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Otter Lake Dam Drilling and Chemical Grouting

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This *Water Operation and Maintenance Bulletin* is published quarterly for the benefit of water supply system operators. Its principal purpose is to serve as a medium to exchange information for use by Bureau of Reclamation personnel and water user groups in operating and maintaining project facilities.

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For further information about the
Water Operation and Maintenance Bulletin, contact:

Jerry Fischer, Managing Editor
Bureau of Reclamation
Inspections and Emergency Management Group (86-68470)
PO Box 25007, Denver, CO 80225-0007
Telephone: (303) 445-2748
FAX: (303) 445-6381
Email: jfischer@do.usbr.gov

Cover photograph *– Outlet works slide gate closed with the lake just starting to pass over the spillway crest.*

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Otter Lake Dam Drilling and Chemical Grouting

This article documents the drilling and chemical grouting of Otter Lake Dam to reduce leakage along lift lines and through the foundation and abutments. The dam is located within Blue Ridge Parkway Park near Big Island, Virginia. Work was started on June 1, 2005, and completed by June 30, 2005.

Otter Lake Dam was probably constructed in the late 1950s. It has a reservoir capacity of approximately 45 acre-feet at the spillway crest. The dam is a concrete gravity dam with a masonry rock overlay on the crest, the upper several feet of the upstream face, and the entire downstream face. The crest, having a length of approximately 144 feet and a width of approximately 3.5 feet, is at elevation 652.5. This crest length includes the overflow spillway within the center of the dam. The dam has a structural height of approximately 26 feet and a hydraulic height of approximately 24 feet. The upstream face has a slope of 1H:12V (horizontal:vertical), and the downstream face is stair-stepped at a variable slope. The downstream face is nearly vertical near the dam crest, and the face transitions to slope at approximately 1H:3V at the downstream toe.

Drilling

A five-person team from the Bureau of Reclamation commenced work on June 1, 2005. Initially, the crew installed temporary fall protection and marked locations for drill holes along the top of the dam starting at the right abutment and proceeding to the left abutment. Access ramps were built to allow safe and efficient movement on the top of the dam, and "permanent" fall protection was installed from the right abutment to and around the gate operator platform. The crew later removed this permanent fall protection as requested by park personnel. After the first 40 feet of fall protection was completed, drilling began on the first core hole at station 0+10 (10 feet from intersection of crest with right abutment) and on the dam centerline at a 75-degree angle toward the right abutment.

Hilti DD 250 E 110-volt electric stand-type drills using AW (1⅞-inch) size, diamond-impregnated coring bits were used to bore the grout holes. Two ⅝-inch-diameter holes were drilled through the cap stone to a depth of 16 inches using a hammer drill at each grout hole location. Then drop-in style anchors were installed, and the drill was anchored with ½-inch all thread rods, nuts, and washers. Setup on each hole varied due to the irregular surface of the granite cap rock. Wood and metal shims were used to level the base and stabilize the drill prior to startup.

The drill holes were started with a 3-foot 7-inch long starter barrel, and as the hole deepened, a 7-foot 6-inch production barrel was put into service. All holes were cored through the dam and approximately 5 feet into the foundation rock. Drill hole orientation consisted of a fan pattern into the left and right abutments and vertical holes through the maximum section. A submersible pump, lowered into the lake, supplied fresh water for drilling and cleanup of the site.

Fifteen production holes were drilled on approximately 10-foot centers starting at the right abutment and proceeding to the left. The drilling was staggered to keep the drills separated by about 40 feet. Water hoses and electrical cords were tied off to the top rail of the temporary fall protection during drilling. This action helped to eliminate possible trips and falls, electrical shock, and other mayhem and helped in overall housekeeping of the job site.

The concrete varied throughout the structure in strength, quality, and drillability. Areas near the slide gate appeared somewhat softer than other areas. In general, the dam-to-rock contact was good, but there was a weak bond from approximately 65 feet in from the left abutment through to 90 feet.

Several breakdowns of the drills occurred, and during those periods, team members removed debris from the downstream face of the dam (including large logs, limbs, moss, grass, and large rafts of leaf debris).

Grouting

As each drill hole was completed, a mechanical packer was installed at the top. Each packer was about 2 feet long and had a variable length of ½-inch polyvinyl chloride (PVC) pipe with a foot valve attached below the packer and reaching to the contact between concrete and foundation rock. This system allowed grout to be injected under a maximum pressure of 100 lb/in^2 at the contact near the bottom of the hole, which allowed travel of grout up the hole to points of intersection with leaking lift lines. The foot valve allowed point injection at depth and eliminated inflow of water into the PVC grout line, which could have caused dilution of the hydrophillic grout. Low injection pressures (less than 15 lb/in^2) were maintained during grouting. Standing water was present in virtually all drilled holes with the exception of the holes located in the weak contact area 65 to 95 feet in from the left abutment (in the drop spillway area). Those holes actually "sucked" water and had higher grout takes.

Prior to grouting, a 5-minute water test was performed at 10 lb/ in^2 with Rhodamine dye. This was done to wet up the joints, to give an idea of the possible chemical grout take, and to detect areas of leakage to allow precaulking prior to injection.

Grouting was accomplished using an air-powered B-10 rocker-style multiratio pump to inject hydrophillic polyurethane resin. The resin was Strata-thane 504 manufactured by Strata-tech of Des Moines, Iowa. The chemical grout and mix water were chilled to 46 degrees to slow the set time and to ensure good grout travel. Grouting began on the far left abutment area, working toward and finishing on the right abutment.

Grout takes were generally high and particularly high in the holes near the abutments. Leakage of grout was observed at the upstream and downstream faces and 5 to 10 feet down from the top of the dam at several locations. These leaks were controlled by intermittent grouting and extensive caulking using oakum, which was pounded into cracks and holes on the downstream rock face. The total amount of chemical grout pumped at a 1:1 ratio was 80 gallons, combined with 80 gallons of water to equal a total of 160 gallons of material pumped to refusal at 15 lb/in^2.

Prior to grouting, water could be heard traveling around the ends of the dam, but after injecting the abutment fan patterns, all downstream leaks ceased, and running water was not discernible. **Most notable by everyone on site was the immediate rise in the lake level upon completion of the right abutment fan holes**.

Demobilization took several days. Park personnel required that the permanent fall protection be removed, and all temporary fall protection measures were removed and core holes and fall protection holes plugged with previously cored material (cemented into the hole) when advantageous to do so. Drilled anchor holes were filled with mortar to match the color of the surrounding dam surface as closely as possible. Packers were removed from the holes, and the holes were then filled with concrete and a broom finish applied.

Coring for Concrete Testing

Several 6-inch-diameter cores were drilled in an attempt to provide mass concrete samples for compression testing in Denver, Colorado; however, it was difficult to provide representative pieces that were long enough to meet test criteria. Most, or all of, the entire concrete core taken appeared to be surface mortar into which the granitic stone facing on the top of the dam was set. It was not representative of the concrete core of the dam.

Budget and Time

The budget was tracked daily from start to finish, and the field team conferred with Denver biweekly on budget and schedule. The costs associated with mobilization, fall protection, drilling, grouting, demobilization, and reporting were approximately $258,000. The project was completed within the projected time.

Weather

Throughout the job, rain, electrical storms, and violent weather in the afternoons would occasionally shut down operations. Temperatures were in the 65 to 98 °F range, and humidity was commonly 85 percent and above.

Safety

The team had a safety and work assignment meeting each morning, and aside from minor scratches, no reportable injuries occurred. The buddy system was in effect, and everyone looked out for each other to ensure we were adequately hydrated. With temperatures ranging from 60 to 98 ºF (mostly 98 ºF) and 85 to 95 percent humidity, it was important to be aware of everyone's condition. Sanitary facilities with a hand wash station were onsite and rented from a local source. Team members working over the downstream side of the dam wore a harness and were tied off.

A temporary fall protection system was in place at all times. Ground fault circuit interrupter (GFCI) switches were used at all times. Sunscreen and insect repellent were made available to everyone.

Poisonous snakes were identified, and the rocky areas they frequented downstream of the dam were hosed down with lake water. This kept these areas cold and wet to encourage them to stay away.

Insects (ticks, chiggers, mosquitoes, gnats, and wasps) were a continual source of annoyance, and 100-percent DEET and "Avon Skin So Soft" were used to deter them.

Conclusions

1. Water flows through the dam and abutments were significantly reduced or eliminated.

2. Grout takes were high in the abutment areas (left and right), and there were lower grout takes in the spillway overflow area (around station 0+70 to 0+100).

3. The amount of water traveling over the spillway increased significantly.

4. Historic and aesthetic qualities of the dam were maintained.

5. All facets of the program were accomplished safely and on time.

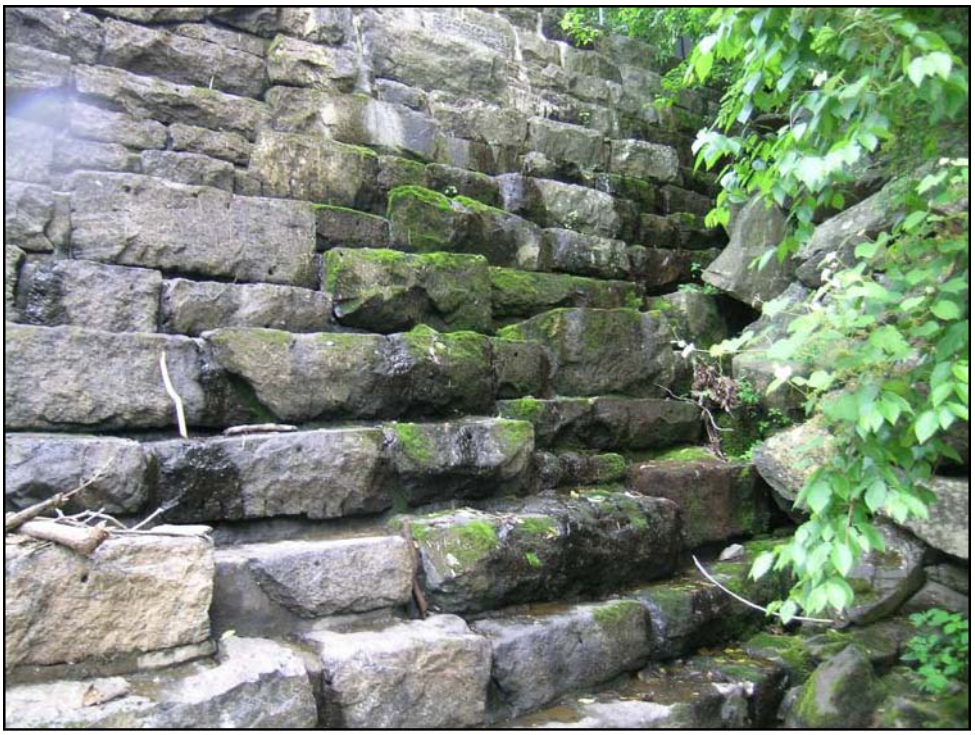

Figure 1.—Left abutment before grouting (June 2, 2005).

Figure 2.—Downstream face (near right abutment) before grouting (June 2, 2005).

Figure 3.—Right abutment and outlet works before grouting (June 2, 2005).

Figure 4.—Support trailer (June 3, 2005).

Figure 5.—Installing temporary fall protection (reduced flow over the spillway due to increased releases through outlet works) (June 3, 2005).

Figure 6.—Installing fall protection and constructing ramps (June 3, 2005).

Figure 7.—View from right side looking downstream at gate operating platform with fall protection in place (June 5, 2005).

Figure 8.—Fall protection in place. Plastic covers the drill hole and baseplate (June 5, 2005).

Figure 9.—View toward left abutment showing fall protection, step, and debris rafts (June 5, 2005).

Figure 10.—View of left abutment from right side of Otter Lake (June 8, 2005).

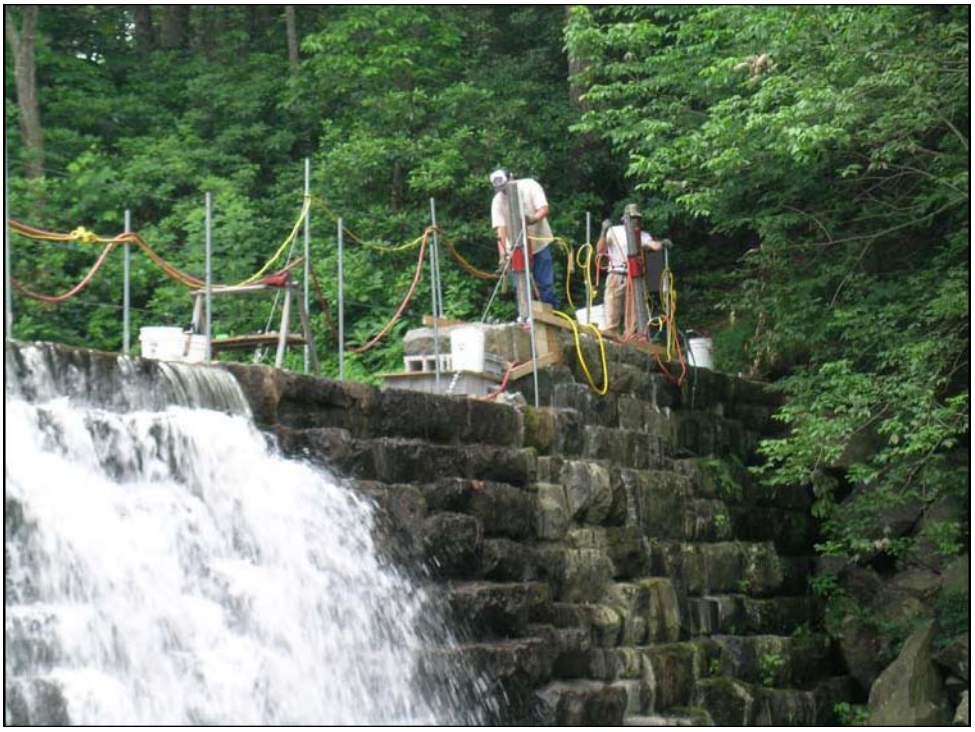

Figure 11.—Drilling left abutment fan holes (June 8, 2005).

Figure 12.—Work station for core barrel disassembly (June 8, 2005).

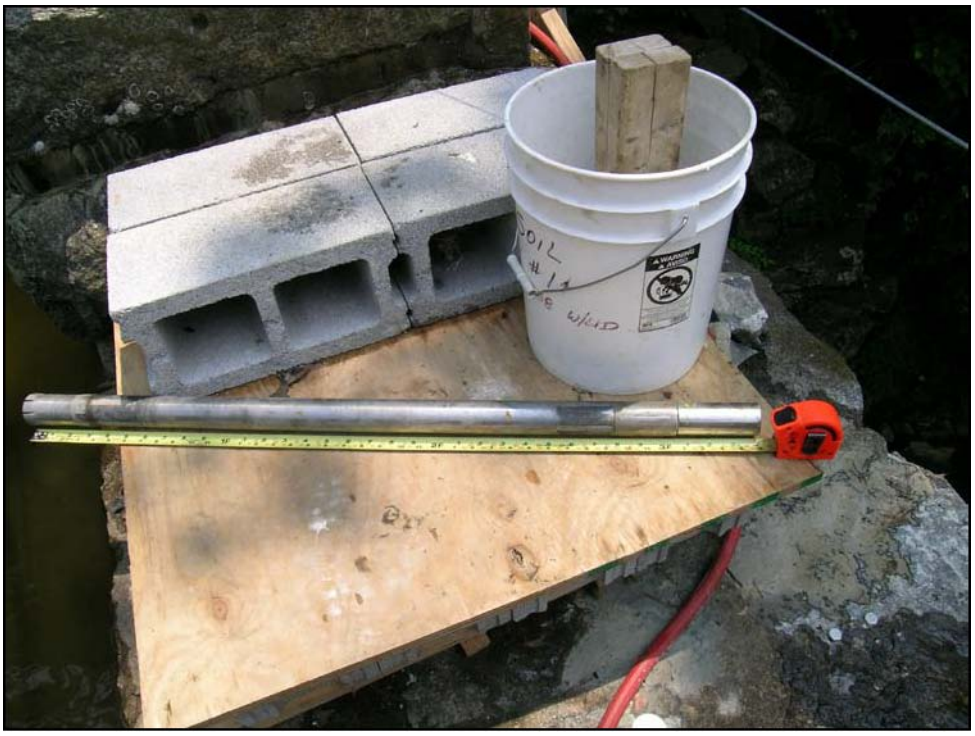

Figure 13.—Starter barrel (June 8, 2005).

Figure 14.—Drill water exiting through upstream cracks (June 10, 2005).

Figure 15.—Drilling near left abutment (June 10, 2005).

Figure 16.—Drilling 75-degree fan hole on the left abutment (June 15, 2005).

Figure 17.—Drilling in spillway section (note ramp to facilitate access at the right) (June 20, 2005).

Figure 18.—Drilling 6-inch core for testing (June 20, 2005).

Figure 19.—Drill core. Note foundation rock (far left), dental concrete (center), and concrete with larger aggregate (far right) (June 15, 2005).

Figure 20.—Six-inch cap rock core (June 22, 2005).

Figure 21.—Water over the spillway and free of debris (June 22, 2005).

Figure 22.—Setting a packer, and B10 rocker grout pump (June 23, 2005).

Figure 23.—Tightening up a mechanical packer in preparation for grouting (June 24, 2005).

Figure 24.—Button head connector attached to top of packer (June 23, 2005).

Figure 25.—Packer set and ready for injection (June 27, 2005).

Figure 26.—Rental compressor supplied air for the grout pump (June 27, 2005).

Figure 27.—Caulking leaks during grouting on the left abutment with oakum and wood wedges (June 27, 2005).

Figure 28.—Grouting completed, face drying up, gate closed, and the lake is beginning to fill more rapidly (June 29, 2005).

Figure 29.—Grouting complete. Outlet works slide gate closed with the lake just starting to pass over the spillway crest (June 29, 2005).

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The purpose of this bulletin is to serve as a medium of exchanging operation and maintenance information. Its success depends upon your help in obtaining and submitting new and useful operation and maintenance ideas.

Advertise your district's or project's resourcefulness by having an article published in the bulletin—let us hear from you soon!

Prospective articles should be submitted to one of the Bureau of Reclamation contacts listed below:

Jerry Fischer, Bureau of Reclamation, ATTN: 86-68470, PO Box 25007, Denver, CO 80225-0007; (303) 445-2748, FAX (303) 445-6381; email: jfischer@do.usbr.gov

Vicki Hoffman, Pacific Northwest Region, ATTN: PN-3234, 1150 North Curtis Road, Boise, ID 83706-1234; (208) 378-5335, FAX (208) 378-5305

Steve Herbst, Mid-Pacific Region, ATTN: MP-430, 2800 Cottage Way, Sacramento, CA 95825-1898; (916) 978-5228, FAX (916) 978-5290

Albert Graves, Lower Colorado Region, ATTN: BCOO-4846, PO Box 61470, Boulder City, NV 89006-1470; (702) 293-8163, FAX (702) 293-8042

Don Wintch, Upper Colorado Region, ATTN: UC-258, PO Box 11568, Salt Lake City, UT 84147-0568; (801) 524-3307, FAX (801) 524-5499

Dave Nelson, Great Plains Region, ATTN: GP-2400, PO Box 36900, Billings, MT 59107-6900; (406) 247-7630, FAX (406) 247-7898