PAP-610

OWYHEE DAM MODIFICATION DESIGN ANALYSIS
HYDRAULIC CONSIDERATIONS

By

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UNITED STATES GOVERNMENT

memorandum

Memorandum

TO : Chief, Concrete Dams Branch, D-3110

DATE: Denver, Colorado June 11, 1992

FROM : Chief, Hydraulics Branch

SUBJECT: Owyhee Dam Modification Design Analysis (MDA) (Safety of Dams)

We have prepared the enclosed discussion of the hydraulic considerations for the MDA of Owyhee Dam. Addressed in this discussion are the effects of dam overtopping and increased head and tailwater on the existing morning-glory spillway. If any further assistance is needed, please contact Kathy Frizell at 236-6159.

Brent W Mefford

Enclosure

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OWYHEE DAM MODIFICATION DESIGN ANALYSIS (MDA)
HYDRAULIC CONSIDERATIONS

by Kathleen Frizell

Introduction

There are two major areas of consideration that need to be addressed from the hydraulic standpoint at Owyhee Dam. These are:

- The effects of the overtopping flows on the dam and the dam abutments and foundation

- The effects of the increased head and tailwater on the existing morning-glory spillway

The following analysis is based on flood routing information from Technical Memorandum No. SOD-OWYD-220-1 that addresses passage of the new probable maximum flood (PMF) through the existing structures at Owyhee Dam. The conclusions from this memorandum were that the dam would be overtopped with or without rehabilitation of the outlets and that the dam would be structurally able to withstand overtopping. The advantage of rehabilitating the outlets is that the amount of overtopping would be reduced and reservoir evacuation could then occur in an acceptable timeframe. No mention was made in the memorandum about the ability of the existing spillway to safely pass the flows associated with the increased reservoir water surface of the PMF.
These data were used in the analyses:

- Normal water surface El. 2670 ft
- New maximum water surface El. 2680.2 ft
- Top of dam El. 2675 ft
- Top of parapet El. 2678.67 ft
- Fixed morning-glory spillway crest El. 2658 ft
- Existing design head over spillway crest = 10.2 ft
- Total maximum head over the spillway = 22.2 ft
- Hydraulic height of dam to river channel at the dam toe 325 ft

- Spillway discharge at normal water surface = 32,200 ft^3/s
- Spillway discharge at maximum water surface = 42,700 ft^3/s
- Discharge coefficient for flow over the dam C = 2.63
- Overtopping head H = 1.5 ft over the parapets (assuming the parapets and posts remain during overtopping)
- Discharge over the dam = 4,030 ft^3/s
- Dam crest length = 833 ft

Overtopping

An overtopping analysis was performed to determine the erosion potential at the dam toe and abutments. The analysis assumed that maximum overtopping occurred. If the amount of erosion predicted at maximum overtopping is acceptable, then no modification to the existing outlets would be required to lessen overtopping.

The overtopping analysis consists of several parts:

- Trajectory of the jet and corresponding impact areas
- Velocity of the jet over locations on the dam abutments and at the intersection with the tailwater
- Possibility of jet breakup during the fall
- Dynamic pressure head acting on the river channel at the dam toe
- Possibility for reduced pressure under the nappe adversely affecting the top of the dam

Trajectory calculations were made using equation 14-3, page 361 of Open Channel Hydraulics (Chow, 1959). These calculations show that the jet will impinge on the upper portion of the dam face above the 0.626 slope and on the rock abutments. The jet will impinge about 95 ft down from the parapet on the dam face and on the abutments where the dam intersects the rock. The jet will impinge on the rock on the left abutment between Sta. 0+00 and Sta. 1+80 and on the right abutment between Sta. 6+40 and Sta. 9+00.

The amount of expected jet breakup during the fall through the atmosphere was analyzed by relating the total drop to the initial jet diameter (Ervine and Falvey, 1987). If the ratio of the fall to the jet thickness is 50 to 100 or more, then full breakup of the jet would be expected. For Owyhee this ratio is about 63 after 95 ft of drop. Therefore, the solid core of the jet should be broken up upon impingement on the dam. Impacts on the rock of the abutments should be minimal given the short fall distance. Unless the abutment rock is very unstable, the small amount of sheet flow across the areas should not produce a hazard to the dam stability. Dynamic pressure fluctuations which often produce major erosion would not be a factor because of the predicted deterioration of the jet core.

Minimal erosion damage should be expected during dam overtopping, and the structural integrity of the dam should not be affected. Therefore, the dam outlets do not need to be rehabilitated for use during the PMF to reduce the overtopping flows.

The small overtopping head will tend to cling to the face of the dam and could produce subatmospheric pressures and nappe oscillations. The posts on the top of the parapet should provide adequate aeration of the nappe, thus eliminating stability problems at the top of the dam during overtopping.

Existing spillway

The following are concerns dealing with the existing morning-glory spillway when passing flows under increased head and downstream tailwater:

- Discharge conditions over the crest when operating under heads that exceed the design value by 12.2 feet.

- Flow conditions in the tunnel portion with 10,500 ft^3/s of additional discharge.

  - Is the tunnel geometry such that free flow will be maintained throughout the tunnel or will the tunnel pressurize due to the increased discharge and/or tailwater?

  - If the tunnel pressurizes, is the tunnel lining sound enough to withstand the pressures associated with the transition from free flow to pressure flow?

  - If not, will a failure of the tunnel lining produce instability of the right abutment and possible failure of the dam?

The early model study report (Lowe, 1944) gives discharge rating curves that show the spillway crest submerging and throat or orifice control beginning at reservoir El. 2672, 14 ft above the crest. At this point, the flow capacity of the spillway is greatly reduced, but the laboratory studies did investigate flow rates nearly as high as the new PMF. The value of 42,700 ft^3/s at 22.2 ft of head can be easily extrapolated from the discharge curves in the report. Therefore, the spillway has the capacity to pass the PMF, but it appears from the model study that control will switch from the crest to the throat or the tunnel. The model study did not provide information on flow conditions in the throat or the tunnel; therefore, historic flows and hydraulic computations need to be used to determine these flow conditions.

Historical records show the spillway has operated up to 15,000 ft^3/s in 1936 and 1940 and to 18,000 ft^3/s in 1952. No damage to any portion of the spillway was reported from the followup inspections. Early prototype spillway flows were documented in hydraulic laboratory reports (Bradley, 1948; Lowe, 1944; and Warnock, 1938). Observations of the spillway during these early spills revealed blowback up the spillway through the jet at the crest for very low flow rates and intermittent "explosions" from the end of the tunnel that sent spray to the top of the canyon walls. This second observation of air pockets being expelled from the end of the tunnel indicates that, even with flow rates significantly less than the original design discharge, a transient hydraulic jump was present in the tunnel. Other than these early observations about flow conditions, information about the tailwater in the downstream river channel is unavailable for Owyhee Dam. Photographs with no spillway flows show the tailwater filling at least half the tunnel. Perhaps the dam operator or the Project Office could be contacted for further data regarding more recent spillway discharges.

The model study discharge curves and the prototype observations during spillway releases both indicate that the end of the tunnel will control, causing pressurization of the entire spillway. The stability of the right abutment of the dam is dependent on the ability of the spillway tunnel to withstand the pressures occurring during the transition from free flow to pressure flow and the pressure associated with full pressure flow. The considerably higher flows and tailwaters of the PMF would assuredly pressurize the downstream tunnel section.

The downstream tunnel of a morning-glory spillway is usually designed to operate under free flow. The computations are based on the spillway geometry, required discharge and head, and the tailwater in the river channel downstream. It

appears that the tunnel for Owyhee Dam is greatly influenced by the tailwater elevation and begins transitioning from free flow to pressure flow at a discharge less than the original design discharge. The transition from free flow to pressure flow is accompanied by make-and-break siphonic action and potentially large pressure fluctuations due to the presence of the hydraulic jump in the tunnel. The tunnel lining would experience pressure fluctuations, vibration, and surging along lengths of the tunnel that range from subatmospheric to fully pressurized. The largest pressure fluctuations occur at the end of the tunnel as the trapped compressed air is expelled. These large pressure fluctuations could cause concern for the integrity of the end of the tunnel. Data on pressure fluctuations in tunnel spillways are quite limited. Hydraulic model studies on the Hoover Dam tunnel spillways indicated instantaneous pressure fluctuations at the end of the tunnel ranging from vapor pressure to available energy head (Frizell, 1985). How to relate these measured dynamic pressures to the prototype is still not fully understood (Frizell, 1985) and requires some judgement and would be difficult to use in analysis. Final analysis of the tunnel flow and lining stability is being completed by the Tunnels Section of the Water Conveyance Branch.

Conclusions

During historical operation, the tunnel portion of the spillway at Owyhee Dam may have already experienced the pressure fluctuations that would be of concern during transition from free flow to pressure flow. Inspections have revealed that the tunnel lining has not been damaged. Further information on any more recent spillway releases could help determine this issue. Therefore, if the spillway tunnel is able to structurally withstand the fully pressurized condition, then the performance of the spillway should not be a concern when addressing the safety of the dam. The design team has determined that even if the very large pressure fluctuations at the end of the tunnel occur, the end of the tunnel is far enough downstream that, even if it fails, the stability of the rock abutment or the dam would not be affected.

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