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The Water Operation and Maintenance Bulletin is published quarterly for the benefit of those operating water supply systems. Its principal purpose is to serve as a medium of exchanging information for use by Bureau personnel and water user groups for operating and maintaining project facilities.

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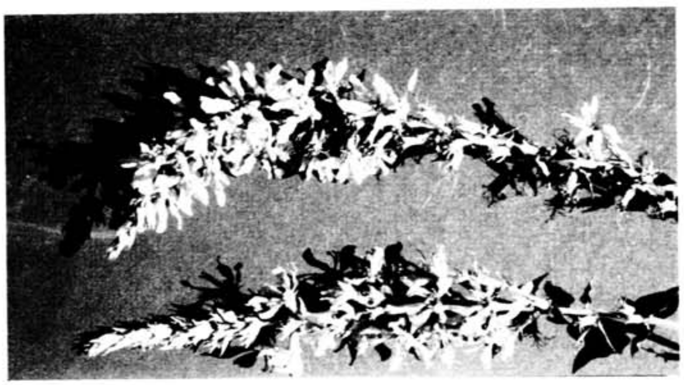

Cover photograph:

Purple loosestrife – Flowers occur on magenta or purplish-pink spikes. One spike can produce as many as 300,000 seeds.

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PURPLE LOOSESTRIFE IN RECLAMATION WATER SYSTEMS

By Fred L. Nibling, Jr.[1]

Purple loosestrife is an emergent perennial aquatic weed which is rapidly becoming a major threat to Reclamation water systems and associated wetland ecosystems. In water conveyance systems, it impedes flow and drainage to the point of completely closing channels. In wetlands, it competes with and excludes all other desirable wetland vegetation such as cattails and rushes, resulting in dense, pure stands. It was introduced into North America in the early 19th Century and has since proliferated along water ways of Canada and the Northern United States. Purple loosestrife produces rather attractive magenta-colored flowers on plants that grow from a few feet to 12 feet tall. In a growing season, a single plant is capable of generating several million seeds which are about the size of finely ground black pepper. Seeds are transported by water, wind, man, waterfowl, and wildlife.

Potential Problem for Reclamation Projects

Western water systems appear to be ideal habitat for purple loosestrife. Impact of the weed on water system operations is major and formidable to manage. The plant grows along the water line in the same habitats as cattails, common reed, and reed canarygrass. An ironic result is the displacement of these difficult to manage weeds by one of even greater tenacity. Water ways may become restricted and even closed, and ditchbank strength and integrity may be damaged as a result of dense weed growth. Seeds are often carried downstream by water currents with many germinating in transit. Plant fragments are also spread by water to become rooted and established in new sites. Vehicles and machinery working in growing areas may become contaminated with seeds and disburse them to new locations. Purple loosestrife is currently encroaching on many sites under Reclamation management. In the Columbia Basin Project, its range has expanded since the early 1960's to 23,000 acres of the Winchester Drain, and currently occupies 55,000 acres of desert wetlands. The value of these areas as a wetland resource has become severely diminished. A major seed source for spread of the weed downstream has also been established.

Impacts on Wetlands

Sites most vulnerable to purple loosestrife are wetlands. The variety of organisms, or species diversity, is an important indicator of wetland health. An important attribute of purple loosestrife is that it grows to the exclusion of all beneficial vegetation. There is no significant habitat value of purple loosestrife to natural fauna except perhaps as a pollen source for bees. The growth of tall domineering stands poses an impenetrable barrier to wildlife and recreation. Infestations may be so dense as to prevent passage to water by young broods of ground-nesting ducks. A common pattern in the Western United States is for the weed to be spread along Reclamation water ways which often interconnect or are otherwise associated with wetland areas.

Control

Current control options include mechanical techniques (excavating, cutting, and manually pulling) and herbicides. Resistance to approved herbicides, abundant seed reserves, and ready regrowth of fragments

[1] Fred Nibling is a Research Botanist, Bureau of Reclamation, Environmental Sciences Section, Research and Laboratory Division, Denver, Colorado.

make it difficult for current management practices to control the plant. The following integrated pest management (IPM) techniques have been used successfully by Mr. Craig Conley, Conservation Agronomist, in the Columbia Basin Project:

Step 1.–Treat with herbicide when plants are in mid-bloom, usually in late July or early August. While some seeds may continue to be formed and survive treatment, this timing is necessary to promote uptake and basipetal translocation of the herbicide which kills the roots. Plants should be sprayed completely with a mix of 1 percent glyphosate and 0.5 percent surfactant. Remember to use the registered aquatic site formulations of both these materials and to avoid overspray onto desirable vegetation.

Step 2.–Burn the dense dead canes during the following winter to kill some of the seeds and to provide clear access for spraying new seedlings.

Step 3.–Treat the newly germinating seedlings in the spring with an approved formulation of 2,4-D. The use of 2,4-D is advantageous since young seedlings are controlled well by this safe and inexpensive herbicide. Also by using a selective herbicide, reestablishment of desirable grass species is promoted. This process may require multiple applications due to the sheer magnitude of the seed reserves.

Biological control is a method which uses one living organism to manage or regulate levels of an undesirable one. A major reason for purple loosestrife expansion in North America may be the lack of effective natural predators and diseases. Biological control, using insect predators from their native European range, is a control method currently being investigated. In concept, this strategy of using a natural predator to control a host is elegant and highly desirable.

Potential benefits include selective removal of purple loosestrife by host specific organisms; i.e., ones which attack only the target weed, leaving desirable native plants unhindered. Living, self-replicating organisms are less expensive than repeated herbicidal treatments. Living organisms are also often mobile enough that they are better able to locate small isolated pockets of weeds than people applying spot treatments. In a further turning of the tables, insect predators are commonly introduced clean and free of their own natural predators and diseases. Organisms being investigated include a variety of insects and diseases. There are currently three insects which have been approved for field testing by a special Government technical advisory group and the U.S. Department of Agriculture – Animal and Plant Health Inspection Service (USDA-APHIS). This new technology is currently in early stages of field development, and such operational biological control methods may not be available for at least 5 years.

Action Needed Now

Purple loosestrife is perfectly suited for invasion and expansion along Reclamation's waterways. Many fear that the slow developmental phase of the weed has passed and that this country has now entered an exponential rate of spread. Each year's passage allows the plant to become more firmly entrenched in its present range with copious seed reserves dramatically increasing the amount of material available for dissemination to new sites. As stewards of the natural ecosystems both within and associated with Reclamation projects, it is crucial that the rampant spread of this noxious weed be addressed by those responsible for its management.

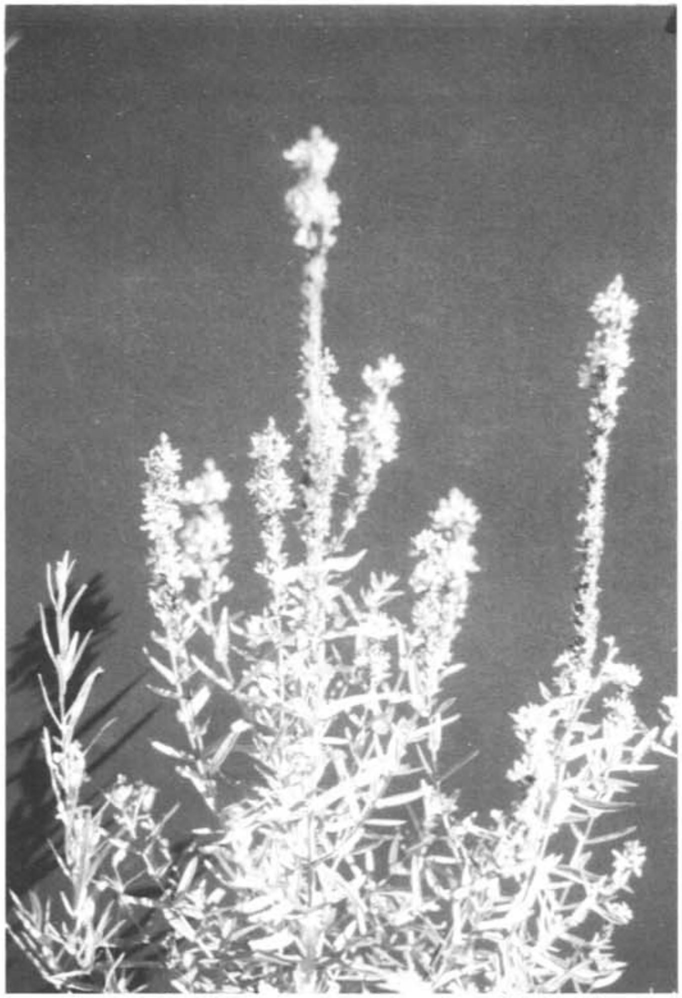


Figure 1.–Plants range from 2 to 23 feet in height. They are most easily located during the peak of the flowering season which occurs between mid-July to mid-August.

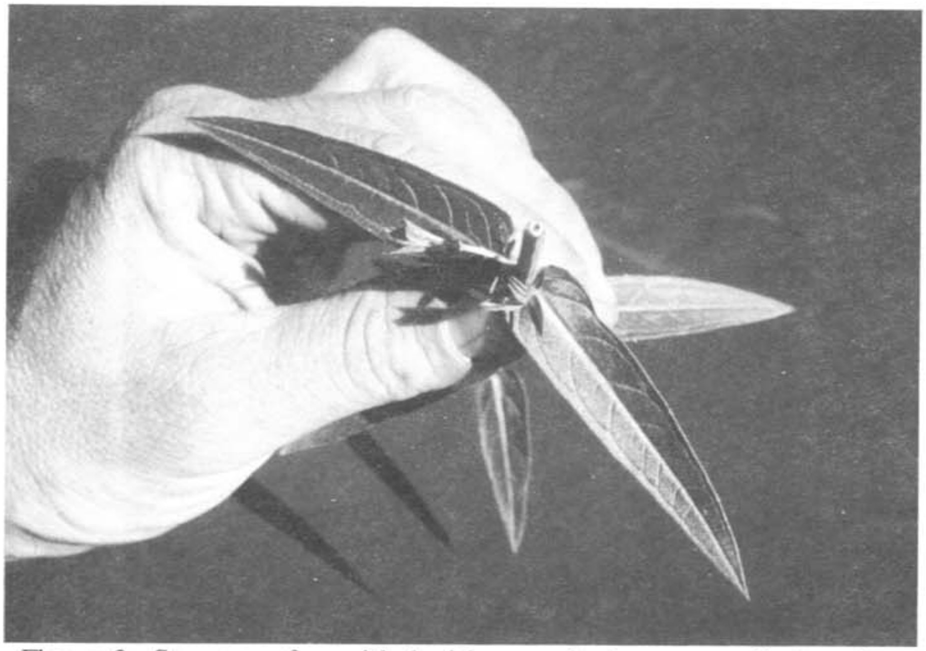


Figure 2.–Stems are four-sided with opposite leaves usually in pairs. In winter, the stems or canes dry to a caramel-tan coloration.

Figure 3.–The Winchester Wasteway in the Columbia Basin Project has approximately 23,000 acres of dense purple loosestrife. This once valuable habitat for waterfowl and other wildlife has been severely degraded by the invasion of this plant.

SALVAGING A SEVERELY SILTED INTAKE STRUCTURE

by Mark J. Beutler[1]

The Hyrum Project, an irrigation project completed by Reclamation (Bureau of Reclamation) in 1935, includes the 116-foot-high Hyrum Dam which is located in northern Utah's Cache Valley about 70 miles north of Salt Lake City. The Dam is a rolled earthfill structure that impounds a reservoir of 19,000 acre-feet. The dam stores water from the Little Bear River which heads in the rugged 9,000-foot-high Wasatch Mountains east of Hyrum, Utah. The Hyrum Project has 21 miles of canals and a pumping plant. The project serves 6,800 acres of privately owned and intensely cultivated land.

The South Cache Water Users Association (Association) maintains and operates the project. Over the past several years, the Association has reported a diminished outlet works capacity for Hyrum Dam. Two underwater dives in 1981 and 1987 confirmed that the outlet works intake structure was severely silted. Silt deposition was obstructing the lower 8 feet of the 10-foot-high structure's exterior. The 1987 divers reported:

> "It appears that the bank of the lake is washing or slumping in and covering the intake structure. It is possible that the flow through the structure is the only thing that is keeping the intake from being covered over totally. If a high debris situation or a landslide is encountered, the intake structure could be rendered nonfunctional."

To remediate the problem, the Association signed a repayment contract with Reclamation in April 1990 for an R&B (rehabilitation and betterment) loan to rehabilitate the outlet works, spillway, and distribution facilities. The Association employed a private engineering consulting firm to prepare designs and specifications and to oversee construction activities for the R&B Program.

Reclamation's Hyrum Project R&B Report had proposed that the most economical long-term solution to the problem would be to extend the intake structure by constructing an additional intake on top of the existing structure. The usable storage capacity of Hyrum Reservoir would not be affected by this proposal since the top of the extended structure would remain well below the dead storage pool elevation. The intake structure was examined to verify its structural condition, soundness, and dimensions. Construction was completed in November 1990.

The newly constructed extension is 10 feet high with a base dimension of 13 feet 8 inches by 15 feet 8 inches. The structure consists of a frame fabricated of 8- by 8-inch structural steel tubing which is 5/8 inch thick, with removable trashracks constructed of 6- by 3/4-inch steel bar placed vertically on 6-inch centers (figure 1). Following fabrication and prior to underwater assembly, the extension metalwork was cleaned by sandblasting and painted with three coats of coal-tar epoxy.

Divers working under water from a barge at depths of between 40 and 50 feet cleaned the existing intake structure and installed the new extension in less than 1 month. Trashracks were removed from the top of the original structure and discarded. The 3- to 6-foot accumulation of silt and cobble inside the intake structure was removed by divers who jetted the material through an 8-inch-diameter pipe, using the airlift method.

[1] Mark Beutler is a Civil Engineer, Operation and Maintenance Branch, Bureau of Reclamation, Provo Projects Office, Provo, Utah.

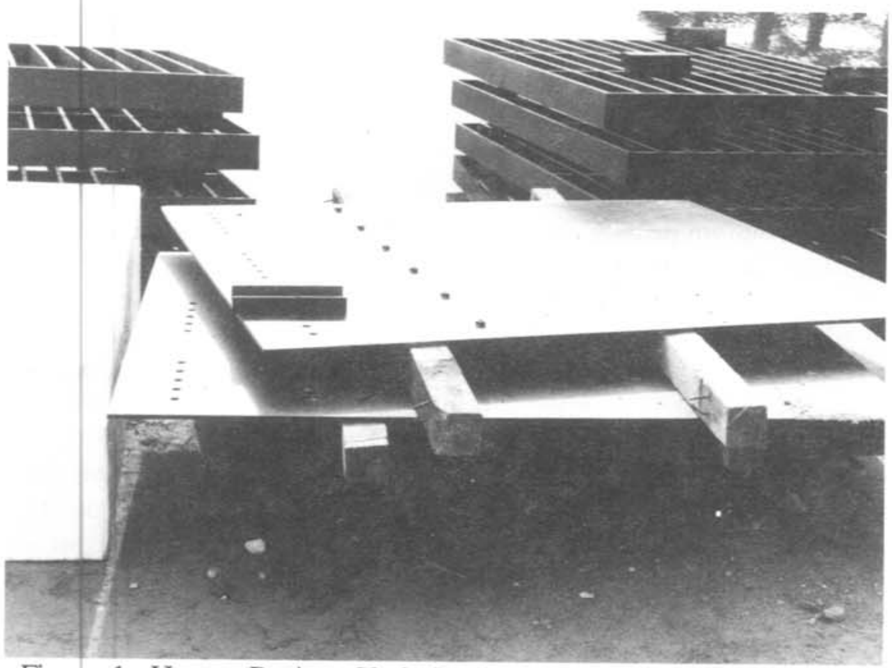


Figure 1.–Hyrum Project, Utah. Intake structure extension components are stacked at boat ramp prior to installation. The steelplates in the foreground were fabricated as permanent coverings for all vertical openings of the original trashracks. Trashracks for the new structure extension are stacked in the background.

An air compressor mounted on the barge floating above the structure supplied air under pressure for the jetting process. This method of removal was slower than anticipated because of frequent plugging of the pipe with cobble. The unanticipated cobble most likely originated from the adjacent steep abutment from which the rock had rolled through the trashracks, either during construction or over the 55-year period of reservoir operation.

A larger volume of material than anticipated had to be removed, because the silty material outside the structure continually sloughed into the structure during the cleaning. To keep new sediment from filling the structure following cleaning, 1/2-inch-thick steelplates were lowered from the barge into the structure and bolted in place to cover all vertical openings of the original trashrack.

Two airbags having a 12-ton lifting capacity were attached to the frame of the intake extension during assembly in the shallow water at the boat ramp (figure 2). The extension was then transported to the intake area by a barge equipped with a 20-ton-capacity crane which lowered and placed the new structure on top of the existing structure (figure 3). Four specially designed anchor brackets were used to bolt the extension in place, as illustrated in the isometric drawing (figure 4). With the new structure in place, water released from the reservoir flows through the trashracks of the new extension and drops vertically into the original intake structure and, in turn, through the outlet works tunnel.

Figure 2.–Hyrum Project, Utah. New intake structure extension being transported by barge for installation at the outlet works intake.

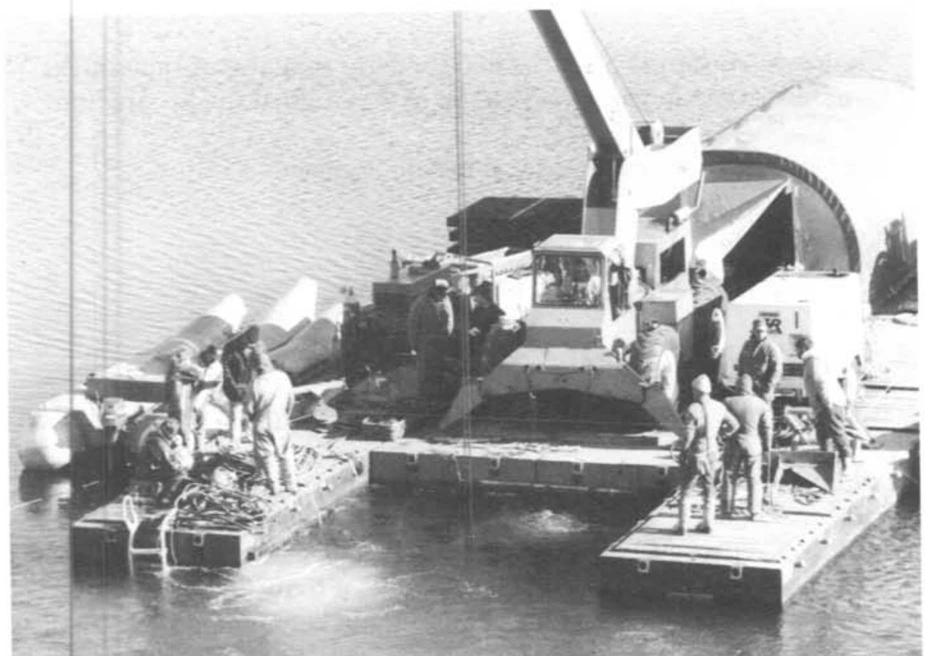


Figure 3.–Hyrum Project, Utah. Installation of new intake structure extension in progress. The crane shown in the photograph is lowering the intake structure as it is guided and secured in place by divers.

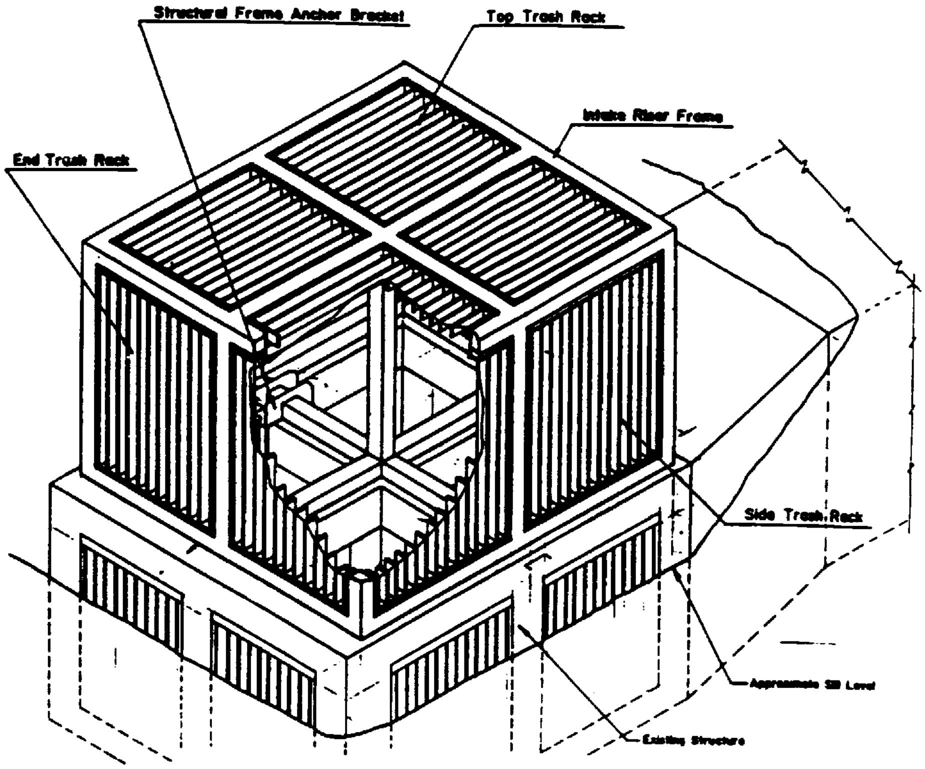


Figure 4.–Hyrum Project, Utah. Isometric drawing of new intake structure extension mounted on top of the original intake structure.

Construction costs for the intake structure extensions are itemized as follows:

Fabrication of extension	$ 48,000
Installation of extension	50,000
Cleaning of original intake structure	106,000
Total cost	$204,000

Cleaning soil materials from the original intake structure accounted for over 50 percent of the total cost.

Two methods were initially considered for removal of the material: (1) the airlift method, and (2) the diver-controlled clamshell bucket. The airlift method was selected to avoid possible damage to the structure from the bucket. When the selection was made, the size and large amount of cobble found inside the structure was not expected. In view of the volume of rock material removed, a substantial cost savings could most likely have resulted had the clamshell bucket method been used.

This modified intake structure has now operated through two irrigation seasons with no apparent problems.

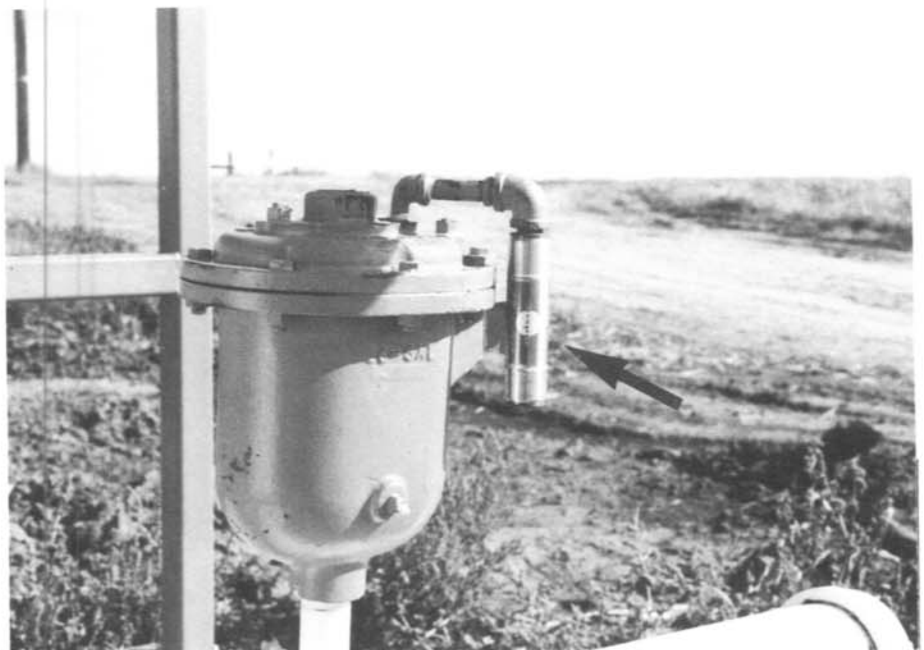
THERMALLY ACTIVATED VALVE FOR FROST PROTECTION[1]

First Permanent Solution

The St. Mary River Irrigation District (SMRID) is using a new method for frost protection of air valves on irrigation pipeline turnouts. Thermally activated valves (TAV) are being installed on new air valve installations to prevent damage from early spring or late fall frosts.

In the fall of 1988, the SMRID began experimenting with various methods to find a solution. Miles Kasun, irrigation technologist with the district and Ron Renwick, district engineer, felt that some type of insulation may be the answer. "We tried wrapping the valves with insulation but this didn't work very well. Next we tried insulated jackets similar to those used in the oil fields but again they weren't the answer," says Kasun.

Our engineering staff designed, built, and used a steel insulated canister that fit tightly over the valve. These work well, says Kasun, but must be taken on and off for inspection.



Arrow points to TAV installed on air valve. Preferred location of TAV is now off the top of valve to ensure flow through entire air valve.

Thermally activated valves or "TAV's" respond to temperature differentials by means of a thermal actuator placed in the fluid stream. When the ambient air temperature drops, the glycerin piston begins to expand and water dribbles from the "TAV." As water seeps through the air valve and "TAV," warmer water is drawn from the buried pipeline and warms the piston causing the valve to modulate closed. Full flow through the "TAV" is seldom reached. The "TAV" constantly modulates between ambient and fluid temperatures.

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"TAV's" are available in several set points, says Kasun. The St. Mary River Irrigation District is using "TAV's" with a –1 °C set point. This allows the valve to start opening at approximately +3 °C and continue to open and be fully open only if the fluid temperature reaches –1 °C.

Warren Bridge, supervisor of the eastern block of the district, began installing the "TAV's" in 1990. He has 18 of the valves in operation now and has experienced no problems." This past year I opened up all 18 air valves to see if any damage had occurred to any of the mechanisms. None was evident," he concludes.

The district has installed 55 of the TAV's and plans on more.

For more information, please contact Miles Kasun, Irrigation Technologist, St. Mary River Irrigation District, PO Box 278, Lethbridge, Alberta T1J 3Y7; telephone (403) 328–4401.

FROM THE FARM PERSPECTIVE[1]

Pipeline Laterals: Bane or Blessing?

Connecting a pump suction intake directly into a pipeline can have its problems says Wally Chinn, P.Eng., head of the irrigation development section, Alberta Agriculture. Of the more than 2,600 kilometres (1,600 miles) of canal rehabilitated under the Irrigation Rehabilitation and Expansion Program, one-third [or almost 850 km (530 miles)] are reconstructed utilizing some form of pipeline. This is not to mention those additional pipeline works developed within the districts outside of the program.

The opportunities and operating circumstances that pipeline deliveries provide both the district and the irrigator are varied. However, when irrigators eliminate their pumping ponds or sumps and connect their pump suction intakes directly to the lateral pipeline, circumstances can arise. These are often overlooked and can impact the successful operation of the pumping unit. This is particularly true where electric pumping units are used.

Often, says Chinn, a previously adequately sized pumping power unit (withdrawing water from an open sump), is then connected to the pipeline lateral with "free pressure" available. On the other hand, a new pumping unit can be installed without full knowledge of the pipeline operating pressures. In these cases motor overload, nuisance trips, or premature burnout can occur.

Figure 1, says Chinn, may held explain why this "free energy or pressure" causes motor overload. The curves presented are typical and unique to both a pumping unit and the system the pump delivers water to. Curve "A" is the Performance Curve for the pump in question. Curve "B" is the System Curve for the sprinkler system it is supplying. Both curves reflect their hydraulic relationships to flow rate (Q) and pressure (H). Where the two curves cross (pt. "X"), that is where the whole system will operate [e.g., 60 L/s at 43 metres of head (951 gal/min at 141 feet of head)]. Curves "M1," "M2," and "M3" are another part of the pump performance rating graphs which combine the specific pump efficiencies to yield the size of the required power unit (motor). In the case of pt. "X," the pump will have to be connected to a minimum of a 50 hp motor as the real power demand is approximately 48 hp.

In addition, figure 1 includes the System Curve "C" for the lateral supply pipeline to be installed. It indicates a "maximum" operating pressure available to the pump of approximately 8 metres (26 feet) of head. Because of this "bonus" pressure into the pump, the pipeline system curve represents a "booster" situation and as a result is additive to the pump performance curve. This means that the actual output from the pumping unit is now as indicated by pt. "Y," where the System Curve "B" crosses the boosted Pump Curve "D" [e.g., 67 L/s at 47 metres of head (1,062 gal/min at 154 feet of head)].

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Figure 2.–Electric pump site.

When it comes to electric motors, a slight oversizing of the unit will cost negligibly more to operate. When a pump requires 48 hp input power, that is all there is for power consumption regardless of whether a 50 hp or a 60 hp unit is used. This is another case where it is important that both the district and the water user have all the facts to facilitate effective irrigation development.

For more information, contact Wally Chinn, P.Eng.; Head, Irrigation Development Section; Alberta Agriculture; Agriculture Centre; Lethbridge, Alberta T1J 4C7; telephone (403) 381-5864.

Editor's Note: There are over 377 registered landslide areas identified on Reclamation projects that have the potential to affect operations. This article offers some control methods that have been used successfully by the Colorado Department of Transportation, which could be adapted to Reclamation projects.

USING COMPUTER SIMULATION TO ANALYZE ROCKFALL HAZARDS

Richard D. Andrew[1]

Predicting and controlling rockfall along Colorado Highways has been a high priority for the Colorado geotechnical community. Until recently, predicting rockfall behavior has been extremely subjective at best. Many of the existing rockfall models had proven to be inaccurate and unrealistic in characterizing real-life rockfall occurrences with variable slope conditions. The inability to characterize a rock in motion led Colorado engineering geologists with the CDOT (Colorado Department of Transportation) and the CGS (Colorado Geological Survey) to develop, test and adopt the CRSP (Colorado Rockfall Simulation Program). Since its first release in late 1987, the program has been used to analyze a number of hazardous rockfall areas along the Interstate 70 project through Glenwood Canyon in Colorado. This in turn, has lead to the development of some fairly innovative mitigation techniques. Three devices have undergone extensive testing and have been applied to several locations along this scenic highway with an impressive record of performance.

For years engineering geologists with the CDOT the CGS have attempted to understand the random behavior of rocks in motion and control their effects on Colorado's highways. Many of the mountainous roadways traverse hazardous rockfall areas that exhibit extensive and highly variable slope conditions, which are difficult to analyze in terms of rock velocity and bounding height. During construction of the Interstate 70 project through Glenwood Canyon, these conditions were encountered along with the added concern of minimizing the environmental impact of the mitigation procedures. The CRSP was developed to provide an understanding of rockfall behavior along the highly irregular canyon walls. The program models varying slope conditions and provides information on the velocities, bounding heights, and energies of falling rocks at any point along the slope. This information is critical in determining the most appropriate type and location of mitigation. The program has also been vital as a communication tool between engineering geologists, landscapers, designers, and the administrative staff, providing insightful information on rockfall behavior on proposed grading designs.

With the capability to predict rockfall behavior has come the development of three innovative methods for controlling rockfall. These methods include the **tire attenuator**; the **Colorado flex post fence**; and more recently, the use of **geosynthetics as reinforcement** in rockfall barriers. These systems have undergone extensive field testing and have proven to be effective in controlling rockfall, provided they are installed in the proper location and configuration as determined by CRSP. Several locations throughout Glenwood Canyon have received these systems for mitigation of rockfall hazards. Each of these three devices is relatively low in cost compared to many of the existing proprietary systems.

[1] Richard D. Andrew is the Project Geologist, Glenwood Canyon Project, Colorado Geological Survey, 1313 Sherman Street, Denver CO 80203; telephone (303) 866-2611.

CRSP (Colorado Rockfall Simulation Program)

The CRSP was developed in 1987 by Timothy Pfeiffer, who at the time was an engineering geologist on the Glenwood Canyon Project, and Dr. Higgins of the Colorado School of Mines. The model was created in response to a need by the Glenwood Canyon geotechnical staff for an accurate and reliable tool for modeling rockfall behavior. Existing models, such as the model developed by Arthur Ritchie of the WDOT (Washington Department of Transportation) (1)[2], lacked the ability to correctly predict the behavior of rockfall in highly variable slope conditions while others were awkward and time consuming. Christopher Evans, a graduate student at the University of Arizona, conducted a study comparing four rockfall models. The four models included: CRSP, ROCKSIM (developed by the North Carolina Department of Transportation), Evert Hoek's rockfall program (from Golder Associates), and Arthur Ritchie's ditch design criteria. Evans compared the results from 8 different slopes for a total of 260 rockfall events. He concluded that CRSP was the most consistent in predicting rockfall behavior and recommended its use in designing rockfall catch benches in surface mining (2).

Input parameters.–CRSP was designed to provide bounding heights and velocities of a rock in motion and the amount of kinetic energy the rock possesses at any given location along the slope. This information is necessary in designing the most effective and economical mitigation system.

The model is achieved by converting the physical characteristics of the slope and the properties of the predicted rockfall into a numerical data file. The interaction of these characteristics or factors, as they are referred to by Pfeiffer and Higgins, are varied with each rockfall event (figure 1). This is done to depict the irregularities along the slope and accounts for the randomness of every event.

The most important aspect in predicting rockfall behavior is that of slope geometry. Ritchie documented that slope length and angle are related to velocity, while bounding height is related to slope irregularities (1). CRSP models slope geometry by converting slope survey data into a Cartesian coordinate system, where a change in the slope angle is represented by a different line segment or cell (3).

Another slope geometry factor that greatly influences rockfall behavior is that of surface roughness. Surface roughness is defined as the maximum probable variation in the slope with respect to rock size (4,5). Variations in the slope can significantly alter the angle at which the rock impacts the surface. CRSP randomly alters this impact angle within the constraints set by the maximum slope variation and the size of the rock. Changes in surface roughness, along the slope, will also be represented by discreet cells for each zone.

[2] Numbers in parentheses pertain to references at end of article.

Factor	Parameter
Slope geometry	Slope inclination Slope length Surface roughness
Slope material properties	Elastic coefficients Frictional coefficients
Rock geometry	Rock size Rock shape
Rock material properties	Rock durability Rock mass Elastic coefficients Frictional coefficients

Figure 1.–Parameters determining behavior of rockfall (4).

Other characteristics that affect rockfall behavior are vegetation, soil and rock composition, and bedrock properties (3,6). The values for these characteristics are empirically derived and quantified as the normal coefficient of restitution and the tangential coefficient of frictional resistance. The normal coefficient of restitution represents the resistance perpendicular to the surface, while the tangential direction is parallel to the surface (1,3,5).

The final factors that influence rockfall behavior are the geometry and material properties of the rock in motion. These factors are determined through extensive observations made in the field. A range of rock sizes and types should be used to analyze the rockfall behavior on a slope. Normally the maximum rock size from an event will result in a fairly conservative form of mitigation. However, in some conditions, smaller rocks will tend to have higher bounding heights and may clear a barrier designed for something larger. The program will accurately model these different interactions, but it should be noted that the accuracy of the results is dependent on the quality of the input data.

Data output.–CRSP uses the input data to produce a model which represents the slope and rock interaction. Equations of gravitational acceleration and conservation of energy are applied to the model to describe this interaction (3). Information regarding the behavior of the rock along the slope includes: maximum and average bounce heights, maximum and average velocities, a graphical representation of the slope profile, and the position of the simulated rock every tenth of a second along the slope. Total kinetic energy may also be obtained at any location along the slope.

CRSP provides objective information on rock behavior. Slopes that seem fairly consistent in terms of gradient changes may, in fact, have very distinct zones of acceleration and deceleration or variations in bounding heights. CRSP models these slope variations and accurately predicts their effects on rockfall behavior.

Application

For years, the Glenwood Canyon geotechnical staff, with the assistance of traffic control personnel, have been monitoring rockfall events on and around the I-70 improvement project. A database was established which reflected the areas that received the highest incidence of rockfall. It was from these data, in addition to extensive field review, that led geologists to prioritize the rockfall prone areas. CRSP was used to analyze these areas and to assist in determining the most suitable mitigation system. As a result of this study, CDOT and CGS engineering geologists have developed three innovative and economical methods for controlling rockfall.

<u>Tire attenuator</u>.–Engineering geologists with the CDOT and the CGS developed the tire attenuator system during the calibration of CRSP at the West Rifle test site near Rifle, Colorado (figure 2). It is designed to absorb kinetic energy and reduce bounding heights from incoming rockfall and the return to its original position without maintenance intervention. The system utilizes columns of used tires on rims supported on a series of 3-inch steel pipes. The pipes are attached to a large diameter wire rope that is suspended across a gully or draw. Rock anchors are used to secure the wire rope assembly to bedrock on either side. A facade may be placed downslope of the tire elements consisting of 8-inch wooden posts suspended from a separate wire rope to address aesthetic concerns. Locations that are best suited for the attenuator are in rockfall chutes located near the upper extent of a talus deposit. Rocks detach from the source area and encounter the tire attenuator while energy in the rock is at or near maximum. After impact, most of the energy is absorbed, thus increasing the probability that the rock will be deposited on the talus and will not travel down to the roadway (7).

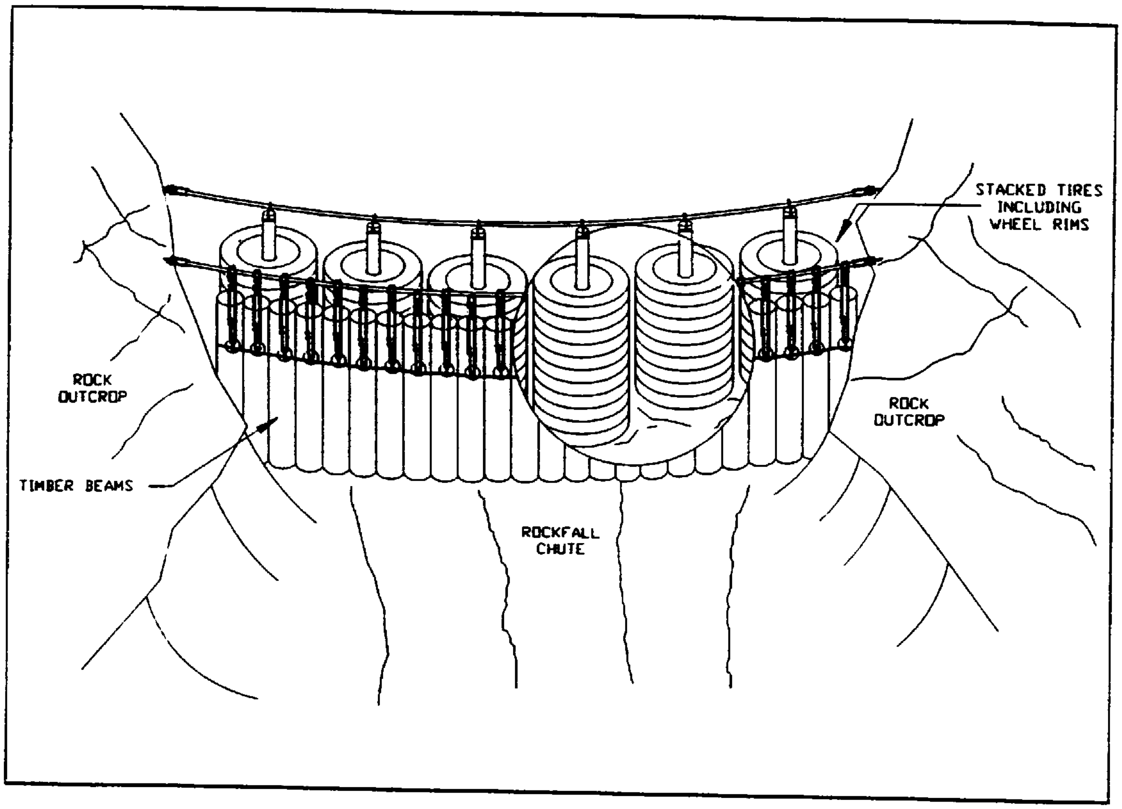

Figure 2.–Tire attenuator.

Until recently, assumptions concerning the tire attenuator's effectiveness have been qualitative, based on video review and field test data. Drs. Graham Mustoe and Peter Huttlemaier at the Colorado School of Mines have an ongoing contract with the Colorado Department of Transportation to analyze the data and provide design guidelines for this system.

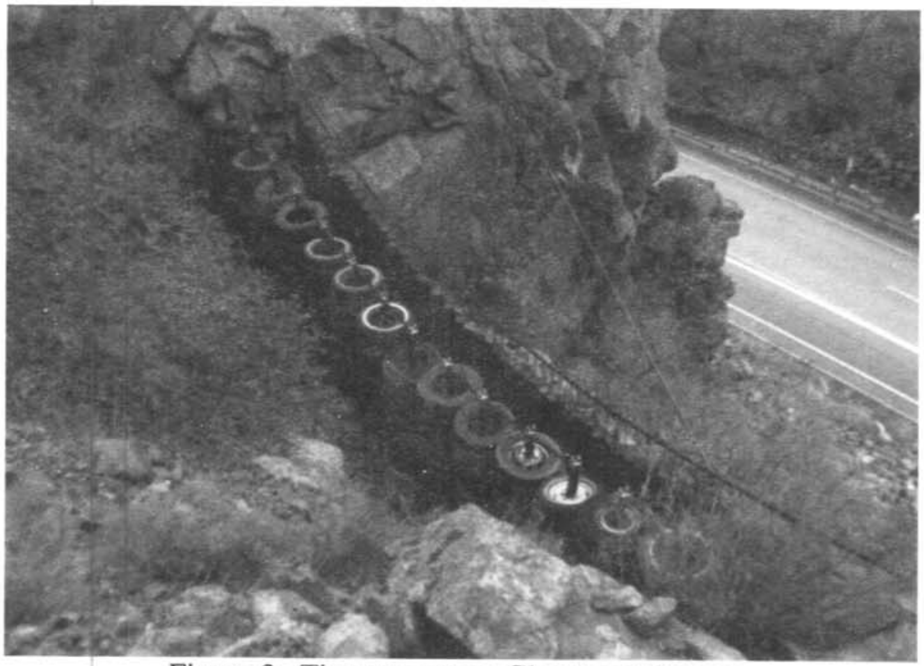

Figure 3.–Tire attenuator–Glenwood Canyon.

CRSP integrates with this system by providing the optimum location based on the incoming velocity and bounding height. The effects of the attenuator on the resulting rockfall may also be determined by analyzing the kinetic energy of the rock at the designated location and subtracting the energy lost to the system. The rock is then restarted from this location with the reduced velocity and modeled for the effects that the remaining slope will have on rockfall behavior. Thus the location of the attenuator may be modified through repeating the program until the desired level of mitigation is achieved.

Three locations in Glenwood Canyon that have been prone for rockfall have received the tire attenuator system with promising results. Although they have been in place for only a few years, early indications are that they are performing well. Due to their remote locations, it was important to select a maintenance free mitigation system such as the tire attenuator. These areas have favorable conditions for this system which include a long run out zone for deposition of material not retained in the attenuator and narrow rockfall chutes which are necessary for the wire rope installation.

Colorado rockfall flex post fence.–Several existing proprietary fences were considered at various locations throughout the canyon, but most of these systems employed components that were highly expensive and difficult to maintain. The goal of the flex post fence was to construct a durable and effective rockfall barrier, and one that utilized surplus and inexpensive elements. This was accomplished by designing a fence that would distribute the energy from a rock impact throughout the entire length of the barrier, and redirect the rock to an energy absorbing collision with the ground.

Prestressing tendons form the fence posts in this system, and are a key component in the design concept (figure 4). Several configurations of the post were tested during the summers of 1989 and 1990. The most durable utilized nineteen, 270,000 lb/in^2, 0.6-inch-diameter tendons grouted in two sections of 3-1/2-inch-inside-diameter steel casing. The lower casing was 4 feet long, and was grouted in to the ground to provide stability to the post. The upper casing was 9 feet 6 inches long and was used above the ground to sheath the tendons and to provide the vertical support for the wire mesh. The flexibility of the posts was provided by leaving 18 inches of the tendons uncased near the ground surface; the overall height of the posts was 11 feet. Maccaferri rock mesh strengthened with steel aircraft cables provides the net material in the fence. The netting was initially placed on the uphill portion of the fence; however, it was found during testing that the fence was more effective when the netting was placed on the downhill side of the posts. It was observed that when the netting was placed on the downhill side, the interaction between the fence and rock was more prolonged, thus enabling more components of the fence to react to the impact.

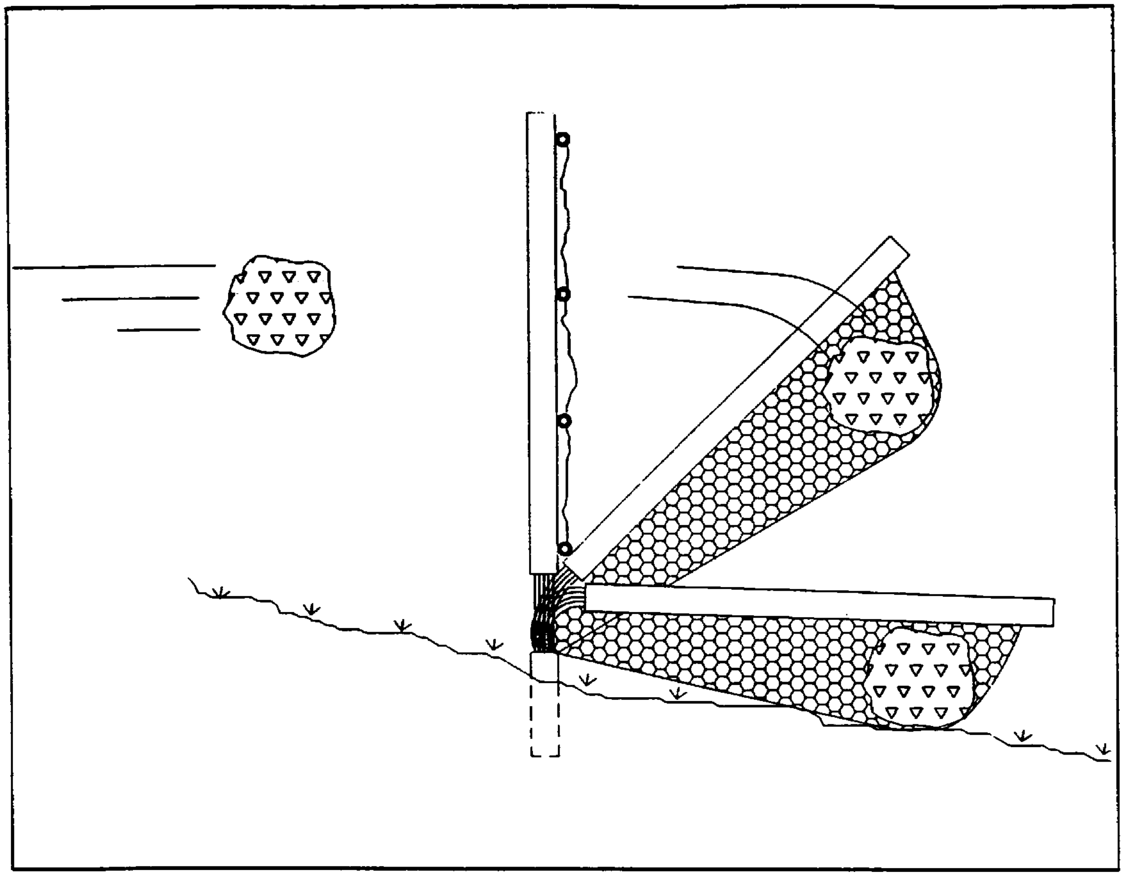

Figure 4.–Colorado flex post fence(8).

Dr. George Hearn of the University of Colorado was retained by the Colorado Department of Transportation to analyze the test data and video footage to evaluate the performance of the fence and provide design guidelines for future fence construction. He developed a large-deformation dynamic analysis program, written in FORTRAN, to analyze the interaction between the rock and the fence system. The study found that for small impacts, the fence structure flexed and absorbed the rockfall energy distributing the load as anticipated. However for larger events, the kinetic energy is initially absorbed through the inertial resistance of the fence as with the smaller impacts, but when the fence becomes taut, the rock is redirected to the ground where the remaining energy is absorbed (8).

The Colorado flex post rockfall fence has been utilized in many locations on the Glenwood Canyon Project, and construction has recently been completed throughout the canyon as part of a comprehensive rockfall mitigation project for the 15-mile-long stretch of I-70. CRSP was used to analyze all of these locations and provide the criteria for location and height. A long-term monitoring program is currently under consideration to evaluate the effects that prolonged usage will have on the performance of the fence.

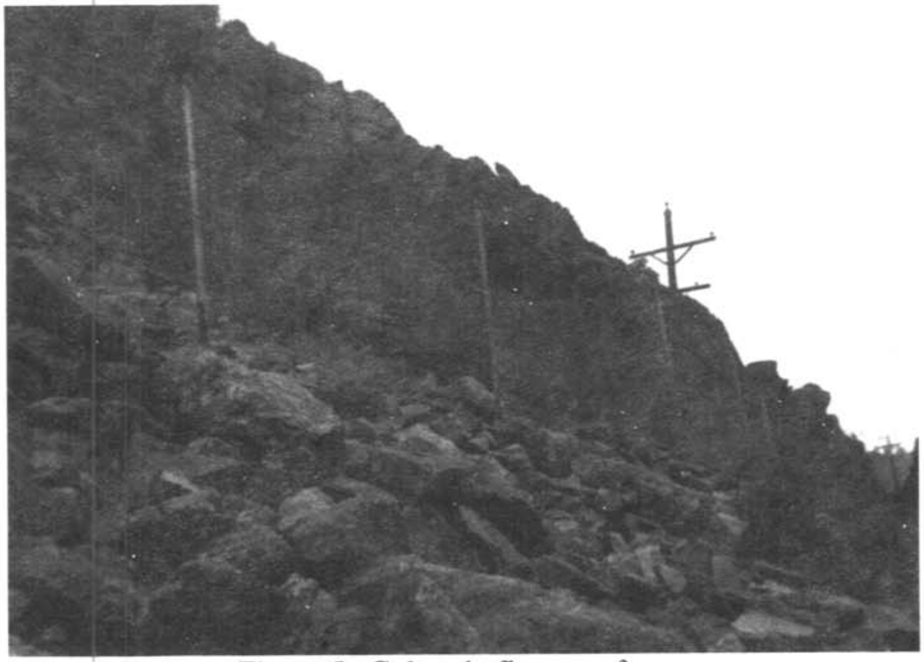
Figure 5.–Colorado flex post fence.

Rockfall occurs at numerous locations throughout Glenwood Canyon; however, one location has been of special concern for years. The area is just west of the Shoshone Dam along the Hanging Lake rest area on-ramp. This area has accounted for a number of rockfall events with two exceptionally large events during the summer of 1985. One event caused several injuries, one of which was nearly fatal.

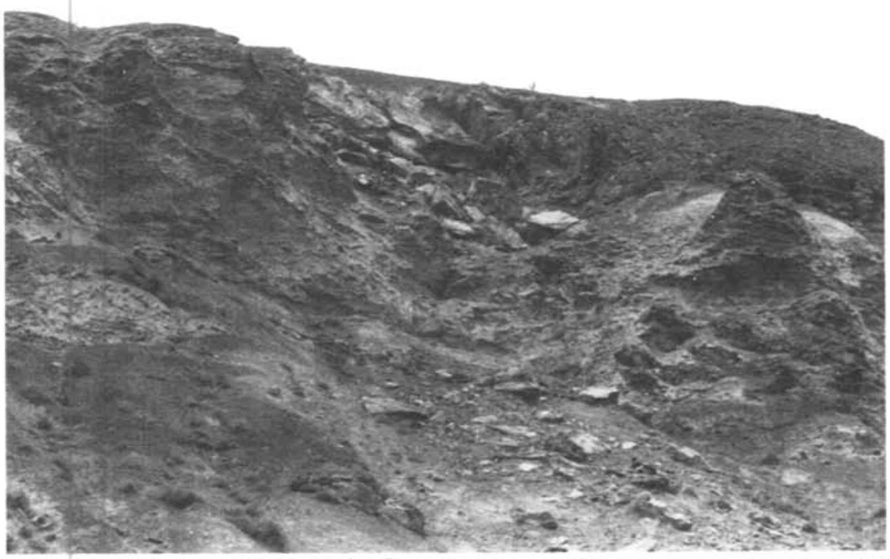
Figure 6.–Gypsum source area.

The talus slope is composed of mostly large granitic and quartzite boulders deposited at an angle of 36°. This deposit extends up approximately 600 feet from the roadway to the base of a 70-foot-high cliff composed of granitic basement rock. From the crest of this cliff, the slope continues for another 790 feet at an angle of 47° for an overall slope length of 1,210 feet. The source area is located approximately 500 feet above the top of the slope, composed of Cambrian Sawatch Quartzite. The quartzite is interbedded with thin dolomitic layers which tend to be less resistive to weathering than that of the quartzite. The formation is jointed perpendicular to the bedding planes, which in conjunction with the highly weathered dolomite beds, results in large blocks toppling away from the face along the jointing planes. Some of the smaller rockfall occurs from a raveling cut near the base of the talus deposit which was a result of poor grading techniques during the old Highway 6 construction. The majority of this smaller rockfall has been contained in the ditch adjacent to the highway.

Prior to the development of CRSP, mitigation for this site had always been considered costly, and debate would arise on the selection of the most appropriate form of rockfall control to be utilized. Recently, the program was used to evaluate the slope and it was determined that the Colorado flex post fence would be the most efficient application. The program indicated that just above the raveling cut, velocities and bounding heights were at a level that the flex post fence would be most effective in controlling the maximum probable rock of 3 feet. The rock size was determined from the prior rockfall events. The smaller rockfall associated with the old highway cut will be addressed by the construction of a two-tiered mechanically stabilized earth retaining wall system.

Geosynthetic Reinforced Impact Walls

Arthur Ritchie of WDOT observed the implications of angular momentum on rockfall behavior and addressed its control through his ditch design criteria (1). However, in many mountainous regions, space and aesthetic constraints will not allow the use of a wide catch basin. During the evaluation of several rockfall zones in Glenwood Canyon, it became apparent that there was a need of near vertical foreslopes in catch basins in areas where large ditch widths could not be constructed. Large boulders gain a substantial amount of energy while rolling down slopes of gradients less than 1-1/2 vertical : 1 horizontal. Due to the high rotational velocities associated with these events, boulders tend to "climb out" catch basins with foreslopes of less than 0.75 vertical : 1 horizontal, depending on the width of the ditch. Engineering geologists with the Colorado Department of Transportation and the Colorado Geological Survey tested a double-sided geosynthetic reinforced wall for use as a rockfall barrier at the West Rifle site. The purpose of these tests was to establish design guidelines for an impact wall to be constructed in Glenwood Canyon, and to understand the limitations of geosynthetics in dynamic loading conditions. Large boulders were rolled down the 300-foot-long slope to an impact with the wall below until failure occurred. Information gathered from video coverage, strain gauges, and survey data is being used to determine the effects that the impact has at various locations along the entire length of the barrier (figure 7). Some of the more favorable aspects of this wall system include economical benefits through the use of on-site backfill materials, application in areas with spatial constraints and the ability to apply a variety of facades meeting established aesthetic requirements.

On November 15, 1990, the Glenwood Canyon geotechnical staff was contacted to investigate a rockfall that had occurred earlier that morning at a location 10 miles to the east of the Glenwood Canyon project. Several large boulders, averaging 4 to 6 feet in diameter, had detached near the crest of the hillside from a contorted zone in the Eagle Valley Evaporite formation. The formation is Pennsylvanian in age and consists of soft gypsiferous shales and bedded crystalline gypsum. Some of the boulders managed to roll across the westbound lane of I-70 and had come to rest in the highway median. Most, however, were deposited in the Interstate, closing one lane until maintenance crews removed the material.

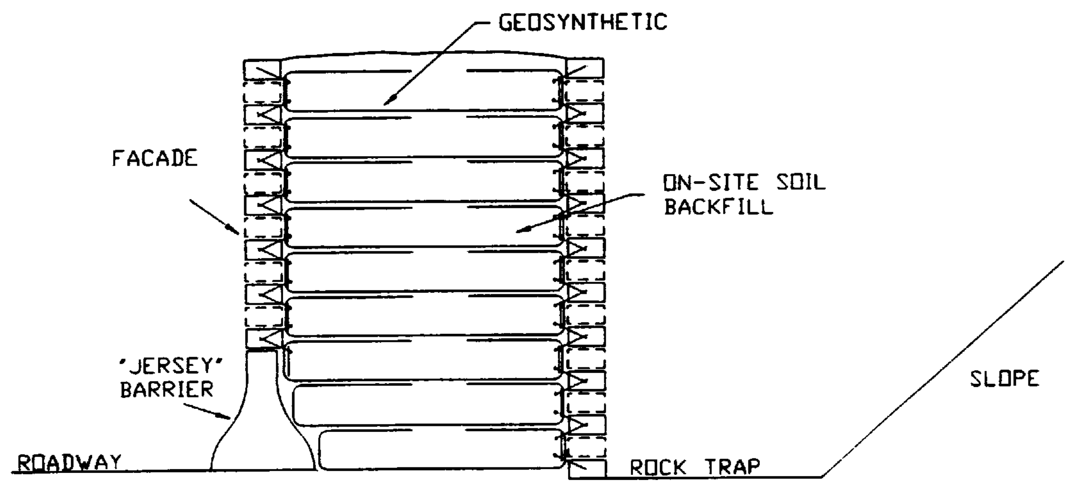

Figure 7.–Geosynthetic rockfall barrier

It was apparent that this was a continual rockfall area by the presence of older gypsiferous boulders in the median. Closer investigation of the source area revealed that the majority of unstable material had not yet detached. Two large boulders, each measuring 8 feet in diameter, had wedged near the base of a funnel-shaped source area, and were blocking an additional 20 to 30 yards of material. Scaling was considered; however, explosives would be necessary to remove the unstable material, and it was felt that there may be a risk of destabilizing surrounding stable materials. In order to remove all of the potentially unstable material, an excavation of upwards of 2,000 yd^3 and a 2-week completion period would have been required. It was concluded that a large berm would be the most appropriate mitigation method for controlling impending and future rockfall hazards. A warning system composed of flashing lights and sirens was installed to alert construction workers if any of the large boulders detached from the hillside prior to completion of the berm.

CRSP was used to model the slope and predict future rockfall behavior. The program indicated that a 35-foot-wide ditch would be required in front of a 15-foot-high impact wall, with the impact surface constructed to near vertical. The wall height and vertical configuration were necessary to insure that the large boulders would not climb the wall face due to the high rotational velocity. Prior to construction of the barrier, the hillside just above the proposed impact wall location was altered to a channel configuration. This was done to insure that all future rockfall would be contained and directed toward the wall. A composite wall was constructed utilizing a tire faced geosynthetically reinforced soil and L-Walls to a height of 18 feet. Behind the wall was a 25-foot-wide berm, required for the predicted high impact energies and to blend the feature into the hillside.

The composite wall and ditch configuration were tested by blasting the large boulders loose from the funnel-shaped chute, releasing the material trapped by the boulders. All of the material removed by the blast was retained by the impact wall, including the two 8-foot-diameter boulders. The resulting feature was an inexpensive, effective impact barrier that conforms with the surrounding environment.

In July of 1991, the remaining unstable rock released, and the entire fall was contained by the mitigation design.

Conclusion

CRSP has been instrumental in analyzing complex slope conditions in and around the Glenwood Canyon Project. This information has been necessary in determining the most appropriate and cost-effective methods for controlling hazardous rockfall. As a result of the CRSP research, three inventive and economical mitigation devices have emerged, the tire attenuator, the flex post fence, and geosynthetic reinforced rockfall barriers. Based on the tire attenuators already installed in the canyon, the average cost including materials and installation is approximately $200 per linear foot. The average cost of the existing flex post fence systems is $150 per linear foot, while preliminary estimates for the geosynthetic barriers have been $50 to $100 per linear foot. Through the use of these three systems developed in conjunction with CRSP, the integrity of Colorado's transportation facilities and the safety of motorists have been greatly enhanced.

It should be noted that this program, like any modeling program, is designed to provide insight; and it should not take the place of a sound qualitative assessment, but should be used to support the assessment with an accurate statistical measurement of rockfall behavior.

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PENSTOCK AND OUTLET WORKS GUARD GATE AND VALVE TESTING

By Bill Duncan[1]

Most outlet works, powerplants, and large pumping facilities feature guard gates or valves upstream of the main regulating gates and valves. The primary function of the upstream gate or valve is to shut off the waterflow in the event of a downstream failure or for maintenance of downstream features. These guard gates and valves are not frequently operated and there is concern that they may not function in the event of a downstream failure. Reclamation requires these guard gates and valves to be tested on a regular basis. This paper summarizes the objectives and requirements of Reclamation's guard gate and valve testing programs.

The definition of a guard gate or valve is "a gate or valve located upstream from main regulating and control gates and valves or upstream from pumps and turbines."

Guard gates and valves are also commonly known as headgates; and emergency, storm, service, and maintenance gates and valves.

The primary functions of a guard gate or valve are to:

a. Shut off waterflow for maintenance of the regulating or control gates and valves, or for maintenance of turbines and pumps

b. Shut off waterflow in an emergency such as a pipe rupture or control or regulating gate failure

c. Shut off waterflow in the event of loss of control or damage to a pump or turbine

Reclamation has implemented two distinctly different guard gate and valve test programs.

a. Bureau-wide Power Penstock Guard Gate and Valve Test Program

b. Bureau-wide Outlet Works Emergency/Guard Gates and Valves Test Program

Power Penstock Guard Gate and Valve Test Program

The Bureau-wide Power Penstock Guard Gate and Valve Test Program was begun in 1969, revised in 1974, and revised again in 1990. (Figure 1 is a copy of the test schedule.) The program was developed to verify proper operation of guard gates and valves above hydroelectric turbines and large pumps. The guard gates and valves were designed for full-flow closure. The penstocks are adequately vented or structurally designed to take the vacuum or pressure surges. The program established test procedures and reporting procedures and maximum intervals between tests. The general requirements of the program included:

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a. A simulated full-flow emergency closure of a gate should be made just prior to reconditioning of the gate.

b. A balanced closure should be performed after a gate or valve is reconditioned.

c. Unbalanced closure tests for valves are not required as a balanced closure is an adequate test.

d. Balanced closure tests on all guard gates and valves should be done annually.

e. Unbalanced full-flow tests should be performed on all guard gates not less frequently than every 10 years nor more frequently than every 5 years. Intervals were established to meet individual plant maintenance schedules.

The Project Office or Maintenance Center has the following responsibilities:

a. Schedule and perform tests
b. Document test results
c. Initiate appropriate maintenance and repairs

Responsibilities of the Denver Office include:

a. Assist with preparation and review of test procedures
b. Review test schedules and results during power O&M reviews
c. Support tests with instrumentation as required
d. Support repairs or replacements as required

There are many types of guard gates and valves including:

Butterfly valve	Coaster gate	Fixed-wheel gate
Needle valve	Slide gate	Ring-seal gate
Rotovalve	Radial Gate	Ring-follower gate
High-pressure gates	Jet-flow gates	Paradox

The consequences of guard gate or valve failure at a powerplant or large pumping plant include:

a. Wicket gate failure—runaway unit.–Uncontrolled draining of reservoir, possible destruction of the powerplant and dam, resulting in power revenue losses

b. Ruptured pipe, penstock, spiral case.–Flooding and destruction of the powerplant, uncontrolled draining of reservoir, possible destruction of the dam, and endangerment to downstream population and property

Outlet Works Emergency/Guard Gates and Valves Test Program

The other gate and valve testing program is directed at guard gates and valves and regulating gates and valves at water resource facilities and outlet works without Reclamation powerplants. Unlike the penstock guard gates, outlet works high-pressure guard gates were generally designed only as maintenance gates to be closed under balanced head conditions. During full-flow closure, the outlet works conduit may have insufficient venting. Excessive pressure reduction can cause water column separation and result in a damaging pressure surge or can cause collapse of the outlet pipe.

The consequences of guard gate or valve failure in an outlet works include:

a. Ruptured pipe.–Uncontrolled draining of the reservoir, destruction of the outlet works, possible destruction of the dam

b. Control gate or valve failure.–Uncontrolled release from outlet works, draining of the reservoir

c. Guard gate fails to open to allow emergency evacuation of the reservoir.–Possible destruction of the dam

In 1979 as a result of SEED (safety evaluation of existing dams) and RO&M (review of operation and maintenance) examinations, it was agreed we could no longer accept these consequences.

In 1980 the Denver Office began a program to identify the outlet works which had deficient air venting. Generally only those installations where the emergency gate is located a distance of more than five times the height of the gate opening upstream from the regulating gate or valve were in question.

The Division of Electrical and Mechanical Engineering obtained field data, evaluated the venting requirements and recommended modifications where necessary. Evaluation basically consisted of calculating the negative pressure which could collapse the pipe, calculating the negative pressure produced by closure from various gate openings and calculating the size air vent required to prevent collapse. In some cases the size of the air vent required was too large to be practical, and stiffener rings for the pipe were recommended. Mr. Edward (Skip) Peters, Steel Pipe and Special Equipment Section, Denver Office, developed and performed most of the analytical procedures.

Outlet works were divided into two classifications:

Group 1.–Outlet works with no potential for collapse of the downstream conduit as a result of gate or valve operation under unbalanced head conditions

Group 2.–Outlet works which may have the potential for collapse of the downstream conduit in the event that the air supply is not adequate during emergency closure of the gate or valve

In 1991, the Operation and Maintenance (O&M) Engineering Branch, in cooperation with the Division of Electrical and Mechanical Engineering initiated the Outlet Works Emergency/Guard Gates and Valves Test Program.

The program is directed at guard gates and valves upstream of regulating or control gates and valves at Bureau of Reclamation outlet works.

The basic objectives of the program are to:

a. Develop low-risk test procedures

b. Provide a schedule for "one time" testing at all outlet works

For group 1 outlet works, testing has begun as part of the RO&M and SEED examinations. The tests are performed by the review teams, and test results are incorporated into the examination reports.

For group 2 outlet works, the program has three steps:

a. Complete air vent studies and provide recommendations for modifications to the air vent system or the conduit.

b. Retrofit with air valve assemblies to admit sufficient air to prevent collapse or install stiffeners on the conduit to prevent collapse.

c. Schedule a specific test separate from RO&M and SEED. The tests are coordinated by the Denver Office. Site-specific procedures may be required.

Figure 2 is a flow sheet developed for the program.

The following test procedures were developed for the group 1 outlet works:

a. Verify normal gate operation and proper SOP (Standing Operating Procedures) for regulating gate by cycling open and closed.

b. Cycle guard gate or valve under balanced head conditions.

c. Cycle the guard gate or valve through a 10 percent linear or rotational travel distance starting with the gate or valve fully closed and the downstream conduit dewatered (unbalanced head conditions).

It was expected that this test would verify maximum hoist or operator capability under unbalanced head without the risk associated with a full flow closure.

However, test experience has shown that not all guard gates are capable of opening under unbalanced conditions. The Denver Office is evaluating modification of the test procedure to allow a full or partial flow emergency closure test for some types of guards gates.

Figure 3 is a copy of the actual test data sheet for Yellowtail Dam outlet works. The ring-follower gate would not open under unbalanced head and the test was terminated. Figure 4 is a copy of the revised test procedure which has not yet been performed.

A "Report of Results" form has been developed for the group 2 facilities. Figure 5 is a copy of the completed form for Sanford Dam.

Test instrumentation requirements will depend on the type of gate or valve, whether the tests have been performed before, modifications to the air vent or conduit and previous operational problems.

The basic test equipment recommended includes:

a. Pressure transducers on the hydraulic system
b. Position/distance transducer to measure gate travel
c. Strip chart recorder
d. Data sheet and pencil

Optional test equipment that should be considered includes:

a. Pressure transducers on each side of the hydraulic cylinder to determine the actual force required to move the gate or valve and indicate leakage past the piston seals

b. Pressure transducers in the conduit between the guard gate and regulating gate

c. Vibration measuring equipment on the conduit and gate or valve

Data sheets for the test should be similar to figures 3 and 4, including the following information:

a. Operating times
b. Operating pressures
c. Maximum pressures
d. Notes or measurements on vibration

In the future we expect outlet works gate and valve testing to become a routine part of operations and maintenance.

The Field Office or Project Office will have the primary responsibilities to:

a. Schedule and perform tests
b. Document test results
c. Initiate appropriate maintenance and repairs

The Denver Office will have responsibilities to:

a. Assist with preparation and review of test procedures
b. Review test schedules and results during RO&M and SEED reviews
c. Support tests with instrumentation as required
d. Support repairs or replacements as required
e. Create a single data base on locations and types of gates and valves at Reclamation facilities including gate and valve testing procedures and scheduling data for outlet works gate and valves and penstock guard gates and valves

The Operation and Maintenance Engineering Branch, D-5850, will be coordinating the Denver Office activities. Questions and comments should be directed to Mr. Ernie Bachman, Mechanical Engineer, D-5850.

Figure 1
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PENSTOCK GATE AND VALVE TESTING PROGRAM

Type of Gate or Valve	Test Required	Frequency
Butterfly valve, BV	Balanced closure	Annual
Roto valve, RV	Balanced closure	Annual
Coaster gate, CG	Unbalanced closure	5 years
Cylinder gate, CYG	Unbalanced closure	5 years
Fixed-wheel	Unbalanced closure	5 years
Ring-follower, RF	Unbalanced closure	5 years
Radial-gate, RG	Unbalanced closure	5 years
Ring seal, RS	Unbalanced closure	5 years
Slide gate, SG	Unbalanced closure	5 years
Sloping roller gate, SRG	Unbalanced closure	5 years

These are general guidelines, and tests should be performed only on gates and valves known to be in good condition and only when test procedures have been developed or approved by the Denver Office.

Exceptions as of January 1, 1990:

Hoover cylinder gates - No tests due to possible vibration problems.

PN - Hungry Horse

GUARD GATE AND VALVE TEST SCHEDULE

Plant	Gate/valve	Unbalanced closure test frequency	Balanced closure test frequency	Date of last test	Date of next test	Comments
Hungry Horse	FW1	5 years				
	FW2	5 years				
	FW3	5 years				
	FW4	5 years				Overdue

BV - Butterfly valve	RF - Ring-follower	RS - Ring seal
CG - Coaster gate	RG - Radial gate	SG - Slide gate
FW - Fixed wheel	SRG - Sloping roller gate	CYG - Cylinder gate

MP - Tracy Office and Folsom Office

GUARD GATE AND VALVE TEST SCHEDULE

Plant	Gate/valve	Unbalanced closure test frequency	Balanced closure test frequency	Date of last test	Date of next test	Comments
Folsom	FW1	5 years		1984	1986	Overdue
	FW2	5 years		1977	1987	Overdue
	FW3	5 years		1984	1994	
Nimbus	FW1	5 years		1981	1991	
	FW2	5 years		1981	1991	
New Melones	SRG	5 years	Gate cannot be tested until penstock fill system modification is completed.			
O'Neill - Siphon		N/A				
Tracy - Siphon		N/A				

BV - Butterfly valve	RF - Ring-follower	RS - Ring seal
CG - Coaster gate	RG - Radial gate	SG - Slide gate
FW - Fixed wheel	SRG - Sloping roller gate	

LC - Lower Colorado Dams Projects

GUARD GATE AND VALVE TEST SCHEDULE

Plant	Gate/valve	Unbalanced closure test frequency	Balanced closure test frequency	Date of last test	Date of next test	Comments
Parker	FW1	5 years				Overdue
	FW2	5 years				Overdue
Davis	FW1	5 years		1984		Overdue
	FW2	5 years		1981		Overdue
	FW3	5 years		1982		Overdue
	FW4	5 years		1985		Overdue
	FW5	5 years		1983		Overdue
Hoover	BVA1		Annual			
	BVA2		Annual			
	BVA3		Annual			
	BVA4		Annual			
	BVA5		Annual			
	BVA6		Annual			
	BVA7		Annual			
	BVA8		Annual			
	BVA9		Annual			
	BVN1		Annual			
	BVN2		Annual			
	BVN3		Annual			
	BVN4		Annual			
	BVN5		Annual			
	BVN6		Annual			
	BVN7		Annual			
	BVN8		Annual			
	CYG1	Cylinder gates are not included in test program at this time due to possible vibration problems.				
	CYG2					
	CYG3					
	CYG4					

BV - Butterfly valve	RF - Ring-follower	RS - Ring seal
CG - Coaster gate	RG - Radial gate	SG - Slide gate
FW - Fixed wheel	SRG - Sloping roller gate	CYG - Cylinder gate

UC - Curecanti Field Division

GUARD GATE AND VALVE TEST SCHEDULE

Plant	Gate/valve	Unbalanced closure test frequency	Balanced closure test frequency	Date of last test	Date of next test	Comments
Blue Mesa	FW	5 years		1989		
	BV1		Annual	1989		
	BV2		Annual	1989		
Morrow Point	FW1	5 years		1982		
	FW2	5 years		1982		
Crystal	WM	5 years		No record of test		Due
Upper Molina	RV		Annual	1988		
Lower Molina	RV		Annual	1988		

BV - Butterfly valve	RF - Ring-follower	RS - Ring seal
CG - Coaster gate	RG - Radial gate	SG - Slide gate
FW - Fixed wheel		

Figure 1 - Continued
Page 6 of 6

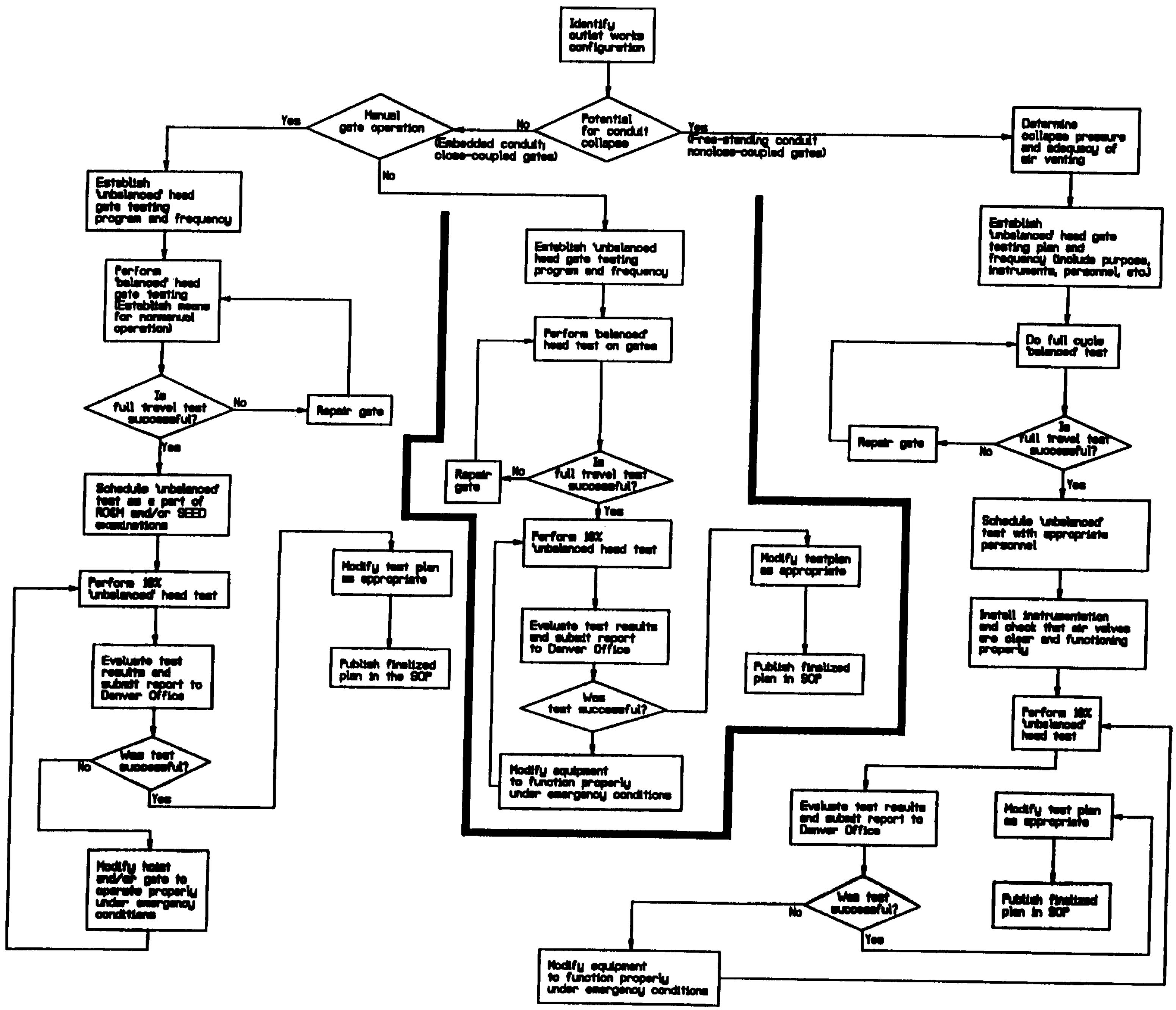
GP - Eastern Colorado Projects

GUARD GATE AND VALVE TEST SCHEDULE

Plant	Gate/valve	Unbalanced closure test frequency	Balanced closure test frequency	Date of last test	Date of next test	Comments
Estes	BV1	NR	Annual	no data		
	BV2	NR	Annual	"		
	BV3	NR	Annual	"		
	SG	NR	Annual	"		
Marys Lake	FW	5 years		"		
Granby	BV1-76	NR	Annual	1/89	1/90	
	BV2-76	NR	Annual	2/89	2/90	
	BV3-76	NR	Annual	3/89	3/90	
	BV1-88	NR	Annual	1/89	1/90	
	BV2-88	NR	Annual	2/89	2/90	
	BV3-88	NR	Annual	3/89	3/90	
Willow Creek	BV1	NR	Annual	11/88	11/89	
	BV2	NR	Annual	11/88	11/89	
Green Mountain	RS1	5 years				Overdue
	RS2	5 years		7/82		Overdue
Mount Elbert	FW1	5 years	Tested balanced annually - no data on unbalanced tests			
	FW2	5 years				
Flatiron	BV1	NR	Annual	11/88		
	BV2	NR	Annual	2/89		
	BV3	NR	Annual	6/89		
Pole Hill	FW	5 years		12/86		
Big Thompson	SG	5 years		6/87		

BV - Butterfly valve	RF - Ring-follower	RS - Ring seal
CG - Coaster gate	RG - Radial gate	SG - Slide gate
FW - Fixed wheel		

Unbalanced testing of outlet works guard gates - flowchart



GATE AND VALVE TEST PROCEDURE AND DATA SHEET

Dam: Yellowtail Dam and Powerplant, Original Test Procedure

Feature: Outlet works

Date of test: 5/22/92

Equipment tested: Hollow-Jet Valve 1, HJV1
Ring-Follower Gate 1, RFG1

Test procedure and data:

1. **Inspect air valve:** There is a manually operated gate valve adjacent to the RFG which is used to bleed air from the conduit between the RFG and HJV during the filling process. The valve functioned satisfactorily during the filling process.

2. **Open RFG under balanced head:**

   Time to open: 6:33
   Opening hydraulic pressure: 125 lb/in^2
   Pressure switch trip: 1,900 lb/in^2

3. **Open HJV to maximum allowable opening**

   Max. allowable opening: 18 percent
   Approximate flow: 1,000 ft^3/s
   Time to open: 1:25
   Opening hydraulic pressure: 975 lb/in^2

4. **Close HJV**

   Opening: 18 percent
   Time to close: 1:48
   Closing hydraulic pressure: 590 to 950 lb/in^2

5. **Close RFG under balanced head**

   Time to close: 7:33
   Closing hydraulic pressure: 175 lb/in^2

6. **Open RFG under unbalanced head to 10 percent and close**

   a. **Open HJV**

      Time to open: 45 percent in 54 minutes

   b. Open RFG to 10 percent

      Valve would open less than 1 percent, and pressure switch would shut down hydraulics at 1,900 lb/in^2. TEST TERMINATED

GATE AND VALVE TEST PROCEDURE AND DATA SHEET

Dam: Yellowtail Dam and Powerplant, Recommended Test Procedure

Feature: Outlet works

Date of Test:

Equipment tested: Hollow-Jet Valve, HJV
Ring-Follower Gate, RFG

Test procedure and data:

1. **Inspect air valve:**

2. **Open RFG under balanced head:**

   Time to open:
   Opening hydraulic pressure:
   Pressure switch trip:

3. **Open HJV to maximum allowable opening**

   Max. allowable opening:
   Approximate flow:
   Time to open:
   Opening hydraulic pressure:

4. **Close HJV**

   Opening:
   Time to close:
   Closing hydraulic pressure:

5. **Close RFG under balanced head**

   Time to close:
   Closing hydraulic pressure:

Figure 4
Sheet 2 of 2

6. **Open RFG under balanced head**

   a. **Open HJV to maximum allowable opening**

      Time to open:
      Opening hydraulic pressure:

   b. **Close RFG under maximum allowable flow**

      Time to close:
      Closing hydraulic pressure:

UNBALANCED HEAD GATE TESTING PROGRAM
Group 2 Facilities

Report of Results

General Information

1. Facility name: Sanford Dam
2. Project name: Canadian River Project, Texas
3. Region: Great Plains
4. Date of test: April 15, 1992

5. Size and type of emergency gate: 6'6" x 8'0" high-pressure gate located in the gate chamber at station 14+17.85

6. Gate manufacturer: Information not available

7. Gate operator type: Hydraulic hoist

8. For hydraulic systems: Design operating pressure - 1,000 lb/in^2
Normal operating pressure - 650 lb/in^2
Design relief valve setting - 1,050 lb/in^2
Normal relief valve setting - 1,050 lb/in^2

9. Reservoir elevation: 2895.23 feet

Air Venting

See memorandum dated April 4, 1991, to Regional Director, Billings, Montana, Attention GP-430; from Chief, Electrical and Mechanical Engineering Division; subject: Required air venting for high-pressure gates.

10. Was additional air venting recommended for this facility? Yes
Type and size: One 10" and one 8" automatic air valves
Has it been installed: No
Approximate date of installation: ___________

11. Proper operation of air vacuum/air release valve verified? Not installed

At time of test or otherwise (please explain)? ______________________________
____

12. Air valve piping inspected both inside and out? Yes

    Condition: Air vent piping is in good condition (exterior). Air vent holes downstream of high-pressure emergency gate should be kept open.

Regulating Gate

13. Percent of full travel gate operated through under unbalanced conditions: 40 percent

14. Operation during site visit: 100 percent open to closed
    If not, date of operation _______. Verified in log? Yes

15. Date gate last operated using backup system: March 28, 1991
    Verified in log? Yes Percent of full travel: 100 percent

Emergency Gate (balanced operation)

16. Gate operated through a full cycle under balanced conditions? Yes

17. Operation during site visit? Closed - 10 percent open - closed (0.8')
    If not, date of operation __________ Verified in log? Yes

18. System pressure during balanced operation: 650 lb/in^2

Emergency Gate (unbalanced operation)

19. Type of gate position indicator utilized: Digital readout

20. Ten percent gate operation successful? Yes

21. Maximum system pressure (or current and voltage) recorded during operation: 925 lb/in^2

22. Gate position at maximum reading: Cracking open
    Maximum gauge reading of 925 lb/in^2 was recorded as the gate started to move into open position. There was no significant difference between cracking, opening, and closing pressures.

Provide narrative of test procedure if warranted for any unusual conditions or anomalies. Add any RO&M (review of operation and maintenance) recommendations you feel necessary to ensure that these described deficiencies are corrected (attach additional sheets as required): No new RO&M recommendations required or observed for the outlet works at this facility.

By ______________ Date: ___________

Copies to: ____________________

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

Prospective material should be submitted through your Bureau of Reclamation Regional office.