FLOOD HAZARD FROM LAKES AND FAILURE OF DAMS IN UTAH

By Kimm M. Harty and Gary E. Christenson
Utah Geological and Mineral Survey

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ABSTRACT

Parts of Utah are subject to lake-flooding hazards from large fluctuations of lake shorelines and intermittent flooding of dry lakes, mud/salt flats, and marshes. The greatest potential for damage from lake flooding is along the Wasatch Front, where much of Utah's population is in close proximity to Great Salt Lake and Utah Lake. Lake-flooding hazard elsewhere is more localized and generally confined to the topographically lowest portions of closed basins in western Utah. The map identifies areas subject to such flooding and is intended as a guide to local governments and regulatory agencies to indicate general hazard areas. For planning purposes, it is advisable to perform detailed studies to further assess the hazard and, if necessary, recommend mitigation measures in these areas.

Flooding may occur downstream from dams in the event of a dam failure, and the potential flooded areas for which studies are available are shown on the map. Inundation studies have been completed for only a small percentage of dams in Utah, and many more areas than are shown are at risk. The purpose of illustrating these areas is to inform planners, regulatory agencies, community officials, hazard mitigation and emergency response personnel, and private citizens of the potential hazard from dam failures.

INTRODUCTION

Flooding in Utah is a common occurrence and frequently affects areas along stream channels and in river flood plains. However, flooding may result from causes other than normal overbank flow in streams and potentially occurs over large areas not generally recognized as subject to flooding. In Utah, this includes: 1) shoreline flooding due to lake-level fluctuations in lakes with no outlet or with outlets which restrict flow, and 2) downstream inundation caused by the failure of dams. The purpose of this map is to show these two types of flood-hazard areas so that the hazard can be recognized and addressed before and during development. Although development is generally regulated in areas subject to normal stream flooding, flooding caused by lake-level fluctuations or failure of dams is not always considered.

The most extensive areas of Utah prone to lake flooding are in the Great Basin of western Utah where lakes, dry lake beds, and extensive mud/salt flats and marshes occur on the floors of many closed basins. Most of these basins have no surface outlets, and water is lost only through evaporation and, in some basins, through infiltration. Fluctuations in the levels of the lakes and periodic flooding of dry lakes and mud/salt flats may inundate large areas. The recent rise of Great Salt Lake and flooding of Sevier Lake indicate the severity of the hazard.

The resulting property damage, destruction of wildlife habitat, and disruption of transportation routes demonstrate the need to consider the hazard prior to development. The areas shown on the map indicate where this type of flooding may occur and should be considered in planning. They are based on flood levels reached in the historical or recent geologic past as reconstructed from historical records or topographic and geologic features. They do not represent levels with any particular statistical probability of recurrence based on meteorologic and hydrologic records.

Although lake-flooding hazards are generally confined to western Utah, flood hazards due to potential dam failures are distributed throughout the state. Most of the major dams are in the Rocky Mountain and Colorado Plateau regions, but flooding caused by failure may affect population centers outside these areas at great distances downstream. An evaluation of the extent of possible flooding requires specialized studies considering reservoir capacity, inflow to the reservoir, downstream valley geometry, and an assumed failure scenario. Few such studies have been completed in Utah. Those completed to date are shown on the map, and it must be noted that these do not reflect an assessment of the potential for dam failure. They also do not show the full downstream extent of flooding but generally stop at a reservoir, lake, populated area, political boundary, or confluence with a larger river. Some flooding may continue downstream beyond the limits shown. Because dam failures are rare, many people are unaware of the extent of flooding possible should a dam fail with the reservoir at full capacity. The 1976 failure of Teton Dam in southeastern Idaho, and the 1983 failure of the DMAD Dam in Millard County highlighted this hazard and the threat it poses to life and property.

SCOPE OF WORK

Mapping potential flood zones of lakes, dry lakes, and other intermittently flooded areas was accomplished using published and unpublished lake-elevation measurements from the mid-1800s to the present, written historical accounts of flooding, and topographic and geologic maps showing the extent of mud and other modern lake deposits. Aerial photography was used in conjunction with other information to determine lake-fluctuation history for Rush Lake (Tooele County) and Sevier Lake. Photography was also used in areas northeast of Sevier Lake to determine the extent of flooding in 1983 and 1984. Discussions with various government officials aided in defining local areas of flooding. In illustrating flood-hazard zones around larger lakes, consideration was not given to the effects of structures or projects that have altered natural flood areas. For example, potential flood zones surrounding Great Salt Lake were drawn according to topographic elevation and do not consider the dikes or pumps used to mitigate flooding or contain evaporation ponds. Inundation of shoreline areas of Great Salt Lake or Utah Lake due to tectonic tilt or seiches associated with earthquakes is addressed on a forthcoming map.

Stream flooding was not included in the scope of this report and map. At a 1:750,000 scale, the zone of potential flooding is usually too narrow to show on a map. Maps depicting 100-year stream flooding in most populated areas of the state have been prepared for the National Flood Insurance Program and are available from the Utah Division of Comprehensive Emergency Management.

Dam failure inundation areas were taken from unpublished reports and maps prepared by the U.S. Bureau of Reclamation, U.S. Soil Conservation Service, U.S. Forest Service, Utah Division of Water Rights, and the Utah Geological and Mineral Survey (UGMS). Inundation models can be used to calculate the development of a breach, a breach hydrograph (flow versus time), the height and travel-time of a flood-wave, and the contribution of mainstream and tributary inflow. For large dams, the U.S. Bureau of Reclamation assumes failure caused by a flood event and uses complex numerical models (including the National Weather Service (NWS) DAMBRK model) which consider a "characteristic flood." The U.S. Forest Service (USFS) also uses the NWS DAMBRK model but does not incorporate any inflow to the reservoir, resulting in a comparatively conservative estimate of downstream flooding. The Utah Division of Water Rights (UDWR) Dam Safety Section calculates dam failure inundation elevations using the NWS DAMBRK model and the HEC-1 and HEC-2 models of the U.S. Army Corps of Engineers. They do not map inundation areas but calculate inundation elevations at downstream channel cross sections (Matt Lindon, UDWR, oral communication, February, 1987). The UGMS model determines the flood elevation at downstream channel cross sections using Manning's equation of flow. Inundation areas between cross sections are estimated. Neither the USFS or UGMS models consider inflow to the reservoir during failure.

In 1983, the U.S. Soil Conservation Service began conducting inundation analyses for newly-built dams. Its "Simplified Dam-Breach Routing" model is used mainly for small dams and debris basins and requires the use of valley-parameter charts that list representative downstream channel cross-section geometries and slope angles. The U.S.Bureau of Reclamation, U.S. Forest Service, U.S. Soil Conservation Service, and UDWR models consider gradual breach growth and development of the breach hydrograph, and then route the flow down the valley. The UGMS model considers instantaneous failure of the entire dam (W.F. Case, Utah Geological and Mineral Survey, oral communication, February, 1987) and is a "worst-case" scenario that is less likely to occur than others using gradual breach development.

The map shows all dams for which inundation studies have been completed and indicates the agency performing the study. The inundation area is shown where possible at 1:750,000 scale. Most inundation studies are for high-hazard dams. The hazard rating (usually low, moderate, or high) is assigned by the Utah Division of Water Rights to all dams in Utah other than those constructed by the U.S. Bureau of Reclamation. The hazard rating does not reflect the structural integrity of a dam but does indicate the potential for loss of life and property in the event of a dam failure. According to regulations governing dam safety in Utah (Morgan and Hall, 1986, p. 7), the rating of high-hazard is given to dams which, if failed, "...could cause loss of life and/or extensive economic loss." A moderate rating applies to dams that "...could cause appreciable economic loss but would not normally cause loss of life," and low-hazard dams are those which, if failed, "...could cause minor economic loss and no loss of life."

Dams given a rating of low, moderate, or high hazard but for which inundation studies have not been done are also shown on the map. However, only dams capable of impounding at least 20 acre-feet (nearly 25,000 m^3) of water are shown, except for a few smaller dams that are classified as high-hazard. The Utah Division of Water Rights generally does not require the submittal of formal design plans, and does not conduct regular inspections of dams less than 20 acre-feet in size (Chad Gourley, UDWR, oral communication, October, 1987). A distinction has been made between dams impounding a reservoir or lake and those which function as debris basins, dikes, retention/detention ponds, regulation ponds, or tailings ponds.

LAKE FLOODING

Potential flood-hazard areas are shown for perennial lakes subject to large shoreline fluctuations and for dry lakes and other intermittently flooded areas such as mud/salt flats and marshes. Perennial lakes are those which gain water from aquifers and have contained water throughout historical time. The only such lakes which are subject to large shoreline fluctuations are Great Salt Lake and Utah Lake. All other perennial lake fluctuations are either too small to show at this map scale or are sufficiently regulated by engineered structures such that they pose very little hazard. The maximum extent of flooding of these lakes (that is, the maximum reservoir level) is shown on the base map. Dry lakes are defined as those which lose water to aquifers and occur in the lowest parts of closed basins which have been dry at some point during historical time. They are also commonly termed playas, ephemeral lakes, or intermittent lakes. Dry lakes may flood seasonally or may only flood in response to large runoff events. Following major flooding, they may remain flooded for decades (for example, Sevier Lake and Rush Lake). Other intermittently flooded areas include mud and salt flats and marshes. These areas occur around lakes or dry lakes in low-lying basin floors where gradients are gentle and where local closed depressions or obstructions to flow cause local ponding. These areas generally experience seasonal or short-term flooding in direct response to storms or runoff but may remain flooded for extended periods, particularly in shallow ground water areas.

PERENNIAL LAKES

Until the spring of 1986, the peak historic elevation of Great Salt Lake was about 4211.5 feet (1283.7 m) (Arnow, 1984). This level was reached in the early 1870s and is based on a relative elevation estimate of water depth over the Stansbury Bar (Gilbert, 1890). Direct measurements of the lake's elevation began in 1875 (Currey and others, 1984). The lake dropped slowly from this time, reaching an historic low elevation of 4191.35 feet (1277.52 m) in 1963. Above-average precipitation in recent years caused Great Salt Lake to attain a new historic peak elevation of 4211.85 feet (1283.77 m) in June 1986. This rise of the lake has caused significant damage to structures and property along the shoreline and within the lake (power lines, causeways, dikes). Great Salt Lake has risen more than 20 feet in a little over 20 years, which indicates that significant lake fluctuations can occur within a relatively short time.

Depicted on the map is the historic high lake elevation (4211.85 feet - 1283.8 m), as well as the 4217-foot (1285.3 m) topographic contour. A consensus of hazard mitigation personnel, policymakers, and lake experts has recommended the latter contour as a "Beneficial Development Area" (BDA) whereby further development on land below this elevation should be restricted (Utah Division of Comprehensive Emergency Management, 1985). A series of topographic thresholds divides Great Salt Lake from the Great Salt Lake Desert at elevations between 4213 and 4217 feet (1284.1 and 1285.3 m). When surpassed by a rising lake, these thresholds accommodate a large increase in the surface area of the lake with a disproportionately smaller increase in lake volume. The resulting increase in evaporative losses tends to stabilize the lake level (U.S. Bureau of Land Management, 1986). Such an increase in surface area took place artificially when pumping of water from Great Salt Lake into the Great Salt Lake Desert began in April 1987, as part of the "West Desert Pumping Project." The resulting increase in surface area of the lake is intended to increase total evaporation from both bodies of water so that the level of Great Salt Lake will drop and further damage from flooding will be avoided. With the present design, the pumping system can be effective when the main body of Great Salt Lake is above an elevation of 4208 feet (1282.5 m) and, with modifications, it could operate efficiently down to an elevation of 4202 feet (1280.8 m) (James Palmer, Utah Division of Water Resources, oral communication, November, 1987). Above 4217 feet (1285.3) elevation, the lake flows naturally into the Great Salt Lake Desert. Despite implementation of the pumping project, flooding remains a hazard within and around the boundaries of Great Salt Lake.

Identification of flood hazard zones associated with Great Salt Lake is the subject of considerable research including studies in paleoclimate, geochemistry, and static shoreline levels. There is geologic evidence that Great Salt Lake has attained the proposed BDA elevation of 4217 feet (1285.3 m) in the last few hundred years and at least once more within the last 3000 years (Currey and others, 1984). The 4217-foot (1285.3 m) contour therefore represents a flood level whereby land below is at significantly more risk from periodic flooding than is land at higher elevations. Recent work has identified the highest level attained during the last 10,000 years (post-Gilbert stage of Lake Bonneville) to be 4221 to 4222 feet (1287 m) (D.R. Currey, oral communication, July, 1987). This can be considered an improbable, very long-term maximum flood level not likely to be reached during the useful life of structures existing or built today (Genevieve Atwood, oral communication, July, 1987). Active research into the Holocene history of Great Salt Lake continues at the University of Utah and UGMS, and details of the history as presented above are subject to revision as new data are collected.

Utah Lake has operated as a reservoir since the late 1800s when a dam was placed across the Jordan River at the outlet (Hyatt and others, 1969; Cordova, 1970). Lake-level regulation and flooding quickly became a legal issue between Salt Lake Valley irrigators and Utah Valley farmers owning land around the lakeshore. As a result of an 1885 lawsuit, a "compromise" lake level of 4489.34 feet (1368.35 m) was established as the highest elevation which could be maintained artificially by regulating flow into the Jordan River. Another lawsuit in 1983 revised the compromise level to 4489.045 feet (1368.261 m) (Bruce Hall, Utah County Engineer's Office, oral communication, October, 1986). Despite outflow control, Utah Lake has experienced shoreline flooding similar to that of Great Salt Lake. Spring runoff in 1983 and 1984 produced an historic high level of 4494.7 feet (1369.9 m) in 1984. The historic low of 4480.5 feet (1365.7 m) occurred in 1935, a fluctuation of approximately 14 feet (4.26 m) during historical time.

Recent efforts to control flooding of Utah Lake have included increasing the discharge capacity of the dam and dredging the Jordan River. Under current conditions, the lake is not expected to rise higher than about 4491 to 4492 feet (1369 m), and the anticipated result of a program of maintenance and dredging is to keep the lake level below 4493 feet (1369.5 m). The map depicts this latter, maximum projected elevation, and the lake as shown corresponds to the 1983 compromise lake level of approximately 4489 feet (1368 m).

Increased precipitation and runoff in the early 1980s also caused flooding of Bear Lake in extreme northern Utah. Although the relatively steep shoreline gradient and outlet control structures did not allow significant expansion of the lake's surface area, rising water levels permitted wave damage to structures along the shoreline. Current studies, including this one, focus on flooding associated with gradually rising lake levels but, as noted, flooding around many of the larger perennial lakes in Utah can occur rapidly by means of wind-induced waves generated during storms.

DRY LAKES AND OTHER INTERMITTENTLY FLOODED AREAS

With the exception of Rush Lake in Tooele County, there are no data on historical water-level fluctuations for dry lakes and other intermittently flooded areas shown on the map. This is chiefly because most of these features have retained water for only brief periods throughout most of historical time, and they are located in unpopulated areas of western Utah. Sevier Lake in west-central Utah is the largest of the dry lakes in the state. An even larger area of possible flooding includes the vast mud and salt flats in the Great Salt Lake Desert, although flooding generally occurs locally in scattered areas rather than simultaneously in the entire region. These areas are periodically flooded in response to heavy rainfall or rapid snowmelt, but little information is available on the frequency or magnitude of flooding events. Under the West Desert Pumping Project, a portion of the Great Salt Lake Desert north of I-80 is now flooded.

Dry lakes and areas subject to periodic flooding were mapped according to landforms (mud/salt flats, dry and intermittent lakes) defined on topographic maps. The U.S. Geological Survey 1:100,000-scale metric maps and Army Map Service 1:250,000-scale maps were the primary sources used to define dry lakes and mud flat regions. U.S. Geological survey 7.5-minute topographic quadrangle maps were used to further refine boundaries, particularly in the Great Salt Lake Desert. The northern and eastern boundaries of this area approximate the 4220-foot (1286 m) topographic contour.

Rush Lake occupies the northern portion of Rush Valley in Tooele County. Elevation measurements have been taken periodically since 1978 (Carlos Garcia, U.S. Soil Conservation Service, written communication, April, 1986). Characteristic of many terminal lakes in Utah, Rush Lake has been rising in recent years. For the 8-year period of 1978 to 1986, the lake has risen 12 feet (3.7 m), with 10 feet (3 m) added between 1983 and 1985. Written accounts and aerial photographs show that Rush Lake has fluctuated such that it was the size of a "small pond" during the early 1860s (Gilbert, 1890), and marsh-like to dry in the late 1950s to mid-1970s. The lake is thought to have reached its greatest height in 1876 or 1877, but depth or elevation measurements were not taken at that time. However, the lake was measured to be 4.25 miles (6.8 km) long by a surveying party in 1872 when it was near its highest level (Gilbert, 1890). This length corresponds to an approximate elevation of 4979 feet (1518 m), the lake elevation which appears as the potential flood area on the map. The lake has recently peaked at 4967 feet (1514 m), or about 12 feet (3.7 m) lower than the suspected elevation reached in 1872. Recent lake expansion has caused damage to power lines and great losses of surrounding croplands and some pasture land (Carlos Garcia, oral communication, August, 1986).

Geologic evidence shows that prehistoric Sevier Lake, called Lake Gunnison, was at times substantially higher than present Sevier Lake. Reconstruction of the lake's history through shoreline surveying and age-dating has recently been done by Oviatt (1987) and is summarized here. Between 12,000 and 10,000 yr B.P., Lake Gunnison flowed northward continuously into the Great Salt Lake basin through the "Old River Bed" topographic threshold, currently at 4590 feet (1399 m). Well-preserved shorelines around the lake were formed at this time and are presently at 4560 feet (1390 m) elevation. The difference between the outlet threshold level and the shoreline elevation around the lake is believed due to variations in the amount of isostatic rebound which occurred at both places. Age-dating of lake deposits shows the lake was below 4530 feet (1381 m) between 10,000 to 3000 yr B.P., and that it reached approximately 4535 feet (1382.3 m) between 2000 to 3000 yr B.P. A distinct beach ridge was identified at 4527 feet (1379.8 m) and tentatively dated as occurring between about 1400 and 1700 A.D.

Sevier Lake has remained largely dry throughout much of historical time. In 1872 the lake was 28 miles (45 km) long (Gilbert, 1890), and approximately 4529 feet in surface elevation (Oviatt, 1987). By 1880 the lake was almost dry (Gilbert, 1890). Sevier Lake has risen in recent times as a result of increased precipitation and surface inflow. Unlike Great Salt Lake and Utah Lake, this rising trend has had little impact on human activities as there is little land use along the shoreline. The potential flood boundary shown on the map is only slightly larger than that of the current lake (not shown). The lake outline depicted on the base map was drawn at a time when the lake was much smaller. As the lake rises, the greatest increase in area is to the northeast in the vicinity of the Sevier River delta. Measurements of the lake in recent years have consisted of some volumetric estimates and depth soundings (Rulon Christensen, U.S. Geological Survey Water Resources Division, oral communication, March, 1986), but direct surface elevations have not been measured. However, gravel beaches deposited in 1984 or 1985 were recently surveyed at an elevation of 4524 feet (1378.9 m) (Oviatt, 1987). In the event of a steady increase of water inflow, Sevier Lake would expand only slightly except along the Sevier River in the region of the delta.

Northeast of Sevier Lake and south of Delta lie a number of areas which were flooded in the 1980s. These were formerly marshes but were flooded by a rising water table as well as surface inflow. Above-average precipitation in 1983 and 1984 caused flooding of the Sevier River and adjacent areas, inundating Utah Highway 6/50 and much area to the north of the highway (Roger Walker, Sevier River Commission, oral communication, March, 1986). The 1983 DMAD dam failure also contributed to this flooding. Aerial photographs and field inspections have shown that many of the areas inundated in 1983 and 1984 remained flooded as of May 1986. Shallow ground-water levels are believed responsible for the persistence of these flooded areas.

There are numerous small dry lakes throughout the Great Basin that are subject to periodic flooding. Some of the larger of these for which some information is available include Salt Marsh Lake in northwestern Millard County, Little Salt Lake in Parowan Valley, and Rush and Quichapa Lakes in the Cedar Valley area of Iron County. Spring-fed Salt Marsh Lake in Snake Valley has been known to contain up to 2 feet (0.6 m) of water in winter months, drying out during the summer (Gilbert, 1890). Little Salt Lake in Parowan Valley is a ground-water discharge area which periodically collects surface runoff. It is threshold-controlled and could maintain a lake 10 feet (3 m) deep before spilling westward into Rush Lake through Parowan Gap (Nielson, 1983). Rush Lake collects water from flash-flood events and may retain it depending on ground-water levels in the area. In the mid-1970s, slight ground-water declines due to increased well pumping caused drying of the lake (Bjorkland and others, 1978). Quichapa Lake receives runoff from a variety of creeks and historically has been completely inundated. Water remained in the lake for over two years in the early to mid-1970s as a result of heavy runoff (Bjorklund and others, 1978). These lakes and the smaller dry lakes throughout the remainder of western Utah are periodically flooded from spring runoff and cloudburst storms.

DAM FAILURE INUNDATION

There are more than 1000 recorded water-retention structures currently in use in Utah, of which over 650 are capable of impounding at least 20 acre-feet of water (Utah Division of Water Rights, 1987). Included among the total are evaporation and mine tailings ponds, dikes, and debris basins, as well as dams impounding reservoirs along perennial streams. Most inundation studies, and therefore most of the areas shown on the map, concern the latter category.

The standard classification of a dam "failure" includes the occurrence of an unintentional release of water from the dam and does not require complete failure with release of all impounded water. Thirty-three dam failures prior to 1984 have been documented in Utah, of which only 8 experienced complete failure (Wes Dewsnup, Utah Division of Comprehensive Emergency Management, oral communication, August, 1986). In Utah, most dam failures to date have occurred during a flood and were the result of overtopping and/or erosion around spillways and outlets. Structural and foundation failures caused by seepage, piping, and landsliding have also occurred (Dewsnup, 1987). Most of these failures have been in relatively small dams in sparsely populated areas. Larger dams are more rigorously designed, constructed, and inspected and thus are less subject to such failures. However, many dams may be vulnerable to failure during earthquakes. The potential for damage is highest along the Wasatch Front where large earthquakes are expected and where large numbers of people and structures are found downstream from dams. Failure may occur due to ground shaking, liquefaction of foundation materials, landsliding, deformation, or overtopping of dams by waves generated in reservoirs. Inundation areas shown on the map assume a complete dam failure, as may occur during an earthquake, with reservoirs at full capacity.

Approximately 20 percent of all dams in Utah are classified as high-hazard dams, and dam failure inundation studies have been completed for about one-third of the approximately 200 such dams and for a small percentage of moderate-hazard dams. Most of these were undertaken by the U.S. Bureau of Reclamation, U.S. Forest Service, and Utah Division of Water Rights, with four completed by the U.S. Soil Conservation Service. The Utah Geological and Mineral Survey completed three inundation studies outside Salt Lake County (Case, 1983, 1984a, 1986), and one for Salt Lake County which considers potential failure of 11 dams (eight high-hazard, three moderate-hazard) and five natural lakes (Case, 1988). The following dams/reservoirs and lakes were included in the Salt Lake County study and are shown (although not labeled) on the map: Bingham Creek and a nearby small reservoir, Jordan Valley Water Purification Reservoir I, Lower Bells Canyon Reservoir, White Pine Lake, Secret Lake, Red Pine Lake (and an unnamed lake nearby), Lake Mary-Phoebe, Silver Lake, Dog Lake, Lake Catherine, Lake Martha, Twin Lakes, Mountain Dell Reservoir, and Red Butte Reservoir.

In some areas, potential failures of separate dams result in overlapping of inundation areas. This is the case along the Green River in Uintah County and the Weber and Ogden Rivers in Weber County. In these areas, flooding from the dam failure producing the largest inundated area is shown. Near Jensen on the Green River, the inundation area from Steinaker Dam is shown, but flooding may occur from failures of either Steinaker or Red Fleet (formerly "Tyzack") Dams located on upstream tributaries. At Ouray, the inundation area for Soldier Creek Dam is shown although flooding may result from failures of Red Fleet, Steinaker, Starvation, Bottle Hollow, Upper Stillwater, Midview, or Soldier Creek Dams. In Weber County, overlap occurs in downstream areas of the Weber and Ogden Rivers near Great Salt Lake from failures of Echo, Lost Creek, Pineview, and Arthur V. Watkins Dams. In this area, inundation from the latter two dams is shown. Where inundation areas overlap, the map does not represent inundation resulting from successive or simultaneous dam failures except in three areas. Failure of Soldier Creek Dam on the Strawberry River is predicted to cause overtopping and failure of the downstream Starvation Dam, and the inundation area for Soldier Creek Dam below Starvation Dam incorporates these floodwaters (U.S. Bureau of Reclamation, 1982a). Likewise, inundation areas shown along the Weber River downstream of Echo Dam consider a successive failure of Echo Dam caused by failure of Wanship Dam. Inundation areas shown for Salt Lake County consider simultaneous failures of 11 dams and 5 lakes. In this worst-case scenario, stream channels, including the Jordan River, are assumed to be at bankfull stage at the time of failure (W.F. Case, oral communication, October, 1986). Inundation areas, especially near Great Salt Lake therefore represent the probable maximum extent of flooding.

Both the Utah Geological and Mineral Survey (Case, 1985b) and the U.S. Bureau of Reclamation (1985a) produced similar inundation maps for Deer Creek Dam in Wasatch County. The latter version is illustrated on this map. An inundation map showing worst-case flooding in downstream areas of the Spanish Fork River in Utah County was prepared for potential failure of the "dam" created by the Thistle landslide of 1983 (Anderson and others, 1984). This inundation area is not shown on the map, however, because Thistle Lake has been permanently drained and the landslide no longer impounds water. The inundation area shown for Smith-Morehouse Dam in Summit County is an underestimation of potential downstream flooding because the original dam for which the study was done has recently been replaced with a larger one. Dam failure inundation mapping below some dams did not cover areas where population density is low, leaving gaps along some streams such as the Green River between Jensen and Ouray.

Only 11 inundation studies have been done for detention ponds and debris basins which are typically drained after flooding or debris-flow events, and thus present a potential hazard to downstream areas for only short time periods. Inundation studies for diking structures are likewise few in number, with only one study completed (Arthur V. Watkins Dam, Willard Bay; U.S. Bureau of Reclamation, 1984a). For the Arthur V. Watkins Dam, most of the inundation area lies within the present Great Salt Lake and potential lake-flood area already shown on the map. As instructed by the Utah State Legislature, studies have recently been completed on the feasibility of constructing a network of dikes within Great Salt Lake (the "Inter-Island Diking Project") as a means to control shoreline flooding (Rollins, Brown and Gunnell, Inc., and Creamer and Noble Engineering, 1987). Because no structures have yet been authorized or built, no inundation studies are shown.

RECOMMENDATIONS

The map is intended to be used by planners and community officials as a guide for identifying areas which are susceptible to flood hazards. The map can also be used by regulatory agencies and local governments as justification for requiring further studies in hazard areas. However, due to the scale of the map, flood boundaries shown should be taken only to indicate general areas of possible flooding. The level of confidence with which a flood hazard exists within the mapped boundaries varies considerably. Therefore, the map should not be used to formulate site-specific decisions and is not sufficient for developing local government ordinances and regulations. Regarding potential flooding of Great Salt Lake, adoption of the Beneficial Development Area, encompassing the zone from the shoreline of Great Salt Lake up to an elevation of 4217 feet (1285.3 m), would involve recognition that the land is at risk from periodic flooding of Great Salt Lake and that continued planning and land management techniques are needed, in addition to the West Desert Pumping Project, to minimize impacts of future lake rises in this zone.

Although few inundation studies have been completed for dams in Utah, the map serves to alert planners, local officials, emergency response personnel, and private citizens to the availability of information regarding potentially flooded areas should these dams fail. Where a city or other entity is shown on this map to be in a potential inundation area, planners can acquire the detailed inundation studies from the sources indicated on the map and listed in the references for this report to determine the extent of potential flooding. In many cases, these detailed studies are sufficiently accurate to be used by local emergency response personnel to determine the areas of their jurisdictions that will require warning, evacuation, and/or rescue should dam failure occur, and to identify the safest and most readily accessed areas for refuge.

CONCLUSIONS

The lake-flooding hazard is more widespread in northwestern Utah than in any other area of the state. Great Salt Lake lies in the topographically lowest part of the Great Basin of western Utah and is prone to large changes in shoreline location with relatively small changes in lake level. The greatest potential for damage by lake flooding is along the Wasatch Front area, where much of Utah's population is in close proximity to Great Salt Lake and Utah Lake. In other areas of Utah, lake-flood hazard is more localized, confined generally to dry lakes and mud/salt flats in the topographically lowest parts of valleys.

Dam failure inundation areas are considered to be accurate depictions of the probable extent of flooding if a dam at full capacity failed. It should be noted, however, that variations in the methods of calculating inundation areas (for example, assuming water release by instantaneous dam failure versus flood-water overtopping with more gradual failure) produce variations in mapped inundation areas. These differences are small, however, and insignificant at the scale of the map. It is important to note that inundation studies have been done for only a small percentage of dams in Utah. Thus, many more areas in the state are subject to potential inundation than are shown.

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UTAH GEOLOGICAL AND MINERAL SURVEY

606 Black Hawk Way
Salt Lake City, Utah 84108-1280

THE UTAH GEOLOGICAL AND MINERAL SURVEY is one of eight divisions in the Utah Department of Natural Resources. The UGMS inventories the geologic resources of Utah (including metallic, nonmetallic, energy, and ground-water sources); identifies the state's geologic and topographic hazards (including seismic, landslide, mudflow, lake level fluctuations, rockfalls, adverse soil conditions, high ground water); maps geology and studies the rock formations and their structural habitat; and provides information to decisionmakers at local, state, and federal levels.

THE UGMS is organized into five programs. Administration provides support to the programs. The Economic Geology Program undertakes studies to map mining districts, to monitor the brines of the Great Salt Lake, to identify coal, geothermal, uranium, petroleum and industrial minerals resources, and to develop computerized resource data bases. The Applied Geology Program responds to requests from local and state governmental entities for site investigations of critical facilities, documents, responds to and seeks to understand geologic hazards, and compiles geologic hazards information. The Geologic Mapping Program maps the bedrock and surficial geology of the state at a regional scale by county and at a more detailed scale by quadrangle.

THE INFORMATION PROGRAM distributes publications, answers inquiries from the public, and manages the UGMS Library. The UGMS Library is open to the public and contains many reference works on Utah geology and many unpublished documents about Utah geology by UGMS staff and others. The UGMS has begun several computer data bases with information on mineral and energy resources, geologic hazards, and bibliographic references. Most files are not available by direct access but can be obtained through the library.

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STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES
UTAH GEOLOGICAL AND MINERAL SURVEY

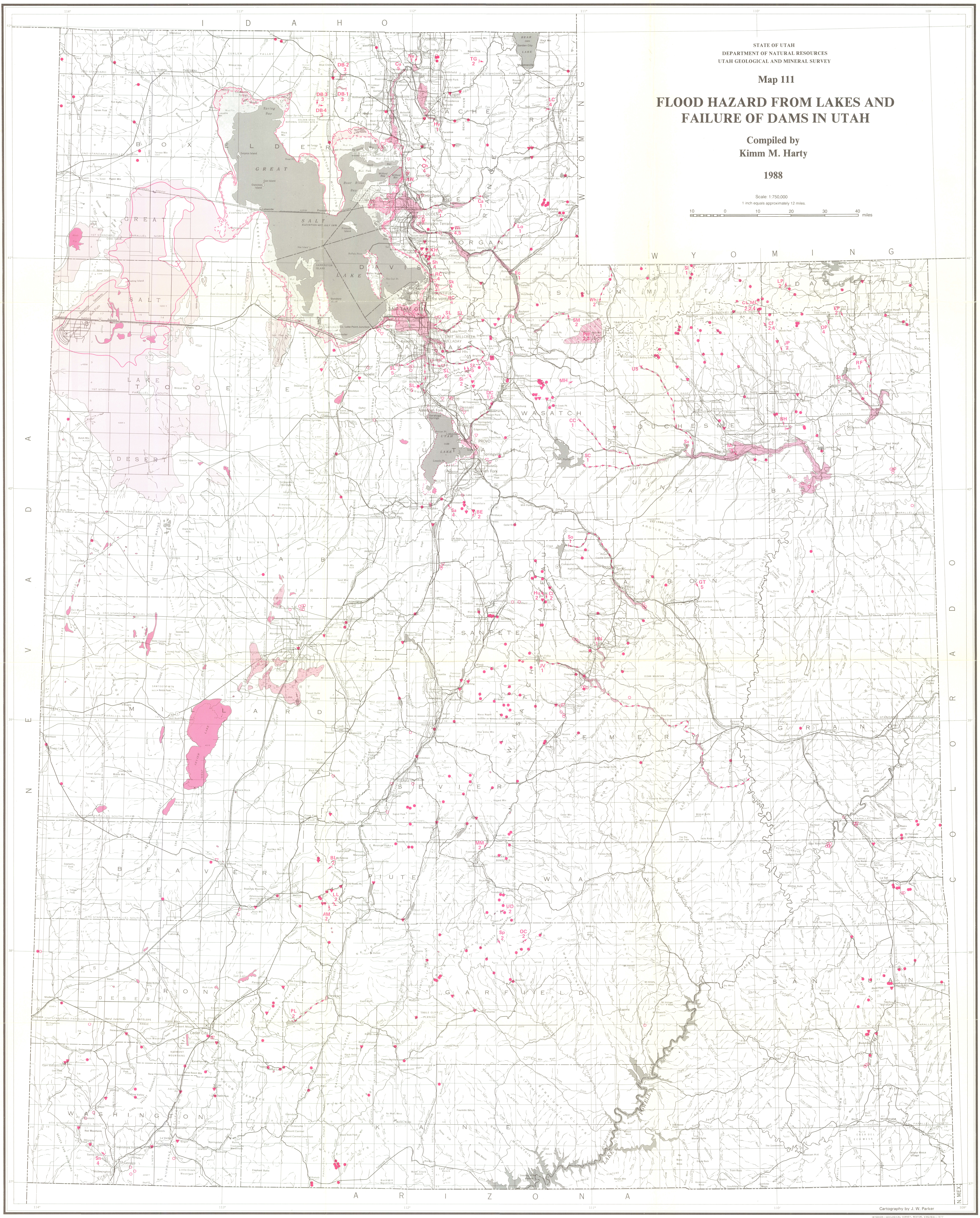
Map 111

FLOOD HAZARD FROM LAKES AND FAILURE OF DAMS IN UTAH

Compiled by
Kimm M. Harty

1988

Scale: 1:750,000
1 inch equals approximately 12 miles.



Cartography by J. W. Parker

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1977

POTENTIAL FLOODING FROM RISING LAKE LEVELS

Approximate historic high level of Great Salt Lake reached in 1986 (4212 feet); indicates maximum extent of lake flooding in historical time.

Late prehistoric high level of Great Salt Lake, last reached around 1700 A.D. (4217 feet); indicates maximum extent of lake flooding in past several hundred years and probable zone of greatest modern flood hazard.

Maximum projected flood level for Utah Lake with post 1984 improvements (4493 feet); historic high flood level (4494.7 feet) was reached in 1984 (not mapped).

OTHER AREAS OF POTENTIAL LAKE FLOODING

Dry lakes; includes approximate historic high levels of lakes such as Sevier Lake and Rush Lake which contained water in 1986 but have been dry in historical time.

Mud/salt flats, chiefly surrounding Great Salt Lake and in the Great Salt Lake Desert.

Flooded marshes, includes only areas of known historical flooding in Sevier Desert area.

DAM FAILURE INUNDATION

Inundation Areas Mapped

Ca
1

Name of dam (see list of dams)
Agency completing dam failure inundation study (see list of agencies)
Direction of flow and areas of inundation too narrow to depict
Potential dam failure inundation area

Note: For locations subject to flooding from more than one dam, the inundation area from the largest contributing dam/reservoir is shown. indicates dikes of Arthur V. Watkins Dam around Willard Bay, SL indicates inundation from simultaneous lake and dam failures in Salt Lake county.

The full extent of flooding downstream is not shown; studies only map flooding to a reservoir, lake, confluence of a larger river, or a political boundary and commonly leave gaps where rivers cross unpopulated areas.

Inundation Areas Not Mapped

GT
1

Dam symbol, direction of flow (arrow), name of dam (GT), and agency (1) completing dam failure inundation study. The studies have been done, but either the entire inundation area is too narrow to illustrate or only maximum flood elevations have been calculated.

PW
2,4

Area of numerous dams in the headwaters of the Provo and Weber Rivers for which inundation studies have been completed, includes three high-hazard, five moderate-hazard, and five low-hazard dams for which no inundation studies were performed.

Agencies Completing Dam Failure Inundation Studies

1. U.S. Bureau of Reclamation
2. U.S. Forest Service
3. U.S. Soil Conservation Service
4. Utah Division of Water Rights
5. Utah Geological and Mineral Survey

Dams

AM	Anderson Meadow
AW	Arthur V. Watkins (dike around Willard Bay)
BC	Barton Creek*
BE	Big East
BL	Blue Lake
BH	Bottle Hollow
Ca	Causey
Ch	Chatfield
CL	Chepeta Lake
Cl	Cleveland
Cf	Cliff Lake
CC	Current Creek
Cu	Cutler
DB-1	Debris Basin 23-A*
DB-2	Debris Basin 21-B*
DB-3	Debris Basin 28*
DB-4	Debris Basin GS-1*
DC	Deer Creek
EP	East Park
Ec	Echo
GT	Grassy Trail
Hu	Huntington
HN	Huntington North
Hy	Hyrum
JV	Joes Valley
JP	Julius Park
Ka	Kaysville
KH	Kaysville-Holmes Creek*
LL	LaBaron Lake
LC	Little Creek
LP	Long Park
Lo	Lost Creek
Mi	Midview
MH	Mill Hollow
MM	Mill Meadow
ML	Moccasin Lake
Ne	Newton
OC	Oak Creek
OP	Oaks Park
PL	Panguitch Lake
Pi	Pineview
PW	Dams in headwaters of Provo and Weber Rivers
RF	Red Fleet
RC	Rudd Creek*
SL	Salt Lake County dams and natural lakes
Sn	Santa Clara*
Sa	Santaquin*
So	Scofield
Sh	Shepard Creek*
Si	Silver Lake
SM	Smith-Morehouse
SC	Soldier Creek
Sp	Spectacle Lake
Sv	Starvation
Sl	Stateline
St	Steinaker
Sk	Stone Creek*
TG	Tony Grove
UD	Upper Donkey
US	Upper Stillwater
Wa	Wanship
Wh	Whitney
Wi	Wilkinson

*Debris basin or detention/retention pond

Inundation Study Not Performed*

High-hazard dam or diversion structure impounding a reservoir.

High-hazard dam forming a debris basin, dike, detention/retention pond, regulation pond, or tailings pond.

Low- or moderate-hazard dam or diversion structure impounding a reservoir.

Low- or moderate-hazard dam forming a debris basin, dike, detention/retention pond, regulation pond, or tailings pond.

Low- or moderate-hazard dike longer than one mile in length.

*Symbols may represent more than one dam where dams are closely spaced.