RECLAMATION

Managing Water in the West

Canal Operator Manual

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
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MISSION STATEMENTS

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

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.

Disclaimer

Reclamation developed this manual to provide basic guidance to help canal operators promote safe and effective operations and maintenance for canal systems. These complement—not replace—experience and sound judgment. This is general information useful for typical canal systems. As each canal system has unique designs and features, these general guidelines cannot substitute for facility or operating-specific guidance and specifications. Every operating entity is different, and this advice and strategies may not be suitable for your situation.

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Contents

Why this Manual Matters

This manual can help canal operators safely and effectively operate and maintain canals.

Reclamation has constructed approximately 8,000 miles of canal, with 25,000 miles of distribution laterals in the Western United States. Two-thirds of these facilities have been transferred to non-Federal operating entities to perform operations, maintenance, and replacement (OM&R). Routine maintenance and constant vigilance can reduce the occurrence of expensive repairs and prevent breaches in a canal system.

Typical Reclamation canal in a rural area.

Typical Reclamation canal in an urbanized area.

Most Reclamation canals were built in remote, rural areas. Over the years, increasing populations and expanding communities near these canals has resulted in approximately 1,000 miles of Reclamation canals in urbanized areas. As a result of this urbanization, a canal operator's job is more important—and more challenging—than ever.

Why your work is important

You operate and maintain canals to deliver water.

Your customers depend on you to:

Reclamation water irrigating row crops.

Keep the canal system running

Reclamation water irrigates 10 million acres of farmland and serves one in five western farmers. 31 million people use 10 trillion gallons of Reclamation water for municipal, residential, and industrial, uses.

Prevent failures

Prevent canal failures because they:

- Interrupt water deliveries
- Damage property
- Put people at risk
- Increase costs

Diligent operation and active maintenance (O&M) of the canal system are your tools to defend against these potential impacts.

Flooding from a breach in a Reclamation canal embankment.

Keep alert! We all need alerts!

ALWAYS

LOOK AT THE CANAL REGULARLY

EXAMINE ANY SIGNS OF PROBLEMS OR KNOWN TROUBLE SPOTS

REPAIR, BEFORE IT GETS WORSE

TELL YOUR SUPERVISOR AND CO-WORKERS ABOUT ANY PROBLEMS

SCHEDULE ROUTINE MAINTENANCE AND REPAIRS

Operations: Running Smoothly

Operating a canal properly is like driving a truck—drive it safely and follow the manufacturer's recommendations, and you won't have many problems. **Good operations are key to delivering water and preventing failures.** Most importantly, use checks, turnouts, and wasteways to maintain water depth and wasteways for draining. Fill and drain canals slowly to prevent damages. Control the canal system either manually at the gate or from a local or remote operating system.

Watering Up: Filling the Canal

Fill the canal slowly!

- Filling the canal too fast can cause large waves that can cause scour damage to the canal prism.
- Filling slowly will help you ensure new features are performing as intended.

As the canal is filling, watch for:

- Seepage from or outside of the canal embankment
- Boils outside of the canal embankment
- Whirlpools in the canal
- Wave action downstream from the headgates.

Always open headwork gates slowly so that turbulence does not sweep beyond the check structure. Canal protective structures are designed to accommodate turbulence from changing water velocity, depth, or flow paths.

Downstream from the check gate structure. Notice the turbulence in the water extends past the length of the concrete transition, causing scour to the unprotected canal sidewalls.

Watering Up: Filling the Canal —continued

Act!

- Find out what the maximum acceptable filling rate is for each canal and lateral. If you do not know, work with your supervisor or watermaster to ensure that these are defined.
- Open the gates **slowly** to control the filling and minimize waves.
- If the water is too turbulent, lower the gates until a backwater is developed. Then continue to open gates.
- After the flow has stabilized and any turbulence has disappeared, set the gate at the desired position. Then continue to open gates.

Operating Canal Reaches: Controls

Why?

Canals convey water downstream through a series of controlled canal reaches, separated by check structures or "checks." Checks serve to help regulate the water level in a canal reach. They can also be used to limit the amount of water leaving the canal if there is a failure. Checks have two parts:

- Gates can make small adjustments for more flexible operations and can provide for automation of the check structure.
- Weirs and stoplogs can make larger adjustments that may require more planning.

Use checks in a daily balancing act to keep enough water for deliveries while avoiding too much water in the canal—which can exceed the allowable freeboard and eventually overtop the canal.

Typical check structure with gates and stoplogs.

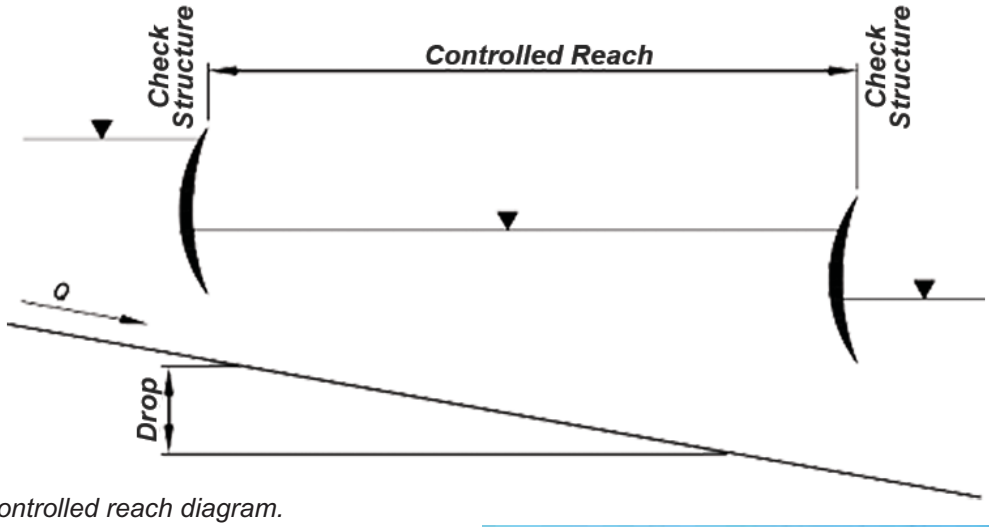
Operating Canal Reaches: Controls —continued

What?

A **controlled reach** is that section of the canal identified by the water contained between structures, including checks, wasteways, diversion dams, etc., where the structures are used to control flow rates or required water surface elevations. They may also limit the amount of water to be discharged in the event of a failure.

Know the canal system.

- How many controlled reaches are in the system?
- Where are the check structures on each controlled reach?
- How much of a drop in slope is there between each reach?



Controlled reach diagram.

Know what turnouts and wasteways are within each reach.

Turnouts from larger canals feed smaller canals including private laterals or ditches.

Wasteways divert surplus flows from the main canal into a natural or constructed channel to protect the canal system, preventing water from overtopping and damaging canal embankments and nearby properties.

Typical turnout.

Operating Canal Reaches: Controls —continued

Act!

Water out equals water in minus deliveries and losses. Work with your watermaster and supervisor to manage inflows and plan deliveries so that water **depth** in canal reaches **remain constant**.

Use gates, turnouts, and wasteways to control the water entering and exiting canal reaches to:

- Keep the water depth throughout all canal reaches relatively constant.
- Minimize tailwater or waste.
- Use turnouts and wasteways (if needed) to evacuate water in downstream reaches if there is too much water in upstream reaches.

Operating Canal Reaches: Freeboard

Why?

Freeboard in a canal allows stormwater flow to be accommodated within the canal, provides additional capacity to handle extra flows (when operators do not make expected deliveries), protects from occasional wind-generated waves, and handles possible effects from misoperations.

Water above the freeboard can cause embankment erosion and possible overtopping of the canal.

Water operations exceeded the top of the concrete lining, scouring the canal embankment.

Operating Canal Reaches: Freeboard —continued

Uhart?

The more freeboard you have, the more flexibility you have for operations.

Freeboard is the designed vertical clearance above the maximum design water surface to:

- Prevent embankment erosion caused by wind waves on the water surface
- Act as a safety feature to provide for unexpected higher-than-normal flows and water surfaces caused by:
  - ► Sedimentation in the canal
  - ► Temporary abnormal operations
  - ► Excess flows caused by storm runoff entering the canal

Golf course grading of this fairway removed the earthen freeboard.

Water levels are impinging on the freeboard.

Operating Canal Reaches: Freeboard —continued

Act!

- Make sure water isn't running in or over the freeboard.
- Change flows slowly to keep waves to a minimum and avoid eroding freeboard.
- If freeboard has been lost or there is not enough freeboard, work with your watermaster or supervisor to correct the problem or change operations to accommodate that loss.

Drawing Down: Dewatering the Canal

Why?

Rapid **dewatering** can:

- Crack or displace concrete lining panels
- Cause sloughing and erosion of the canal prism in earth lined canals

What?

Dropping the water level in a concrete-lined canal too quickly while the water level in the soil behind the lining has not dropped can create pressure differences between the water level in the canal and the water level in the soil. This difference in pressure behind the lining causes cracks or displacement of the concrete lining.

As you **dewater**, monitor the canal looking for:

- **Seepage**
- **Cracks**
- **Displacement of concrete lining**

If you see these symptoms under normal dewatering conditions, immediately stop dropping the water level and address the problem.

Engineering Fact:

It only takes slightly more than 1 foot of water pressure difference to float a piece of concrete.

Damaged canal lining.

Act!

Follow each canal's specified dewatering rates, if provided, in the Standing Operating Procedures (SOP). Otherwise, a good rule of thumb is to **limit the dewatering rate to no more than 1 foot per day and no more than 6 inches per hour.**

Accounting for All Water

Why?

Tracking where the water goes is extremely important to understand and report the losses or unauthorized water uses to help create an effective system.

What?

While on your rounds, look for:

- ► Open gates when they should not be open, or gates that are open too much
- ► Applying water to lands outside the authorized project boundaries or service area
- ► Irrigating more acreage than allowed
- ► Over-drafting or taking more water than allotted
- ► New pipes, pumps, garden hoses, or other systems being used to convey unauthorized water

These issues will cause problems in canals and damage canal embankments:

- **Over delivery.** Delivering more water to a few users than they should get will upset other users who are not getting their alloted water.
- **Unauthorized water deliveries/withdrawals.** Keep an eye out for new pipes and pumps installed to deliver unauthorized water withdrawals.

Unauthorized pipe (above).

Unauthorized suction line (left).

—continued

Accounting for All Water —continued

- **Poor Measurement.** In some cases, the only accurate flow measurement is at the point of diversion. The type of turnout may not lend itself to accurate calibration or lack of maintenance has reduced its accuracy.

- **Flow Wasting.** Wasting occurs when there is more water in the canal than is needed for deliveries. Good operations limit the amount of water wasted from a canal and wasteway. Wasting prevents water from being used for the intended purpose and should be avoided whenever possible. However, wasting water can be a valuable operational tool during emergencies to prevent more harm.

- **Operational issues.** Gates may not be working effectively. Gates that are stuck in the "open" position can waste water.

- **Operational waste.** Operational waste stems from causes such as poor scheduling, turnout flow reduction, power failure, pump shutoff, gates closing, or flow obstructions.

Prevent losses and wastes from canals by documenting any problems and working with your watermaster or supervisor to address them.

- **Establish and follow notification procedures for unauthorized use violators.**

- **Prevent operational issues.** Notify your supervisor or watermaster. Perform maintenance to ensure gates are operating correctly and not wasting water.

- **Prevent operational wastes.** Notify your supervisor or watermaster. Correct poor scheduling, turnout flow reduction, power failure, pump shutoff, gates closing, flow obstructions, or any condition that will contribute to wasting water.

- **Reduce seepage.** Monitor active seepage areas. Use markers to show the extent of seepage or take photos of the area each time you stop by to have a photo log. If the seepage increases, document this and work with your supervisor or watermaster to schedule repairs.

Preventing Overtopping

Why?

You never know when water will come roaring into the canal system—causing **overtopping**. Moreover, unexpected inflows from outside sources can exceed canal capacity and dump sediment into the canal. Canals can overtop because of:

- **Storm events**
- **Obstructions in the canal system**
- **Delivery/operational errors or conflicts**

Heavy rain caused materials from the surrounding mesa to flow and deposit a dirt plug into the canal and caused upstream overtopping.

Aside from wasting water and flooding property, if overtopping continues, it can erode the embankment and cause failures.

What?

While on your rounds, pay attention to situations that can cause overtopping, including:

- **Storm Events.** The volume of water entering the canal system from a storm depends on:
  - ► The watershed's physical characteristics (Where can water run down a hillside and into a canal?)
  - ► The storm's intensity. (Three inches of rain dumped in a few hours may cause more damage than a rain gently spread out over a couple of days.)

—continued

Preventing Overtopping —continued

What?

Conditions can change: a rainstorm on a dry watershed may yield only moderate runoff, but if another storm rains on the now saturated watershed, the runoff will be much greater and immediate.

- **Obstructions** in the canal prism can be caused by canal bank slumping, silt buildup, vegetation within the canal prism, trash, ice damming, or adjacent landslides.

Landslides and other hazards adjacent to the canal could become active during the next rainstorm and result in overtopping in canals.

- **Misoperations.** Open gates or other operational errors where inflows are greater than outflows for some time can cause overtopping or failures

Act!

Keep refining the canal system operations to avoid overflows—**take action to prevent overtopping**.

- Always keep canals, wasteways, and crossings clear of excessive vegetation, silt, or debris, so they can better handle storm events.
- Know how to correctly operate the canal system so you can efficiently respond to storm events.
- Watch the weather and operate canals to respond to divert storm runoff:
  - ► Use inline storage, and wasteways to move the flow through the canal
  - ► Use freeboard to accommodate extra flows, but try to maintain freeboard as soon as possible in case of another emergency
- **If you see overtopping, notify your supervisor or watermaster immediately and document the conditions. Be prepared to implement your Emergency Management or Action Plan.**

Maintenance: Catch Problems Early

Just as making sure your truck gets regular oil changes and stays in good shape will prevent costly repairs later, keeping the canals in good repair saves costs later. The earlier you find and address a problem, the easier and less expensive it is to solve.

Your overall operational success depends on good maintenance to repair current problems and prevent future problems. The key is developing a maintenance schedule, consistently doing the work as scheduled, and following up to ensure the repairs are effective.

Vegetation: Clear the Canal Prism

Why?

Willows, trees, dense brush, and weeds in the canal or the canal prism can restrict access and contribute to water losses. Vegetation within the canal prism can:

- Make inspection and maintenance of the canal more difficult
- Decrease the canal's ability to carry water or to make deliveries through turnouts
- Restrict flows and allow sediment to settle within the canal
- Attract and provide habitat for burrowing animals

Roots can create seepage paths for water to escape the canal.

What?

Identify and remove vegetation growing within the canal prism and restricting flows.

Vegetation crowds the canal prism.

Plants growing in the joints of concrete lining and breaking the concrete panels.

Vegetation can move into cracks and control joints, creating more damage and displacing concrete lining as it grows.

—continued

Vegetation: Clear the Canal Prism —continued

What?

Vegetation on the bottom of the canal also restricts flows.

Act!

Methods to control weeds not only differ by the type of weed and where it is found, but they also vary widely in regulations, scale, scope, timing, and management objectives.

- Identify the particular problem.
- Work with your supervisor or watermaster to determine a weed control and removal plan.
- Notify Reclamation when vegetation starts to impact water deliveries.

Consider the types of weeds to be controlled and the habitats they occupy when determining what to do to remove them. Special training and permitting may be required for many methods.

Aquatic vegetation and weed control options include:

- **Mechanical means.** Draglines, chains, hydraulic excavators and underwater mowing machines can be used to temporarily reduce aquatic weeds. Once the aquatic weeds are dislodged, remove and dispose of weeds (using large power-driven equipment) so they do not restrict flows.

—continued

Vegetation: Clear the Canal Prism —continued

- **Water level manipulation.** Draining and drying canals after the irrigation season can effectively control aquatic weeds.

- **Herbicides.** Chemicals can be a very effective tool for weed control when used properly. **WARNING:** Improper use could result in poor control of target weeds, damage to crops, and contamination of the environment. Be sure to comply with all regulations for the use of herbicides.

- **Biological control.** Plant-eating animals (such as insects, snails, fish, and turtles) can consume aquatic plants. **WARNING:** Bringing in new species may upset the ecological balance, so work with agencies, universities, etc.

- **Burning.** If permitted, fire may occasionally be used to control vegetation, destroy seeds, and dispose of dry debris. Prescribed burning of canals in the spring or fall can help keep bush growth down. Be sure to keep any burning activities away from rock slope protection and concrete or wooden structures.

- **Mowing.** Grasses and weeds in the canal prism protect the prism slopes from scour and erosion. But if left unmaintained, they restrict flows and obstruct observation.

Vegetation: Prevent Overgrowth on Embankment Slopes

Shallow-rooted vegetation such as grasses and weeds can also provide erosion protection and slope stabilization on the canal embankment.

However, overgrown shallow vegetation can obscure the embankment, making it difficult to spot seepage, boils, cracking, sinkholes, settlement, deflection, or other signs of problems. Keep embankments clear of overgrown vegetation so you can identify these and other problems such as animal burrows, seepage, slope instability as they develop—when they are easier to contain.

Overgrown vegetation can also invite rodents, so clearing also helps avoid problems from developing.

Vegetation: Prevent Overgrowth on Embankment Slopes —continued

Watch for vegetation that encourages animal habitat and obstructs your view.

The vegetation on this canal is overgrown. What is behind all that growth?

With the vegetation removed, pipes, seepage, posts, and a fence emerge.

Dense vegetation on this embankment makes it difficult to determine where this seepage is coming from.

Vegetation: Prevent Overgrowth on Embankment Slopes —continued

Act!

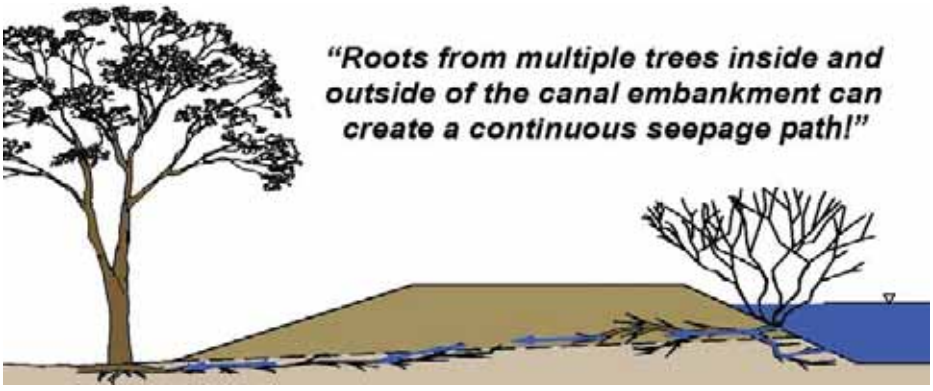
Keep vegetation mowed, particularly at the embankment toe to facilitate observation of potential seepage. Mowing can prevent or reduce the amount of weed flowering and seed production as well when performed frequently through the growing season. If vegetation is out of control, then you either aren't mowing it often enough or your machine/operator isn't reaching all the necessary places.

When vegetation gets into the cracks or control joints and you can not address the underlying problem, spray the weeds. Kill the vegetation before this creates more damage and moves concrete lining.

Vegetation: Get to the Root of the Problem

Why?

Dead or alive, **tree roots cause problems**. Large trees or woody vegetation in the canal prism, near or on embankments have roots that can extend through the embankment to the water in the canal. Trees then either die from natural causes or are cut down, but the roots are still in place. As the roots decay, water can easily travel along the root paths completely through the canal embankment. As water travels along the root path, it erodes the soil along



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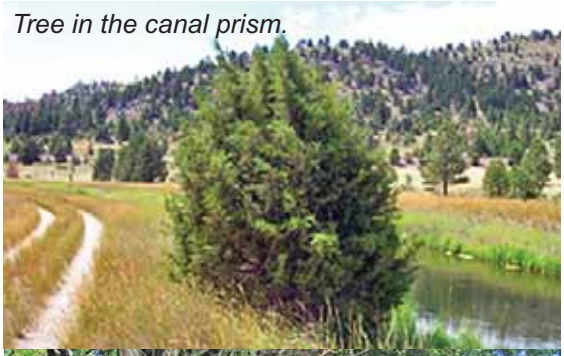
Vegetation: Get to the Root of the Problem —continued

Why?

the root, causing internal erosion and ultimately, an embankment failure.

Tree roots can:

- Loosen the compacted soils in a canal embankment
- Undermine embankment protection and canal lining
- Create pathways for seepage and act as informal "pipes," causing internal erosion
- Create inviting habitat for burrowing rodents
- Expand cracks or joints in concrete walls, canal lining, or pipes
- Plug perforated or open-jointed drainage pipes



Tree in the canal prism.

Trees along the embankment.

What?

The smaller the tree, the cheaper and easier it is to remove it. Make it a habit to remove any little tree you see on the canals.

Trees that need to be removed from near the diversion dam wingwall.

Act!

Prevent vegetation from establishing in cracks or joints of concrete lining or structures.

To allow access and prevent root encroachment and damage, keep trees and other deep-rooted vegetation **15 feet away from the embankment toe.**

Create a map of the canal system with identified trees to discuss with your supervisor or watermaster. Develop a vegetation removal schedule and address the obstacles to controlling vegetation, including:

- Engineering concerns to remove the rootball without compromising the embankment structure
- Cost of removal and maintenance
- Public opinion (trees provide shade)
- Land ownership (trees on private landowner's property, urban backyards, city path, etc.)
- Environmental concerns

—continued

Vegetation: Get to the Root of the Problem —continued

- Herbicide application issues (applicator certification, health and safety, and liability)

Remove roots and repair damage

Remove woody vegetation from the embankment slope and/or toe, including root systems. When removing tree root systems:

- Minimize vertical cuts by "stair stepping" edges of the void created by the root system's removal.
- Repair the embankment by removing loose soil, moisture condition the backfill, then place in lifts and compact with vibratory compaction equipment.

If the tree's size and species indicate that there will be extensive root penetration into the embankment and/or foundation, don't attempt this alone:

- Large root systems may require over-excavating a large volume of soil at the toe and lower portion of the embankment, which may cause seepage and stability issues.
- Work with your supervisor or watermaster.
- A geotechnical engineer should assist in further evaluating the benefits/risks of removing that tree, and take appropriate action based on the results of the evaluation.
- Reclamation's O&M staff and the Technical Service Center are also available if further guidance is required.

Drain and dry before removing

If the canal operates seasonally, then remove and repair at least one month after the canal has been dewatered to allow time for the embankment and/or foundation to drain.

If the canal operates year around, be sure to plan tree removal during scheduled dewatering for maintenance, allowing enough time for the ground to dry out and stabilize. Tree removal on these type of canal embankments may require expensive engineering solutions to facilitate removal without compromising the embankment of an active canal.

Animals/Rodents: Keep Them Out

Making sure animals and rodents are not welcome will help you avoid the expense of evicting them after they do move in. When you see animals, particularly rodents, moving into a canal, get them out!

Grazing livestock can damage and weaken embankment slopes.

Often, rodent burrows extend deep into the embankment and allow water to travel through the embankment. Eventually, the embankment crest can collapse into the widened burrow, breaching the canal.

Animals/Rodents: Keep Them Out —continued

Uhart?

Keep an eye out for grazing cattle or livestock. Cattle and livestock can create trails and break down canal embankment slopes with hoof traffic.

Livestock trail breaking down the canal prism.

Carefully examine areas for rodents and other burrowers that are harder to spot. Watch for the subtle signs that these animals are moving in: new piles of dirt and holes.

From the canal prism:

Aquatic rodents, such as muskrats, typically start burrowing just below the waterline.

Watch for burrow entrances near the waterline.

Water can continue to erode the side walls of the burrow, causing it to enlarge. Eventually, the embankment can collapse into the widened burrow breaching the canal.

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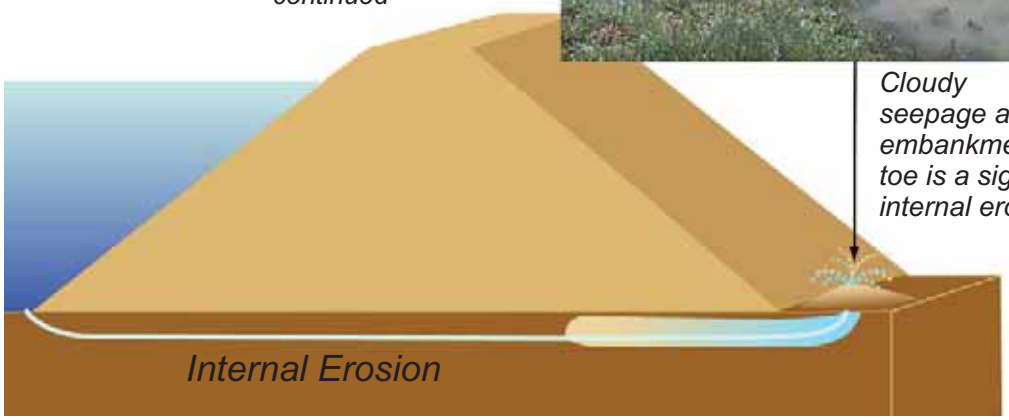


Cloudy seepage at the embankment toe is a sign of internal erosion.

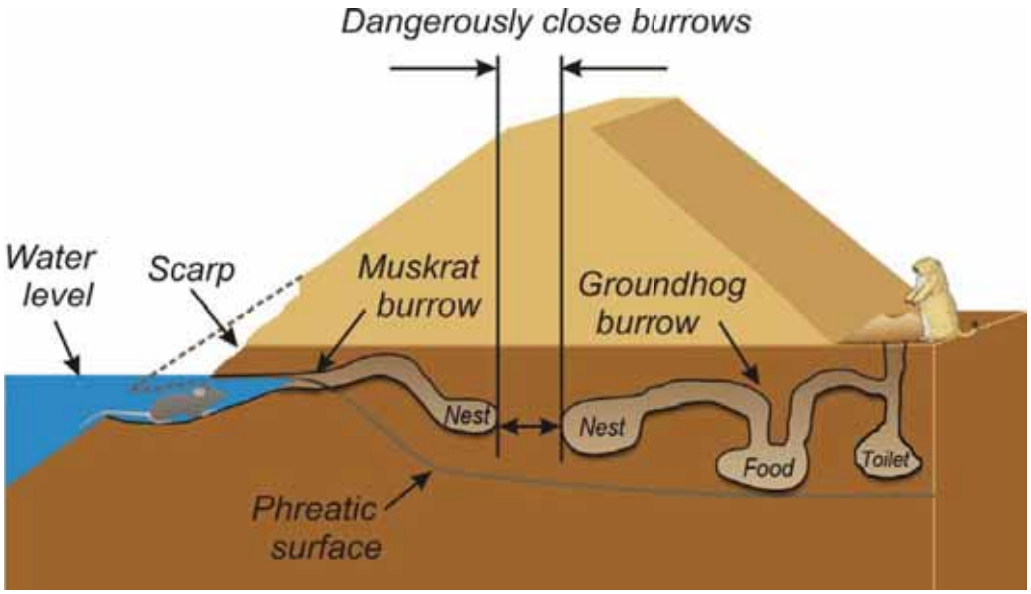
Animals/Rodents: Keep Them Out —continued

From the embankment:

Land rodents, such as gophers and prairie dogs, start burrowing on the outside of the embankment. Look at the crest and outside embankment slopes for holes and fresh dirt.

Rodent holes on the outside can pipe and cause erosion too.

Example of rodent burows through the embankment.



Muskrat digs den in the upstream slope, with the entrance tunnel beginning about 6 to 18-inches below the water line.

Animals/Rodents: Keep Them Out —continued

Act!

If cattle and other livestock are wandering onto a canal, find the owners and ask them to repair their fences to keep livestock on their property.

Deter animals and rodents from the canal area. Methods include:

- **Controlling vegetation.** Limit the amount of cover and food by removing or mowing vegetation.

PERC 412 equipped with a Tandem Axle (used by permission, all rights reserved).

- **Fumigants.** Fumigants, such as gas cartridges, carbon monoxide, or smoke bombs may work. Make sure there is adequate volume and pressure within the animal burrow. Below is an example of a system that probes burrows and fills them with carbon monoxide.
- **Trapping.** Trapping and relocating animals is an effective measure for controlling animals in small areas. Be aware of your state and local trapping regulations.
- **Bait.** Probe to find the animal's main burrow and dispense bait or toxicants into the burrow. Mark the burrow to backfill once the rodents are gone.
- **Shooting.** Shooting may provide some control in rural areas but should not be used as the primary method of control. A valid state hunting license may be required.
- **Armoring slopes.** Install impenetrable meshes on embankment slopes to prevent animals from burrowing into the embankments. Mesh holes need to be smaller than the target animals.
- **Filling burrows.** One option is to pump grout into rodent burrows. Another is to excavate the burrows. Moisture condition backfill, then place in lifts and compact with vibratory compaction equipment.

WARNING: Follow state and local regulations to obtain required permits for the removal or dispatching animals and rodents. Work with local biologists to identify endangered species known to be in the area.

Alien Invaders: Invasive Species

Why?

Invasive plants and animals can quickly take over canals!

Invasive plants and animals can grow rapidly because they have no predators. Identifying and controlling invasive species when they first appear is key.

Alien Invaders: Invasive Species —continued

Uhart?

Invasive species can harm the canal system by:

- Making deliveries more difficult
- Restricting flows
- Clogging trashracks
- Damaging infrastructure
- Creating maintenance difficulties

Watch for any unusual plants or animals taking over the canal system. Be aware of invasive species in your area. Sign up to receive alerts from the NAS Alert System: https://nas.er.usgs.gov/AlertSystem/Register.aspx.

Common culprits include:

Hydrilla has slender, branching stems that can grow up to 25 feet long and form dense strands. It is in Washington, California, and Arizona, but is far more common in the Southwestern U.S.

Hydrilla.

Water Hyacinth is a free floating perennial that can grow 3 feet high and form thick mats. It is in California and most of the Southwestern U.S.

Water hyacinth growth.

Water hyacinth leaf.

Quagga and Zebra Mussels are primarily in the Colorado River system, but have spread to California, Nevada, Arizona, Utah, Colorado, New Mexico, Nebraska, Kansas, and Oklahoma. See the map at www.usbr.gov/mussels/history/map.html to see if mussels are in your state.

Quagga mussels on trashrack.

New Zealand Mudsnails are tiny snails with brown or black cone-shaped shells. These are primarily in the Snake River in Idaho and the Madison River in Montana. Even though they are tiny, they can congregate in large numbers and clog a canal.

Many mudsnails can fit on a dime.

Alien Invaders: Invasive Species —continued

Act!

Pay attention to new plants in the canal prism. If you see an unusual plant or animal:

- Mark the extent of their area and take regular pictures to monitor their spread.
- Take a picture and send it to www.usgs.gov/stopans. The U.S. Geological Survey can identify the species and provide instructions on how to control or remove it.

Invasive plants and animals spread by "hitching" a ride on a boat or other water equipment used in infested water and transported to another water body.

Help prevent the spread:

- Clean all boots, equipment, and everything that came in contact with one canal thoroughly before moving to another, unconnected system
- Avoid driving over seeds or vegetation
- Wash the undersides of trucks and equipment if it has gone through a known invasive weed patch
- Use only certified "weed-free" straw or mulch
- Don't move weed-infested gravel or dirt to a new site

People: Unauthorized Construction

Why?

When people construct **unauthorized "modifications"** to canals, they can create unsafe conditions and compromise effective water deliveries.

What?

Watch for signs of potential new construction, such as survey flags, ground leveling, equipment, new fences, billboards, etc.

Improvised bridges over a canal:

- Encourage unauthorized access to areas off limits to the public
- May impede access for maintenance equipment in the canal
- Create liability and safety problems for your district
- May not be designed to carry the heavy loads of modern equipment
- May create a load on the canal, cracking canal linings and harming embankments

This bridge could not support the weight of this truck.

Look for changes on the embankment:

- Any construction on an embankment is a problem unless it is approved to actually widen or strengthen the embankment.

—continued

People: Unauthorized Construction —continued

Uhart?

- Using embankment material as a borrow source for construction elsewhere weakens the embankment and decreases freeboard.
- Buried utilities, utility lines, and poles on the crests and slopes of embankments obstruct access and could damage the embankment.

The right side and toe of this canal embankment has been cut away for use as an access road.

Power pole in the embankment slope and fence at the embankment toe.

Someone installed a culvert and made a "road crossing" with old concrete for their pivot wheel to cross the canal.

Improvised culvert installations. If not sized or installed correctly, they can restrict the canal flow and result in overtopping.

Act!

Write down the location and take pictures of perceived unauthorized construction.

Notify your supervisor or watermaster of any problems.

Immediately report any new signs of unauthorized modifications or abuses of the canal system.

Keep warning signs up to deter future activities on canals.

Sign to reduce unauthorized activities on the canal.

People: Urban Encroachment

Why?

People now build houses and cities near what had been rural.

Urbanization impacts can:

- Compromise your ability to deliver water
- Impede access to maintain the canals

Moreover, O&M on urban canals is even more critical—breaches or failures can result in population at risk and property damage.

Reclamation defines an Urbanized Canal reach where failure could affect over 100 people or cause property damage greater than $5,000,000.

Development with retaining wall at embankment toe next to road.

What?

Examples of urban encroachment that can impact the canal's O&M include:

- Swimming pool excavations too close to the canal toe allow canal seepage to come to the surface.
- Terracing, landscapes, and gardens on the embankment slopes introduce vegetation and roots that can weaken the embankment and create seepage paths. This also requires irrigation on the embankment slope, which can further weaken the embankment slope.

Swimming pool at the toe of a canal.

A large tree and irrigated lawn on the downhill embankment of a canal.

The backyard at the toe of this concrete canal flume embankment shelters trees and harbors seepage from the canal.

—continued

People: Urban Encroachment —continued

What?

- Structures such as retaining walls, fences, buildings, and houses built at the toe of canal make it difficult to access the canal to perform O&M.

- Privately installed structures such as retaining walls, or buildings that cut embankment toes during construction can cause structural stability problems in the canal embankment.

Fences close to the embankment toe do not allow enough room for you to perform O&M.

Because of this retaining wall, water only needs to seep through ten feet of embankment to inundate this property rather than through the wider original embankment.

Act!

- When you see urbanization on or near the canal, note the location and immediately notify your supervisor or watermaster.

- Catch encroachments as soon as possible. Stopping someone when they lay the first stone is easier than after they have completed the wall.

- Have your supervisor or watermaster pay attention to town or county planning commission meetings regarding proposed developments along canal embankments.

- Closely monitor new or existing seepage areas in people's backyards.

People: Vandalism and Sabotage

Why?

People with bolt cutters, spray paint, or guns can threaten water deliveries.

If vandalism or theft damages canal structures, it can impact operations and be expensive to repair and replace.

What?

Watch for any and all clues for sabotage, theft, or vandalism which may impact your district's ability to deliver water. Check for missing equipment or parts of equipment.

If there are bullet holes in the cover (left) and interior (right) of the equipment, inspect for damages.

Make sure that all security features (gates, locks, fences, security alarms, cameras) are maintained and that no one has tampered with them. Keep the public out of unauthorized areas.

Vandalized solar panel.

Shot-up sign and cut chain-link fence.

If you see some damage, look for other damages.

People: Vandalism and Sabotage —continued

Act!

If you identify vandalism or damages, notify your supervisor or watermaster. Develop a plan to respond and repair. Actions include:

- Verify that the automated control system is still working. If not, you may need to go to manual operations to make water deliveries and maintain flow levels in the canals.
- Work with local law enforcement. You may need to explain that damage to the system means that your customers don't get water, or that people are at risk from canal incidents or failures.
- Quickly repair damage to maintain the system operations. Graffiti should be covered as soon as possible so that it does not invite further trouble.
- Post signs to keep the public away from the canal system. Consider multilingual signage.

Seepage

Why?

Don't let water seep from any canal!

If the seepage flow from the canal is fast enough, it can move soil particles, causing internal erosion and resulting in piping and failure of the embankment. Identify seepage and repair it before the canal fails.

Moreover, the less water that seeps means more water for your customers.

What?

Monitor and document canal flows, precipitation, and downslope groundwater levels.

Watch for signs of newly developing or worsening seepage, which may include:

- Wet spots getting larger.
- Water flowing from the canal.

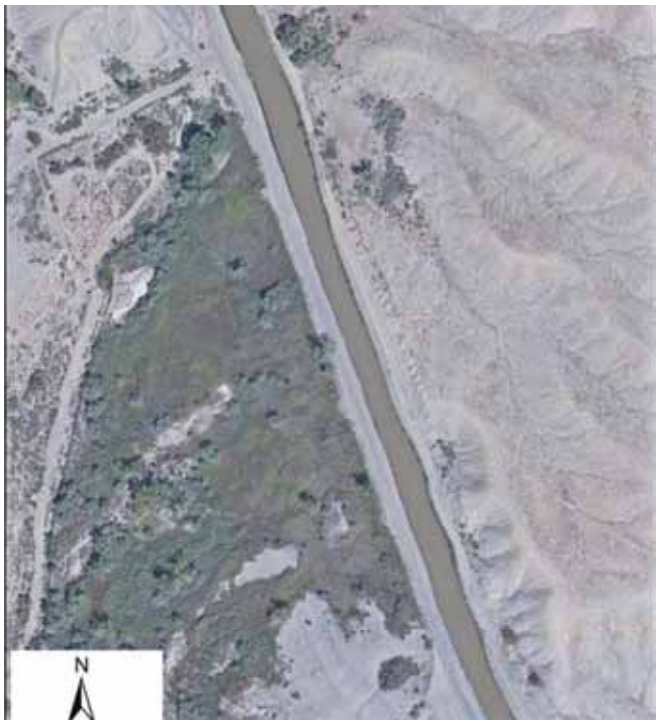
—continued

Seepage from a canal into the road below.

Seepage —continued

What?

- Water ponding at the embankment toe, or wet areas on the embankment slope.
- Green and/or water-loving vegetation in an otherwise dry location.
- Sand boils indicate that soil particles are piping or moving through the embankment and can result in internal erosion and failure of the embankment.



This aerial view shows a dry area, but thriving vegetation shows where the canal is seeping.

Sand boils.

- Cloudy seepage water exiting the embankment or toe indicates that the water is moving soils and causing internal erosion.
- Depressions in the embankment can indicate seepage pathways are growing and beginning to collapse.

The depression on this embankment is just above a seepage area on the embankment toe.

Act!

Things to do when you **identify** a seep:

- If you find signs of newly developing and/or worsening seepage, immediately notify your supervisor or watermaster and Reclamation to determine if further action is necessary.
- Monitor seepage areas more frequently during and after significant storm events, and during periods of peak water levels. Measure the seep's flow rate by:

  ► Controlling water and measure flow rate with weirs or even a five-gallon bucket.

—continued

Seepage —continued

Act!

► Taking pictures regularly, both of the seep location and the canal side of the embankment to document changes.

► Marking seepage areas with stakes to monitor if the seepage area grows outside of those stakes.

- Alert your supervisor or watermaster and Reclamation if the flow rate increases.
- If you see cloudy seepage water, **ACT FAST**. Notify your supervisor or watermaster and contact Reclamation to design and repair immediately.

Sandbag ring.

To temporarily **stabilize** a seep, until engineers can assess and provide a proper repair design, you could:

- Adjust check structures to lower the canal water surface by two feet.
- Provide a blanket of concrete sand and then a gravel layer to temporarily retard piping of embankment material.
- Build a sandbag ring to raise the water surface level above the seepage or sandboil—even two feet of head can make a difference.

Example of Aqualastic placement following concrete surface preparation.

To temporarily **repair** a seep:

- Place fine-grained soils on the inside of the canal prism just upstream of the suspected seepage path. Water seeping through the canal may carry the soil with it and plug the hole.
- Treat cracks and joints in concrete canal lining with Aqualastic or an equivalent product.
- Work with a geotechnical engineer to inject chemical grout to fill seepage paths.

Pressure grouting to fill seepage paths behind the concrete lining.

Plugs and Clogs: Keep Canals and Wasteways Clear

Why?

Keep the canal and wasteways **free of obstructions** so they are able to operate correctly at all times.

A plugged trashrack can back up water and cause overtopping.

Obstructions in the canal can create false readings—altering measurements and automatic operations.

What?

Find the source of any problem—this may be a symptom of a larger issue. Watch for anything in the canals and wasteways, including:

- Silt or mud
- Trash, debris, or litter
- Lawn clippings or fall leaves
- Cars or other vehicles
- Dead bodies and animals
- Rocks, soils, and landslides
- Excess vegetation
- Illegal dumping

This concrete/aggregate plant is discharging wash water directly to a canal and loading the channel with mud.

Top: Litter can slow down flows and plug up pipes/culverts.

Bottom right: Excessive vegetation in wasteways prevents rapid evacuation of water.

Plugs and Clogs: Keep Canals and Wasteways Clear —continued

Act!

Make sure canals and wasteways are clear to carry water:

- Clear obstructions.
- Clean trashracks so water continues to flow.
- Occasionally dredge to remove excessive sedimentation and vegetation.
- If channels are eroding or sloughing, then riprap or other types of protection may be needed.
- Educate people not to trespass and dump trash and lawn clippings into canals. Report "repeat offenders" to law enforcement.

Clearing a trashrack.

- Post signs and work with the community to prevent litter.
- Fencing or restrict access to "hot spots."
- Work with your supervisor or watermaster and others to improve safety measures if you repeatedly find cars, dead animals, etc. in a particular location.
- Notice the flow patterns. Watch for changes in flows that might signal underwater obstructions or failure, such as significant turbulence.

Plugs and Clogs: Monitor Drains, Pipes, and Undershots/Overshots

Why?

Drains, turnouts, culverts, outlet pipes, undershots/overshots, and other crossings on canals can cause problems:

- During storm events, they can direct storm water into the canals. If canals can't handle that extra water, they may overtop.
- Pipe penetrations provide places where water can flow or "pipe" along the outside of the pipe and cause internal erosion in the embankment.

Plugs and Clogs: Monitor Drains, Pipes, and Undershots/Overshots —continued

Pay attention to utility conduits and any pipe penetrations in canal embankments. Around utilities, pay attention to sink holes, wet spots, discolored water, and unusual odors that may come from utilities crossing the canal.

Investigate pipes to make sure that they continue to carry water:

- Note distressed or corroding pipes that can allow water to seep outside of the pipe, which can cause cover material to collapse. This can ruin the pipe and breach the embankment.
- Look at pipe joints for cracks/breaks since these locations tend to be weak points on pipelines that fail first.
- Always note seepage along the outside of pipes (both on the embankment and canal prism).
- Deflection, subsidence, displacement, or bulges of pipe segments. Shine a flashlight through the pipe to identify these issues.
- Sedimentation or plugging in the pipe.
- Unusually turbid discharge water.

Seepage entering a corrugated metal pipe (CMP) conduit through a defect.

Plugged CMP culvert.

Inspect all pipe penetrations for signs of seepage, piping, improper backfilling, damaged pipe, or plugged outlets or pipes, such as:

- Clogging
- Algae or other vegetation
- Rust staining
- Calcite deposits
- Wet spots, depression, and sinkholes
- Water around the culvert or depressions in the sand
- Erosion/scour damage at the pipe inlet or outlets.

—continued

Plugs and Clogs: Monitor Drains, Pipes, and Undershots/Overshots —continued

Pay extra attention to the following types of pipe crossings, culverts, or turnouts. These features are prone to failure due to freeze/thaw problems, improper construction, joint failures, deflection, or corrosion:

- Vitrified clay pipe
- Corrugated metal pipe
- Corrugated high-density polyethylene (HDPE) pipe

If pipes cross below the canal, where accessible, look for seepage. Listen for dripping water as that indicates water is seeping from the canal down into the drain, culvert, or pipe.

When driving the O&M road, look upstream of and downstream from undershots and overshots to see that they have clear drainage paths; look for and remove obstructions such as vegetation, debris, and litter.

Canal undershot with plugged outlet.

Note on a map where drains, pipes, culverts, undershots/overshots, etc. are located.

Keep on top of issues:

- Drains, pipes, and culverts are difficult to examine and determine if they are plugged. Clear obstructions so you can verify structural integrity and proper operation.
- Silt deposits or standing water in a closed drain's outlet or manhole can indicate a blocked drain downstream. Unplug it.
- When needed, excavate suspect areas to determine the seriousness of the problem and the need for repairs.
- When you think there is a problem in a pipe or siphon and you cannot get inside, examine with remote cameras or use acoustic monitoring.
- If your district is not responsible for the pipe, drain, or culvert, work with your supervisor or watermaster to notify the responsible party to perform maintenance.

Caution: Be aware of confined space conditions.

Keep Mechanical Equipment Running Smoothly

Why?

Keep mechanical features moving—you never know when you might need to open that gate or turnout.

What?

Ensure that all checks, wasteway structures, gates, and valves are exercised through complete cycles periodically. Test using both main and backup power.

Check and Wasteway Structures

- Do they operate at all? Are they difficult to operate?
- Are they leaking?
- Are there large scour pools downstream, which may indicate fast flows from the check structure? This head cutting progressing upstream could eventually undermine the structure.

Exercise to make sure mechanical features operate when you need them to work.

Gates and Valves

- Are they exercised regularly?
- Is there rust, corrosion, or other damage?

Maintain gates so they do not become so corroded that they need to be replaced.

Stoplogs and Seals

- Are rubber seals still flexible? Seals usually crack when they harden.
- Are the guides or the concrete sills damaged?
- Has trash built up?
- Do metal stop logs have any exposed metal that could rust and lead to leaks?
- Is there any corrosion?
- Are stop logs properly protected and stored in known accessible locations?

Automatic Controls

- Are the covers for remote terminal units (RTU) intact?
- Is the machinery working?
- Are the batteries still in place and fully charged?

Keep Mechanical Equipment Running Smoothly —continued

Act!

Check structures and gates. Exercise equipment to ensure you can:

- Move water through the system
- Handle overflows
- Meet quick demands
- Respond quickly to emergencies or canal failures to isolate the canal reach
- Understand lockout and tag-out procedures

Notify your supervisor or watermaster of any mechanical problems.
Schedule regular tests of equipment.

- Exercise the gates
- Test the automatic systems

Keep the equipment in good repair by:

- Painting equipment to protect against corrosion
- Adding a cathodic protection system to prevent further corrosion damage
- Replacing cathodic protection features (such as anodes) as they wear out.

Maintain Canals: Canal Prism-Inner Embankment Slopes

Why?

Keeping canal prisms intact keeps waterways clear for deliveries and prevents even more damage.

When concrete canal linings are damaged, water can move behind the liner and scour or erode the unprotected areas of the interior embankment slopes or the foundation of the canal.

On an unlined canal, water and wind can erode the canal prism or interior embankment slopes and cause sloughing, which may plug the canal.

Where?

On concrete lined canals:

- Check expansion joints
- Look for new cracks or bulges as they appear on the concrete lining. Rapid water changes, age, freeze/thaw, and heat can also cause concrete to buckle or crack.

—continued

Buckle in concrete canal lining.

Maintain Canals: Canal Prism-Inner Embankment Slopes —continued

Uhart?

- Cracks can create openings for water to flow through. This flowing water erodes the side walls of the flaw, causing it to enlarge.
- Watch for voids or missing concrete
- Pay attention to what you construct within the canal. Many features will change the hydraulics and have negative impacts on the canal. All modifications and additions to the canal must be approved by Reclamation in advance.

Scour damage to the invert of the canal from a homemade check structure in the canal.

Holes allow surface water to flow behind the lining and can create large voids behind the lining.

Erosion on left inner bank at cut section below shotcrete lining.

On unlined canals:

- Identify surface erosion and sloughing on the inside of a canal before it causes slumping or collapse of the embankment slopes, to prevent canal plugging and possible breaks.
- Make sure the slopes don't get too steep. Inspect the inner embankment for evidence of existing or developing sloughing, cracking, depressions, bulges, scarps, oversteepened slopes, or slope failures.

—continued

Maintain Canals: Canal Prism-Inner Embankment Slopes —continued

Erosion/ sloughing on the inside prism (left).

Cracks and oversteep slopes (right).

- When the canals dry up, shrinkage (desiccation) cracks can form in clay as the clay shrinks. When the canal is watered up, water will travel down the cracks, through the clay.

Shrinkage cracks on the inner embankment.

Sediment build up on an unlined canal.

Monitor sediment build up. Erosion and subsequent sediment deposition can require ongoing maintenance to prevent the canal alignment from slowly moving over time—especially at canal bends.

Maintain Canals: Canal Prism-Inner Embankment Slopes —continued

Act!

Perform maintenance and regular repairs to avoid major problems such as:

- Experience is required to understand when a particular hole or void may require further investigation or design engineer assistance. Consult with experts and work with your supervisor or watermaster.
- When you fill holes/voids, probe or excavate to further open the hole to see the extent of the void. Then backfill with compacted material.
- Use fine-grained soil to fill small holes/voids.
- If a concrete lined canal is seeping, seal cracks with Aqualastic ® or equivalent product to seal cracks in the lining.

Applying Aqualastic ®.

If the canal prism is sloughing or experiencing erosion, place riprap to protect the inner canal slopes from erosion. Consult an engineer to obtain the correct size of riprap to use and to determine the placement methods and slope. "Flat" concrete pieces without bedding will slide down the embankment and not provide stabilization or protection.

This canal was armored with recycled concrete and asphalt riprap.

Replacing canal concrete lining.

Maintain Canals: Embankment Crest-O&M Road

Why?

O&M roads along canals usually also function as embankments and should be well maintained to:

- Allow equipment to access the canals for maintenance
- Minimize erosion and runoff
- Maintain minimum embankment design width
- Prevent seepage or sediment from entering the canal

What?

On your rounds, **keep an eye on the O&M road** (the embankment crest).

Look for:

- Excessive vegetation which impacts your ability to make observations and provides habitat for rodents
- Rodent burrows
- Signs of internal erosion: voids, depressions, and sinkholes
- Longitudinal cracks, horizontal cracks, and vertical cracks

Voids along the O&M road.

Pay attention to cracks; they can be difficult to see with excessive vegetation.

Act!

Maintain the canal embankment crest:

- Maintain gravel surfacing.
- Maintain the road crest with a motor grader.
- Prevent rutting and "mud puddles" by shaping the crest to promote drainage off of the embankment.

—continued

Maintain Canals: Embankment Crest-O&M Road —continued

Act!

- Keep surface runoff from going into the canal by maintaining the "peanut roll" or windrow —that little mound of soil that prevents runoff from flowing into the canal.
- If you see a void or depression, notify your supervisor or watermaster. Determine the cause and then repair.
- Treat vegetation and rodents
- If you see cracks, notify your supervisor or watermaster and Reclamation immediately to determine the cause and design a repair.

Poor road maintenance has resulted in a berm on the outside edge of the crest of the road that prevents the water from draining off of the embankment.

Windrow from the pass of a motor grader.

Try to determine the cause of the void and repair as quickly as possible.

Maintain Canals: Outer Embankment Slopes & Beyond

Why?

Outer embankment slopes become unstable and "slough" off. Sloughing can cause slipping and slumping of the embankment.

Intense rain can erode the surface of embankment slopes, creating voids on the embankment or slopes and compromising the structural integrity of the embankment.

What?

When you are driving your rounds:

- Look at the outer embankment slopes for rodent holes and excessive vegetation
- Examine all areas of the embankment and toe for irregular ground surfaces (bulges, cracks, or holes)
- Watch for drainage damage down the embankment slope
- Pay attention to any excavations near the toe of the embankment

—continued

Maintain Canals: Outer Embankment Slopes & Beyond —continued

This road was built so close to the embankment that they cut off the toe of the canal embankment.

- Look at slopes for signs of erosion; including rain channels. Storm water will continue to use these paths, carving them even deeper.

Rain channel from intense rain erosion.

- Pay attention for sloughing or slope instability.

Sloughing of the outside slope of the canal embankment.

Maintain Canals: Outer Embankment Slopes & Beyond —continued

Act!

Maintain the canal's outer embankment slopes:

- Repair minor areas of instability by over-excavating the damaged area, backfilling with soil in lifts, moisture conditioning and compacting each lift, and reseeding the slope with native vegetation to protect the slope from erosion.
- If you see evidence of instability or slope failure, notify your supervisor or watermaster and Reclamation immediately.
- Monitor the area of slope failure daily for worsening conditions until repairs are made.

This canal embankment had longitudinal cracking (and excessive vegetation). Repairs of the embankment prevented failures that could have washed into the adjacent river.

Maintain Canals: Concrete Canal Structures

Why?

Concrete lining, drop structures, checks, division boxes, turnouts, flumes and culverts can perform for decades with proper maintenance.

But without constant vigilance, concrete exposed to the elements will experience deterioration over time, and will need to be repaired. Some issues that can result from concrete deterioration or damage:

- Failing joints can result in seepage
- Exposed rebar could rust and weaken the concrete structure
- Cracks can propagate leading to more damage to the structure

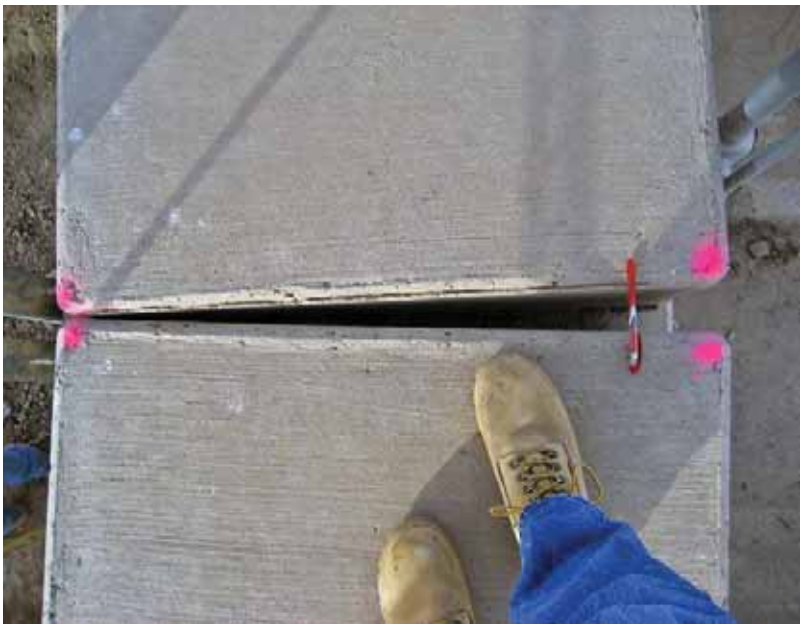
Maintained 1916 concrete turnout with radial gates—this does not look 100 years old!

Maintain Canals: Concrete Canal Structures —continued

Uhart?

Some things to look for:

- Cracks in the concrete
- Concrete spalling, scaling, or a network of fine cracks in the concrete
- Displacement where walls are no longer vertical
- Rust staining or exposed rebar
- Noticeable movement in control joints



Displacement in concrete may be a result of a bigger problem such as overloading of the concrete structure.

Freeze and thaw damage to concrete flume.

Act!

Keep concrete structures in good operating conditions by keeping an eye out for concrete deterioration or movement and notifying your supervisor or watermaster of any issues as soon as you see them.

Work with your supervisor or watermaster and consult a structural engineer and/or a materials engineer to ensure displacement and cracking are not evidence of a structural issue and to determine what repairs or replacements are needed.

Contact Reclamation if you have any questions or need recommendations on how to repair concrete structures.

Reclamation: Review of Operations and Maintenance (RO&M) Examinations

Why?

Periodic inspections of canals and associated features are critical to:

- Ensure safe and efficient canal operations
- Identify actions that need to be taken to maintain and repair canals

What?

Reclamation conducts RO&M examinations at least:

- Every 6 years on rural canals
- Every 1 to 3 years on urban canals

During these examinations, Reclamation inspects the canal embankment, including: the inside canal prism, embankment crest, and outside of the embankment, the area along the embankment toe, wasteways, laterals, check structures, and features associated with the canal.

Reclamation performs:

- **Dewatered/Dry Examinations** to show many canal features that would otherwise be submerged.
- **Watered up/Wet Examinations** to provide valuable information on seepage conditions and canal operations.

During examinations, Reclamation may develop formal O&M recommendations to document the need to maintain the structural integrity of the canal and extend the canal's service life. Recommendations are categorized based on the severity of the problem deficiency:

- **Category 1.** Correct severe deficiencies where **immediate** and responsive action is required.
- **Category 2.** Address an important matter because action is required or needed to **prevent** or reduce further damage.
- **Category 3.** **Improve** and enhance water deliveries and maintenance for the system.

Act!

Your role in Reclamation RO&M examinations:

- Participate with Reclamation staff during RO&M and urban canal examinations.
- Notify Reclamation inspectors of any problems you know about.
- Schedule and complete recommendations in a timely manner to keep the canal operating effectively. Ask Reclamation to provide technical assistance or guidance.

Documentation

Why?

While on your rounds, **document daily activities and observations** including:

- Deliveries
- Incidents
- Seepage areas
- Unusual activities on the canal

Your daily log will help to:

- Notify your supervisor or watermaster of issues and changes on the canal
- Remind you of prior activities
- Inform you about what other canal operators did on your ride during your days off.

What?

In general, your daily log should document information such as:

Operations

- Normal changes in operation of individual gates and positions
- Canal monitoring and observations based on stationing, mileposts, or GPS locations
- Water surface elevations and deliveries

Maintenance

- Major and minor maintenance activities
- Scheduled maintenance
- Startup and stopping of mechanical equipment
- Testing of standby equipment or gate controls
- Exercising of any gates and valves
- Communications network checks performed
- Verifying adherence to SOP, if applicable

Specific Occurrences

- Initial acknowledgment of unusual or emergency conditions (e.g., new seepage area)
- Daily observation and monitoring of problem
- Follow up to address emergency conditions
- Emergency changes in operations
- Record of names and addresses of visitors
- Report of vandalism
- Attending a Review of Operation and Maintenance (RO&M) examination
- Weather conditions or recent natural events

Documentation —continued

- **Document** your daily activities and observations
- Take photographs. Pictures let people see the problem for themselves—some things are difficult to describe in words. Always include something in the photo to show the size (for example, a yardstick, person, or car). Keep your cell phone with you and take regular pictures of trouble spots and anything unusual.
- When issues develop, review your log to help you determine clues to the causes of equipment trouble or development of unusual conditions occurring in the canal system.

Public Safety: Prevention

Why?

Preventing an accident from happening saves lives.

It also prevents operational disruptions. Urgent responses to accidents can have long-lasting consequences to the canal. For example, lowering water levels quickly during an emergency can result in lasting damage to canal linings.

What?

Watch out for potentially dangerous situations surrounding the canal, including places where someone could:

- Fall down steep slopes
- Drown
- Drive into the canal

Make sure that preventative measures are in place, including:

- Ladders and buoys so people and animals can escape
- Gates and fencing to keep people out
- Posts and guard rails to prevent cars from driving in
- Well maintained gravel surfacing to keep vehicles on the O&M road
- Signs to discourage the public from entering the canal

An ounce of prevention is worth a pound of cure.

Buoy line.

Escape ladder just downstream from the rescue team.

This "gate" was installed to prevent all-terrain vehicles from entering the canal.

Act!

Make sure that safety features (buoy lines, fences, signs, etc.) are in place and well maintained.

Notify your supervisor or watermaster when safety features require repairs.

Clearly post all restrictions and hazards associated with the canal along the O&M road, especially at public access points. Signs should use the simplest language possible:

Warning! **Danger!**
Do not swim! **Swift Currents!**

Public Safety: Emergency Management Plan (EMP): "Whatcha Gonna Do?"

Why?

When the canal fails or unexpectedly discharges water, **don't panic… respond efficiently-follow your EMP.**

- When canals breach or fail, they put people and property at risk.
- The EMP provides directions so you can quickly dewater the canal reach to save lives, and minimize property damage.

Canal breach.

What?

An EMP is a formal document that describes how you should:

- Coordinate with emergency management authorities to respond to canal incidents or failures.
- Respond to an uncontrolled release of water from the canal.

Each district's EMP is unique and tailored to a specific canal system. The EMP should include, but is not limited to:

- Response levels to observations or concerns corresponding to internal monitoring and external notification and specific actions to be taken.
- Emergency shutdown procedures to minimize consequences.
- An accurate and current communication directory for notification purposes. Your district should verify these contacts annually during a communications check.

Public Safety: Emergency Management Plan (EMP): "Whatcha Gonna Do?"—continued

Act!

- Carry your EMP in your truck.
- Review the EMP annually and ensure it is up to date.
- In the event of a canal failure follow your EMP to:
  - ► Quickly contact required personnel
  - ► Dewater the canal reach to reduce impacts.

Use your EMP to respond during the next canal failure.

Dewatered canal following a breach.

Definitions: What Are They Really Saying?

Annulus: The void between a pipe and the ground or within a double pipe.

Automatic operation method: A control system that upgrades the manual method of canal system operation to an automatic controlled system operation.

Bore waves: See translatory waves.

Canal: A channel, usually open, constructed to convey water by gravity to farms, municipalities, industrial uses, and power purposes, etc.

Canal check gate structure: The principal control structure on a canal system, used to maintain upstream water levels and regulate flow in downstream canal pools and canal side turnouts.

Canal incident: An uncontrolled release of water from a canal regardless of the cause; including adverse seepage conditions and other near failure events. Notify Reclamation of any canal incident.

Canal operator : The individual responsible for controlling the canal system on site based upon the flow schedule established by the watermaster at the central headquarters.

Canal prism: The shape of the canal as seen in cross section. The prism can include embankments, hillsides, and road features next to the canal.

Canal pool: Canal section between check structures.

Canal pumping plants: Lifts the main canal flow to a higher elevation. Canal pumping plants can be located near the head of the canal, or along the canal alignment, or may be used as the headworks structure. The pump intake or connector canal may be from a reservoir or from another larger main canal system. Some canal systems, because of topography, require relift pumping plants in line with the canal system

Canal reach: Segment of the main canal system consisting of a series of canal pools between major flow control structures such as pumping plants and reservoirs. Sometimes, reach boundaries are defined by significant changes in canal capacity.

Canal side pumping plants: Pumps water from a canal to delivery points, typically into a pressurized delivery pipeline. Occasionally pumps directly to a center pivot irrigation system, or to a small delivery canal or field located at a higher elevation.

Canal system: Delivers water from a primary source of supply to several diversion points or canal side turnouts to smaller distribution systems.

Check structure: A structure used to regulate the upstream water surface and control the downstream flow in a canal.

Control system: An arrangement of electronic, electrical and mechanical components that commands or directs the regulation of an automated canal system.

Conventional operation method: Canal system control on site by operations personnel including, canal operator and watermaster.

Culvert: A pipeline carrying a stream or open drain under a road or canal.

Distribution system: Series of canals, laterals, and pipelines that deliver water from the main canal side turnout to water users or to smaller distribution systems.

Diversion dam: A small dam commonly constructed on a natural river channel and designed to check or elevate the water level for diversion into a main canal system. The diversion dam also could be used to store and regulate inflows released from an upstream storage reservoir.

Drain blanket: A layer of pervious material placed to facilitate drainage of the foundation and/or embankment.

Drop structure: A structure that conveys water to a lower elevation and safely dissipates the excess energy resulting from the drop.

Emergency Action Plan (EAP): A formal document that identifies potential emergency conditions at a dam and specifies actions to be followed to minimize loss of life and property damage. The EAP describes actions the dam operator will take to moderate or alleviate a problem at the dam, as well as actions the dam operator, in coordination with emergency management authorities, will take to respond to incidents or emergencies related to the dam.

Emergency Management Plan (EMP): A formal document that is a similar to an EAP in an abbreviated format. The EMP describes the actions the canal operating entity/office will take to moderate or alleviate an uncontrolled release of water from the canal or incidents or failures related to the canal and coordinate as well as actions the operating entity, in coordination with emergency management authorities, will take to respond to incidents or failures related to the canal. The canal EMP may be an appendix to the project dam EAP.

Erosion: Surface displacement of soil caused by weathering, or abrasion, and transporting.

Examination report: A written report that documents the condition of the facility during the examination, operation and maintenance activities accomplished since the last examination, and recommendations necessary for the continued safe and efficient operation of the facility.

Freeboard: The additional lining and bank height above the normal designed water surface level in an embankment. In a lined canal, the amount of freeboard is equal to the amount of vertical clearance of canal lining plus the embankment available above the normal design water depth. In an unlined canal, the amount of freeboard is the amount of vertical clearance of embankment above the maximum design water depth.

Freeze-thaw damage: Damage to concrete caused by extreme temperature variations as noted by random pattern cracking. Damage is accelerated by the presence of water and is commonly more severe on the south-facing side of structures.

Gate: A device that controls the flow in a canal, conduit, pipe, or tunnel without obstructing any portion of the passageway when in the fully open position.

Grout: A fluid mixture of cement and water used to seal joints, cracks and voids in foundations. May include sand and other chemical additives as directed by a "grouting engineer."

Head: The difference in number of feet between two water surface elevations. Also known as "pressure."

Head loss: The energy per unit weight of water lost due to transitions, bends, etc.

Heave: The upward movement of land surfaces or structures due to subsurface expansion of soil or rock, or vertical faulting of rock.

Inundation zone: The estimated area below a canal that could flood if the canal failed.

Invert: The lowest point of the interior of a canal, circular conduit, pipe, or tunnel.

Inverted siphon: Used to convey canal flow by gravity under drainage channels, rivers, depressions, roadways, or other structures, and return the canal flow to a downstream point only slightly lower in elevation than the upstream end of the siphon. An inverted siphon, sometimes referred to as a "sag pipe," is a closed conduit designed to flow full under pressure.

Lateral: A channel that conveys water from a canal to a farm, municipality, etc.

Lining: Any protective material used to line the interior surface of a canal, conduit, pipe, or tunnel.

Log: A dated, written record of performed operation and maintenance items or observations pertinent to a structure.

Municipal and Industrial (M&I): Water that is provided for municipal and industrial purposes. Operations and Maintenance (O&M): Activities including monitoring and control of the day-to-day water transfers, and providing the efficient maintenance and repairs to continue safe canal and associated features operations.

OM&R: Operation, maintenance, and replacement.

Piezometer: An instrument which measures pressure head or hydraulic pressures in a conduit or hydraulic pressures within an embankment; at the foundation because of seepage or soil compression; or on a flow surface of a spillway, gate, or valve.

Phreatic line: The elevation of saturated soil. Often the phreatic line will be slightly below the canal water level within the canal embankment and get lower farther away from the canal.

Pipe: A circular conduit constructed of any of a number of materials that conveys water by gravity or under pressure.

Piping: The action of water passing through or under an embankment while carrying some of the finer materials with it to the surface at the downstream face. Also known as "internal erosion." The downstream end of the piping is not necessarily always seen.

Population at Risk (PAR): The estimated number of people within the inundation areas as a result of water released from a canal, during its failure. The value is based on the estimated number of people within dwellings, buildings, cars, camping areas, etc., inside the inundation zone.

Ramping rate: The rate that water is added to or removed from the canal, for example, 1 foot per 24 hour period.

Reach: The area of a canal or lateral between check structures.

Recommendation: An action required by facility management to implement a Reclamation operations and maintenance (O&M) practice, local practice, or industry standard, or a suggested improvement based on the "category" of the recommendation.

Remote operation: Operation of mechanical features from an off-site location other than at the feature.

Reserved works: Facilities operated and maintained by Reclamation.

Reservoir: Collects and stores water from storm runoff and snowmelt. It is the primary source of supply of project water. Usually, large storage reservoirs are located upstream of the main canal system. Storage reservoirs include:

- **Offline reservoir:** Constructed to the side of the main canal rather than in a natural river or drainage channel. Normally, it requires a pumping plant to lift water from the main canal into the reservoir. The offline reservoir is used primarily to store surplus water runoff during the winter season for use during the irrigation season.

- **Inline reservoir:** Constructed in line with the canal and is essentially a large pool of the main canal. Small inline reservoirs primarily are used to regulate the main canal flows to maintain a balanced operation. Inline reservoirs also may be used for carryover storage.

- **Regulation reservoir:** Constructed either as an offline or as an inline reservoir of the main canal system. The purpose of the regulation reservoir is to reduce the mismatch between downstream demands and upstream water supply to maintain a balanced operation.

Riprap: The broken rock or boulders placed on upstream and downstream faces of embankments to provide protection from erosion caused by wind or wave action. Typically, riprap uses processed and graded rock with rough and irregular faces.

Sand boil: Seepage with particles of sand bubbling up at the ground surface.

SCADA: (Supervisory Control and Data Acquisition) is a system operating with coded signals over communication channels so as to provide control and data collection from remote equipment.

Seepage: The slow movement or percolation of water through small cracks, pores, interstices, etc., from an embankment, abutment, or foundation.

Seismic: Of or related to movement in the earth's crust.

Settlement: The sinking of land surfaces from subsurface compaction, usually occurring when moisture is added deliberately (hydro-compaction) or by nature, causes a reduction in void volumes.

Sinkhole: A steep-sided depression formed when subsurface embankment or foundation material is removed, causing the overlying material to collapse into the resulting void. Commonly caused by piping of materials or the dissolving of underground limestone formations.

Slough: Movement of a soil mass downward along a slope because of a slope angle too great to support the soil, wetness reducing internal friction among particles, or seismic activity. It is also called a slope failure, but this usually indicates a rather shallow failure.

Spalling: The loss of surface concrete, usually caused by impact, abrasion, compression, or poor concrete mix quality.

Standing Operating Procedures (SOP): A comprehensive document that provides guidelines and procedures for operations of a specific canal. Its purpose is to ensure adherence to approved operating procedures.

Stoplogs: A set of interchangeable fabricated steel or wood units lowered between walls or piers to close a water passage in a dam, conduit, spillway, etc.; the logs are inserted in slots one at a time. A lifting beam may be used to install or remove them.

Subsidence: The large scale sinking of land surfaces, typically caused by the removal of subsurface water, oil or other extractions.

Toe: The contact location between the embankment fill surface and the original or natural ground surface.

Toe drain: Open-jointed tile or perforated pipe located at the toe of an embankment, used in conjunction with horizontal drainage blankets to collect seepage from the embankment and foundation and convey the seepage to a controlled location downstream from the canal.

Transferred works: A Reclamation facility where a non-Federal entity carries out the OM&R under a transfer contract.

Translatory waves: Up and down surges due to a change in flow velocity within the canal prism (for example, from raising or lowering gates, pump actions, or opening and closing turnouts). Also called bore waves.

Trashrack: A metal or reinforced concrete device placed at the intake of a gate structure, conduit, pipe, or tunnel that prevents the entrance of debris into the associated intake.

Tunnel: An enclosed channel that is constructed by excavating through natural ground. A tunnel can convey water or house conduits or pipes. May be concrete lined or left as natural rock depending on the use and structural stability of the bedrock.

Turnout: A structure used to divert water from a supply channel to a smaller channel or pipeline. Based upon the characteristics of the downstream distribution system, turnouts may be:

- **Gravity-flow:** Diverted into a smaller canal system
- **Pipe-flow:** Diverted into a pipe system
- **Pump-flow:** Diverted into an open intake structure of a pumping plant which then lifts the water, under pressure, to a higher elevation

Urbanized Canal Reach: A canal reach located in an urbanized area and identified by the water contained between structures including, checks, wasteways, diversion dams, etc., where the structures may be used to control or limit the amount of water to be lost in the event of a failure. An urbanized canal reach is defined as either of the following:

- **Criteria-Defined:** A canal reach where failure would result in an estimated PAR greater than 100 and/or an estimated property damage of greater than $5,000,000.
- **Defined by Engineering Judgment:** A canal reach determined by the responsible Reclamation regional/area office to be classified as an urbanized canal reach, based on sound engineering judgment factors.

Valve: A device used to control the flow in a conduit, pipe, or tunnel that permanently obstructs a portion of the waterway.

Wasteway: Structure used to divert surplus flow from the main canal into a natural or constructed drainage channel to protect the canal system and adjacent property from damage. Surplus flow may result from storm runoff into the canal, a sudden and unforeseen large flow rejection from a turnout diversion, an unexpected gate closure, or plugging of a siphon. Typical wasteway systems have an overflow or gated diversion structure from the main canal, a drop or chute structure, and a wasteway channel downstream.

Water conveyance structure: Any structure that transports water from one location to another.

Watermaster: A manager selected by the district board, who oversees water deliveries and the maintenance of canals, distribution pipes, and laterals to distribute water to the districts' users.

Waterstage recorder: A motor-driven (spring wound or electric) instrument for monitoring water surface elevation.

Weir: A low dam built across a river to raise the level of water upstream or regulate its flow.

Weep hole: A drain embedded in a concrete or masonry structure intended to relieve pressure caused by seepage behind the structure.

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“Who Ya Gonna Call?” . . . Reclamation

You are not alone.

Call Reclamation for technical experts to help you with:

- **Emergencies.** If something is seriously wrong, call us fast.
- **Repair plans.** Figure out the best way to repair canals to prevent bigger problems.
- **Facility modifications.** All modifications and additions to the canal must be approved by Reclamation in advance.
- **Head Scratchers.** If something does not look right with a canal or you need to solve problems.
- **Operation and maintenance programs.** Prepare technical manuals, standards, and guidelines for consistent O&M.
- **Design and construction activities.** Plan for new projects, including natural resources and other challenging issues.
- **Something innovative.** Developing and implementing new technology

For locations of Reclamation offices go to: www.usbr.gov/main/offices.html

“Who ya gonna call?”