SPOTLIGHT ON GLEN CANYON DAM

Wedged into a deep sandstone gorge on the Colorado River, Glen Canyon Dam impounds water for more than 180 miles to form beautiful Lake Powell. Each year, millions of visitors are drawn to the lake, but recreation provides only a small part of the benefits offered by the lake and the dam which formed it. Lake Powell's dependable supply of water for irrigation, municipal and industrial use, and hydropower generation benefits millions of people far from its spectacular shores.

How the Site for Glen Canyon Was Selected

The lower section of Glen Canyon was first considered for a damsite in the early 1920's. The final site for Glen Canyon Dam was carefully examined and selected by a group of Bureau of Reclamation engineers and geologists working from 1946 to 1948. There were three main criteria in choosing this particular site:

1. The area forming the reservoir basin could contain an immense amount of water.
2. The canyon walls and bedrock foundation were strong and stable enough to safely support a high dam.
3. A large source of good rock and sand for making concrete aggregate to build the dam was close by on Wahweap Creek just 5 miles from the construction site.

Construction History

Glen Canyon Dam was authorized by the U.S. Congress in April 1956. The first blast occurred on October 15 that same year, signaling the start of construction.

In April 1957, the prime construction contract to build Glen Canyon Dam was awarded to Merritt-Chapman and Scott Corporation. Until June 1960, the emphasis was on rerouting the river and excavating – drilling tunnels, blasting to bedrock for the foundation, and carving into the canyon walls for the abutments of the dam. The canyon was actually shaped to fit the dam.

Concrete placement began in the summer of 1960 and continued day and night until September 1963, when the final "bucket" was dumped. The "bucket" used was a huge container holding 24 tons of damp concrete. In all, it took over 400,000 buckets of concrete to build Glen Canyon Dam.

Glen Canyon Dam is a concrete arch structure. It has a structural height of 710 feet and a crest length of 1,560 feet.

The turbines and generators that produce the hydroelectric power were installed between 1963 and 1966. Glen Canyon Dam was dedicated on September 22, 1966.

The spillway tunnels at Glen Canyon Dam were not used continuously until the 1983 floods on the Colorado River. With discharges of approximately 30,000 ft^3/s, severe cavitation and erosion damages occurred in both tunnels. The majority of the damage was located in the elbow areas after a drop of 500 feet from the spillway crest. Aeration slots were provided to eliminate future cavitation damage. In 1984, over 16,500 yd^3 of concrete were used to repair the tunnels (see figure 1).

Glen Canyon Dam, Lake Powell, and the Navajo Reservation

Glen Canyon Dam, Lake Powell, new paved highways, and the incorporated town of Page have remarkably transformed a large area of the Utah-Arizona canyon lands.

Before 1956, the land near the future damsite was virtually inaccessible. When the Glen Canyon Dam construction crews arrived, they found they had to drive 200 miles to cross from one side of the canyon to another.

Glen Canyon Bridge was completed in 1959 and, together with the connecting highways, permitted trucks by the thousands to deliver equipment and materials for the dam and for the new town of Page.

Nearby Navajo Indians, who pastured livestock on meager desert grass in the area, suddenly found themselves near stores, schools, and medical care. Many Navajos worked on the construction of Glen Canyon Dam.

Land for the town of Page and the south side of Lake Powell, formerly a part of the Navajo Indian Reservation, was exchanged by the Tribe for equivalent land in southeastern Utah. The town is carved from the desert and was first designed as home base for the thousands of men and women and their families associated with the construction and operation of Glen Canyon Dam. At the peak of Glen Canyon Dam construction, Page had about 7,500 residents. The town was incorporated under the laws of the State of Arizona in March 1975 and has a population of about 6,000.

The Canyon, the Lake, and the Dam

From the concrete barrier of Glen Canyon Dam, upstream for more than 180 miles, Lake Powell's blue waters lap at cliffs, buttes, and gentle sands. Hour by hour, earth-tone colors change as shadows creep through the canyon.

Rain and wind sometimes sweep across the lake, but are quickly gone. This is desert and the sun dominates.

Lake Powell is awesome, vast, overwhelming — it is ever changing, always sublime.

Lake Powell

Glen Canyon Dam backs Colorado River water through Glen Canyon to form Lake Powell, one of the most scenic lakes in the world. When full at 3,700 feet above sea level, Lake Powell is 186 miles long. The shoreline distance - backing in and out of numerous side canyons - is an incredible 1,960 miles.

Lake Powell started filling on March 13, 1963, when diversion tunnel gates were partially closed. Although the filling rate varied because of erratic precipitation, the lake usually peaked a little higher each year. In 1980, it was completely full and water flowed over the spillway. A test spill was allowed; however, operators at the dam now try to avoid the waste of spilling from a full reservoir without producing hydroelectric power.

To meet its intended purpose, Lake Powell must fluctuate. During spring runoff, May through July, the lake normally rises. During the remainder of the year, the lake declines. How much or how fast it drops depends on both the water surface and elevation, how much water is carried over from the previous year, and how much runoff water flows into Lake Powell from the Colorado River system. During a series of low-water years, Lake Powell could drop more than 200 feet below its maximum elevation, but that would be highly unusual.

Rainbow Bridge

A star attraction of the Glen Canyon National Recreation Area is Rainbow Bridge. This wonder is the largest natural bridge on earth. The Navajos call it "Nonnoshoshi" or "the rainbow turned to stone."

Rainbow Bridge is 290 feet above the bottom of the streambed. It has a span of 278 feet and a minimum thickness at the top of 42 feet across. When full, Lake Powell's waters are 48 feet deep directly beneath the arch, but the water surface is still 21 feet below the lowest part of the bridge abutments.

When Lake Powell began to fill, there was some concern that the stability of Rainbow Bridge would be threatened by the rising water. Precise surveys conducted semiannually since Lake Powell entered Rainbow Bridge National Monument grounds show no discernible movement or change that can be attributed to the presence of standing water beneath the arch. In other words, Lake Powell apparently has no significant effect on the structural integrity of Rainbow Bridge.

The Colorado River Below the Dam

Before Glen Canyon Dam was built, the Colorado River ran warm and muddy red. Now it is clear and cold. Today, stocked rainbow trout thrive in the cold water, often reaching trophy size.

The riverflow fluctuates not as much seasonally as it does daily and weekly in response to power demands from distant towns. During the recreation season, water releases through the dam are no lower than 3,000 ft^3/s. To maintain good boating through the Grand Canyon, maximum water releases are limited to about 32,000 ft^3/s.

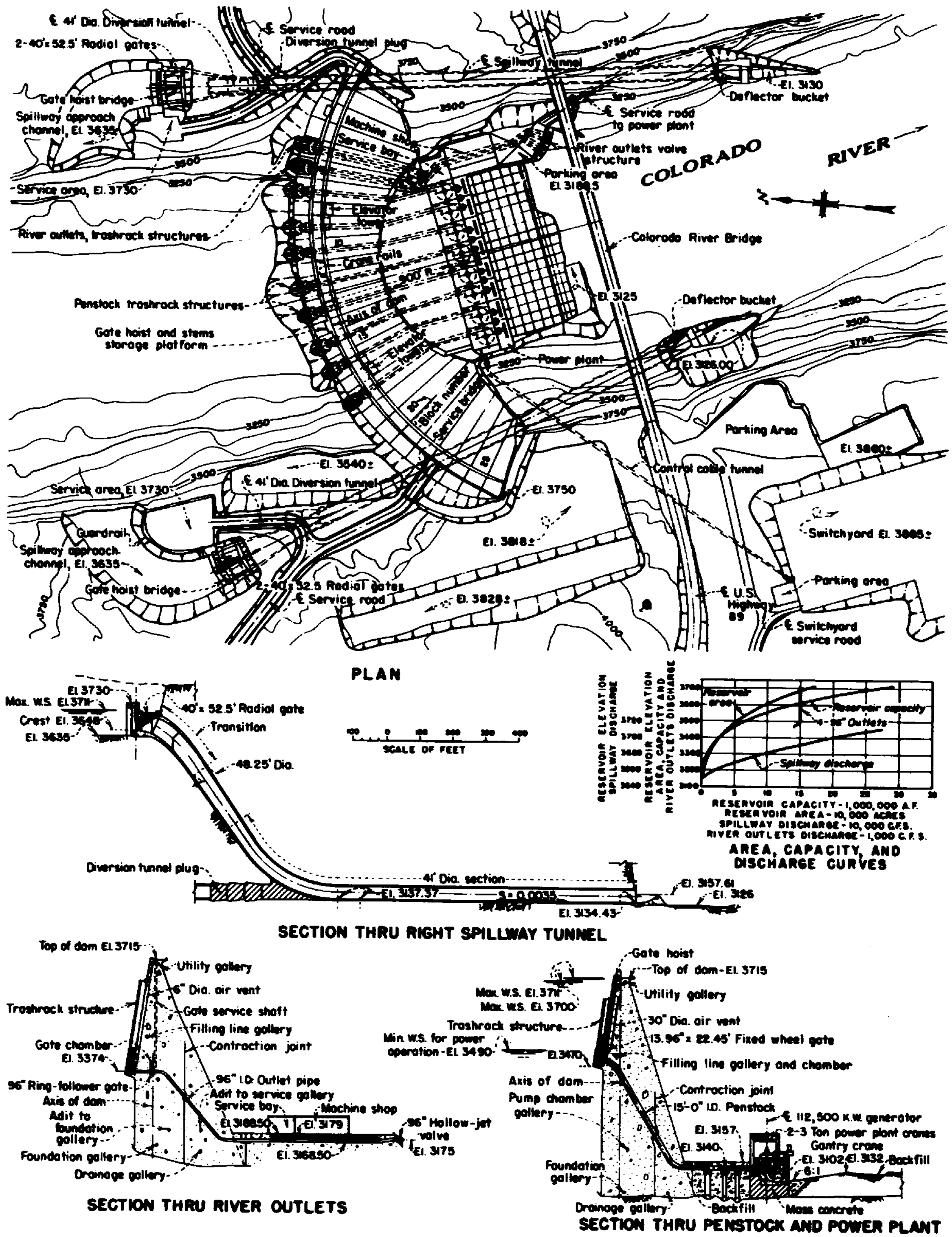
Since water releases from the Glen Canyon Powerplant are usually greater during the day than at night, boaters and campers along the river must take precautions to prevent boats from being grounded as the riverflows decrease.

Glen Canyon Dam and the CRSP (Colorado River Storage Project)

Glen Canyon Dam is the key storage unit in a far-reaching water development plan called the CRSP. The annual flow of the Colorado River is highly erratic, with spring floods that dry to a trickle in the summer and fall. When Glen Canyon was completed and Lake Powell was formed, the irregular flows were brought under control. The now steady flow from the dam and Lake Powell makes water developments possible throughout the Upper Colorado River Basin and provides a regulated supply of water to meet downstream commitments.

To help pay for the construction of Glen Canyon Dam and other Upper Basin water developments, hydroelectric power is produced at the powerplant located at the toe of the dam. At peak load, the powerplant generates more than 1 million kW of hydropower that is sold to public and private power companies.

Other storage units in the CRSP include Flaming Gorge in Utah; Navajo in New Mexico; as well as Blue Mesa, Crystal, and Morrow Point Dams in Colorado.



Glen Canyon Dam and Powerplant, Plan and Sections

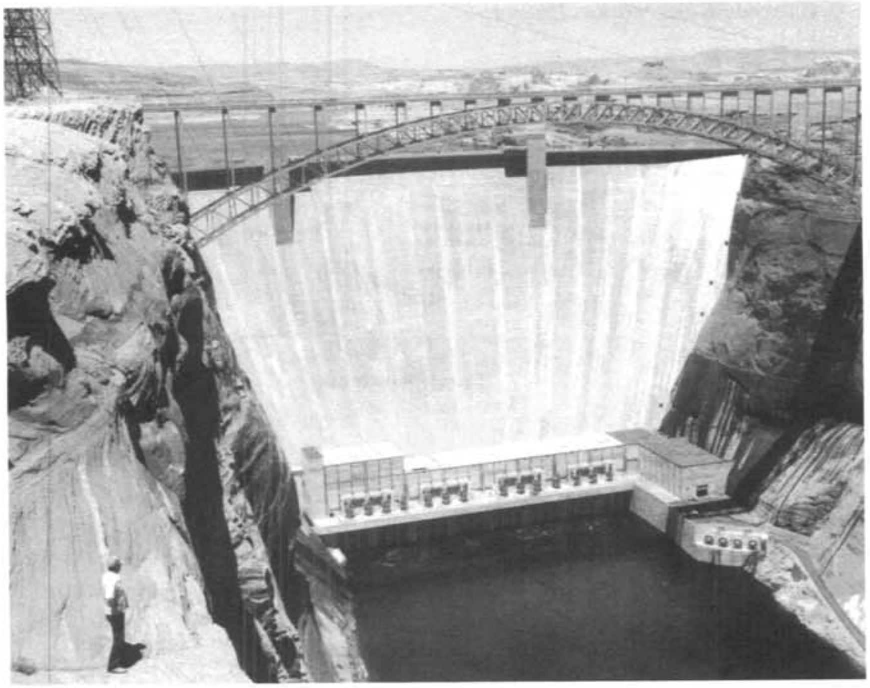


Photo 1. Glen Canyon Dam.

Aerial view looking up stream showing dam and bridge. 5/13/56

Photo 2. Glen Canyon Dam.

Aerial view looking north over town of Page, Arizona. 8/25/66

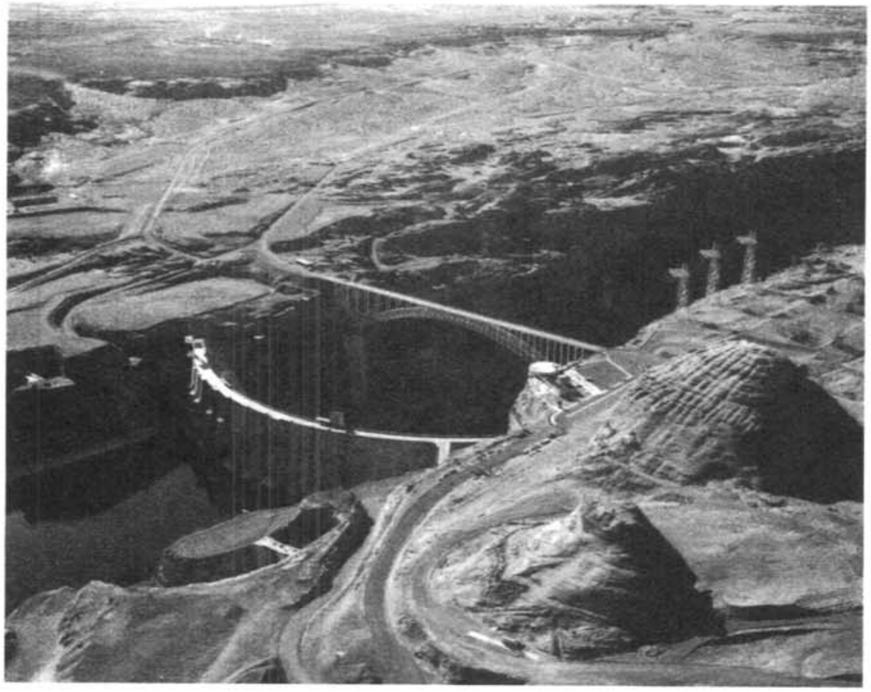


Photo 3. Glen Canyon Dam.

Aerial view showing dam and bridge. Vistors' Center is almost completed on rim of canyon. 5/7/67

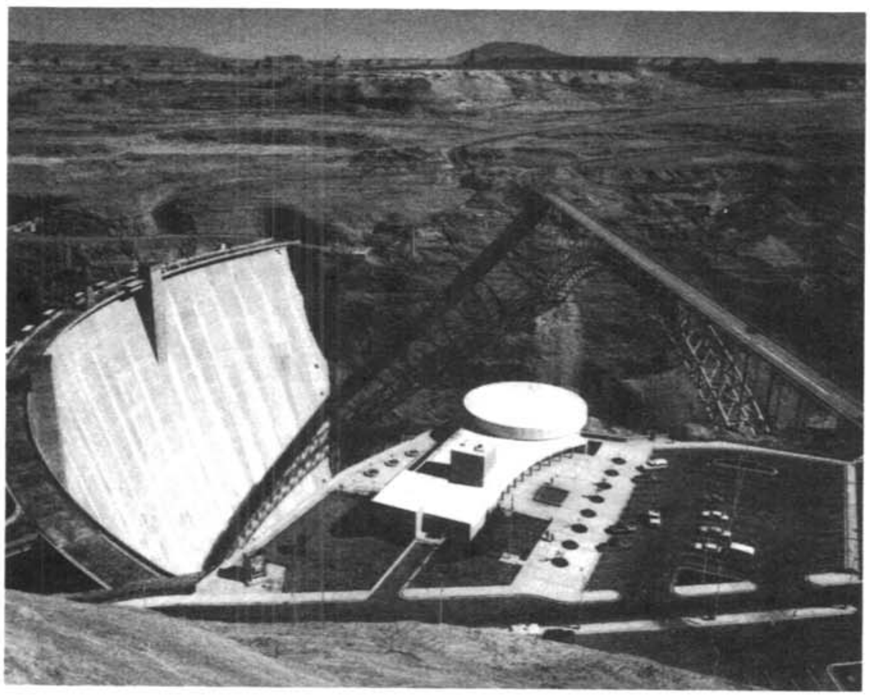


Photo 4. Glen Canyon Dam.

Aerial view of Visitors' Center. Dam and bridge in background. 10/29/70

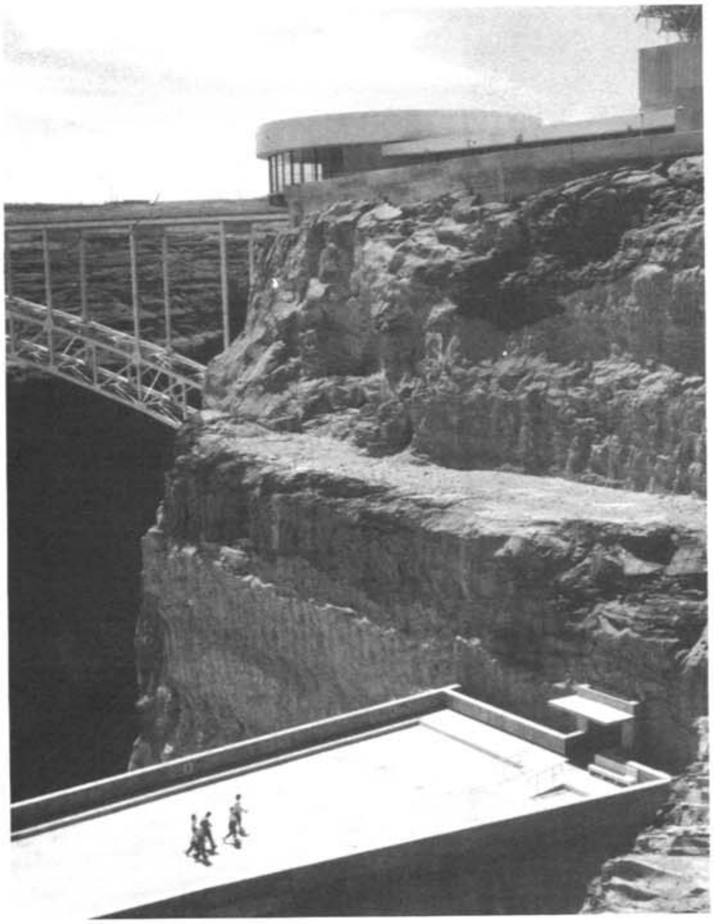


Photo 5. Glen Canyon Dam.

Aerial view showing visitors returning from tour of dam and powerplant. Approaching tunnel to the elevator which will take them 100 vertical feet to Visitors' Center at top of photo. 5/29/68

Photo 6. Glen Canyon Dam.

Aerial view looking downstream to dam, showing Lake Powell in foreground. 9/29/65

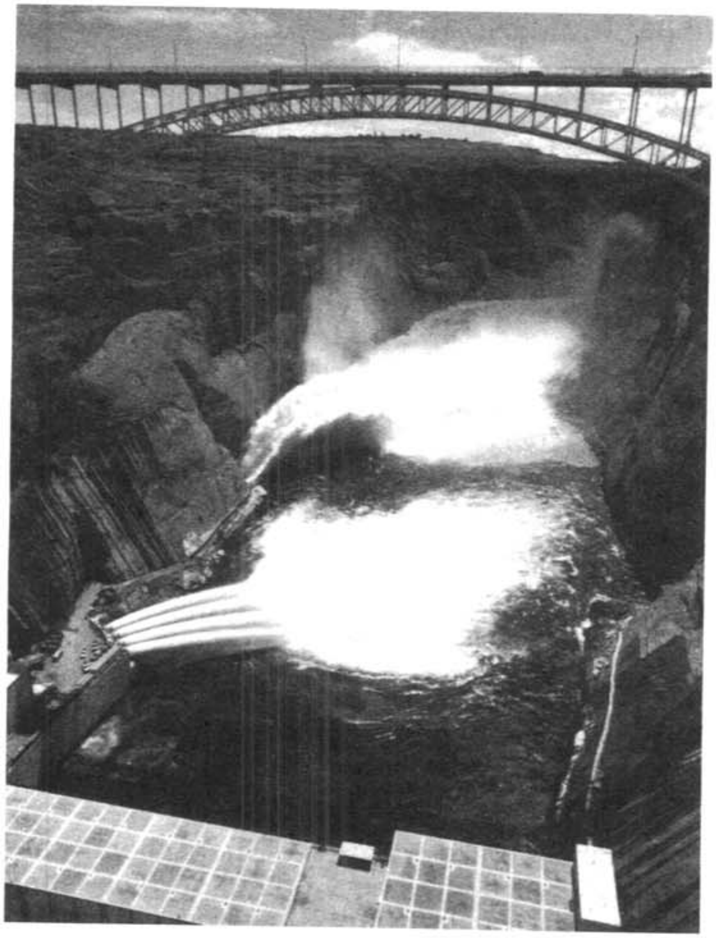


Photo 7. Glen Canyon Dam.

Aerial view of left spillway and hollow-jet valves in operation. 8/12/84

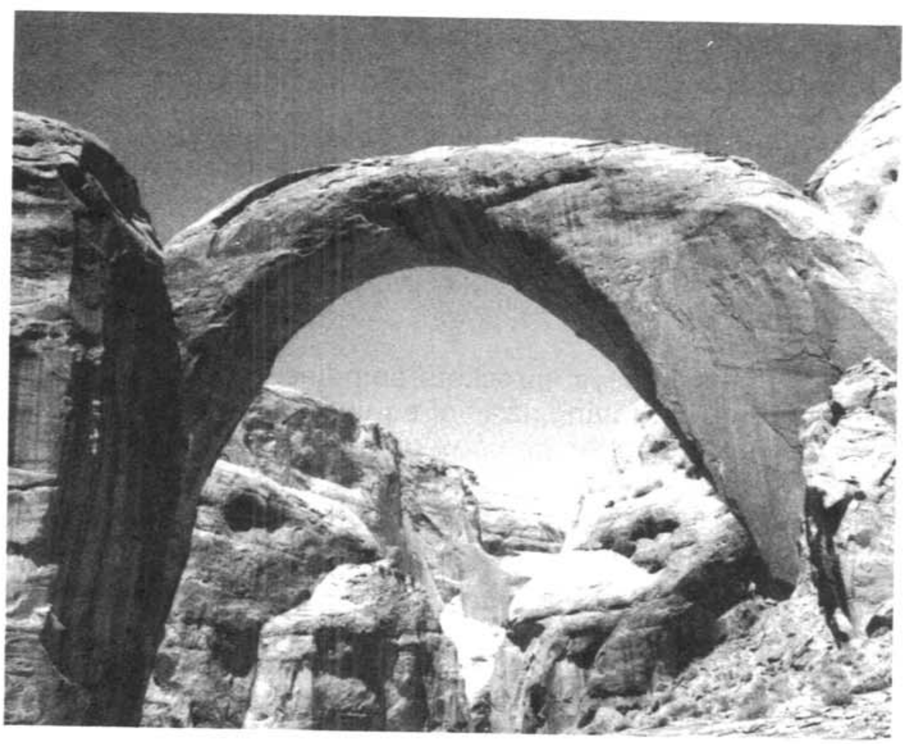


Photo 8. Rainbow Bridge.

A great natural stone arch at the foot of Navajo Mountain near Lake Powell in Utah. 5/8/65

POLICY FOR SAFETY RECOMMENDATIONS[1]

During RO&M (Review of Operation and Maintenance) Examinations

During RO&M reviews, the examiner should identify any safety-related deficiencies which could cause personal injury to operating personnel and/or the general public. Examples of such deficiencies include improper electrical wiring, broken handrails, and lack of protective screens over chain- or belt-driven motorized equipment. Depending on the severity of the safety concern, a category I or 2 recommendation should be issued and reported in the associated RO&M report.

Extracts from the Bureau's Construction Safety Standards are quoted below. These excerpts and the accompanying photographs are typical of safety deficiencies which should be reported.

Electric Wiring and Apparatus

12.1.1. "Code Requirement.–Electrical installations, temporary or permanent, shall comply with the applicable provisions of the National Electrical Safety Code, National Electric Code, and applicable State codes, unless otherwise provided by regulations or this section." This includes any exposed electrical wiring which is a code violation.

Wall Openings

15.2.1. "Requirement.–Wall openings, from which there is a drop of more than 4 feet and the bottom of the opening is less than 3 feet above the working surface, shall be guarded with a standard guardrail or guardrail components to afford protection to a height of 42 inches above the working surface. A standard toeboard shall be provided where the bottom of the wall opening is less than 4 inches above the working surface."

15.2.2. "Extension platforms.–Extension platforms, outside of wall openings, erected to provide access for materials, equipment, or personnel, shall be protected on exposed sides by a standard guardrail and toeboard." This includes broken or missing handrails, damaged walkways, etc.

Unscreened Reciprocating Equipment

19.14.2. "Guarding.–Belts, gears, shafts, pulleys, sprockets, spindles, drums, flywheels, chains, or other reciprocating, rotating, or moving parts of equipment shall be guarded or isolated in order that they do not endanger persons or property. Guarding shall comply with the standards set forth in the current edition of ANSI B15.1, 'Safety Standard for Mechanical Power Transmission Apparatus.'" This includes any unscreened motor-driven equipment operators whether part of the original design or a postconstruction modification.

[1] This policy for safety recommendations was developed to create a greater consciousness among examiners of facilities in operational status and to ensure any deficiencies which could cause injury or death to facility operators are corrected by the operating entity.

In addition to the above safety matters, the RO&M examiner will report instances of poor housekeeping since this can adversely affect the safe working environment of operating personnel. Facilities should have an overall appearance of orderliness and operating buildings and yards should be clean, neat, and free of strewn or discarded material, parts, or equipment.

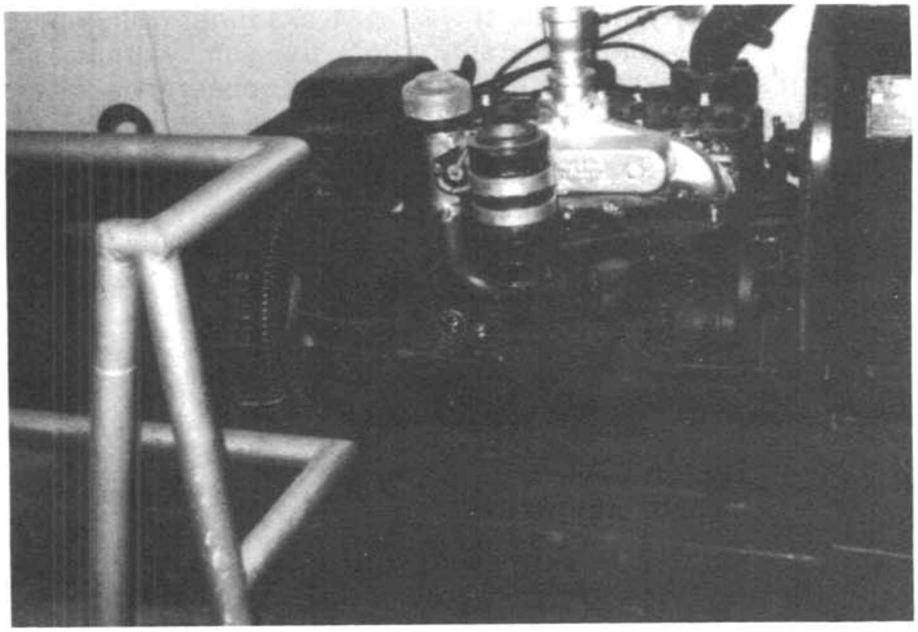


Photo 1. - Potential for gasoline fire or explosion. Carburetor is inoperable and replacement parts are no longer available. Gasoline is poured into engine in order to operate.

Photo 2. Potentially hazaardous intake tower. A safety buoy line should be installed to prevent swimmers and boaters from drifting into intake tower. A sign should also be posted warning recreationists of high-velocity flows.

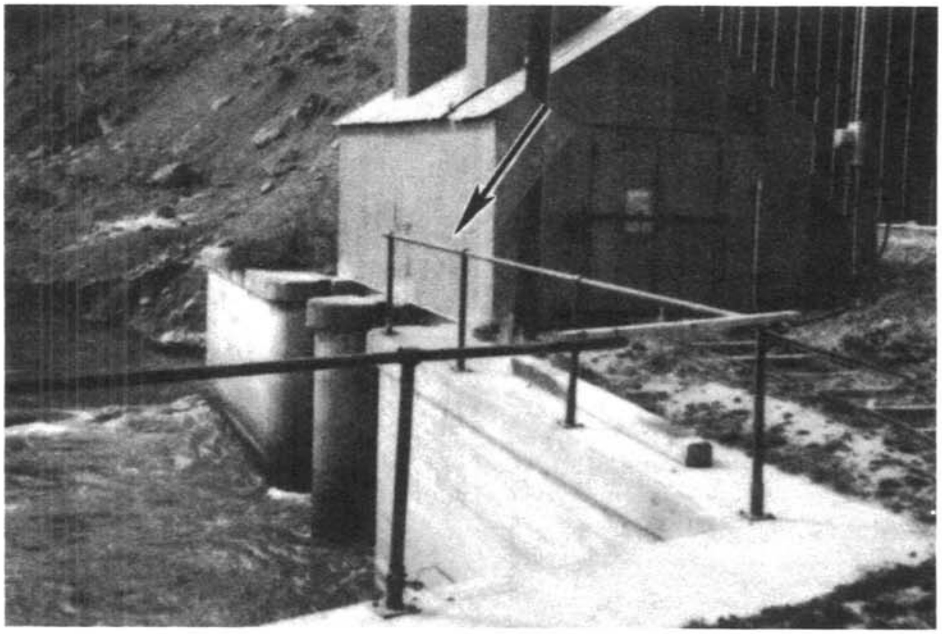


Photo 3. - Broken guardrail has been patched with a timber board and should be replaced with a pipe of original design. Also, the guardrail should be extended to the equipment house to prevent anyone from falling through the opening.

Photo 4. - Closeup view of above photo showing opening.

Photo 5. - Grab bars are needed to allow operating personnel to climb safely through the roof hatch.

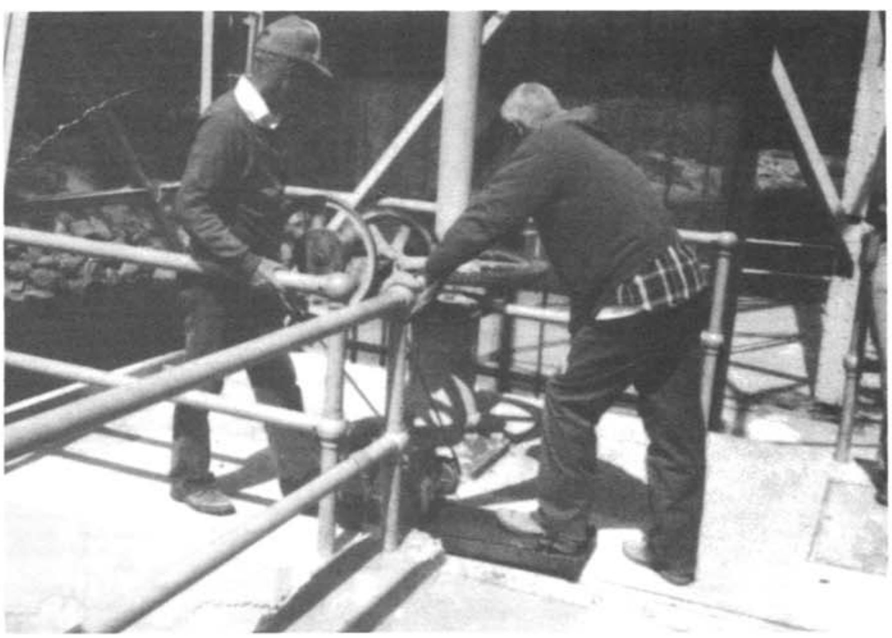


Photo 6. - Unscreened motor-driven gate operator. A rubber fan belt is connected between a 3-hp gasoline engine and a 14-inch-diameter pulley on the handcrank shaft. Tension in the belt is maintained by foot pressure against the engine base. The equipment should be screened because serious injury can result.

Photo 7. The safety screens around the motor-operated gears can protect operators from serious injury.

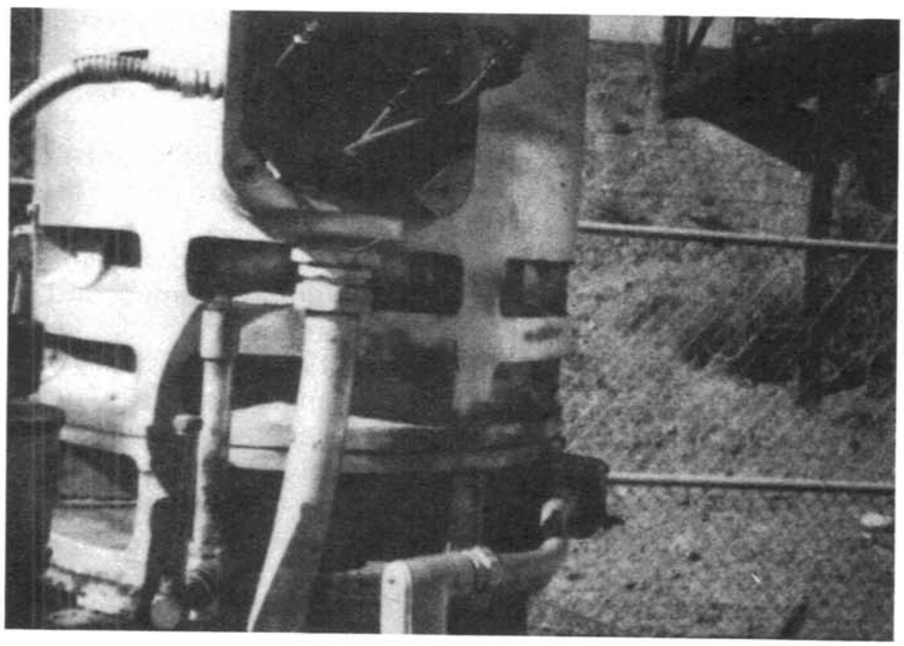


Photo 8. The missing faceplate should be replaced. Exposed electrical wiring on the motor junction box can cause serious injury to operating personnel.

CRITERIA[1] FOR THE
REMOVAL OF TREES, OTHER VEGETATIVE GROWTH, AND
RODENT BURROWS FROM EARTH DAMS, DIKES, AND
CONVEYANCE FEATURES (1987)

Proper maintenance of dams, dikes, water conveyance features, and appurtenant structures requires the periodic removal of all undesirable vegetation within a defined area around these features. If not removed, the effect of this growth may be detrimental to the safe operation of the features and can also lead to structural failure. Properly maintained natural or planted grass cover on or about these structures is the exception to the above.

Tree growth on or near embankment dams, dikes, and water conveyance structures is undesirable. Uprooted or decaying trees may lead to the establishment of voids, shortened seepage paths, a weakness in the embankment, and/or damage to nearby structures. Mature trees on or near these structures also provide seed stock that can result in establishment of new growth as well as create a continuous maintenance problem.

Other than the natural or planted grasses, shallow-rooted chaparrals should also be removed because they can inhibit proper examination and monitoring of conditions such as seepage, settlement, cracking, etc. This vegetation may also encourage rodent activity by providing a food source for the burrowing animals as well as shelter against predators. These animals can also detrimentally affect embankment dams and other structures by burrowing and intercepting the phreatic surface in these dams and structures.

The following criteria are to be used for all Bureau embankment dams and major diversion dams, dikes, conveyance features, and appurtenant structures (refer to the attached sketch and photos).

1. All trees and other deep-rooted growth, including stumps and associated root systems, are to be removed from earth dam embankments and dikes. Upstream and downstream groin areas are to be free of trees and other woody growth within 25 feet beyond each contact for conifers[2] and 50 feet for deciduous trees. The old root systems should be removed and the excavated volume replaced and compacted with material similar in character to the surrounding area to prevent the development of piping action. Seedlings are to be removed at the first opportunity to minimuze future maintenance, expense, and damage to the embankment.

2. Except for grass cover, unlined spillway inlet and outlet channels are to be free of vegetation which may significantly impede waterflow. Similarly, and to prevent damage to concrete sidewalls and floors, or riprap sideslopes, woody growth is to be removed within 25 feet of the outside edge of these structures for conifers and 50 feet for deciduous.

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[1] These criteria were developed by the Bureau's water operations staff and supersedes the vegetative growth removal guidelines published in Water Operation and Maintenance Bulletin No. 131. The revised criteria established clear zones to better view changing conditions at Bureau dams, dikes, and conveyance features.
[2] Conifers are cone-bearing evergreen trees or shrubs which include pines, firs, and spruce. Deciduous trees and shrubs are those which shed their leaves annually.

3. Properly maintained grass cover is acceptable on the downstream face of dams and dikes to prevent erosion damage, control weeds, and to enable the structure to be routinely examined and monitored.

4. For open canals, laterals, drains, and other minor facilities, the above criteria apply except that the minimum distance from the outside edge of the prism should be 15 feet for conifers and 30 feet for deciduous. For embankments supporting these structures, the 15- and 30-foot distances shall be measured from the toe of the fill.

5. To provide access and prevent root encroachment in pressure conduit conveyance systems, the clearance distance should be 15 feet from the outside edges of the pipeline for conifers and 30 feet for deciduous.

6. Burrowing rodents are to be prevented from establishing habitats in and around facilities in accordance with the above clearance distances. Associated rodent burrows are to be backfilled and compacted with material similar to that of the surrounding area to prevent the development of piping action.

As discussed above, the removal of trees and brush on or near structures is necessary to prevent deterioration and allow proper surveillance. However, excavations into or near these structures can be hazardous in some situations. Because of this danger, such removal must be carefully planned and executed, and should be approved by an engineer experienced in the design and construction of the pertinent structure.

The above minimum distances should be increased if suspected or known problems exist at the facility. This increase applies to groin areas, slope cuts, abutments, fills, areas upstream or downstream from a dam, and elsewhere as appropriate. As an example, a damp or ponded area 120 feet below the toe of a dam that is partially concealed by vegetation should be examined and, as necessary, cleared of vegetation to permit surveillance of the area, construction of drains and monitoring equipment (piezometers, weirs, etc.), or access to the area.

These criteria apply to concrete dams as well; however, variances may apply due to geologic conditions, topography such as steepness of abutments, and other factors.

The above criteria may need to be modified for specific instances in which rights-of-way, the National Environmental Protection Act, the presence of endangered species, landscaping, or other constraints exist. However, it is the responsibility of the examiner to make recommendations enforcing the above criteria; and then, the appropriate administering office will determine if these constraints apply and the extent to which the recommendation(s) can be completed.

The following sketch and photographs illustrate these criteria. Also included is a summary of vegetation root systems which were the basis for establishment of the clearance distances. Your attention is called to the radial extent of root growth of cottonwoods and the need to increase the above clearance distances for mature trees of this type.

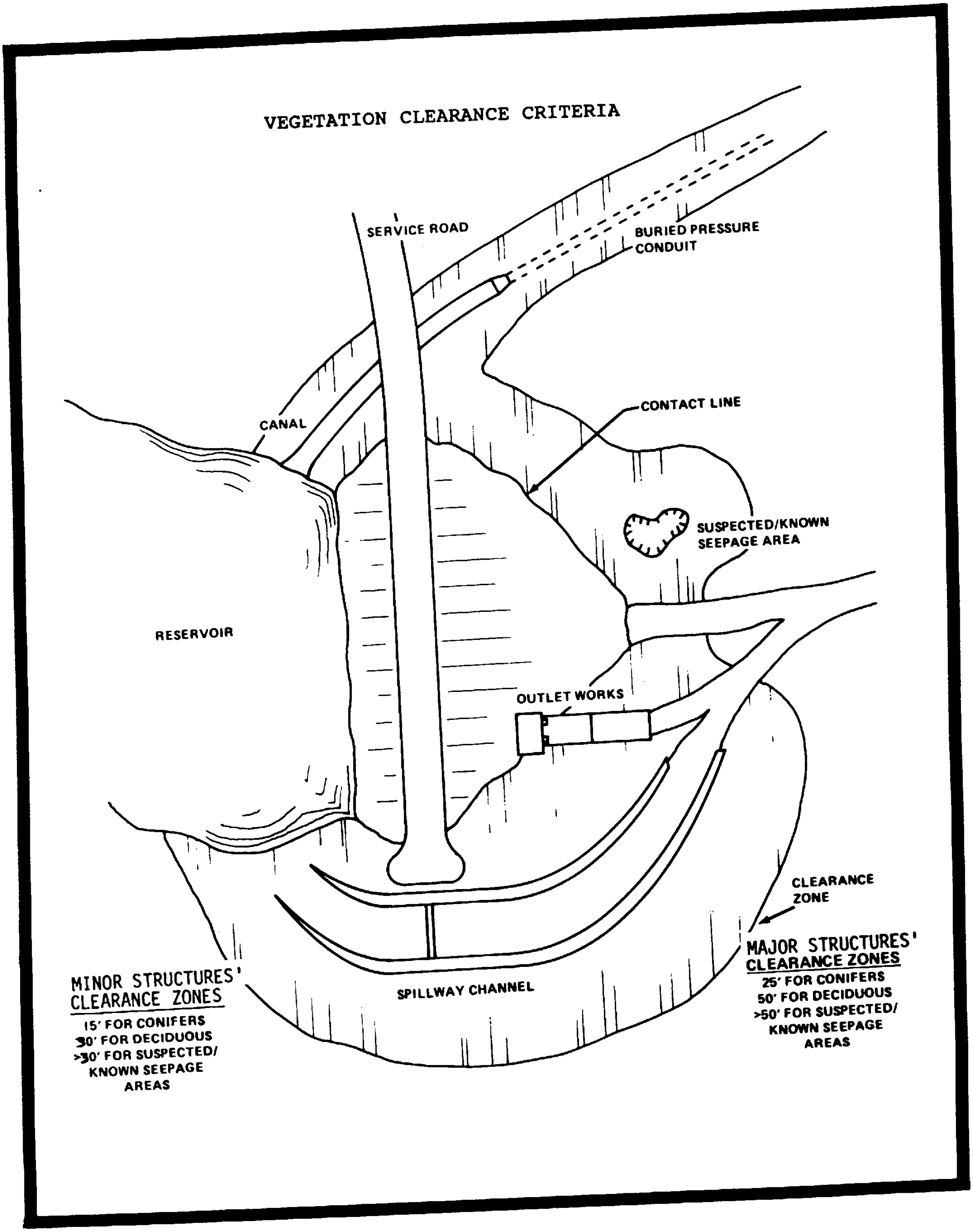
VEGETATION CLEARANCE CRITERIA
SERVICE ROAD
BURIED PRESSURE CONDUIT
CONTACT LINE
CANAL
SUSPECTED/KNOWN SEEPAGE AREA
RESERVOIR
OUTLET WORKS
CLEARANCE ZONE
MAJOR STRUCTURES' CLEARANCE ZONES
25' FOR CONIFERS
50' FOR DECIDUOUS
>50' FOR SUSPECTED/ KNOWN SEEPAGE AREAS
MINOR STRUCTURES' CLEARANCE ZONES
15' FOR CONIFERS
30' FOR DECIDUOUS
>30' FOR SUSPECTED/ KNOWN SEEPAGE AREAS
SPILLWAY CHANNEL

Photo 1. - The dense conifer stand has been allowed to grow in the lower end of an unlined spillway and will adversely affect and impede flood flows.

Photo 2. - Conifers and deciduous trees are established in a large area immediately upstream of the dam (arrow) and need to be removed to permit surveillance of any problems such as reservoir seepage which is known to exist.

Photo 3. - Conifers have established themselves in the seepage area to the right of the valve house (arrow). They should be removed because they are partially concealing the seepage area and any evidence of adverse changes that may occur.

Photo 4. - The vegetation clearance zone and natural grasses on the embankment satisfy the criteria.

Photo 5. - The mature conifers (arrows) can provide seed stock for the emerging juvenile conifers located on the abutment contact.

Photo 6. - Apron downstream of the toe of the embankment. The conifers on the apron are masking the stilling basin and any evidence of problems that may exist in these areas.

Photo 7. - The soil around the root system of the mature conifer (arrow) has been eroded by fluctuating reservoir levels and wave action. This conifer needs to be removed because it can fall and destroy the access bridge or equipment on the intake tower.

Photo 8. - Exposed root system of conifer in above photo.

Photo 9. - The chaparral-type growth on the outside slope of the canal fill is concealing exit points of subsurface seepage channels. Material eroded from the fill has been deposited at the toe of this slope (arrow).

Photo 10. - Conifers have established themselves on the downstream face of this saddle dike and can conceal evidence of any problems in this area.

Photo 11. - Mature conifers have established themselves on both the upstream and downstream faces of this low saddle dam. Surveillance of rodent habitats and structural problems is difficult to perform.

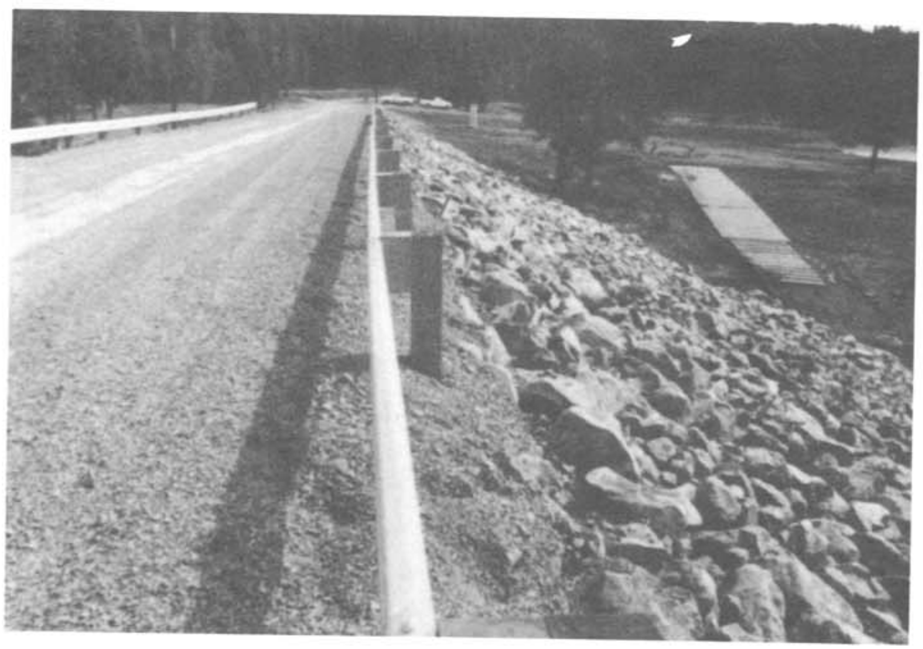

Photo 12. - The two conifers near the right upstream abutment can provide annual seed stock for more conifers and result in the spread of undesirable growth in this area.

ROOT CHARACTERISTICS OF COMMON WOODY VEGETATION IN THE WESTERN UNITED STATES

ROOT SYSTEMS - TREES

Basic Information:

Generally speaking, trees throughout the world do not have well-defined taproot systems. Their root systems are shallow. The depth of the roots is influenced by the their location and conditions present (light, oxygen within the soil, soil type, tree age, abundance or lack of moisture in the environment, etc.). As a rule of thumb, the major roots (greater than 1-inch diameter) are located within 2 to 3 feet of the surface.

Martin H. Zimmermann and Claud L. Brown in their book, Trees–Structure and Function (pp. 55-56), do an excellent job in summarizing the form and extent of roots:

> "Many woody plants possess a characteristic pattern of root development even if grown under different environmental conditions. Inherent differences in patterns of root development are especially noticeable during early seedling growth; but root systems often become greatly modified in later years by environmental influences such as soil texture, water availability, and overall nutrition. For these reasons the depth and extent of lateral roots is highly variable even within the same species. Contrary to what many laymen believe, the bulk of the root system of most trees growing on medium textured soils (loams and clay-loams) is within 3 feet of the surface. The majority of the smaller absorbing roots lie in the upper 6 inches of the forest soil. Density of spacing or competition among individual trees has a pronounced effect on the extension of lateral roots; therefore, generalized statements on the extent of lateral root development have little meaning. In open-grown trees, it is common to find lateral roots extending out 2 to 3 times beyond the radius of the crown, although the majority of the absorbing roots may lie within the area circumscribed by the periphery of the crown. More specific data on the form and extent of root systems in trees are found in Kramer and Kozlowski (1960), Toumey (1929), and Busgen and Munch (1929)."

Spruce: This tree has an extremely shallow root system. The width of the lateral radial spread of the roots can be as much as the height of the tree.

Ponderosa: The taproot, although not well defined, may reach 8 to 10 feet deep. (This would be an extremely large tree to have roots this deep.) The width of the lateral radial spread of the roots can be as much as the height of the tree and beyond.

Lodgepole: The taproot, although not well defined, may reach 10 feet deep. (Again, this would be an extremely large tree to have roots this deep.) The width of the lateral roots may be as much as the height of the tree and beyond.

Englemann Spruce - Subalpine Fir: Both these root systems are shallow and spreading. Tree growth is extremely slow.

Aspen: Fairly shallow root system - no taproot. Aspen can reproduce by root suckers or seedlings. Aspens do not like to grow in areas where the soil has been disturbed.

Cottonwood: Cottonwoods do not have a taproot but do have sinker roots which are similar to taproots. Sinker roots are roots that extend straight down from a lateral root and usually follow a crack in the ground. These roots may extend 3 or 4 feet in depth. Their major function is water and food storage as are the taproots. Lateral roots nearly always extend past the width of the limbs and can easily extend for 150 feet or more. This tree is extremely sensitive to even minor water drawdown.

Russian Olive: Russian Olive trees have a shallow root system and their lateral spread is usually 3 to 4 feet or more beyond their limb width.

Willow: Willows do not have a large taproot although sinker roots can be quite deep (6 to 8 feet deep).

Chinese Elm: Chinese Elms may have roots that extend 4 feet down into the ground. The lateral width of their roots usually extends well beyond the width of their limbs.

ROOT SYSTEMS - BUSHES

Sagebrush: Average size sagebrush generally has a taproot 4 to 6 feet deep. Larger sagebrush may have taproots 15 feet deep with lateral roots 10 to 16 feet long.

Fourwing Saltbush: Taproots up to 20 feet deep.

CONTACTS:

Information obtained from the offices of the U.S. Forest Service, the Bureau of Land Management, and the Denver City Forester, Denver, Colorado; Colorado State University Horticulture Department, and the Rocky Mountain Station, Fort Collins, Colorado.

CASE STUDY

LEMON DAM–CONCRETE SPILLWAY INLET WALL FAILURE

Dam:	Lemon
Project:	Florida
State:	Colorado
Type:	Zoned earthfill
Completed:	1963
Functions:	Irrigation, flood control, recreation
Crest length:	1,360 feet
Hydraulic height:	215 feet
Active capacity:	39,030 acre-feet
Surface area:	622 feet

Design Characteristics: Lemon Dam is a zoned earthfill structure with a structural height of 284 feet and a crest length of 1,360 feet. The spillway is on the right abutment of the dam and consists of an approach channel, concrete inlet structure, concrete ogee crest section, open concrete chute, concrete stilling basin, and outlet channel discharging into the Florida River.

Evidence: The first sign of a problem with the spillway concrete wall was in July 1966, when minor deflections were noted. Additional deflection occurred during the winter of 1966-1967. During the winter of 1971, an additional I to 1-1/2 inches of deflection occurred, with the total deflection now being 4-1/2 inches on the right wall and 5-1/2 inches on the left wall. Some rupturing was also noted at the base of the right inlet wall. During April 1973, at the request of the Acting Regional Director, the Director of Design and Construction at the E&R Center conducted a special examination of the spillway entrance walls. Total deflections had now reached up to 12 inches, and repair was recommended within the year.

Incident: Beginning in 1966, progressive deflections were noted in both concrete spillway inlet walls. By 1973, deflections as much as 12 inches were apparent; and on May 14, 1973, the left wall failed and fell into the spillway. The incident did not cause any operational problems.

Causes: Lemon Dam receives significant snowfall and experiences large variations in surrounding temperatures with extremely low temperatures. In 1967, it was believed that due to the temperature variations, surface water was entering between the concrete walls and the backfill; and subsequent freezing action was causing the walls to deflect.

Upon examination of the exposed reinforcement at the base of the wall stems during the reconstruction, it was discovered that only one-third of the required face wall movement reinforcement extended into the footings. In addition, for the left face wall that had overturned, only stubs of moment reinforcing bars protruded above the footing, and only two or three of these showed the characteristics of tension failure. It appeared that most of the bars did not extend continuously into the face wall, and two-thirds of the bars did not extend into the wall footing. Lack of proper reinforcement was probably the major cause of the failure of the spillway entrance walls.

Remedy: Since it was determined the deflections were caused by freezing action in the impervious soil blanket behind the concrete walls, a portion of the backfill was excavated and a pervious blanket of soil was placed beneath a layer of impervious soil. Several pipe drains extending to the base of the wall penetrated the pervious backfill. Insulation board, 1-1/2 inches thick, was placed between the back face of the walls and the pervious backfill. Seepage wells to collect the pipe drainage and heaters were installed at the base of the walls to allow drains to operate through the winter months. The curved inlet walls were replaced with adequate reinforcement anchoring the walls to the footings.

Conclusion: Although above-normal runoff was expected when the wall failed in 1973, sufficient storage capacity and outlet works capacity existed to avoid using the spillway. Both inlet walls were replaced and no major interruption of service was experienced. The replacement walls have experienced no problems.

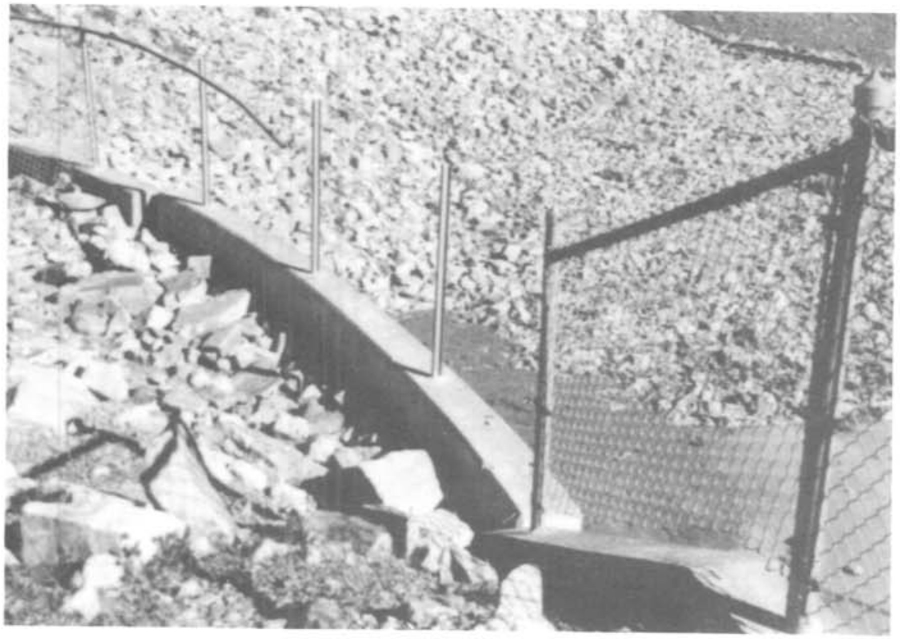

Photo No. 1. - Lemon Dam

Right wall of spillway approach channel. Deflection of the wall damaged the fence.

9/17/73

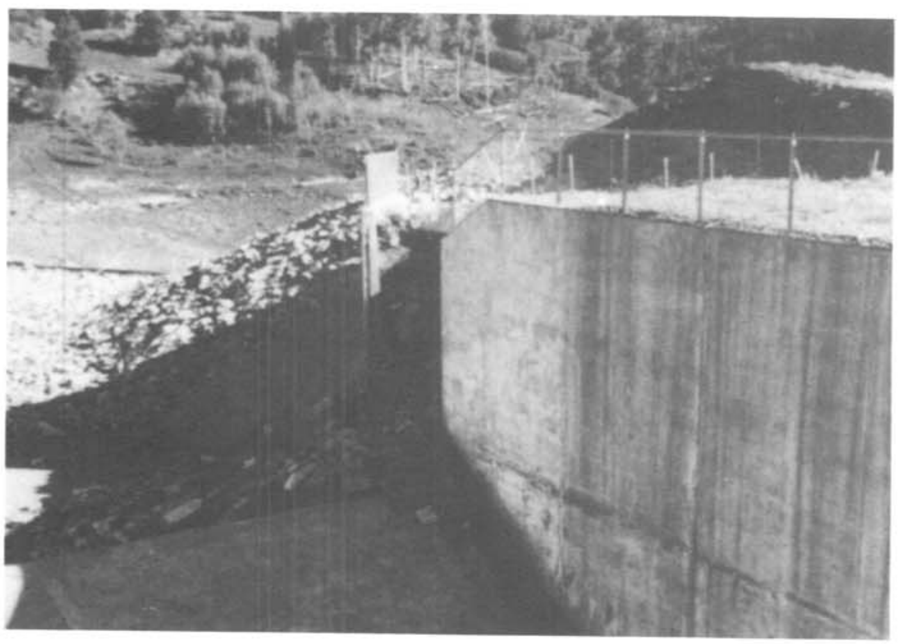

Photo No. 2. - Lemon Dam

Left wall of spillway approach channel. Failure was result of repeated cycles of frost action on saturated fill.

9/17/73