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Hydro Review
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Controlling the Flow

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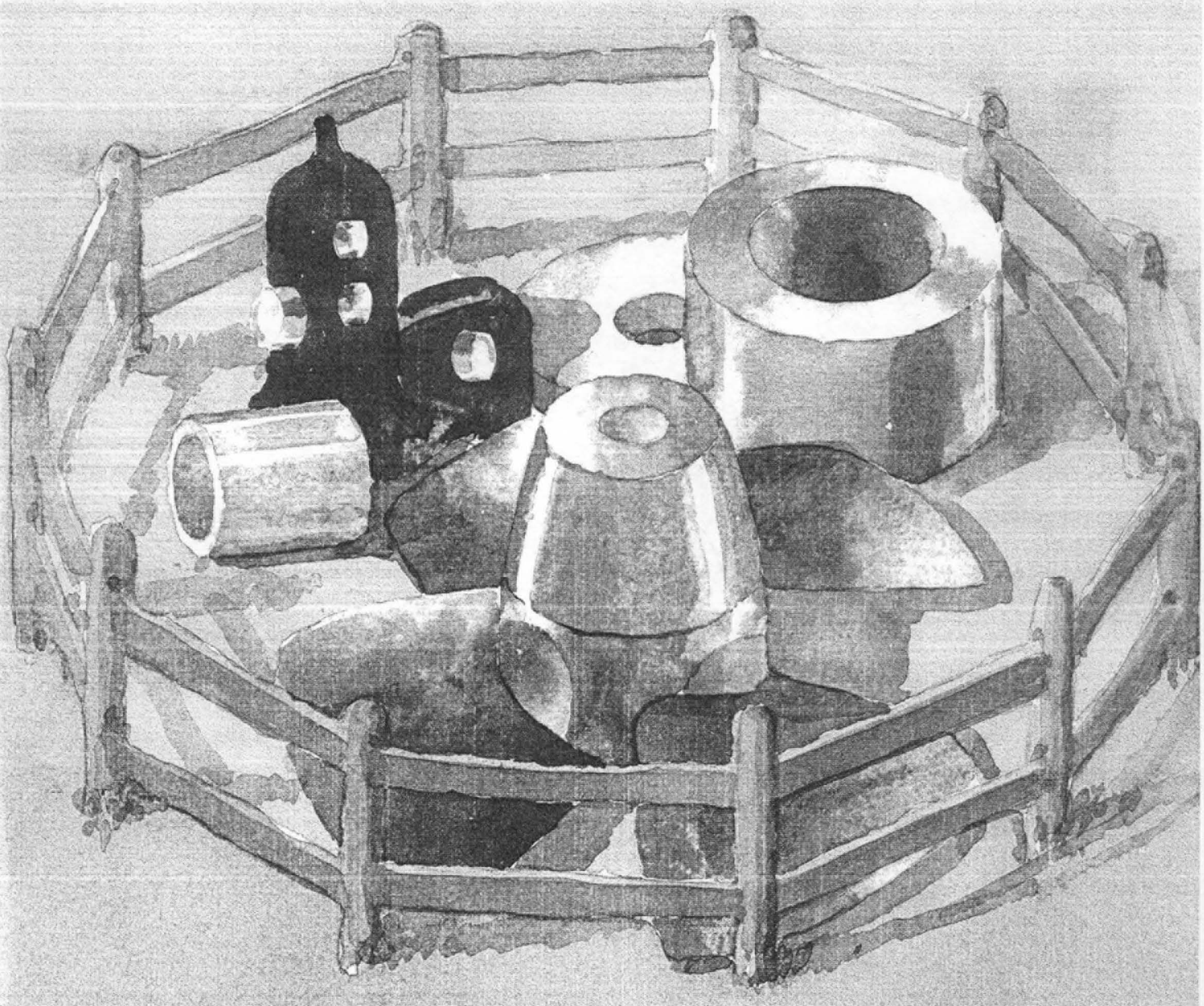


Preventing Abrasion Damage in Stilling Basins: Controlling the Flow

During the past three decades, about 40 Type II stilling basins — a standard design for dams by the U.S. Department of the Interior's Bureau of Reclamation — have sustained damage caused by a persistent recirculating flow pattern.

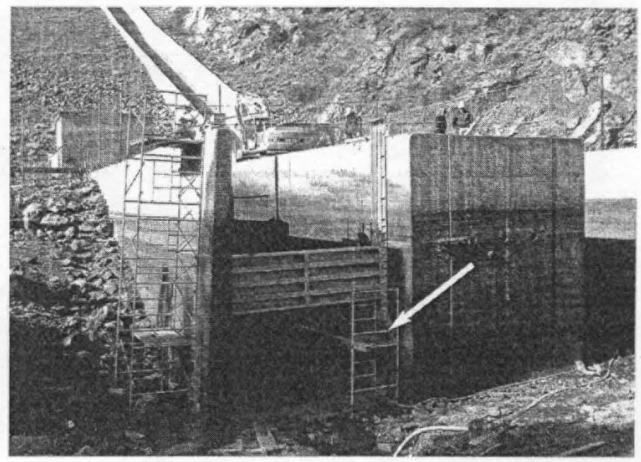
Research sponsored by Reclamation's Science and Technology Program and conducted by the Water Resources Research Laboratory (WRRL) in Denver, Colo., determined that materials such as sand, gravel, and rock are being carried up into the basins by a reversing flow produced over the basin end sill during normal operation. Once these materials are in the basin, turbulent flow continually drags the materials against the concrete, causing severe damage. The drawings in Figure 1 show this reversing flow and corrected flow.

Often, abrasion damage has occurred to the extent that reinforcing bars are exposed. Reclamation repairs the damage, only to see the same damage occur again within one or two operating seasons. As a result, Reclamation spends hundreds of thousands of dollars to repeatedly repair this type of damage.

Research conducted by WRRL demonstrated that the installation of engineered flow deflectors can improve flow distribution significantly to minimize or eliminate the potential for materials to be carried into stilling basins. This increases the life of the basin, and reduces or eliminates the need for repairs.

Mason Dam demonstration

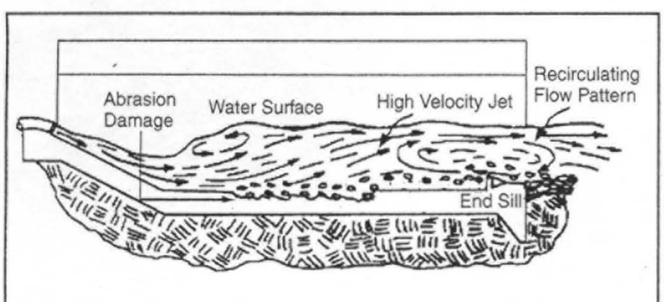
Reclamation engineers determined that the Mason Dam outlet works stilling basin, a typical Type II basin with a long history of abrasion damage, was an excellent candidate for a field demonstration of this technology. Once proven, the technology would be directly applicable to many other facilities of similar design.



A flow deflector (arrow) installed over the end sill in the outlet works stilling basin at Mason Dam in Oregon is designed to minimize reverse circulation that carries abrasive materials into the basin, causing extensive damage to the basin's concrete.

Mason Dam, completed in 1968, is located on the Powder River in Baker County, Ore., approximately 17 miles southwest of the city of Baker. Reclamation constructed the dam to store water used for irrigation. The outlet works is normally operated from about April through September to provide flow in the Powder River. A spillway adjacent to the outlet works, which has its own stilling basin, provides additional spill capacity, though it has never spilled since the dam was built. Mason Dam's Type II stilling basin — a widely- used standard application — is a hydraulic jump energy dissipation basin designed for flows released from high dams and large canal structures. The basin contains chute blocks at the upstream end and a dentated (notched) sill at the downstream end to help shorten the jump and to exert a stabilizing effect.

Reclamation engineers constructed a 1:7 physical model in the WRRL laboratory to investigate hydraulic conditions in the Mason Dam outlet works stilling basin and to study the relationship of deflector size, angle, and position to flow patterns over the basin end sill. Following the model study, WRRL engineers and technicians designed and built a full-sized flow deflector prototype for the Mason Dam stilling basin.



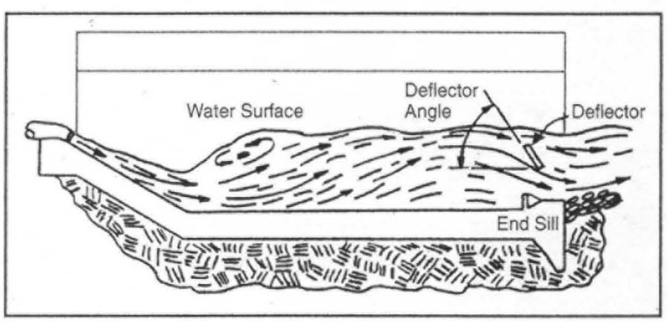


Figure 1: The drawing on the left shows the recirculating flow pattern produced during normal operation of a Type II stilling basin, a standard Bureau of Reclamation design. Reversed flow carries abrasive materials into the basin, where turbulent flow continually drags the materials against the basin's concrete, causing severe damage. Installation of a flow deflector (right drawing) over the end sill eliminates the reversed flow and abrasive action.

As of February 2003, field tests were underway to verify the effectiveness of the design and to develop information for more widespread applications.

Details of the model investigations

In their laboratory work, engineers used the physical model to evaluate hydraulic conditions in the stilling basin and downstream apron area for the range of operating conditions expected in the prototype. All dimensions reported here are prototype scale dimensions.

Data obtained from velocity and dye streak tests identified the location and thickness of the main jet rising from the basin floor and the transition point where velocities change from a downstream direction to an upstream direction for each condition tested. These transition points were used to determine the optimal elevation for the deflector. In addition, similar data determined the most effective deflector angle, height, and lateral locations within the basin, thus optimizing flow conditions over the range of operating conditions expected. Scientists investigated deflectors from 3 to 5 feet high, spanning the width of the basin, and angled from 40 to 90 degrees within a full range of vertical and lateral locations in the basin.

In addition to designing a model for Mason Dam, Reclamation engineers used these investigations to develop a method for generalizing the deflector design for similar basins based on velocity profiles measured at the end of each basin. For future installations, velocity data measured on-site can be used to determine the optimal design and location for a deflector specific for a particular basin.

Prototype design and installation

The final deflector design for the Mason Dam outlet works stilling basin is 5 feet high, angled between 80 and 90 degrees, and positioned about 11 feet above the basin invert above the end sill. The Baker Valley Irrigation district installed the prototype deflector at Mason Dam in October 2002.

The basin operated in the summer of 2003 with the deflector lowered into optimum position as determined from the model study. Field tests in August 2003 verified that the deflector significantly improved the hydraulic flow patterns over the basin end sill and kept the basin predominantly free from entraining materials. Tests also showed that flows less than 300 cubic feet per second (cfs) can be used to flush materials from the basin that may have entered the basin from other sources.

In addition, basins of this type normally show signs of abrasion damage within one to two operating seasons after repair. In an underwater inspection of the basin in August 2003, divers noted that new concrete poured in 2002 "was very smooth and in excellent condition, with no signs of any erosion or wear." Reclamation plans further tests and inspections in August 2004.

Reclamation has applied for a patent for this technology, and is seeking a company interested in producing and marketing the device under license.

— By Leslie Hanna, hydraulic engineer with Reclamation's Water Resources Research Laboratory in Denver, Colo., and the principal investigator on this project. She may be contacted at (1) 303-445-2146; E-mail: lhanna@do.usbr.gov.