DAM FAILURE

5.1 Identifying and Profiling Dam Failure Hazards
5.2 Assessment of Local Dam Failure Vulnerability and Potential Losses
5.3 Assessment of State Dam Failure Vulnerability and Potential Losses
5.4 Mitigation Efforts for Dam Failure Hazards

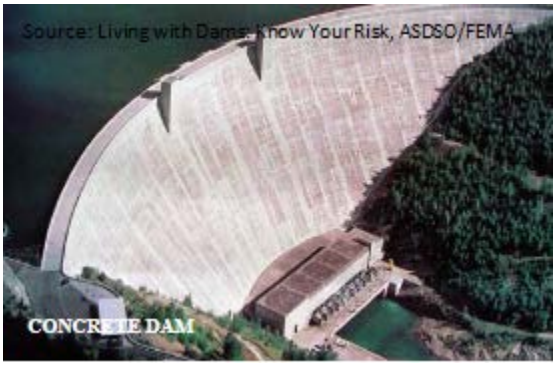
5.1 Identifying and Profiling Dam Failure Hazards

The purpose of a dam is to store water, or other liquid borne materials for any of several reasons, such as human water supply, irrigation, livestock water supply, energy generation, containment of mine tailings, recreation, pollution or flood control. Many dams fulfill a combination of the above functions.

Types of Dams

Manmade dams may be classified according to the type of construction material used, the methods used in construction, the slope or cross-section of the dam, the way the dam resists the forces of the water pressure behind it, the means used for controlling seepage, storage characteristics (on a watercourse, off-stream, above or below ground level), and occasionally, according to the purpose of the dam. The materials used for construction of dams include earth, rock, tailings from mining or milling, concrete, masonry, steel, timber, miscellaneous materials (such as plastic or rubber) and combinations of these materials.

Embankment dams are the most common type of dam in use today. Materials used for embankment dams include natural soil or rock or waste materials obtained from mining or milling operations. An embankment dam is termed an “earthfill” or “rockfill” dam depending on whether it is comprised of compacted earth or mostly compacted or dumped rock. The ability of an embankment dam to resist the reservoir water pressure is primarily a result of the mass weight, type and strength of the materials from which the dam is made.



Concrete dams maybe categorized into gravity and arch dams according to the designs used to resist the stress due to reservoir water pressure. The most common type of concrete dam is a concrete gravity dam. The mass weight of concrete and friction resist the reservoir water pressure.

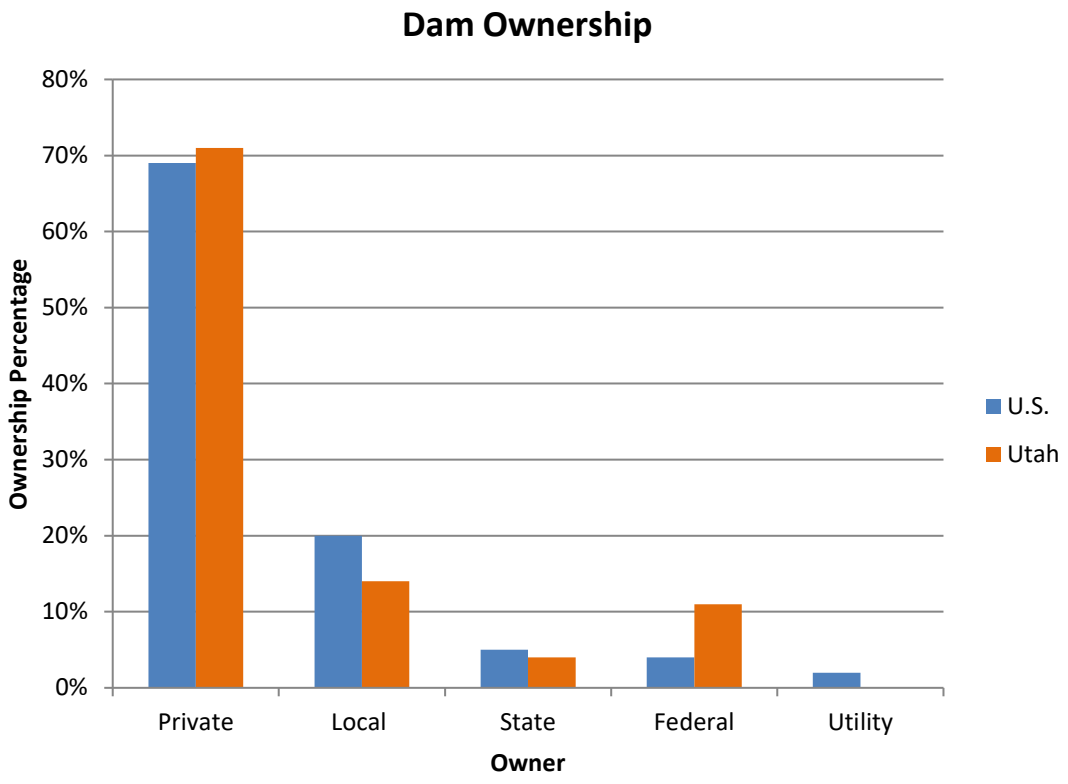
A buttress dam is a specific type of gravity dam in which the large mass of concrete is reduced, and the forces are diverted to the dam foundation.

Ownership

Dams are owned and operated by many different types of owners. Sometimes they only serve the interest of the owner—for instance in the case of a neighborhood association that wants its homes built around a lake—and sometimes they serve the interest of communities—for instance in the case of a water supply utility. Downstream development affects a dam's risk. Dams that used to be out in the rural areas, affecting nothing but open fields, are now affecting neighborhoods and industrial areas. Due to increased development, dam failure consequences have become much higher.

Dams are unique components of the U.S. infrastructure in that most dams are privately owned. Dam owners are solely responsible for keeping their dams safe and financing maintenance, repairs and upgrades. Dam maintenance, repairs and upgrades can be expensive. Price tags for non-Federal dam rehabilitation projects commonly range from $100,000 to millions of dollars per dam. Such high price tags place a huge burden on dam owners, many of whom cannot afford to maintain their dams (Living with Dams: Know Your Risk, ASDSO/FEMA).

Figure 1. Dam Ownership in the United States vs. Utah



Source: https://damsafety.org, Dam Safety Performance Report: Utah

Dam Safety Rules

The following are Utah dam safety rules that are in effect as of February 1, 2018:

> Rule R655-10. Dam Safety Classifications, Approval Procedures and Independent Reviews
>
> Rule R655-11. Requirements for the Design, Construction and Abandonment of Dams
>
> Rule R655-12. Requirements for Operational Dams

Details and full text are available at https://rules.utah.gov/publicat/code/r655/r655.htm.

Profiling Hazard Event

Dams can pose risks to those living downstream if they are not maintained and operated correctly. Some dams increase safety risks to an often unaware public when they age, deteriorate or malfunction, releasing sudden, dangerous flood flows. There are over 85,000 dams in the U.S. Most every state has at least several hundred dams. More than half of these dams are older than 50 years and many are in need of extensive rehabilitation. Many communities in the United States are impacted by at least one dam. In many cases large populations, vital elements of our infrastructure, jobs, and businesses are located downstream of dams. When dams fail or malfunction, they can adversely affect people, their livelihood and property. Dam failure floods are almost always more sudden and violent than normal stream, river or coastal floods. They often produce damage that looks like tornado damage. The number of dams that pose a risk to human life is steadily increasing. In the last decade, the number has increased by over 1,000 to a total of about almost 14,000. The cause of this increase is a combination of new dam construction and/or downstream development (Living with Dams: Know Your Risk, ASDSO/FEMA).

The State Dam Safety Section has developed a hazard rating system for all regulated dams in Utah. Downstream life and property, the size, height, volume, and incremental risk/damage assessments of dams are all variables used to assign dam hazard ratings in Dam Safety's classification system. Using the hazard ratings system, dams are placed into one of three classifications: high, moderate, and low (damsafety.org, "Dam Safety, Performance Report for the State of Utah").

> **High Hazard**: is typically defined as a dam whose failure or faulty operation will cause loss of human life and significant property destruction.
>
> **Moderate/Significant Hazard**: is typically defined as a dam whose failure or faulty operation will cause significant property destruction.

Low Hazard: is typically defined as a dam whose failure or faulty operation will cause minimal property destruction.

The National Inventory of Dams (NID) contains a list of around 87,000 dams in the U.S. In addition to housing an inventory of the dams in Utah, they have also collected condition data on state regulated dams since 2009. The NID ranks dam conditions as the following:

Satisfactory – No existing or potential dam safety deficiencies are recognized.

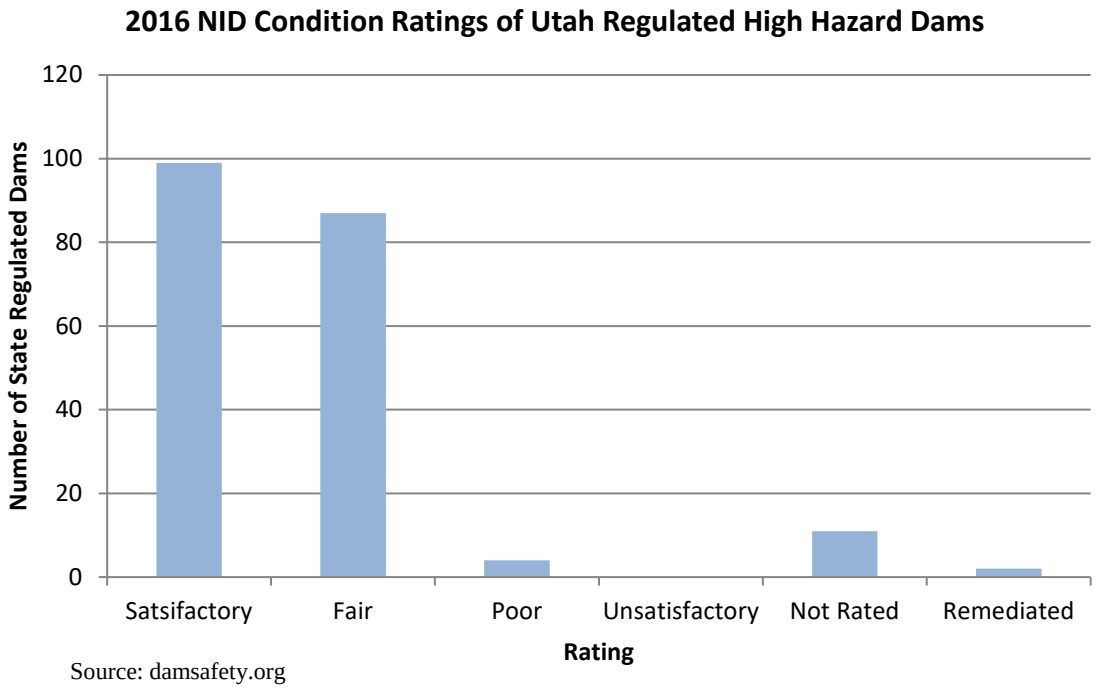
Fair – No existing dam safety deficiencies are recognized for normal loading conditions. Rare or extreme hydrologic and/or seismic events may result in a dam safety deficiency.

Poor – A dam safety deficiency is recognized for loading conditions which may realistically occur. Remedial action is necessary.

Unsatisfactory – A dam safety deficiency is recognized that requires immediate or emergency remedial action for problem resolution.

Not Rated – The dam has not been inspected or has been inspected but, for whatever reason, has not been rated.

Figure 2. Condition Ratings of Utah's Regulated High Hazard Dams



Source: damsafety.org

According to the 2017 Dam Safety State Program Statistics, Utah contains the following list of NID and state regulated dams:

Total NID Dams	833
Total NID High Hazard Dams	242
Total State Regulated Dams	698
Total State Regulated High Hazard Dams	209
Total State Regulated Significant Hazard Dams	197
Total State Regulated Low Hazard Dams	292

The Utah Division of Water Rights houses a large database of dams in Utah, which is much for inclusive than the database housed by the NID. They have categorized the dams by several inspection categories. These include uninspected dams, inspected dams (general), inspected dams (flood control), inspected dams (industrial), inactive dams, dams inspected by other agencies, federally inspected dams, dams planned or being designed, dams under construction, and other. See Table 1. The database contains a list of 6072 dams, with 256 of those dams being ranked as high hazard. See Map 1 and Tables 2 - 6.

Table 1. Utah Dam Inventory

Utah Dam Inventory

County	State Inspected (General)	State Inspected (Flood Control)	State Inspected (Industrial)	Federally Inspected	Inspected by Other Agencies	Uninspected	Inactive	Planned	Under Construction	Other	Total
Beaver	14	2	0	0	0	81	5	0	0	0	102
Box Elder	17	5	0	4	1	281	4	0	0	0	312
Cache	11	1	1	2	1	239	2	0	0	0	257
Carbon	7	2	3	1	0	443	4	1	0	1	462
Daggett	4	0	0	1	2	86	2	0	0	0	95
Davis	17	12	0	17	0	39	4	0	0	3	92
Duchesne	30	0	0	5	6	245	18	0	0	5	309
Emery	28	6	5	2	0	438	5	0	0	3	487
Garfield	18	0	2	0	9	145	3	0	0	2	179
Grand	3	3	5	0	1	127	2	0	0	1	142
Iron	13	7	0	0	1	160	8	0	0	3	192
Juab	6	2	1	0	0	18	1	0	0	1	29

Kane	17	2	0	0	2	120	4	0	0	3	148
Millard	6	1	9	0	0	36	0	1	0	2	55
Morgan	5	0	1	2	0	18	1	0	1	0	28
Piute	6	0	0	0	0	20	0	0	0	1	27
Rich	18	0	0	0	0	518	1	0	0	3	540
Salt Lake	19	22	4	1	0	210	23	0	0	3	282
San Juan	23	0	1	0	1	147	7	1	0	1	181
Sanpete	29	2	0	0	11	199	6	1	0	4	252
Sevier	20	7	0	0	9	76	3	0	0	1	116
Summit	28	0	0	6	17	262	4	0	0	3	320
Tooele	8	2	1	0	0	57	7	0	0	2	77
Uintah	34	4	4	5	6	294	2	0	0	3	352
Utah	26	14	0	1	3	200	12	1	0	4	261
Wasatch	21	1	0	5	0	142	9	0	0	0	178
Washington	18	16	2	0	1	179	1	3	0	1	221
Wayne	5	0	0	0	10	47	5	1	0	0	68
Weber	5	8	0	7	0	57	15	0	0	2	94
N/A	3	0	0	1	0	0	80	2	0	128	214
Total	459	119	39	60	81	4884	238	11	1	180	6072

Source: Data from Utah Division of Water Rights, https://www.waterrights.utah.gov/cgi-bin/damview.exe?Startup, 2018.

Map 1. Utah High Hazard Dams

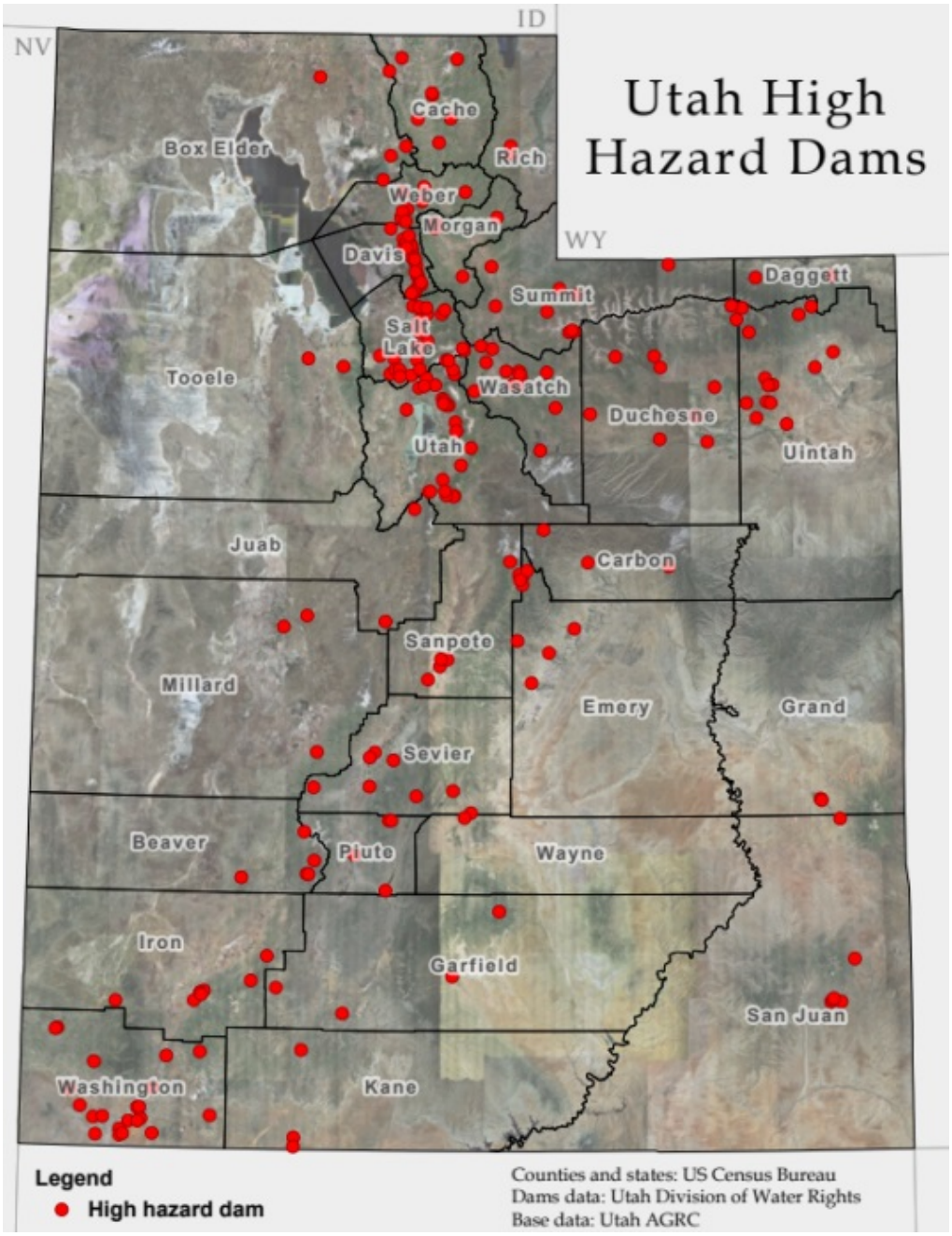


Table 2. High Hazard Dams in Utah

Dam Name	County	Dam Name	County
KENT`S LAKE NO 1 (UPPER)	Beaver	HOBBS	Davis
KENT`S LAKE NO 2 (MIDDLE)	Beaver	HOLMES	Davis
MANDERFIELD (A.K.A. BEAVER)	Beaver	KAYSVILLE	Davis
ROCKY FORD (BEAVER)	Beaver	SDID - #1 - BOUNTIFUL-OAKRIDGE	Davis
THREE CREEKS (BEAVER)	Beaver	SDID - #2 - BOUNTIFUL-NORTH CANYON	Davis
BLUE CREEK	Box Elder	SDID - #4 - VALLEYVIEW #1	Davis
BOR ARTHUR V WATKINS	Box Elder	BIG SAND WASH DAM	Duchesne
MANTUA	Box Elder	BIG SAND WASH EAST	Duchesne
PACIFICORP - CUTLER	Box Elder	BIG SAND WASH WEST	Duchesne
THREE MILE CREEK (PERRY CITY FCD) DB	Box Elder	BOR MOON LAKE	Duchesne
BOR HYRUM	Cache	BOR STARVATION	Duchesne
BOR NEWTON	Cache	BOR STILLWATER (UPPER)	Duchesne
LOGAN CITY - DRY CANYON	Cache	BROWNS DRAW	Duchesne
LOGAN FIRST DAM	Cache	CHEPETA LAKE	Duchesne
PORCUPINE	Cache	CLIFF LAKE (DUCHESNE)	Duchesne
TONY GROVE LAKE DAM	Cache	MIDVIEW (LAKE BOREHAM)	Duchesne
BOR SCOFIELD	Carbon	RED CREEK (DUCHESNE)	Duchesne
GARLEY CANYON DAM	Carbon	TWIN POTS	Duchesne
GRASSY TRAIL	Carbon	ADOBE WASH REGULATING RESERVOIR	Emery
BOR FLAMING GORGE	Daggett	BOR HUNTINGTON NORTH	Emery
LONG PARK (DAGGETT)	Daggett	BOR JOES VALLEY	Emery
ADAMS	Davis	CLEVELAND	Emery
BOR FARMINGTON EQUALIZING RESERVOIR	Davis	MILLER FLAT	Emery
CENTERVILLE - BARNARD CREEK (UPPER) DB	Davis	MILLSITE	Emery
CENTERVILLE CANYON DEBRIS BASIN	Davis	PACIFICORP - ELECTRIC LAKE	Emery
DAVIS COUNTY - FARMINGTON POND	Davis	OAK CREEK (A.K.A. UPPER BOWNS)	Garfield
DAVIS COUNTY - MILL CREEK DB #2	Davis	PANGUITCH LAKE	Garfield
DAVIS COUNTY -BARTON CREEK DB	Davis	TROPIC	Garfield
DAVIS COUNTY -HOLMES CREEK DB	Davis	WIDE HOLLOW	Garfield
DAVIS COUNTY -HOOPER DRAW DB	Davis	MOAB CITY - TUSHER CANYON DETENTION	Grand
DAVIS COUNTY -MUTTON HOLLOW DB	Davis	MOAB CITY - WALKER CANYON DB	Grand
DAVIS COUNTY -PARRISH CREEK DB	Davis	MOAB CITY - WHITE CANYON RETENTION	Grand
DAVIS COUNTY -RICKS CREEK DB	Davis	CEDAR CITY - FIDDLER CANYON DB #2	Iron
DAVIS COUNTY -SHEPARD CREEK DB	Davis	CEDAR CITY DRY CANYON DB	Iron
DAVIS COUNTY -STONE CREEK DB	Davis	CEDAR CITY STEPHENS CANYON DB NORTH	Iron
DAVIS/WEBER COUNTY CANAL CO. KAYSVILLE	Davis	CEDAR CITY STEPHENS CANYON DB SOUTH	Iron
DAVIS/WEBER CO. CANAL CO. LAYTON POND	Davis	LEIGH HILL RESERVOIR	Iron
DAVIS/WEBER CO. CANAL CO. SUNSET POND	Davis	NEWCASTLE	Iron
DEUEL CREEK	Davis	RED CREEK (IRON)	Iron
FARMINGTON IRRIGATION - RESERVOIR B	Davis	YANKEE MEADOW	Iron
FARMINGTON IRRIGATION - RESERVOIR C	Davis	MONA	Juab
HAIGHT CREEK (LOWER)	Davis	SEVIER BRIDGE	Juab
HAIGHT CREEK (UPPER)	Davis	ALTON RESERVOIR	Kane

Dam Name	County	Dam Name	County
JACKSON FLAT RESERVOIR	Kane	SANDY CITY - EAST SANDY ELEMENTARY	Salt Lake
KANAB CITY - TOM`S CANYON FLOOD CONTROL	Kane	SANDY CITY - FLAT IRON MESA	Salt Lake
CORN CREEK	Millard	SANDY CITY - STORM MOUNTAIN DB	Salt Lake
DMAD	Millard	SOUTH JORDAN RDA DB	Salt Lake
GUNNISON BEND	Millard	TWIN LAKES (SALT LAKE)	Salt Lake
BOR EAST CANYON	Morgan	WHITE PINE	Salt Lake
BOR LOST CREEK (MORGAN)	Morgan	BLANDING CITY NO. 3	San Juan
COBBLE CREEK DAM (MORGAN)	Morgan	BLANDING CITY NO. 4	San Juan
NORTHWEST	Morgan	KENS LAKE	San Juan
SILVER LEAF	Morgan	LOYD`S LAKE(MONTICELLO)	San Juan
BOX CREEK - LOWER (BEAVER CREEK)	Piute	RECAPTURE CREEK	San Juan
BOX CREEK - UPPER (BEAVER CREEK)	Piute	STARVATION CANYON	San Juan
OTTER CREEK	Piute	DAIRY DAM	Sanpete
PIUTE	Piute	FAIRVIEW LAKE	Sanpete
BIRCH CREEK NO. 2	Rich	GUNNISON	Sanpete
WOODRUFF CREEK	Rich	HUNTINGTON	Sanpete
DRAPER PRESSURE IRRIGATION PROJECT	Salt Lake	NINEMILE	Sanpete
ENSIGN DOWNS DB (AKA VICTORY ROAD DB)	Salt Lake	PALISADES LAKE	Sanpete
JORDAN VALLEY WATER PURIFICATION UPPER	Salt Lake	ROLFSON	Sanpete
KENNECOTT MINE BINGHAM CREEK	Salt Lake	COTTONWOOD WASH DETENTION BASIN	Sevier
LAKE MARY-PHOEBE	Salt Lake	DAIRY CANYON DETENTION BASIN	Sevier
LITTLE DELL	Salt Lake	FORSYTH	Sevier
LITTLE VALLEY	Salt Lake	GLENWOOD DEBRIS	Sevier
MOUNTAIN DELL	Salt Lake	JOHNSON	Sevier
OQUIRRH LAKE DAM/KENNECOTT DAYBREAK	Salt Lake	KOOSHAREM	Sevier
POINT OF THE MOUNTAIN RAW WATER RES	Salt Lake	SAND H DEBRIS	Sevier
RED BUTTE DAM	Salt Lake	THREE CREEKS (SEVIER)	Sevier
RED PINE	Salt Lake	BOR ECHO	Summit
RIVERTON CITY - 3200 WEST POND	Salt Lake	BOR LOST LAKE	Summit
RIVERTON CITY - 4200 WEST POND	Salt Lake	BOR STATELINE SUMMIT CO.	Summit
RIVERTON CITY - BLACK RIDGE RESERVOIR	Salt Lake	BOR TRIAL LAKE	Summit
SALT LAKE CO-CREEKSIDE PARK (BIG CTTNWD)	Salt Lake	BOR WANSHIP	Summit
SALT LAKE CO.-BIG COTTONWOOD (SPENCER`S)	Salt Lake	BOR WASHINGTON LAKE	Summit
SALT LAKE COUNTY - SCOTT AVENUE	Salt Lake	BOYER LAKE	Summit
SALT LAKE COUNTY - SUGARHOUSE	Salt Lake	DEER VALLEY SNOW MAKING RESERVOIR	Summit
SALT LAKE COUNTY CHANDLER DRIVE (#13)	Salt Lake	SMITH AND MOREHOUSE	Summit
SALT LAKE COUNTY FEDERAL HEIGHTS (#1A)	Salt Lake	WHITNEY	Summit
SALT LAKE COUNTY SHRINERS (#12)	Salt Lake	GRANTSVILLE	Tooele
SALT LAKE COUNTY-ROTARY GLEN PARK	Salt Lake	NEWFOUNDLAND DIKE	Tooele

Dam Name	County	Dam Name	County
SETTLEMENT CANYON	Tooele	UTAH COUNTY - HOBBLE CREEK DEBRIS BASIN	Utah
BOR RED FLEET	Uintah	UTAH COUNTY - SANTAQUIN DEBRIS	Utah
BOR STEINAKER	Uintah	WINWARD (PETE)	Utah
BOTTLE HOLLOW	Uintah	BOR CURRANT CREEK	Wasatch
BROUGH	Uintah	BOR DEER CREEK	Wasatch
BULLOCK DRAW	Uintah	BOR JORDANELLE	Wasatch
COTTONWOOD	Uintah	BOR SOLDIER CREEK	Wasatch
EAST PARK	Uintah	CENTER CREEK NO. 1	Wasatch
LAPOINT	Uintah	CENTER CREEK NO. 2	Wasatch
M&S DAM	Uintah	CENTER CREEK NO. 3	Wasatch
MONTES CREEK	Uintah	DEER VALLEY	Wasatch
OAKS PARK	Uintah	DUTCH CANYON DAM - MIDWAY IRRIGATION	Wasatch
PARADISE PARK	Uintah	JONES	Wasatch
RED WASH	Uintah	LINDSAY (BENNETT) LOWER	Wasatch
WHITEROCKS LAKE	Uintah	MILL HOLLOW	Wasatch
BIG EAST	Utah	WASATCH COUNTY LAKE CREEK DEBRIS BASIN	Wasatch
BOX LAKE (PAYSON CITY)	Utah	WITT LAKE	Wasatch
HIGHLAND CITY - NORTHWEST PRESSURE IRR.	Utah	ASH CREEK	Washington
HIGHLAND CITY PRESSURE POND	Utah	BAKER	Washington
LEHI CITY SANDPIT RESERVOIR	Utah	ENTERPRISE (LOWER)	Washington
LINDON CITY DRY CANYON DEBRIS BASIN	Utah	ENTERPRISE (UPPER)	Washington
LINDON CITY IRRIGATION PROJECT ZONE II	Utah	GUNLOCK	Washington
LINDON CITY IRRIGATION PROJECT ZONE III	Utah	GYPSUM WASH	Washington
MAPLE LAKE	Utah	HURRICANE CLIFFS	Washington
NORTH UTAH COUNTY - BATTLE CREEK	Utah	IVINS BENCH	Washington
NORTH UTAH COUNTY - DRY CREEK	Utah	KOLOB CREEK	Washington
NORTH UTAH COUNTY - SILVER LAKE FLAT	Utah	QUAIL CREEK	Washington
NORTH UTAH COUNTY - TIBBLE FORK	Utah	QUAIL CREEK SOUTH DAM	Washington
NORTH UTAH COUNTY-GROVE CREEK DB	Utah	SAND HOLLOW NORTH DAM	Washington
PAYSON RESERVOIR	Utah	SAND HOLLOW WEST DAM	Washington
PROVO CITY - ROCK CANYON DB	Utah	SOUTH CREEK - WASHINGTON COUNTY	Washington
PROVO CITY - SLATE CANYON DB NO. 2	Utah	ST. GEORGE CITY - NAVAJO D.B.	Washington
PROVO CITY - SLATE CANYON DB NO. 3	Utah	ST. GEORGE CITY-CITY CREEK D.B.	Washington
SANTAQUIN PRESSURE IRRIGATION RESERVOIR	Utah	STUCKI DEBRIS	Washington
SARATOGA SPRINGS - ISRAEL CANYON	Utah	TOQUER (ANDERSON JUNCTION)	Washington
SARATOGA SPRINGS SECONDARY WATER POND 8	Utah	TUACAHN WASH LOWER DETENTION BASIN	Washington
SPANISH FORK PRESSURE IRRIGATION POND	Utah	WARNER DRAW	Washington

Dam Name	County	Dam Name	County
WARNER VALLEY	Washington	SOUTH OGDEN CITY BURCH CREEK DEBRIS	Weber
MILL MEADOW	Wayne	TEN ACRE LAKE	Weber
BOR CAUSEY	Weber	WEBER/BOX ELDER - A RESERVOIR	Weber
BOR COMBE EQUALIZING RESERVOIR	Weber	NARROWWS RESERVOIR DAM	n/a
BOR OGDEN RIVER EQUALIZING RESERVOIR P	Weber	NARROWS PROJECT (GOOSEBERRY)	n/a
BOR PINEVIEW	Weber	WASHAKIE DAM	n/a
NORTH OGDEN CITY ORTON PARK/2100 NORTH	Weber	PARK CITY MTN RESORT SNOWMAKING POND	n/a
OGDEN CITY - SULLIVAN HOLLOW	Weber	NEW WIDE HOLLOW	n/a
SOUTH OGDEN CITY BURCH CREEK (GLASMANN)	Weber	BARNEY`S CREEK(AIRPORT#2)DETENTION BASIN	n/a

Significant Dam Failure Events:

21 Mile Dam Failure

The 21 Mile Dam failed in Elko County, Nevada on February 8, 2017 due to heavy runoff and snowmelt. The water broke free from the earthen dam and flooded the community of Montello, Nevada, damaged Union Pacific property, and entered extreme northwestern Utah causing road damage.

Laub Detention Dam Failure

Laub Detention Dam failed on September 11, 2012. A severe storm with heavy rainfall occurred prior to the failure. Numerous homes, businesses and roads were damaged. No lives were lost. A Presidential Disaster Declaration was declared for Washington County on November 3, 2012. The Dam was rebuilt in 2013 and was renamed "Tuacahn Wash Lower Detention Basin."

Quail Creek

Quail Creek dam failed on New Year's Eve, 1988, due to extensive foundation seepage. Failure caused approximately $12 million in damage and cost approximately $8 million to rebuild. No lives were lost.

Trial Lake Dam Failure
Trial Lake Dam failed in 1986 from piping of organics in the foundation contact. The BOR rebuilt the dam and the Corps repaired the damaged river channel.

DMAD Dam Failure
DMAD Dam failed in 1983 and a transient was killed trying to cross the flooding river on a suspended wire. The Gunnison Bend Dam was consequently breached proactively to keep it from overtopping.

Little Deer Creek
Little Deer Creek dam failed on its first filling on June 16, 1963, due to extensive foundation seepage. The catastrophic failure resulted in Utah's first dam failure fatality killing Bradley Galen Brown, a four-year-old boy.

Map 2. Utah Dam Failure Events

5.2 Assessment of Local Dam Failure Vulnerability and Potential Losses

Dam safety and dam construction, although improving, is still an imperfect and subjective discipline. Many dams can fail each year, however, the need to store water justifies the associated risks. To assess vulnerability by jurisdiction, the total number of dams classified as having a high hazard rating in each county were ranked (see Table 2B-2 and 2B-3). Thus, a county's level of risk is purely a function of the number of high hazard dams in the county. However, one should keep in mind many factors can cause a dam to fail.

Table 3. Number of Dams by Hazard Rating Per County

Utah Dam Hazard Rankings					
County	Low	County	Moderate	County	High
Rich	529	Salt Lake	29	Salt Lake	29
Emery	445	Summit	28	Davis	28
Carbon	410	Weber	27	Utah	25
Uintah	289	Sanpete	26	Washington	21
Box Elder	272	Utah	26	Uintah	14
Summit	265	Sevier	23	Wasatch	14
Duchesne	258	Emery	20	Duchesne	12
Cache	236	Washington	19	Summit	10
Sanpete	206	Davis	17	Weber	10
Utah	195	Duchesne	17	Iron	8
Salt Lake	181	Uintah	12	Sevier	8
Washington	177	Beaver	10	Emery	7
Iron	161	Box Elder	10	Sanpete	7
San Juan	161	Iron	11	Cache	6
Garfield	150	Wasatch	10	San Juan	6
Wasatch	148	Garfield	7	N/A	6
Kane	139	San Juan	7	Beaver	5
Grand	116	Grand	6	Box Elder	5
Daggett	86	Juab	6	Morgan	5
Sevier	83	Millard	6	Garfield	4
Beaver	81	Morgan	5	Piute	4
Tooele	62	Rich	5	Carbon	3
Wayne	54	Tooele	5	Grand	3
Weber	50	N/A	5	Millard	3
Davis	42	Cache	4	Rich	3
Millard	41	Carbon	4	Tooele	3
N/A	26	Kane	4	Daggett	2

Piute	20	Daggett	3	Juab	2
Juab	19	Wayne	3	Kane	2
Morgan	16	Piute	2	Wayne	1
Total	4918	Total	357	Total	256

Source: Data from Utah Division of Water Rights, https://www.waterrights.utah.gov/cgi-bin/damview.exe?Startup, 2018.

Table 4. Utah Dam Hazard Rankings - 1

Utah Dam Hazard Rankings by Dam Type - 1												
	State Inspected General	L	M	H	State Inspected Flood Control	L	M	H	State Inspected Industrial	L	M	H
Beaver	14	3	6	5	2	0	2	0	0	0	0	0
Box Elder	17	10	4	3	5	1	3	1	0	0	0	0
Cache	11	5	3	3	1	0	0	1	1	0	1	0
Carbon	7	5	1	1	2	0	2	0	3	3	0	0
Daggett	4	0	3	1	0	0	0	0	0	0	0	0
Davis	17	0	1	16	12	0	2	10	0	0	0	0
Duchesne	30	15	7	8	0	0	0	0	0	0	0	0
Emery	28	14	9	5	6	3	3	0	5	3	2	0
Garfield	18	9	5	4	0	0	0	0	2	2	0	0
Grand	3	2	1	0	3	0	0	3	5	4	1	0
Iron	13	5	4	4	7	0	3	4	0	0	0	0
Juab	6	3	1	2	2	0	2	0	1	0	1	0
Kane	17	15	1	1	2	1	0	1	0	0	0	0
Millard	6	1	3	2	1	0	0	1	9	7	2	0
Morgan	5	0	2	3	0	0	0	0	1	1	0	0
Piute	6	0	2	4	0	0	0	0	0	0	0	0
Rich	18	12	4	2	0	0	0	0	0	0	0	0
Salt Lake	19	3	2	14	22	2	8	12	4	1	2	1
San Juan	23	11	6	6	0	0	0	0	1	1	0	0
Sanpete	29	7	15	7	2	0	2	0	0	0	0	0
Sevier	20	3	13	4	7	1	2	4	0	0	0	0
Summit	28	6	18	4	0	0	0	0	0	0	0	0
Tooele	8	3	3	2	2	2	0	0	1	1	0	0
Uintah	34	16	7	11	4	4	0	0	4	3	1	0
Utah	26	5	7	14	14	2	3	9	0	0	0	0
Wasatch	21	7	5	9	1	0	0	1	0	0	0	0
Washington	18	4	2	12	16	1	9	6	2	2	0	0
Wayne	5	1	3	1	0	0	0	0	0	0	0	0
Weber	5	1	2	2	8	1	3	4	0	0	0	0
N/A	3	1	2	0	0	0	0	0	0	0	0	0
Total	459	167	142	150	119	18	44	57	39	28	10	1

Table 5. Utah Dam Hazard Rankings - 2

Utah Dam Hazard Rankings by Dam Type - 2													
	Federally Inspected	L	M	H	Inspected by Other Agencies	L	M	H	Other	L	M	H	N/A
Beaver	0	0	0	0	0	0	0	0	0	0	0	0	0
Box Elder	4	2	1	1	1	1	0	0	0	0	0	0	0
Cache	2	0	0	2	1	1	0	0	0	0	0	0	0
Carbon	1	0	0	1	0	0	0	0	1	0	0	0	1
Daggett	1	0	0	1	2	2	0	0	0	0	0	0	0
Davis	17	3	13	1	0	0	0	0	3	2	0	0	1
Duchesne	5	1	0	4	6	6	0	0	5	0	0	0	5
Emery	2	0	0	2	0	0	0	0	3	1	0	0	2
Garfield	0	0	0	0	9	9	0	0	2	1	1	0	0
Grand	0	0	0	0	1	1	0	0	1	0	0	0	1
Iron	0	0	0	0	1	1	0	0	3	0	1	0	2
Juab	0	0	0	0	0	0	0	0	1	0	0	0	1
Kane	0	0	0	0	2	2	0	0	3	1	1	0	1
Millard	0	0	0	0	0	0	0	0	2	0	0	0	2
Morgan	2	0	0	2	0	0	0	0	0	0	0	0	0
Piute	0	0	0	0	0	0	0	0	1	0	0	0	1
Rich	0	0	0	0	0	0	0	0	3	0	0	1	2
Salt Lake	1	1	0	0	0	0	0	0	3	1	0	2	0
San Juan	0	0	0	0	1	1	0	0	1	1	0	0	0
Sanpete	0	0	0	0	11	11	0	0	4	1	1	0	2
Sevier	0	0	0	0	9	9	0	0	1	0	0	0	1
Summit	6	0	0	6	17	17	0	0	3	0	0	0	3
Tooele	0	0	0	0	0	0	0	0	2	1	0	0	1
Uintah	5	2	0	3	6	6	0	0	3	2	1	0	0
Utah	1	0	1	0	3	3	0	0	4	1	0	1	2
Wasatch	5	1	0	4	0	0	0	0	0	0	0	0	0
Washington	0	0	0	0	1	1	0	0	1	0	1	0	0
Wayne	0	0	0	0	10	10	0	0	0	0	0	0	0
Weber	7	1	2	4	0	0	0	0	2	0	0	0	2
N/A	1				0	0	0		128	7	1	6	114
Total	60	11	17	31	81	81	0	0	180	19	7	10	144

Table 6. Utah Dam Hazard Rankings - 3

Utah Dam Hazard Rankings by Dam Type - 3															
	Uninspected	L	M	H	N/A	Inactive	L	M	H	Planned	L	M	H	Under Construction	M
Beaver	81	74	1	0	6	5	4	1	0	0	0	0	0	0	0
Box Elder	281	255	1	0	25	4	3	1	0	0	0	0	0	0	0
Cache	239	228	0	0	11	2	2	0	0	0	0	0	0	0	0
Carbon	443	399	0	0	44	4	3	1	0	1	0	0	1	0	0
Daggett	86	82	0	0	4	2	2	0	0	0	0	0	0	0	0
Davis	39	35	0	0	4	4	2	1	1	0	0	0	0	0	0
Duchesne	245	225	3	0	17	18	11	7	0	0	0	0	0	0	0
Emery	438	420	5	0	13	5	4	1	0	0	0	0	0	0	0
Garfield	145	126	1	0	18	3	3	0	0	0	0	0	0	0	0
Grand	127	108	3	0	16	2	1	1	0	0	0	0	0	0	0
Iron	160	149	1	0	10	8	6	2	0	0	0	0	0	0	0
Juab	18	15	2	0	1	1	1	0	0	0	0	0	0	0	0
Kane	120	117	1	0	2	4	3	1	0	0	0	0	0	0	0
Millard	36	33	0	0	3	0	0	0	0	1	0	1	0	0	0
Morgan	18	14	2	0	2	1	1	0	0	0	0	0	0	1	1
Piute	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0
Rich	518	516	1	0	1	1	1	0	0	0	0	0	0	0	0
Salt Lake	210	152	15	0	43	23	21	2	0	0	0	0	0	0	0
San Juan	147	140	0	0	17	7	6	1	0	1	1	0	0	0	0
Sanpete	199	182	6	0	10	6	5	1	0	1	0	1	0	0	0
Sevier	76	68	7	0	1	3	2	1	0	0	0	0	0	0	0
Summit	262	238	10	0	14	4	4	0	0	0	0	0	0	0	0
Tooele	57	49	2	0	6	7	6	0	1	0	0	0	0	0	0
Uintah	294	254	3	0	37	2	2	0	0	0	0	0	0	0	0
Utah	200	172	15	0	13	12	12	0	0	1	0	0	1	0	0
Wasatch	142	134	2	0	6	9	6	3	0	0	0	0	0	0	0
Washington	179	168	7	0	4	1	1	0	0	3	0	0	3	0	0
Wayne	47	37	0	0	10	5	5	0	0	1	1	0	0	0	0
Weber	57	35	17	0	5	15	12	3	0	0	0	0	0	0	0
N/A	0	0	0	0	0	80	17	1	0	2	1	1	0	0	0
Total	4884	4445	105	0	343	238	146	28	2	11	3	3	5	1	1

Table 7 displays the number of high hazard dams and the population for each county. Salt Lake, Davis, Utah, and Washington counties have the highest number of high hazard dams and are also some of the highest populated counties. Wayne, Daggett, Kane, Juab, and Millard counties have the lowest number of high hazard dams and are also some of the least populated counties.

Table 7. Rankings by County of Population per High Hazard Dam

Ranking	County	Population per High Hazard Dam	High Hazard Dams
1	Salt Lake	38,906	29
2	Weber	24,884	10
3	Utah	24,709	25
4	Tooele	22,378	3
5	Cache	21,082	6
6	Davis	12,456	28
7	Box Elder	10,994	5
8	Washington	7,886	21
9	Carbon	7,070	3
10	Iron	6,535	8
11	Juab	5,899	2
12	Millard	4,492	3
13	Sanpete	4,290	7
14	Summit	4,077	10
15	Kane	3,780	2
16	Grand	3,353	3
17	Wayne	2,738	1
18	San Juan	2,724	6
19	Sevier	2,721	8
20	Uintah	2,615	14
21	Morgan	2,345	5
22	Wasatch	2,230	14
23	Duchesne	1,736	12
24	Emery	1,525	7
25	Beaver	1,369	5
26	Garfield	1,310	4
27	Rich	790	3
28	Daggett	526	2
29	Piute	402	4

Source: Utah Division of Water Rights, https://www.waterrights.utah.gov/daminfo/; Ken C. Gardner Policy Institute, http://gardner.utah.edu/state-and-county-level-population-estimates/.

Estimating Potential Losses by Jurisdiction

Analyses of the total area per county that is susceptible to dam failure inundation were conducted. High hazard dams and dam inundation area shape files were provided by the Utah Division of Water Rights and the Bureau of Reclamation (BOR). The BOR and state dam failure inundation areas were clipped from each county in order to calculate the total area of potential loss per county. The BOR data provides various dam failure scenarios, such as sudden failure and sunny day failure. The highest potential inundation area was used for each listed BOR dam as to prevent overlapping and multiple summations of BOR dam inundation areas. Areas of potential loss due to dam failure inundation for each county were calculated using the "calculate geometry" function in ArcGIS.

In addition, the percent total potential inundation areas per county were also calculated to demonstrate how much risk due to dam failure inundations exists in each county. This was calculated by dividing the total area of the county by the total potential dam failure inundation area of the county. Maps were then created that visualize this distribution of potential dam failure inundation risk areas per county. All of the LHMPs did not report the number of their structures in dam failure inundation areas, as well as any damage or loss estimates.

The total potential inundation area by county and percent potential inundation area is listed in the following table and displayed on the following map. Millard, Uintah, Weber, Iron, and Duchesne counties have the most total potential inundation areas with over 900 total square miles of dam inundation are and a population of around 370,000 people. Weber County is by far the most populated of those top five counties with over 250,000 people. Kane, Rich, Wayne, Carbon, and Grand have the least total potential inundation areas with only a combined total of 38.51 square miles of dam inundation area. These counties are also some of the least populated counties in the state. Weber, Uintah, Salt Lake, Millard, and Utah counties have the highest percent potential inundation area with Weber County having by far the most percent potential inundation area by county with 20.34%. This is almost 4 times as much as the next highest county. Kane, San Juan, Wayne, Grand, and Garfield counties have the least percent potential dam inundations areas in the state.

Table 8. Potential Dam Inundation Area in Utah

County	Total Area (sq. miles)	Total Potential Inundation Area (sq. miles)	Percent Potential Inundation Area	Total Population (2017 Census Estimate)
Beaver	2,585.45	41.84	1.62%	6,386
Box Elder	6,729.22	57.39	0.85%	54,079
Cache	1,171.96	39.04	3.33%	124,438
Carbon	1,484.21	11.55	0.78%	20,295
Daggett	718.9	24.74	3.44%	1,029
Davis	634.81	21.06	3.32%	347,637
Duchesne	3,248.13	111.51	3.43%	20,026
Emery	4,468.82	67.77	1.52%	10,077
Garfield	5,205.38	21.17	0.41%	5,078
Grand	3,683.14	12.57	0.34%	9,674
Iron	3,301.35	118.34	3.58%	51,001
Juab	3,405.39	17.9	0.53%	11,250
Kane	4,104.87	0.55	0.01%	7,567
Millard	6,837.36	321.82	4.71%	12,863
Morgan	610.44	23.51	3.85%	11,873
Piute	765.63	17.5	2.29%	1,420
Rich	1,085.45	6.83	0.63%	2,391
Salt Lake	805.18	38.67	4.80%	1,135,649
San Juan	7,929.93	18.74	0.24%	15,356
Sanpete	1,601.07	33.35	2.08%	30,035
Sevier	1,916.99	65.99	3.44%	21,316
Summit	1,880.34	28.56	1.52%	41,106
Tooele	7,286.50	67.44	0.93%	67,456
Uintah	4,502.71	233.28	5.18%	35,150
Utah	2,140.90	85.53	3.99%	606,425
Wasatch	1,208.45	13.48	1.12%	32,106
Washington	2,431.64	35.7	1.47%	165,662
Wayne	2,464.95	7.01	0.28%	2,719
Weber	659.43	134.16	20.34%	251,769

Map 3. Total Potential Dam Inundation Area by County

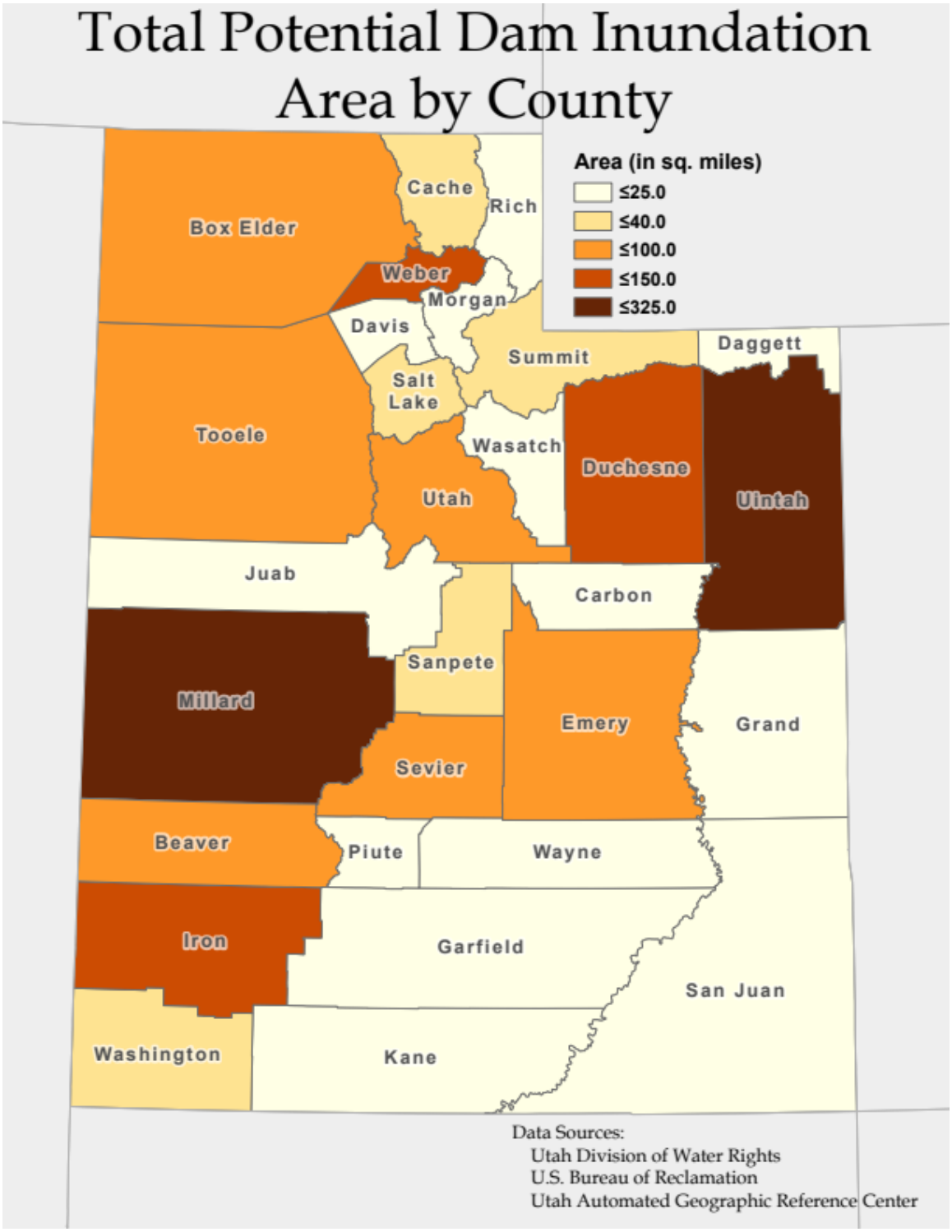


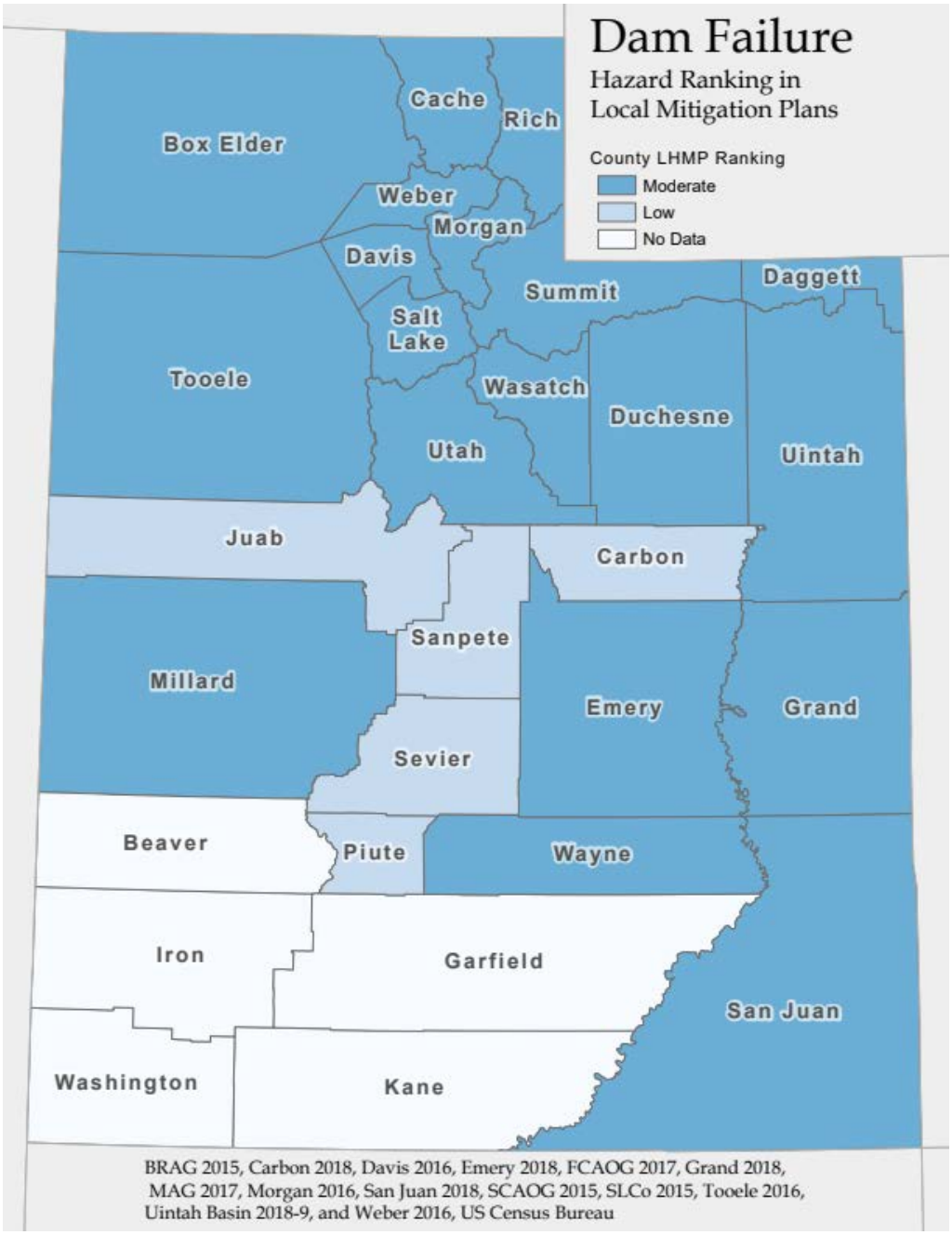
Table 9. Total Potential Dam Failure Inundation and Population Percentage

County	Percent Potential Inundation Area	Percentage of Utah's Population (2017 data)
Beaver	1.62%	0.2%
Box Elder	0.85%	1.7%
Cache	3.33%	4.0%
Carbon	0.78%	0.7%
Daggett	3.44%	0.0%
Davis	3.32%	11.2%
Duchesne	3.43%	0.6%
Emery	1.52%	0.3%
Garfield	0.41%	0.2%
Grand	0.34%	0.3%
Iron	3.58%	1.6%
Juab	0.53%	0.4%
Kane	0.01%	0.2%
Millard	4.71%	0.4%
Morgan	3.85%	0.4%
Piute	2.29%	0.0%
Rich	0.63%	0.1%
Salt Lake	4.80%	36.6%
San Juan	0.24%	0.5%
Sanpete	2.08%	1.0%
Sevier	3.44%	0.7%
Summit	1.52%	1.3%
Tooele	0.93%	2.2%
Uintah	5.18%	1.1%
Utah	3.99%	19.6%
Wasatch	1.12%	1.0%
Washington	1.47%	5.3%
Wayne	0.28%	0.1%
Weber	20.34%	8.1%

A map was also created that shows the hazard ranking of Dam Failure for each county as reported in the LHMPs (see Map 4). The hazard ranking is calculated from a combination of severity (categorized from 0-4) and frequency (categorized from 0-4). This allows for a ranking from 0-8 when combined.

Based on the reporting in LHMPs, the majority of the state has moderate ranking for dam failure. Carbon, Juab, Sanpete and Sevier counties are ranked low and the Five County AOG region did not provide sufficient data for a ranking to dam failure.

Map 4. Dam Failure Hazard Rankings from LHMPs



Vulnerable Structures and Dam Failure

Vulnerable structures and loss estimates to dam failure were not reported in LHMPs. Therefore, the general building stock data in HAZUS was used to estimate potential building exposure to dam inundation. Two dam inundation data sets for this analysis were used: one is from the Utah Division of Water Rights and the other is from the Bureau of Reclamation (for official use only data). These updates occurred on the Census Tract level. Within the HAZUS database, the "hzBldgCountOccupT" and the "hzExposureOccupT" tables in addition to the Census Tract vector data were used. This analysis assumes that all of the buildings in a Census Tract are evenly distributed through the Tract.

The results of the analysis are found in Table 10. The analysis was performed as follows. First, all of the buildings from the all HAZUS occupancy class were added together to derive the total number of buildings per Tract. Next, all of the exposure values were added to derive the total building value per Tract. These two values were used to determine the average value per structure in each Tract. The number of buildings exposed to the dam inundation hazard was estimated by dividing the area of each Tract in the hazard area by the total Tract area and then multiplying this percentage by the total number of buildings in the Tract. To determine the estimated building value exposure, the number of buildings was multiplied in each Tract in the hazard area by the estimated building value for that Tract. These results were aggregated to the county level using the Dissolve tool in ArcMap. Lastly, 2010 Census Population values (the most current in the HAZUS database) were used to determine a per capita exposure to dam inundation based on the estimated building value exposure in each county.

Based on the above analysis, Utah, Salt Lake, Weber, Davis, and Washington counties have the highest estimated number of buildings in dam inundation areas. These are also the most populous counties in the state. Morgan, Sevier, Tooele, Utah, and Emery counties have the highest percent building value exposure to dam inundation with 50.02%, 42.50%, 38.50%, 33.62%, 32.36% respectively. Sevier, Morgan, Grand, Emery, and Tooele counties have the highest per capita loss to dam inundation with $39,423, $36,486, $31,616, $30,561, and $26,563 respectively.

Table 11 lists the estimated daytime and nighttime population in dam inundation areas. Utah, Salt Lake, Weber, Davis, and Tooele counties have the highest estimated daytime and nighttime population in dam inundations areas. The counties with the highest percent daytime population in dam inundation areas are Sevier, Duchesne, Morgan, Tooele, and Grand counties. Sevier, Duchesne, Morgan, Tooele, and Grand counties have the highest percent daytime, population in dam inundation areas with 51.21%, 45.46%, 45.44%, 40.50%, and 38.45% respectively. Morgan, Sevier, Duchesne, Tooele, and Utah counties have the highest percent nighttime population in dam inundation areas with 46.66%, 45.29%, 38.63%, 34.95%, and 33.02% respectively.

Table 10. Utah HAZUS Building Stock Exposure to Dam Inundation

County	Total Population (2017 Census Estimate)	HAZUS Number of Buildings	HAZUS Total Building Value	Estimated Buildings in Inundation Areas	Estimated Building Value Exposure	Percent Building Value Hazard Exposure	Per Capita Hazard Exposure
Beaver	6,386	2,850	$572,419,000	417	$99,918,443	14.63%	$15,646
Box Elder	54,079	17,554	$4,211,895,000	845	$197,350,547	4.81%	$3,649
Cache	124,438	33,221	$9,080,968,000	3,068	$727,261,265	9.24%	$5,844
Carbon	20,295	9,369	$1,994,938,000	1,954	$378,317,973	20.86%	$18,641
Daggett	1,029	1,182	$150,401,000	13	$1,722,639	1.10%	$1,674
Davis	347,637	92,557	$27,013,422,000	12,048	$3,391,484,153	13.02%	$9,756
Duchesne	20,026	9,500	$2,019,795,000	2,126	$479,324,087	22.38%	$23,935
Emery	10,077	4,676	$906,997,000	1,513	$307,965,106	32.36%	$30,561
Garfield	5,078	3,933	$789,683,000	185	$35,950,210	4.70%	$7,080
Grand	9,674	4,827	$1,046,323,000	1,209	$305,854,408	25.05%	$31,616
Iron	51,001	17,237	$3,826,638,000	3,971	$909,419,675	23.04%	$17,831
Juab	11,250	3,660	$924,941,000	13	$3,084,034	0.36%	$274
Kane	7,567	6,020	$1,052,599,000	5	$1,203,899	0.08%	$159
Millard	12,863	5,327	$1,182,268,000	1,214	$266,410,756	22.79%	$20,711
Morgan	11,873	3,197	$905,106,000	1,599	$433,192,637	50.02%	$36,486
Piute	1,420	972	$167,635,000	138	$24,053,037	14.20%	$16,939
Rich	2,391	2,515	$542,621,000	99	$21,535,080	3.94%	$9,007
Salt Lake	1,135,649	310,571	$98,684,444,000	41,384	$13,353,268,953	13.33%	$11,758
San Juan	15,356	5,875	$986,455,000	70	$11,187,921	1.19%	$729
Sanpete	30,035	10,519	$2,502,214,000	451	$80,902,384	4.29%	$2,694
Sevier	21,316	8,822	$1,922,617,000	3,749	$840,332,647	42.50%	$39,423
Summit	41,106	20,484	$6,718,738,000	1,721	$474,665,591	8.40%	$11,547
Tooele	67,456	19,102	$4,809,515,000	7,354	$1,791,834,932	38.50%	$26,563
Uintah	35,150	11,856	$2,834,340,000	971	$206,236,871	8.19%	$5,867
Utah	606,425	134,568	$38,755,008,000	45,244	$13,233,012,495	33.62%	$21,821
Wasatch	32,106	10,598	$2,734,364,000	2,257	$616,759,879	21.30%	$19,210
Washington	165,662	54,511	$12,241,252,000	7,114	$1,791,320,236	13.05%	$10,813
Wayne	2,719	1,658	$337,652,000	43	$8,248,156	2.59%	$3,034
Weber	251,769	78,697	$21,053,228,000	13,976	$3,932,797,438	17.76%	$15,621

Source: Utah Automated Geographic Reference Center (county boundaries); U.S. Census Bureau (2017 population estimates)

Table 11. Estimated Daytime and Nighttime Population in Inundation Areas

County	Estimated Daytime Population in Inundation Areas	Percent Daytime Population in Inundation Areas	Estimated Nighttime Population in Inundation Areas	Percent Nighttime Population in Inundation Areas
Beaver	568	8.89%	911	14.27%
Box Elder	1,023	1.89%	2,009	3.71%
Cache	6,379	5.13%	11,092	8.91%
Carbon	3,606	17.77%	4,402	21.69%
Daggett	2	0.19%	1	0.10%
Davis	43,350	12.47%	42,209	12.14%
Duchesne	9,104	45.46%	7,736	38.63%
Emery	3,353	33.27%	3,048	30.25%
Garfield	220	4.33%	341	6.72%
Grand	3,720	38.45%	2,809	29.04%
Iron	12,687	24.88%	11,694	22.93%
Juab	0	0.00%	0	0.00%
Kane	22	0.29%	0	0.00%
Millard	811	6.30%	2,329	18.11%
Morgan	5,395	45.44%	5,540	46.66%
Piute	111	7.82%	159	11.20%
Rich	101	4.22%	272	11.38%
Salt Lake	170,786	15.04%	137,641	12.12%
San Juan	43	0.28%	92	0.60%
Sanpete	1,992	6.63%	1,070	3.56%
Sevier	10,915	51.21%	9,655	45.29%
Summit	1,786	4.34%	3,273	7.96%
Tooele	27,323	40.50%	23,574	34.95%
Uintah	3,089	8.79%	1,818	5.17%
Utah	213,133	35.15%	200,251	33.02%
Wasatch	11,279	35.13%	7,529	23.45%
Washington	22,235	13.42%	20,127	12.15%
Wayne	13	0.48%	32	1.18%
Weber	67,570	26.84%	42,045	16.70%

A vulnerability analysis was conducted based on 17 criteria from the dam failure risk assessment. These 17 criteria come from tables 1, 3, 7, 8, 10, 11, and 12. Each of the criteria was ranked from 1 to 29 for each county. The ranking numbers were combined for each county and then the totals were ranked from 1 to 29 to determine a vulnerability ranking. The counties with the lowest total ranking number would indicate the highest overall vulnerability to dam failure. Table 13 shows the results of this analysis. The most vulnerable areas to dam failure based on the analysis are along the Wasatch Front (Utah, Salt Lake, and Weber counties), along with Sevier and Iron Counties.

Table 12. Dam Failure Vulnerability Score of Utah Counties*

Rank	County	Vulnerability Score
1	Utah	66
2	Salt Lake	106
3	Weber	118
4	Sevier	121
5	Iron	132
6	Tooele	134
7	Duchesne	162
8	Davis	164
9	Washington	179
10	Emery	181
11	Morgan	182
12	Wasatch	196
13	Grand	218
14	Cache	219
15	Summit	230
16	Carbon	232
17	Uintah	235
18	Millard	244
19	Box Elder	293
20	Sanpete	295
21	Beaver	303
22	Piute	330
23	Garfield	348
24	Rich	358
25	Daggett	380
26	San Juan	383
27	Juab	403
28	Wayne	405
29	Kane	417

*Based on 7 criteria from dam failure risk assessment.

For the SHMP 2019 update, the SHMPC looked at the county LHMPS to gather data on the vulnerability and losses of people, residential units, commercial units, and critical facilities for each county that reported such data. Only 10 counties reported data related to dam failure in their LHMPs. The counties with the most people vulnerable to dam failure were Salt Lake (120,703), Weber (38,738), and Tooele (19,349) with a total of around 195,000 people vulnerable to dam failure. There were over 63,098 residential units, for a total value of over $11 billion dollars, and 7001 commercial units, for a total value of around $4.5 billion dollars that was reported to be vulnerable to dam failure. Almost 400 critical facilities were also listed as being at risk to dam failure.

Table 13. Dam Failure Vulnerability and Loss from LHMPs

Dam Failure

County	People	Residential Units		Commercial Units		Critical Facilities
		Units	Value	Units	Value	
Box Elder	2570	821	$138,005,476	106	$90,428,808	25
Cache	9636	2974	$627,158,439	159	$158,458,997	61
Carbon						15
Emery						42
Grand						24
Morgan	4016	1323	$268,569,900	33	$8,272,812	
Rich	502	154	$14,735,154	14	$1,198,151	18
Salt Lake	120,703	51,009	$9,665,508,700	6,052	$3,719,874,395	66
Tooele	19,349	5826	$874,487,874	388	$393,307,807	117
Weber	38,738	991	$144,091,400	249	$157,957,771	29
Total	195,514	63,098	$11,732,556,943	7001	$4,529,498,741	397

Development Trend Impacts

There are four high hazard dams and four moderate hazard dams in Utah being planned or designed as of 2018. The names of the high hazard dams are the Garley Canyon Dam, Hurricane Cliffs, Toquer (Anderson Junction), and Warner Valley. Three of these high hazard dams are in Washington County which is one of the most populous and fastest growing counties in Utah. The other high hazard dam being planned is in Carbon County. One moderate hazard dam is under construction as of 2018, the Northside Creek Reservoir dam in Morgan County.

In 2012, the Laub Detention Dam in Washington County failed and flooded several homes and businesses. Washington County is one of the fastest growing areas in the state. Many dams in Utah were built many decades ago and are constructed of earthen materials. As communities continue to grow and encroach in dam failure inundation zones the threat will increase. The regular inspection of dams in Utah will hopefully allow mitigation strategies to be implemented before a catastrophic dam failure in the future.

5.3 Assessment of State Dam Failure Vulnerability and Potential Losses

An updated state facilities data was provided by Utah Division of Risk Management for the 2019 update. This current state facility database is a different database than the last plan update. The updated state facilities shape file was overlaid on top of the Utah state dam failure inundation areas map as well as the federal dam failure inundation locations. Using ArcGIS, each dam inundation area was clipped from a county shape file for each county in Utah. The "select by location" option was then utilized in order to determine how many vulnerable structures exist per county. A total of 1018 state facilities were found to be in dam failure inundation areas, with Salt Lake, Utah, and Weber counties having the bulk of them. Seven counties were found to have no state facilities in dam failure inundation areas: Daggett, Juab, Kane, Piute, Rich, San Juan, and Wayne.

Estimating Potential Losses by State Facilities

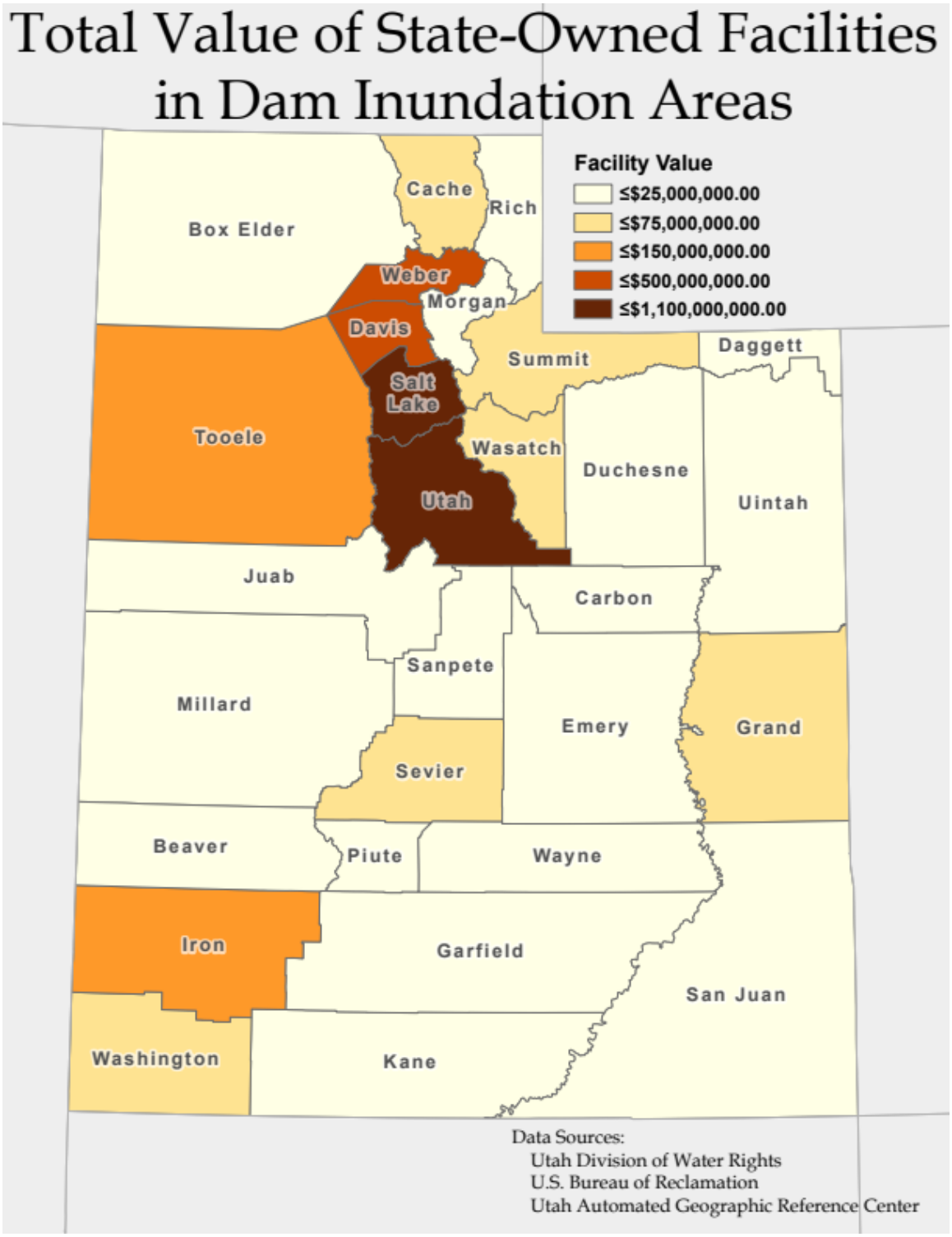
Values estimating the potential losses by state-owned facilities were calculated by summing the current value of each state-owned facility per county that falls within the county's dam inundation areas. Current values of state facilities per county were provided by Risk Management. It is important to note that the current values represent the total value of the facilities located within a dam inundation area. These values assume that in the event of a dam breach, the state facilities within the dam inundation area would be completely destroyed rather than sustaining a particular amount of damage. Therefore, the current values overestimate the damage to state facilities in the event of most dam failures. The state facilities per capita loss to dam failure was also calculated.

State facilities have the greatest to lose in Salt Lake, Utah and Weber Counties. More analysis is needed to understand what is at risk in dam inundation areas. Figure 2B-4 is a map of the state facility per capita loss for dam failure for every county based on the insured value of the state owned facilities residing in their boundaries. Sevier, Morgan, and Duchesne counties have the highest state facility per capita loss for dam failure. All three of these counties have relatively low populations.

Table 14. Total Value of State Owned Facilities in Dam Failure Inundation Area

County	Facilities in Dam Inundation Area	Insured Value of State Facilities	Per Capita Potential Loss
Beaver	0	$0	$0
Box Elder	5	$1,171,739	$21
Cache	24	$43,497,969	$344
Carbon	8	$10,204,854	$481
Daggett	4	$649,100	$617
Davis	61	$430,282,638	$1,234
Duchesne	14	$13,833,709	$664
Emery	28	$11,097,048	$1,040
Garfield	3	$435,827	$83
Grand	26	$25,976,422	$2,582
Iron	41	$104,817,325	$2,005
Juab	5	$164,764	$14
Kane	0	$0	$0
Millard	6	$2,091,896	$155
Morgan	29	$22,891,582	$1,952
Piute	13	$763,882	$475
Rich	0	$0	$0
Salt Lake	299	$959,213,674	$850
San Juan	0	$0	$0
Sanpete	2	$5,313,400	$177
Sevier	49	$74,403,383	$3,418
Summit	10	$37,903,784	$930
Tooele	32	$130,093,980	$1,938
Uintah	18	$19,477,404	$532
Utah	184	$1,099,077,581	$1,779
Wasatch	27	$40,560,310	$1,299
Washington	31	$67,131,118	$405
Wayne	0	$0	$0
Weber	99	$158,079,145	$635
Total	1018	$3,259,132,534.00	$23,630.00

Map 5. State Facilities per Capita Loss for Dam Failure



An analysis of critical infrastructure within dam inundation areas throughout the state shows that there are 775 critical structures and 6337 miles of critical lines within avalanche areas. For a complete list of the critical infrastructure in dam inundation areas see the appendix.

Table 15. Critical Infrastructure in Dam Inundation Areas

Critical Infrastructure within Dam Inundation Area	
	#
Airports	5
Electric Substations	110
Powerplants	2
Healthcare Facilities	254
Schools	294
Police Stations	49
Fire Stations	61
	Miles
Railroads	556
Local Roads	4832
Highways and Interstates	865
NPMS Pipelines	34
Transmission Lines	50

Climate Change Impacts

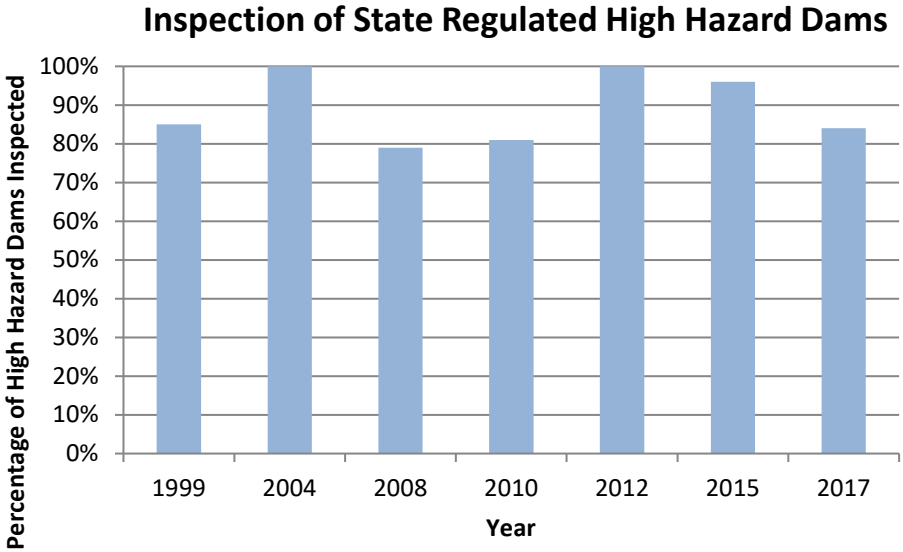
While dam failure is not a natural hazard, changes in climate will increase the risk of dam failure in Utah. For the last millennia, the climate of Utah has experienced periods of intense precipitation and drought.[2] The risk to dam failure in Utah will be increased during prolonged periods of intense precipitation. Changes in weather patterns and incidence of extreme precipitation will increase the risk of dam failure in Utah. In 2017, there were two notable dam failure incidents in the West. One, Oroville Dam in northern California was severely compromised after a warm atmospheric river event dropped several inches of rain-on-snow and caused severe flooding and nearly dam failure. Two, a dam along the Humboldt River in central Nevada failed during the same February 2017 rain event. Local residents near both dams were forced to evacuate; fortunately, no lives were lost in either event. Incidents such as those in northern California and Nevada will be more likely in Utah due to the impacts of climate change.

5.4 Mitigation Efforts for Dam Failure Hazards

The Utah State Engineer has been charged with regulating non-federal dams in the State since 1919. Utah started its own Dam Safety Section in the 1970s within the State of Utah Engineers Office to administer all non-federal dams in response to the Federal Dam Safety Act. In 1990, the legislature directed the State Engineer to regulate all dams in the state, including federally owned dams, except those owned by the Bureau of Reclamation.

The frequency of dam inspection is designated based on hazard rating: The Utah Division of Water Rights inspects high-hazard dams annually, moderate hazard dams biannually, and low-hazard dams every five years.

Figure 3. Percentage of Inspection of State Regulated High Hazard Dams



Source: damsafety.org, Dam Safety Performance Report: Utah (Inspection percentages may vary above and below