however, so there would be adequate time for evacuations and preparations. Were Canton Dam to fail catastrophically (a highly unlikely event, once the current upgrade of the dam is complete), the surge would take 15 hours to reach El Reno, providing plenty of time to evacuate the low-lying areas.

4.14.5 Future Trends

Canadian County communities have had a long experience with the Canadian and North Canadian rivers and their dangers. It is for this reason that the floodplains of the rivers have remained almost entirely undeveloped and catastrophic floods on the river have done so little damage. Canadian County and its communities (with the exception of Okarche) participate in FEMA's National Flood Insurance Program. Although the NFIP does not include Dam Failures, following its policies and guidelines will ensure that the vulnerability of the county, its communities and public schools to the Dam Failure hazard will not increase significantly.

Population

It is not anticipated that the population exposed to Dam Failure will increase.

Buildings

It is not expected that new buildings will be constructed in areas that would be inundated by a major dam failure.

Critical Facilities

No critical facilities are planned that would be inundated by a breach of an existing or proposed dam, including Canton Dam and El Reno Dam. Those facilities that already are in an inundation area, such as the Darlington Campus of Redlands Community College, should ensure that

emergency procedures are in place and the structures can ride out a flood surge with minimal damage and no loss of life.

Infrastructure

Infrastructure will continue to be vulnerable to worst-case dam breaks, particularly of Canton Dam and El Reno Dam, including roads and bridges, power lines, hydrocarbon pipelines, and water and sewer service lines and facilities.

4.14.6 Conclusion

People, property, and infrastructure downstream of dams could be subject to devastating damage in the event of a dam failure. The areas impacted are delineated using dam breach analyses that consider both "sunny day" failures and those that occur under flood conditions. The downstream extent of impact areas and the height to which waters will rise are largely functions of valley topography, downstream conditions, and the volume of water released during failure.

If a dam is classified as high hazard, the failure of that dam would most likely result in loss of life. This classification does not mean the dam is necessarily at high risk of failing.

The most important factors for public safety are the timeliness and effectiveness of warnings given to vulnerable downstream populations.

Based on the information and analysis presented above, Canadian County has a Moderate vulnerability to the very low-probability Dam Failure hazard—providing an overall Low vulnerability rating.

Update Changes

Identified significant changes made from previous Multi-Hazard Mitigation Plans from Canadian County, Calumet, El Reno, Mustang, Piedmont, and Union City are outlined in Appendix E. Changes are based on criteria outlined for Plan Updates in the Local Multi-Hazard Mitigation Planning Guidance document of July 1, 2008.

4.14.7 Sources

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