DAM FAILURE INUNDATION STUDY FOR
DEER CREEK DAM, UTAH COUNTY

by
William F. Case
Applied Geology Group

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Work performed as part of the Earthquake Hazard Reduction Program of the Utah Geological and Mineral Survey
A principal objective of the Utah Geological and Mineral Survey is the identification of areas of Utah that are exposed to geologic hazards. Geologic events such as earthquakes, landslides, and debris flows can cause dams to fail and produce flooding downstream. Inundation mapping is thus an essential ingredient in any comprehensive hazard mapping effort. Deer Creek Dam was chosen for this inundation study, the first by the Utah Geological and Mineral Survey (UGMS), because of special interest expressed by the State Division of Comprehensive Emergency Management and the Utah County Office of Emergency Preparedness. The reservoir is one of the more significant water impoundments along the Wasatch Front and would impact a considerable population if it were to fail. Because topographic maps of Provo River Canyon, downstream from the dam, are exceptional in scale and contour interval, a more accurate inundation map can be produced here than would be possible in most areas.

This report is intended to present the results of the inundation study and to document the procedures adopted by the UGMS in the preparation of inundation area maps. A byproduct of this study is the travel time of the released reservoir water as it moves downstream. With this information, emergency preparedness personnel may estimate time available for escape along evacuation routes. Shelter zones can be established when the potential inundation zone is determined. Potential inundation is but one hazard that must be considered in the siting of critical facilities. It is one hazard, however, that is commonly ignored by both public and private sectors.

I join Mr. Case in extending our gratitude to the U. S. Bureau of Reclamation for their kind assistance with this study.

Bruce N. Kaliser
State Hazard Geologist
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ACKNOWLEDGMENTS

I would like to thank the Utah County Flood Control office and the Utah State Department of Transportation for the use of their large-scale maps of the study area. The Utah State Department of Comprehensive Emergency Management has provided necessary support and assistance. The Bureau of Reclamation, specifically Brent D. Taylor, has provided technical assistance which has made this report possible. Any errors, conceptual or arithmetic, are the author's.

INTRODUCTION

Deer Creek Dam is an earthfill dam on the Provo River in the Wasatch Range east of Utah Valley. The Provo River originates in the western part of Unita Mountains and flows in a northwesterly direction to Utah Lake. The natural flow of the Provo River is augmented by water diverted from the North Fork of the Duchesne River and the Weber River. The Deer Creek Dam is part of the Provo River Project, which delivers Provo River water to metropolitan areas of Utah and Salt Lake Counties. Deer Creek Reservoir, formed by the dam, has a capacity of 152,000 acre-feet. Downstream from the dam the Provo River flows through Orem and Provo. The dam provides flood protection for these communities, but if the dam should fail and release water from Deer Creek Reservoir into the Provo River, parts of these communities would be inundated. The purpose of the study reported here was to determine the area that would be inundated by an instantaneous failure of Deer Creek Dam with the reservoir filled to capacity—the worst-case scenario. The study area extends from Deer Creek Dam to Utah Lake, 20.3 river miles (mileage along streambed, from dam) downstream along the Provo River (fig. 1). U.S. Highway 189 which connects Provo, Utah with Evanston, Wyoming (via
Interstate 80) runs parallel to the Provo River in the study area. Utah Highway 92, the "Alpine Loop" from American Fork which terminates at Wildwood and Highway 189 approximtely 4 miles below Deer Creek Dam, is the only other transportation route out of the Provo River Canyon. The tributaries that flow into the Provo River in the study area are as follows: A) Provo Deer Creek (river mile 0.74) has an approximate maximum discharge on the order of 100 sec.-ft. (Butler, 1966); B) North Fork, which enters the Provo River at Wildwood (river mile 3.95) has an approximate maximum discharge of about 225 sec.-ft. (Butler, 1966); and C) South Fork which enters the Provo River at Vivian Park (river mile 5.32) has an approximate maximum discharge of 125 sec.-ft. (Butler, 1966).

The headlands of the Provo River are in the Uinta Mountains approximately 40 miles east of Deer Creek Dam. Water is transferred from the North Fork of the Duchesne River to the Provo River through the Duchesne Tunnel (I on fig. 1) and from the Weber River along the Weber-Provo canal (fig. 1). The Duchesne Tunnel has a capacity of 600 sec.-ft. and the Weber-Provo canal can route 1000 sec.-ft. The drainage area of the Provo River above the mouth of Provo Canyon (river mile 11) to Deer Creek Dam (river mile 0.00) is 666 sq. mi. (Corps of Engineers, 1971). The Corps of Engineers (1971) has defined the peak discharge of the Intermediate Regional Flood (100-yr flood) to be 3000 sec.-ft. and the peak discharge of the Standard Project Flood ("The most severe combination of meteorological conditions reasonably characteristic of the geographical region, excluding extremely rare combinations") to be 5200 sec.-ft. at the mouth of Provo Canyon. Peak discharges of the Provo River (Corps of Engineers, 1971) are approximately 2200 sec.-ft. at Deer Creek Dam, 3200 sec.-ft. at Vivian Park (river mile 5.32) and 2500 sec.-ft. at Provo, 1300 feet downstream from the bridge at Highway 114 (river mile 17.67).
Most of the population that would be affected by a flood on the Provo River live in Utah County, downstream from the county line at Wildwood (river mile 3.95). Canyon Meadows Sales Offices (river mile 1), Deer Creek Park Campground (river mile 0.75), and residential buildings along Provo Deer Creek are the only populated zones in Wasatch County, upstream from Wildwood, that would be affected by a flood due to Deer Creek Dam failure. A flood along the Provo River below Deer Creek Dam would affect people in the cities of Orem and Provo which have a 1980 census population of 52,399 and 73,907 respectively, and represent 58 percent of the population of Utah County. A flood of the magnitude suggested by this report is expected to indirectly affect at least 100,000 people due to disruption of lifelines. The residential areas downstream from the Utah County line to the canyon mouth include Wildwood (river mile 3.95), Vivian Park (river 5.32), Canyon Glen (river mile 8.2) and Springdell (river mile 8.6). Commercial facilities include River Bend Trailer Park and a general store (river mile 5.05), Bridal Veil Falls tram, etc. (river mile 7.15) and a cafe near Wicks (river mile 9.3). Industrial facilities in the Provo River Canyon include a gravel pit (river mile 10.5) and Utah Power and Light hydropower plant at Olmstead in the mouth of the canyon (river mile 10.8). A hydropower plant at the base of Deer Creek Dam can release 1500 sec.-ft. into the Provo River, enough to cause slight flooding damage in Provo River Canyon. The water transmission facilities (fig. 1) within Provo River Canyon are the Salt Lake City (Deer Creek) Aqueduct (A on fig. 1) which has a capacity of 150 sec.-ft. and routes water from Deer Creek Dam to Salt Lake City, the Provo Reservoir Canal/Murdock Canal (B on fig. 1) which routes water from Murdock/Olmstead diversion dam to the west side of Jordan River Valley, and the Union Canal (not shown on fig. 1) which provides Provo River water to the Olmstead hydropower plant. The
Murdock/Olmstead dam is a gravity dam which diverts approximately 550 sec.-ft. into the Jordan River Valley. Below the canyon mouth 6 canals distribute water along the Wasatch Front (fig. 1), water is routed to the north by the North Union (C on fig. 1), West Union (D on fig. 1), and Lake Bottom (E on fig. 1) canals, and to the south water is routed by the Lower Union (F on fig. 1), Upper Union (G on fig. 1), and Timpanogos (H on fig. 1) canals. The Provo River, after leaving the canyon, passes through the communities of Orem, Caryhurst, Edgemont, Pleasant View, and Provo on its way to Utah Lake State Park. The elevation range of the study area is from 5425 feet at Deer Creek Dam crest to about 4490 feet at Utah Lake.

The geology of Provo River Canyon in the study area is examined to estimate the resistance to hydraulic erosion of the streambed and valley walls. Erosion as defined for the purpose of this report consists of removal of sediment and bedrock by 1) abrasion by transported materials within flood waters such as sand, trees, boulders, etc.; 2) hydraulic plucking or dislodging of sediment and bedrock by flood water pressure; and 3) solution of geologic units by water. Three age groups are represented in the canyon: A) Quaternary-age sediments, which are less than 1.8 million years old; B) Pennsylvanian-age sedimentary rocks (320 to 280 million years old); and C) Mississippian-age sedimentary rocks that were deposited before the Pennsylvanian rocks but after 345 million years ago. The geologic formations in the study area are Great Blue Limestone (Mississippian age), Manning Canyon Shale (late Mississippian or early Pennsylvanian age) and Oquirrh Formation of Pennsylvanian age which is basically sandstone with Bridal Veil Limestone Member.

The Quaternary sediments are unconsolidated or semiconsolidated and are classified by the agent that deposited them (fig. 2): Qal is alluvium/valley
fill (stream deposit), Qow is glacial outwash (glacial sediments deposited by meltwater), and Qls is a landslide deposit. The first letter or symbol is an abbreviation for the age of the unit, i.e., Q = Quaternary, M = Mississippian, P = Pennsylvanian, PM = Late Mississippian/Early Pennsylvanian.

The erosion resistance of geologic units is a function of: 1) age, younger sediments or rocks are normally less lithified and thus more easily eroded; 2) rock type, in a semi-arid climate (the average annual precipitation at Deer Creek Dam is 23 inches, and at Provo and Utah Lake is 16 inches) limestone is very resistant, and will erode into massive blocks the size of which may be controlled by "joints" (fractures in rock caused by similar tectonic forces that produce faults but which do not result in the slippage characteristic of faults), sandstone has moderate resistance, and shale is relatively soft; and 3) density of faulting, an area of intense faulting will have more crushed rock which is easier to erode. The geologic units shown on figure 2 are in the immediate vicinity of the streambed. It is not known how thick the streambed (Quaternary) deposits are in the channel but for a dam failure flood discharge, such as described in this report, the channel in Provo River Canyon is likely to be scoured to bedrock throughout its length. Shroba (1979) reports that the Big Thompson Canyon flood of July 31, 1976 scoured the creeks to bedrock for the length of the canyon, with a flood discharge only 4 percent (31,200 sec.-ft.) of the discharge postulated in this report (845,619 sec.-ft.). Silt, sand, and gravel will be available for flood transport in varying proportions from all the Quaternary deposits along Provo River Canyon. Larger blocks will come from bedrock, with limestone yielding the largest blocks.

HYDRODYNAMIC ANALYSIS

Potential causes of dam failure include overtopping of flood waters over
the dam crest, damage to the structure or foundation due to earthquake shaking, or foundation failure due to piping. Earth dams, such as Deer Creek Dam, may develop a breach that enlarges gradually due to overtopping or piping. The time required for the enlargement of the breach to its maximum size (resulting in the peak flood discharge) may be a few minutes or several hours depending on a multitude of factors including reservoir storage and depth of water behind the dam at the time of failure. Peak depth of flood waters and time to peak discharge just below the dam depend on the breach size, shape, and development time among other factors.

In order to produce an inundation overlay and data layer for a seismic hazard zonation model a worst-case scenario is assumed. The maximum inundated area along the Provo River due to a failure of Deer Creek Dam is utilized. The dam breach is equal to the size of the dam. The reservoir is assumed to be full. Inflow to the reservoir will not be considered because it is minor (less than 1 percent) compared to the magnitude of the dam failure flood discharge. Butler (1966) gives the maximum discharge for the Provo River directly upstream from the reservoir to be approximately 1700 sec.-ft., 0.2 percent of the calculated flood-wave discharge at the dam (845,619 sec.-ft.) due to a hypothetical dam failure. Tributary inflow downstream from the dam was not considered because it, also, is minor (less than 0.1 percent) compared to the calculated dam failure flood discharge.

Emergency plans for evacuation and shelter require not only the geographical extent of flooding but also the minimum amount of time available for evacuation. Because the maximum flood and minimum travel time is desired for this analysis the entire Deer Creek Dam is assumed to fail instantaneously. This postulated event is believed to be extremely improbable. The following analysis will attempt to show the maximum inundation area along the Provo River from Deer Creek Dam to Utah Lake and the
expected flood-wave arrival time at various localities assuming the worst conceivable scenario.

The procedures used for estimating peak discharge at the dam and the attenuation of the flood-wave discharge as it moves downstream are based on Bureau of Reclamation 'Guidelines for Defining Inundated Areas Downstream from Bureau of Reclamation Dams' (1982). The Bureau of Reclamation equation for estimating peak discharge at the dam, in sec.-ft., is: \( Q = 75(D)^{1.85} \), where \( Q \) is the peak discharge and \( D \) is the depth of the water in feet behind the dam at the time of failure which, in this study, is equal to the design hydraulic height of Deer Creek Dam, 155 feet. The calculated peak discharge, \( Q \), using this equation is 845,619 sec.-ft. The equation for estimating downstream discharge attenuation, \( Q_x \), is: \( Q_x = 10^{(\log Q - 0.01x)} \), where \( Q_x \) is the calculated peak discharge in sec.-ft., \( x \) miles below the dam. The equations for \( Q \) and \( Q_x \) are empirical and were derived from data compiled by the Bureau of Reclamation (1982).

Cross-sections were drawn at intervals along the valley to characterize the hydraulic properties of the valley, for example at constrictions or change in slope, in order to accurately determine the inundated areas along the river and to determine the extent of potential flood water encroachment on geologic hazards such as landslides. The shape of each cross-section was approximated by trapezoidal sub-sections to simplify determination of cross-sectional area and wetted-perimeter (cumulative length of channel sides and bottom in contact with floodwater). Many analyses assume the wetted perimeter is basically the same as the width of the channel, however, because of the large-scale maps that were available the channel sides were considered as part of the wetted perimeter. Each trapezoidal sub-section was defined by a top- and bottom-width and their respective elevations. The bottom-width of the initial trapezoidal sub-section for each cross-section is the width of the streambed.
The discharge for each trapezoidal cross-section was calculated using Mannings equation for open-channel flow. The depth in the cross-section approximation is increased until the calculated discharge is contained.

Mannings equation calculates cross-sectional discharge (Qs) as a function of: A) n, a parameter characterizing net channel roughness, which is assumed to be 0.035 in this study, the average value for natural channels according to Linsley (1975); B) s, the topographical gradient of the streambed from the closest upstream cross-section in vertical feet/horizontal feet; C) A, the area of the cross-section in square feet; and D) R, the hydraulic radius of the cross-section, in feet (the cross-sectional area A, divided by the wetted-perimeter of the cross-section). The discharge through the cross-section, Qs, is calculated from Mannings equation where Qs = \((1.49/n) (s)^{1/2}(R)^{2/3}(A)\), in sec.-ft. Code for a hand-held calculator used to compute the peak flood-level elevation at each cross-section. Results compared favorably with the National Weather Service (NWS) Simplified Dambreak Program (SMPDBK). This elevation defines the maximum inundation at the cross-section.

The peak flood elevations and inundated areas between cross-sections is subject to interpretation and must be interpolated using hydraulic logic from values calculated at cross-sections. In a straight channel the water surface is relatively level, i.e., the water surface is at the same elevation on both banks. A curved pathway such as in a natural meander introduces a centrifugal force on the flowing water mass resulting in higher water on the outside of the bend and lower water on the inside of the bend than would occur with a straight channel. Flood waters tend to back upstream as a result of valley constrictions. Increased channel-bottom resistance also increases depth of flood waters due to the fact that vegetation or buildings reduce the velocity of flood waters.
The average velocity of flow at the cross-section, in feet/second, is equal to the discharge, Qs, divided by the area, A. Travel times of the flood crest are estimated because of the number of variables that can influence velocity.

The topographic base maps used are from the Utah State Department of Transportation (UDOT) and Utah County Flood Control Office. The UDOT maps are at a scale 1 inch = 100 feet with a contour interval of 2 feet and cover the Provo River Canyon from Deer Creek Dam to the canyon mouth, about 11 river miles. The Utah County maps have a contour interval of 5 feet, a scale 1 inch = 500 feet, and cover the drainage area from the canyon mouth to Utah Lake, about 9 river miles. It should be noted that the topographic maps used were drafted before the recent (1983-84) increase in precipitation in the Provo River area, therefore the topography of the river valley may have changed slightly.

Sixteen cross-sections, from #1 at the base of Deer Creek Dam spillway to #16 at Utah Lake State Park, were drawn across the Provo River at specific locations (plate 1). Flood-wave crest elevations have been calculated and plotted on plate 1 for all cross-sections except 1 and 16. Cross-section 1 (river mile 0.00) is at the base of the dam 0.16 miles upstream from 2. Cross-section 16 (river mile 20.14) extends from the Utah Lake shoreline on one end to the shoreline on the other end of the section across the Provo River delta. By the time the flood-wave arrives at cross-section 16 it will have exceeded the width of the section therefore the height cannot be calculated. Cross-sections 2, 4, 5, 7, 12, 13, 14, 15 were located to characterize Provo River Canyon hydraulic parameters. Populated areas in the canyon and on the flood plain are covered by cross-sections 2, 3, 6, 8, 10, 11, 13, 14, and 15 (note: some cross-sections are multi-purpose). Cross-
sections 9, 10, 11 are at locations of landslides and glacial outwash. Cross-section widths range from 419 feet (7) to 6464 feet (15) and the depth of the flood-wave ranges from 25 feet at section 15 (the widest cross-section) to 83 feet at cross-section 9 which has the most gentle channel-bed slope along the study reach, 10 ft/mile. Just downstream, at cross-sections 10 and 11, the slopes are 83 ft/mile and 90 ft/mile, the steepest slopes. Cross-section 10 will have the highest average velocity of flood waters, 36 mph (53 ft/s). All cross-section plots showing the flood-wave crest elevation, geology, and diagrammatic topography are in appendix A. Table A-1 in appendix A is a compilation of relevant data used for calculations for each cross-section. All top-widths used in the hydraulic calculations were picked at a topographic threshold if evident (where a channel suddenly widens as the water level rises), or to characterize the slope of valley walls. The smallest top-width and lowest elevation of the cross-section represent the present channel width and streambed elevation as estimated within the contour interval of the base maps.

DISCUSSION

Plate 1 shows the extent of the inundation of Deer Creek Reservoir waters from Deer Creek Dam to Utah Lake. Table 1 lists known obstructions in the study area, their height above the streambed, and the height of the expected flood-wave above the obstruction. Examples of obstructions include: bridges (foot, vehicle, or railroad), weirs, diversion dams, viaducts, and abutments of dismantled structures. The only feature that would not be overtopped by the calculated flood-wave is the bridge at West Center Street (river mile 20.05), however, if the flow velocity is greater than 3 mph (hydraulic calculations indicate that flow velocities would be approximately 10 mph) the
<table>
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<tr>
<th>Obstruction</th>
<th>Top River Elev. (ft.)</th>
<th>Approx. Flood Wave Crest Elev. (ft.)</th>
<th>Approx. Flood Height Above Feature (ft.)</th>
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<td>78</td>
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Table 1. List of Provo River Flood Obstructions - Continued.

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<td>Weir</td>
<td>15.73</td>
<td>4581</td>
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<td>9th No, Provo bridge</td>
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<td>4581</td>
<td>4595</td>
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<td>8th No, Provo bridge</td>
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<td>28</td>
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<td>U.P. railroad bridge</td>
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<td></td>
<td>17.04</td>
<td>4543</td>
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<td>20.17</td>
<td>4490</td>
<td>4495</td>
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bridge piers could be washed out due to erosion of surrounding fill (Corps of Engineers, 1972). Another type of obstruction that occurs in the study area is the embankment of Interstate 15. Although it is estimated that the flood waters may overtop the embankment (table 1) some water would back up on the upslope side of the embankment and would flow to the northwest and southeast (plate 1). Once this water reaches an overpass it would flow through the overpass at a high velocity, particularly if the surface is paved. The "breaks" in the I-15 embankment through which flood waters would flow include the overpass over the railroad tracks about 9th North in Provo, the Center Street overpass, and the intersection of University Avenue and Interstate 15. The ponding upslope of the I-15 embankment would likely extend well into Provo. Below the city and the embankment the flood waters would fan out and deposit debris across the Utah Lake plain.

As a result of flood waters from a Deer Creek Dam failure, the water level in Utah Lake may temporarily rise above an elevation of 4490 foot. The projected maximum water surface elevation increase in Utah Lake would be about 8 inches. If the Jordan River gates were open it is likely that areas along the Jordan River would be flooded although the consequent rise in the Great Salt Lake would be minimal.

Water flowing out of the canyon mouth below the constriction at cross-section 12 would spread out between two bluffs and, as the flooded channel effectively widens below the mouth of Provo River Canyon, flow velocities would steadily decrease. The average velocity of flood waters through cross-section 12 (narrow canyon mouth) would be about 30 mph. As the flooded channel widens the velocities would decrease progressively to 10 mph at section 15 in Provo City. Once the flood waters leave cross-section 15 (river mile 15.63) they would spread out because they are no longer contained
by the river bluffs. Locally the velocity would be higher, for example, over
paved streets, through local constrictions, etc. The velocities in the bluff
area would be of the same magnitude as those in the steepest reaches of the
Big Thompson Canyon flood in Colorado in 1976 (Shroba, 1979). With such high
velocities one would expect similar damage, that is, vehicles smashed beyond
recognition, wood frame houses torn off foundations, masonry buildings
destroyed by debris acting as battering rams, deposition of very
large-diameter debris (natural and man made) in bars nearly 20 feet thick.
All transportation routes within the bluff area (cross-sections 12 to 15) and
within the Provo River Canyon (cross-sections 1 to 11) would be severed. The
bluffs themselves would be undercut and slopes would fail severing the canals
on top. The canals near the mouth of Provo River Canyon would probably be
breached early in the flood and therefore would not likely route flood water
beyond the postulated area of inundation. The Olmstead hydropower plant would
be taken out of service by the flood waters. It would take about one-half
hour, after dam failure for the flood-wave (a 38-foot-high wall of water
loaded with diverse debris) to reach the mouth of the canyon.

Upstream, within the Provo River Canyon, the flood waters would scour the
canyon to bedrock or below depending on local conditions. Sediment that has
been picked up is usually deposited just downstream in the next area of slack
water, except for floating material that wasn't tangled up. The flood waters
would undercut most of the highway fill and railroad fill, and near
cross-section 9, would sever the Salt Lake City Aqueduct and the Union
Aqueduct. All Provo River Canyon communities and facilities would be
flooded. The flood waters would back up approximately 1200 feet into North
Fork (at Wildwood) and probably would back 1000 feet up the South Fork into
Vivian Park. New landslides would be initiated due to bank undercutting and
channel scour by the flood and old landslides would be rejuvenated.
It would take approximately 10 minutes (after dam failure) for the flood-wave to reach Wildwood, the first vehicle escape route out of the canyon. In about 15 more minutes the flood-wave would be at the canyon mouth and approximately 90 minutes after the dam failure flood waters would reach Utah Lake. The average velocity of the flood waters from Deer Creek Dam to Utah Lake would be approximately 15 mph.

Facts that should be considered while planning emergency responses should include the following:

A) People in the Provo River Canyon should not try to drive out of the canyon, but instead should head for high ground. A warning system should be installed in the canyon, one that is not dependent on normal communication channels (telephone or CB). People in the canyon will have less than 1/2 hour to save themselves.

B) Refugee areas would likely be on the northwest and southeast sides of Provo River, the bench at Orem and the BYU campus plateau. North-south highways will be severed. The evacuation paths should be east-west. Even after flood waters have subsided normal transportation routes will be clogged with sediment and debris.

C) Evacuation time below the canyon mouth would range from one-half to one hour.

D) All lifelines (phone, sewer, water, power, gas) may be severed or contaminated. The sewer treatment plants (Timpanogos, Orem, & Provo City) may become inoperative. Administrative operations may have to be moved from Provo.
CITED REFERENCES


Bureau of Reclamation, 1982, Guidelines for defining inundated areas downstream from Bureau of Reclamation dams; Bureau of Reclamation unpublished report.


Corps of Engineers, 1971, Flood plain information Provo River and Rock Canyon Creek, Provo and Orem, Utah: Department of the Army, Sacramento District, 34 pp.

-------1972, Flood plain information Provo River and Slate Creek, Provo, Utah: Department of the Army, Sacramento District, 34 pp.


Table A-1 consists of the top-widths, elevations, slope, and discharge used for the calculations of Flood-wave crest parameters for cross-sections #2 through #15. Diagrammatic representations of cross-sections #2 through #15 follow below the table.
<table>
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### Table A-1. Cross-Section Data

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<th>TOP WIDTH (FT)</th>
<th>ELEVATION (FT)</th>
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<tr>
<td>* 55</td>
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**CROSS-SECTION #2**
- RIVER MILE = 0.16
- SLOPE = 0.0024 ft/ft
- PEAK DISCHARGE, Qx = 842,509 cfs
- FLOOD-WAVE CREST
- ELEVATION = 5347 feet
- PEAK DEPTH = 75 feet
- ARRIVAL TIME = 0.5 min#
- AVE. VELOCITY = 15 mph

| * 67           | 5261            |
| 75             | 5262            |

**CROSS-SECTION #3**
- RIVER MILE = 0.74
- SLOPE = 0.0036 ft/ft
- PEAK DISCHARGE, Qx = 831,332 cfs
- FLOOD-WAVE CREST
- ELEVATION = 5309 feet
- PEAK DEPTH = 48 feet
- ARRIVAL TIME = 2.5 min#
- AVE. VELOCITY = 19 mph

| * 33           | 5250            |
| 150            | 5264            |

**CROSS-SECTION #4**
- RIVER MILE = 1.34
- SLOPE = 0.0035 ft/ft
- PEAK DISCHARGE, Qx = 819,926 cfs
- FLOOD-WAVE CREST
- ELEVATION = 5331 feet
- PEAK DEPTH = 81 feet
- ARRIVAL TIME = 4 min#
- AVE. VELOCITY = 21 mph

| * 70           | 5212            |
| 160            | 5218            |

**CROSS-SECTION #5**
- RIVER MILE = 3.84
- SLOPE = 0.0029 ft/ft
- PEAK DISCHARGE, Qx = 774,060 cfs
- FLOOD-WAVE CREST
- ELEVATION = 5293 feet
- PEAK DEPTH = 81 feet
- ARRIVAL TIME = 11 min#
- AVE. VELOCITY = 21 mph

| * 43           | 5204            |
| 188            | 5208            |

**CROSS-SECTION #6**
- RIVER MILE = 4.20
- SLOPE = 0.0046 ft/ft
- PEAK DISCHARGE, Qx = 767,670 cfs
- FLOOD-WAVE CREST
- ELEVATION = 5258 feet
- PEAK DEPTH = 54 feet
- ARRIVAL TIME = 12.5 min#
- AVE. VELOCITY = 23 mph

| * 35           | 5198            |
| 190            | 5209            |

**CROSS-SECTION #7**
- RIVER MILE = 4.45
- SLOPE = 0.0045 ft/ft
- PEAK DISCHARGE, Qx = 763,264 cfs
- FLOOD-WAVE CREST
- ELEVATION = 5274 feet
- PEAK DEPTH = 76 feet
- ARRIVAL TIME = 13 min#
- AVE. VELOCITY = 25 mph

| * 65           | 5190            |
| 90             | 5192            |

**CROSS-SECTION #8**
- RIVER MILE = 5.05
- SLOPE = 0.0029 ft/ft
- PEAK DISCHARGE, Qx = 752,792 cfs
- FLOOD-WAVE CREST
- ELEVATION = 5231 feet
- PEAK DEPTH = 41 feet
- ARRIVAL TIME = 15 min#
- AVE. VELOCITY = 16 mph

| * 65           | 5190            |
| 90             | 5192            |

(Note: * = streambed width and elevation, # = approximate travel time from dam)
DEER CREEK DAM FAILURE INUNDATION AREA

FLOOD WAVE CREST
(5347 ft Elevation,
75 ft Deep)

5370 -
5350 -
5330 - Quaternary Terrace gravels
5310 -
5290 -
5270 -
5250 -

Quaternary Alluvium (sand and gravel)

Permian/Pennsylvanian OQUIRRH FORMATION (sandstone & cherty limestone)

Diagrammatic Representation of Cross-Section # 2: River Mile=0.16
Scales: Horizontal=1:3281, Vertical=1:410; Vertical Exaggeration=8x
DEER CREEK DAM FAILURE INUNDATION AREA

FLOOD WAVE CREST (5309 ft Elevation, 48 ft Deep)

DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 3: River Mile=0.74
Scales: Horizontal= 1:1333, Vertical= 1:164 ; Vertical Exaggeration=3x
DEER CREEK DAM FAILURE INUNDATION AREA

FLOOD WAVE CREST (5331 ft. Elevation, 81 ft. deep)

5340
5330.5
5321
5311.5
5302
5292.5
5283
5273.5
5264
5254.5
5245

fault(?)

Permian/
Pennsylvanian
OQUIRRAH FORMATION
(Sandstone & cherty
Limestone)

5:

Pennsylvanian/
Mississippian
MANNING CANYON SHALE

Quaternary
Alluvium

Quaternary
Alluvium (sand & gravel)

PROV D R I V E

7 8 9 10 11 12 13 14

Diagrammatic representation of cross-section # 4: River Mile = 1.34
Scales: Horizontal = 1:1057, Vertical = 1:195; Vertical Exaggeration = 5x
DEER CREEK DAM FAILURE INUNDATION AREA

Flood wave crest (5293 ft. elevation, 81 ft. deep)

Pennsylvanian

5237 - QUIRHH FORMATION (sandstone & limestone)

5228 - Alluvium

Quaternary

5219 - Alluvium (sand & gravel)

5210

Diagrammatic representation of cross-section #5: River Mile=3.84

Scales: Horizontal=1:1732, Vertical=1:185; Vertical Exaggeration=9x
DEER CREEK DAM FAILURE INUNDATION AREA

FLOOD WAVE CREST (5258 ft. Elevation, 54 ft. Deep)

---

ELEVATION

FEET

5280 5272 5264 5260 5256 5252 5248 5244 5240 5236 5232 5224 5216 5210 5206 5200

PROVO RIVER (Width, feet)

2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 6: River Mile=4.2
Scales: Horizontal= 1:1038, Vertical= 1:164 ; Vertical Exaggeration=6x
DEER CREEK DAM FAILURE INUNDATION AREA

FLOOD WAVE CREST (5274 ft. Elevation, 76 ft. Deep)

DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 7: River Mile=4.45
Scales: Horizontal= 1:724 , Vertical= 1:175 ; Vertical Exaggeration=4x
DEER CREEK DAM FAILURE INUNDATION AREA

FLOOD WAVE CREST (5231 ft. Elevation, 41 ft. Deep)

Pennsylvania

OQUIRH FORMATION

Bridal Vale Limestone Member

Quaternary Alluvium (sand & gravel)

DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 8: River Mile=5.05
Scales: Horizontal= 1:1754, Vertical= 1:840; Vertical Exaggeration=2x
DEER CREEK DAM FAILURE INUNDATION AREA

FLOOD WAVE CREST (5261 ft. Elevation, 83 ft. Deep)

DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 9: River Mile=6.26
Scales: Horizontal= 1:1375, Vertical= 1:205; Vertical Exaggeration=7x
DEER CREEK DAM FAILURE INUNDATION AREA

FLOOD WAVE CREST (5153 ft. Elevation, 58 ft. Deep)

DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION #10: River Mile=7.25
Scales: Horizontal= 1:756 , Vertical= 1:144 ; Vertical Exaggeration=5x
DEER CREEK DAM FAILURE INUNDATION AREA

FLOOD WAVE CREST (4993 ft. Elevation, 25 ft. Deep)

4990.5
4982
4973.5
4965

Quaternary Landslide (sand & gravel) Quaternary Alluvium

PROVO RIVER (Width, feet)

DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION #11: River Mile=8.68
Scales: Horizontal= 1:1362, Vertical= 1:174; Vertical Exaggeration=8x
DEER CREEK DAM FAILURE INUNDATION AREA

FLOOD WAVE CREST (4864 ft. Elevation, 38 ft. Deep)

4870
4865
4860
4855
4850
4845
4840
4835
4830
4825
4820

Mississippian
GREAT BLUE
LIMESTONE

Quaternary Alluvium (sand & gravel)

DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION #12: River Mile=10.75
Scales: Horizontal= 1:863 , Vertical= 1:103 ; Vertical Exaggeration=3x
DEER CREEK DAM FAILURE INUNDATION AREA

FLOOD WAVE CREST (4828 ft. Elevation, 33 ft. Deep)

Quaternary Lake Sediments (sand & gravel)

Quaternary (sand & Alluvium gravel)

MISSISSIPPIAN GREAT BLUE LIMESTONE

DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION #13: River Mile=11.23
Scales: Horizontal= 1:2373, Vertical= 1:309 ; Vertical Exaggeration=8x
Diagrammatic representation of cross-section #14: River Mile = 12.11

Scales: Horizontal = 1:5501, Vertical = 1:718; Vertical Exaggeration = 8x
DEER CREEK DAM FAILURE INUNDATION AREA

PROVO CITY

FLOOD WAVE CREST (4600 ft. Elevation, 25 ft. Deep)

Quaternary Lake Sediments
Quaternary (sand & gravel)
Alluvium
Quaternary Lake Sediments

Ft. 4689 - 4619.5 - 4550

DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION #15: River Mile=15.63
Scales: Horizontal=1:11404, Vertical=1:1426; Vertical Exaggeration=8x
I

Mile

From U.S. Geological Survey topographic quadrangles Aspen Grove and Bridal Veil Falls.

Plate 1. Inundated Area Resulting from a Postulated Worst-Case Scenario Deer Creek Dam Failure, Provo River, Utah

Explaination
- approximate limit of flooding
- cross-section number
PLATE 1: (continued) INUNDATED AREA RESULTING FROM A POSTULATED WORST-CASE SCENARIO DEER CREEK DAM FAILURE, PROVO RIVER, UTAH

EXPLANATION

- approximate limit of flooding

2 cross-section number