RECLAMATION

Managing Water in the West

Canal Operation and Maintenance:

Animals

U.S. Department of the Interior
Bureau of Reclamation
Office of Policy
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.

Acknowledgements

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Disclaimer

Reclamation developed this manual to provide basic guidance to help canal operators promote safe and effective operations and maintenance for canal systems. This information complements—and does 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 all situations.

Portions of this manual make recommendations for actions to prevent and treat burrowing animal problems. These recommendations were made using the best information available at the time of preparation of this guidance. No statement in this chapter is intended to contradict any law, regulation, statute, or rodenticide product label. Rodenticide labels are subject to change without notice. The rodenticide user is responsible for obtaining, reading, and understanding the current rodenticide product label before handling or using the rodenticide product. Necessary approval and/or permits should be obtained in States where required for applying rodenticides. In addition, certain Federal requirements apply as well that may not be listed on the rodenticide product label. Refer to Reclamation's Manual Policy Pest Management ENV-P02 for additional detail regarding issues related to the Clean Water Act and application rodenticides.

Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the U.S. Environmental Protection Agency (EPA) may issue emergency orders on certain rodenticides to cancel or limit their use if a federally listed species would be impacted. Users of rodenticides are advised to consult with the appropriate agencies and review all available information prior to application of a rodenticide within the range of a federally listed species.

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Acronyms and Abbreviations

APHIS	Animal and Plant Health Inspection Service
CFR	Code of Federal Regulations
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act of 1973
FEMA	Federal Emergency Management Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
HEPA	high-efficiency particulate air
IPM	Integrated Pest Management
IPM Manual	Integrated Pest Management Manual
JHA	Job Hazard Analysis
kHz	kilohertz
MSDS	Material Safety Data Sheet
NPIC	National Pesticide Information Center
PAPR	powered air-purifying respirator
PERC	Pressurized Exhaust Rodent Controller
PI	plasticity index
PVC	polyvinyl chloride
Reclamation	Bureau of Reclamation
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service

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1. Purpose and Scope

This manual is designed to help irrigation districts better understand the impacts that burrowing wildlife can have on the Bureau of Reclamation's (Reclamation) canals. This volume describes how wildlife burrows can lead to a canal failure, types of burrowing animals commonly encountered, how to detect and control burrowing animals, and how to repair damage caused by these burrowing animals. Additional discussion related to livestock damage is also provided.

Reclamation staff are available to provide advice and technical support on Reclamation-owned canals. Contact Reclamation and consider additional engineering support before making modifications to the canal. If you determine work outlined in this manual requires more expertise than your staff can provide, please contact Reclamation for technical support at: www.usbr.gov/main/offices.html.

2. Why Be Concerned with Animals?

Canal failures occur every year and are often attributed to burrowing animals. These failures can cause significant immediate economic damages, loss of project benefits, injuries and even loss of life.

Figure 1. Probing an animal burrow.

2.1. Breach Mechanism

Animal burrows from either the waterside or land side can extend laterally into the canal embankment and/or foundation (Figure 1). Once inundated, the animal burrows shorten the seepage path length. In some cases, a system of animal burrows can extend completely through the embankment section. As seepage flows through the burrow network, embankment materials begin to erode (Figure 2). See Reclamation's Canal Operation and Maintenance: Embankment (Reclamation 2017 [Embankment]) for more information on embankments, seepage, and erosion processes. The type of soil or embankment condition contributes to initiation of erosion and how quickly erosion progresses (silt and sandy soils will progress quickly and clayey soils will progress slowly). If detection and intervention fails, then the system of voids will enlarge to a point where they collapse—leading to a canal breach (Figure 3).

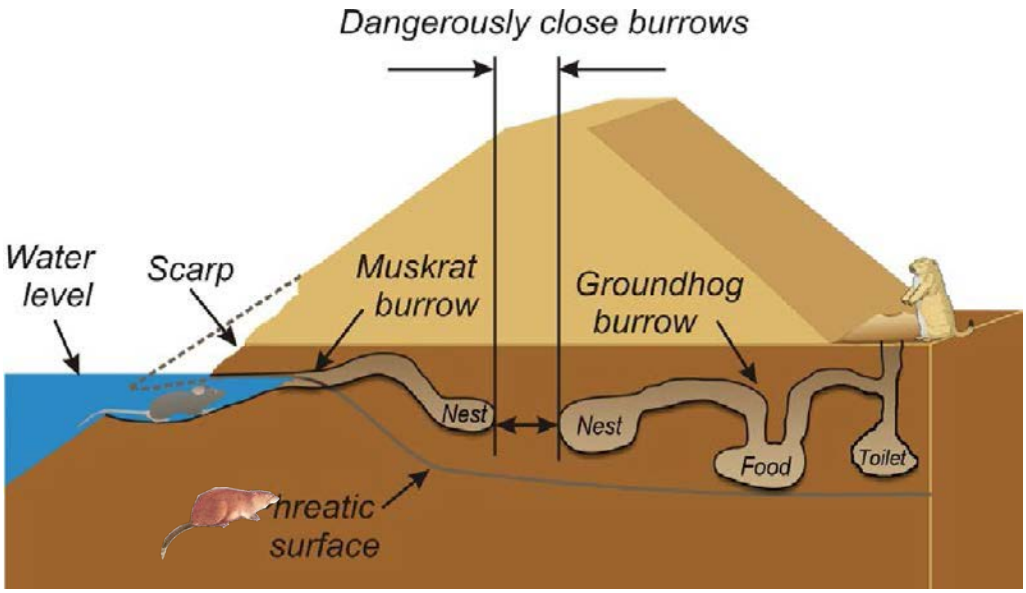

Figure 2. Example of a system of animal burrows that might lead to a canal failure.

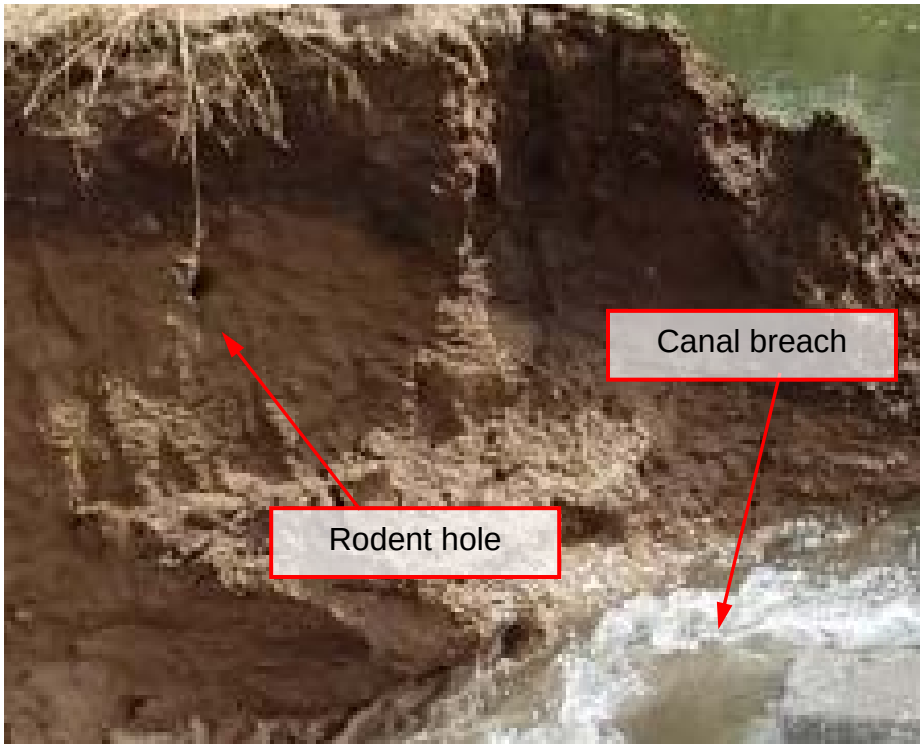

Figure 3. Recent canal failure attributed to animal burrows. Note that rodent holes are not always obvious.

2.2. Types of Burrowing Animals

Burrowing animals are aquatic, water-side and terrestrial, land-side animals. Burrowing animals commonly observed in the Western United States include:

- Muskrats
- Beavers
- Crayfish
- Toads
- Lizards
- Ground squirrels
- Gophers
- Moles
- Prairie Dogs
- Badgers
- Rabbits
- Coyotes
- Fox

Various burrowing animal species will cause differing amounts and sizes (diameter) of associated damage. For example, while muskrat burrows may have a much larger diameter than ground squirrel burrows, the ground squirrel networks may cover a large area and extend across the full embankment section. Numerous small diameter burrows are just as threatening to an embankment as a single large diameter burrow, as there is a higher probability that these burrows are connected.

2.3. Canal Blocking

Beavers and other burrowing animals can block culverts and wasteways with their dens and dams as well as burrow into the embankment and canal prism. These blockages should be removed (along with the beavers themselves) from the canal. If these blockages are not removed, then that beaver den area may have increased bank erosion and slope stability problems as well as impeded flow. Debris from beaver activity will plug up trashracks and create more work for canal operators if these materials flow downstream.

Figure 4. Beaver dam blocking flows (Federal Emergency Management Agency [FEMA] 2005).

Beavers construct dams to create water deep enough to hide from predators as they travel to their shore feeding grounds. Beaver use a variety of materials, such as wood, fiber, metal, wire, and even rocks for their dams (Figure 4).

2.4. Damage from Livestock and Other Large Wildlife

Figure 5. Livestock damage to canal embankment.

Livestock can damage canal embankment slopes by grazing, trampling, and rooting. Livestock also enter the canal prism to water. Hoofed animals can form depressions that lead to erosion gullies which enlarge over time (Figure 5).

Cattle and other wildlife can also damage soil/geomembrane lining systems. Fencing may be required to prevent livestock from watering or grazing on the canal slopes. Work with the owners to discuss the impacts their cattle/livestock have.

If deer or other large wildlife are causing damage, work with local wildlife agencies to identify measures to deter the wildlife's use of the canal.

3. Develop a Wildlife Management Plan

3.1. Why Plan

As part of your Integrated Pest Management (IPM) Plan, an Integrated Wildlife Management Program will establish a systematic approach for identifying, managing, and repairing animal burrow issues. An IPM Plan provides a framework for your staff to follow when dealing with burrowing animals. Your actions cannot be a one-time response to each incident. You need an ongoing, proactive planned approach to identify and address problems before they lead to a breach. Moreover, without a plan, problems are simply likely to continue or to reoccur.

3.2. How to Plan

The IPM Plan should outline an approach for identifying the burrowing animal species, detection and inspections program, options for controlling the species, and methods for repairing the damage. To create and follow the IPM Plan:

- **Determine what animal(s) in your area may pose a threat to the canal system and how to address each species.** Work with University Extension programs, your State Wildlife Agency, your State Director for Animal Damage Control, or the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) to determine what burrowing species could be around the canal system and methods to prevent problems.

- **Plan regular inspections** to catch problems early. If there is any evidence of burrowing, devote resources to identifying and removing the burrowing animal.

- **Treat before the colony becomes a risk to your system.** How big is the colony? Where is the colony? How much of a risk do these burrows pose to the structure of the canal?

- **Prioritize actions.** Address animal burrows where the risks of a failure are the highest first. For example, you may want to prioritize treating areas in urban settings over those in rural settings.

- **Research prevention and control options.** Control options will vary by species, location, and extent of the burrows. Consult with local experts to identify the species and to determine the best time and method to treat and control the species.

- **Determine whether permits are needed in order to remove the species in question, or whether the potential impact on non-target species may restrict control options.** Research and plan for permits and special status species (Endangered Species Act [ESA] and State listed species) considerations.

- **Implement the selected control options.** Follow control plan guidelines and continue to evaluate the site.

- **Monitor the effectiveness of the control methods on reducing the population size.** Select a different method if the treatment is not effective.

- **Repair damages** and monitor the repairs.

4. Prevention is the Best Cure

The costs of preventing, controlling, and repairing burrows are comparatively less than the costs of flood damage (risk of life and properties), loss of project benefits, and litigation costs if a canal break that could have been avoided occurs. Moreover, the earlier you address a problem, the less expensive it will be to fix.

4.1. Communicate and Watch Out!

Keep constant tabs on potential burrows, not only at regular inspections, but throughout the year. Reach out to the community and ask them to keep an eye out for burrows on canal embankments or neighboring properties. Ask everyone who comes into contact with the canal system to look out for potential burrows. Create a “hotline” for the public, landowners, and water users to report signs of rodent or other animal infestation anywhere along the system. Post signs with this number along public access locations and provide this number with your other routine communications to water users. Have open lines of communication with livestock owners to head cattle off at the pass.

4.2. Inspect Regularly

Incorporate frequent inspections into your plan. Inspect embankments, canal prisms, and the embankment crest and toe regularly for burrowing animal activity. Watch for the subtle signs of settlement and colonization, such as new piles of dirt and holes. Implement a regular inspection program, including:

- **Regular annual inspections** at the end of the irrigation seasons to set priorities for maintenance before the next irrigation season.

- **Inspections immediately after mowing** and removing vegetation to look for burrows, tracks, or animal droppings (spoor or scat).

- **Follow-up inspections** once every three months after removing animals and repairing burrows to detect further infestations. If there are new animal burrows, then a new eradication strategy is probably needed.

- **Periodic inspections.** If there are signs of seepage, look for burrows in the area. When water levels are low, look for burrows in the canal prism, which will fill with water when the water level in the canal rises. Treat these burrows before raising water levels in the canal.

Figure 6 through Figure 8 show where to look and examples of what to look for.

Embankment crest, slopes and toe. Burrows on the land side of the embankment.

Figure 6. Gopher or prairie dog burrows.

On the outside of the embankment and the embankment toe. Cloudy seepage is a sign of internal erosion, possibly from animal burrows.

Figure 7. Seepage indicating possible burrows.

In the canal prism. Watch for burrow entrances near the water line, as aquatic rodents typically start burrowing just below the water line.

Figure 8. Aquatic rodent burrows.

4.3. Control the Habitat

Canal systems provide ideal habitat for burrowing animals, especially rodents: embankment soils facilitate burrowing activity, grass provides food and cover, and a lack of trees along the embankment minimize predation risk by raptors.

4.3.1. Vegetation

The presence of grass and other vegetation:

- Provides cover from predators
- Provides a food source for plant-eating animals
- Creates habitat for microorganisms and macroinvertebrates (such as flatworms, crayfish, snails, clams and insects), which in turn provide food for rodents and other potentially burrowing animals.

Figure 9. Ground squirrels amidst vegetation.

Help prevent colonization by rodents and other burrowing animals by minimizing the suitability of potential habitat along canal systems. Managing vegetation consistently and promptly is a cornerstone of effectively preventing settlement by burrowing wildlife (Figure 9). See Reclamation's Canal Operation and Maintenance: Vegetation (Reclamation 2017 [Vegetation]) for more information on controlling vegetation.

4.3.2. Predators

Creating habitat that attracts native predators can help reduce the burrowing rodent population and make embankment habitat less suitable for rodents. Raptors are a commonly incorporated aspect of Integrated Wildlife Management Plans in an agricultural context. Hawks and owls are natural predators to many rodents and can be readily attracted to a specific area with the construction of nest boxes, platforms, and perch poles. These structures are cost-effective and non-hazardous.

Consult with local wildlife agencies before releasing predators or building infrastructure to attract predators. Any predator attraction effort must be coordinated to ensure that predators are not exposed unintentionally to toxicants (such as bait, fumigants, or rodenticides) intended for burrowing rodent control. Additionally, predator introduction, particularly the introduction of non-native predators, can have serious unintended consequences that should be considered in advance.

4.3.3. Ultrasonic and Transonic Chasers

Sound-emitting devices are designed to deter wildlife without harming the animals or environment. Ultrasonic devices emit a loud noise outside of the range of human hearing (18 to 20 kilohertz [kHz]). Rodents have acute hearing, are sensitive to ultrasound, and hold a highly developed sense of smell. Interfering with these senses may help deter rodents from colonizing a particular area.

However, the utility of these devices is likely limited to small areas and may only be a short-term solution. Animals can adapt to most situations, and in a short amount of time they become accustomed to the sound. If the original attractant, such as food, is present, the rodents will return in spite of the sound deterrents, or simply relocate to another part of the canal system. Additionally, ultrasonic devices can be heard by domesticated animals and should not be used around pets.

4.3.4. Discourage Reentry

After an animal has been removed from its burrow, take steps to prevent recolonization:

- If operations allow, dewater the canal each year to encourage aquatic animals to vacate
- Fill in burrows (as discussed in Section 6.1.2 *Embankment Reconstruction*)
- Cover filled burrows entrances with ¾ to 1½ inch aggregate

4.4. Use Physical Deterrents

Physical deterrents may be needed in areas where animal burrowing continues or where loss of infrastructure would pose significant risks to property, operations, and other potential damages. Prior to making any substantial physical changes to Reclamation-owned assets, operating entities must have approval from Reclamation.

4.4.1. Physical Barriers

Physical barriers may prevent some burrowing animal activity if other methods are not effective in keeping wildlife out over the long term. This may work better for a smaller, particularly troublesome area rather than over an entire canal system.

Physical barriers include:

- Using wire netting on canal banks to prevent digging. Install impenetrable meshes with holes smaller than the target animals on embankment slopes. Meshes can be metal with galvanized wire.
- Covering slopes with ¾ to 1½ inch aggregate. Most burrowing animals prefer loose fine grained soils to excavate their burrows. A layer of aggregate on the surface can discourage digging.
- Extending concrete aprons beyond hydraulic structures to detour burrowing along or beneath the structures.

4.4.2. Fences

Fences can help protect an area from intrusive animals. However, before building a fence, determine what animals will need to be kept out. For example, rabbit-

proof fences need to be buried about 1 to 2 feet in the ground, while groundhogs need a 3-foot-high fence. Fences for some animals should be placed at an angle. Before installing fences, work with Reclamation to ensure that these fences do not pose any risks of creating a failure mode along the canal embankments.

4.4.3. Backfill Grouting

Backfill grouting methods may be used to fill the animal burrows but should be considered a deterrent—not a permanent repair. The grout mixture should consist of granular soil/sand, cement, and water blended in a continuous mixer. The grout mixture should be fluid enough to be pumped or gravity fed at low pressure and to conform to the burrow's geometry. Chemical admixtures should be used to make the mix resistant to bleed and shrinkage. Reclamation must be consulted to develop and select an appropriate grout mixture. An injection pipe and air vent should be pushed to the back of the burrow and sealed at the entrance to improve grout travel and filling of the burrow network. Be sure to provide a vent at the burrows entrance to avoid pressure grouting that might further damage the embankment. Hydrated bentonite covered with sand bags may be used to form a seal at the burrow entrance. The grout can then be pumped or gravity fed at low pressure into the burrow until grout flows from the air vent or pressures begin to rise. The injection pipe and vent should be carefully withdrawn during the final phase of grouting and the entrance covered with a sandbag to prevent draining.

This method has a number of limitations and concerns, including:

- The extent of grouting cannot be observed from the surface
- Grout volume measurements can be made but there is no guarantee the burrow system will be completely filled with grout
- Only borrows with an existing entrance can be grouted
- Older burrows whose entrance has collapsed or smeared during cleaning activities will not be filled unless they are connected to burrows with observable entrances

Pressure grouting should be avoided. Pressurizing the burrow network with just a couple pounds per square inch (psi) can result in blowout or hydraulic fracturing and cause more damage to the embankment than the burrow itself.

5. Find and Address Existing Problems

5.1. Determine Which Animal(s) Caused the Damage

You will rarely see the animal causing damage to the canal, but it is crucial to identify it in order to select the appropriate control method. For example, beavers and otters often live in the same habitat, but otters typically use beaver, or other species', dens instead of digging their own. In this case, you may see an otter living in a burrow, but as beavers actually built the burrow, actions should be targeted to control the beavers.

Clues to identify a particular species include:

- Site, type and location of burrows
- Piles of aquatic vegetation on shorelines
- Floating rafts of vegetation on the water
- Tracks, paths, and trails
- Animal droppings (spoor, scat)

Take pictures of any of these materials and consult with experts. Additionally, game cameras are often an inexpensive and effective way to identify the inhabitants of specific burrows.

Contact local wildlife experts to help determine what species inhabit the canal area and provide particular prevention methods for that species. Local wildlife experts may also be able to train your staff on particular tracks and signs to watch for.

Federal Emergency Management Agency (FEMA) 2005 (Animals) provides an excellent reference work, with pictures of specific animals, tracks, and details about their life and behavior. FEMA 2005 has specific prevention tips for various species. (www.fema.gov/media-library/assets/documents/891)

5.2. Remove Animals

Removing animals from the canal system treats the symptoms and does not solve the entire problem—and is only one step in an overall Integrated Animal Management Plan.

5.2.1. Permits and Regulations

Follow Federal, State, and local regulations to obtain required permits for wildlife eradication or relocation, including regulations for using chemicals (rodenticides), traps, or shooting.

5.2.2. Special Status Species

Many wildlife species are protected by Federal, State, or even local laws and agencies. The Endangered Species Act of 1973 (ESA) protects species of plants and animals that are in danger of extinction. Under the ESA, it is illegal for anyone to "take" a species listed as threatened or endangered. The ESA defines "take" as, "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct."

The list of protected species can change from year to year, and regular contact with an agency is required to ensure that no protected species are adversely affected. Furthermore, hunting and trapping regulations in regard to furbearer, game, and non-game species vary. Thus, before taking any actions to control animals, contact the U.S. Fish and Wildlife Service (USFWS) and the appropriate State Wildlife Agency for information about identifying and controlling a wildlife species (for example, hunting and trapping seasons, licenses, and permits).

Work with local biologists to identify protected species known to be in the area. All pest control applicators should undergo "sensitivity training" to be able to recognize protected species. Some control methods, such as poison or traps, could harm non-target species, so it is important to find out in advance what threatened and endangered species are in your area. Although that species might not be the problem species you need to control, you definitely do not want to use a control method that may accidentally kill other species.

Protected species include, but are not limited to:

- Giant Kangaroo Rat (*Dipodomys ingens*), listed as endangered species, is found in the drier regions of the western and southwestern U.S.

- Preble's Jumping Mouse (*Zapus hudsonius preblei*), listed as threatened, is found along waterways in Colorado's Front Range.

- Point Arena Mountain Beaver (*Aplodontia rufa nigra*). This subspecies is listed as an endangered species throughout its range of California.

- Utah Prairie Dog (*Cynomys parvidens*). This species is listed as a threatened species throughout its range of Utah.

- Northern Idaho Ground Squirrel (*Spermophilus brunneus brunneus*). This subspecies is listed as a threatened species throughout its range of Idaho.

5.2.3. Personnel Safety

Wildlife species can be hosts for zoonotic diseases that can be contracted by humans from a live or dead animal. Zoonotic diseases can be contracted indirectly through arthropod vectors, such as fleas or ticks that may be on an animal's body, or directly through a bite or contact with feces, blood, or other fluids. Diseases that can be transferred between wildlife in humans include: plague, hanta virus, Rocky Mountain spotted fever, Lyme disease, leptospirosis, and others. Any method of removing animals should first ensure worker safety. Follow specific instructions for removing animals.

5.2.3.1. Use Protective Gear

Wear personal protective equipment, including, at a minimum:

- Coveralls (disposable, if possible)
- Rubber boots or disposable shoe covers
- Rubber, latex, or vinyl gloves
- Protective goggles

To prevent vector-borne diseases, use mosquito or tick repellent, keep skin covered, and tuck pants into socks.

To ensure that workers can breathe safely, use appropriate respiratory protection devices. These include a half-mask air-purifying (or negative-pressure) respirator with a high-efficiency particulate air (HEPA) filter or a powered air-purifying respirator (PAPR) with HEPA filters. Follow State and local regulations and test that the mask fits before beginning any work that needs to use a respirator.

Decontaminate personal protective gear after removal at the end of the day. All potentially infective waste material (including respirator filters) from clean-up operations that cannot be burned or deep-buried on site should be double-bagged in appropriate plastic bags. The bagged material should then be labeled as infectious (if it is to be transported) and disposed of in accordance with local requirements for infectious waste.

5.2.3.2. Disposing of Dead Rodents or Nests

Quick disposal of dead rodents in sealed plastic bags and proper flea control are also important aspects of rodent control.

The Centers for Disease Control and Prevention provide these instructions:

- Wear rubber, latex, or vinyl gloves when cleaning up dead rodents or nests.
- Spray the dead rodent or nest and the surrounding area with a disinfectant or a mixture of bleach and water.
- Soak rodent, nesting materials or droppings in solution for five minutes before wiping up with a paper towel or rag.

- Place the dead rodent or nesting materials in a plastic bag and seal tightly. Place the full bag in a second plastic bag and seal.
- Coordinate with local waste management companies to dispose of these sealed bags in accordance with local requirements. For example, deposit these bags into dumpsters or bury them underground deeply enough that corpses won't be dug up by dogs or other scavengers.
- Remove gloves, and thoroughly wash hands with soap and water (or use a waterless alcohol-based hand rub when soap is not available and hands are not visibly soiled).

See The Centers for Disease Control and Prevention, *Cleaning up After Rodents*.

5.2.4. Traps

Trapping can help control animals in small areas. Comply with all Federal, State, and local trapping regulations. Place traps in locked areas or in tamper-proof trap stations. Do not leave set traps in open areas unattended. Unset and remove traps placed in populated areas when staff leave the site.

Work with local wildlife professionals to distinguish native rodent species from non-native species. Use live traps to capture protected native species. Once caught, rodents become trap-wise and are more difficult to trap, so release these animals far from the place they were trapped. Do not release non-native rodents, such as roof rats or house mice, into the wild.

A trap's effectiveness depends on the species to be removed. First identify the animal and then develop a control plan.

General tips for traps include:

- **Place the traps where the rodents are**. Determine the animals' current paths and burrows to place traps effectively.
- **Place traps where children, pets, and other species are not.** Avoid sensitive locations or prevent unauthorized access.
- **Check traps regularly.**
- **Use safety equipment.**

5.2.5. Chemical (Rodenticides)

Along with other controls, rodenticides can be used as a part of our Integrated Animal Management Plan. IPM encourages using more benign options, and judicious use of rodenticides only after carefully analyzing all other options for efficacy and cost-benefits and considering environmental consequences. In many situations, nonchemical methods may be more effective, less costly, or less time consuming over the long term.

5.2.5.1. Do Your Homework

There are many different active ingredients registered as rodenticides in the United States. They can be grouped together according to how they work. Some rodenticides, called anticoagulants, stop normal blood clotting (e.g., bromadiolone, chlorophacinone, difethialone, brodifacoum, and warfarin). Other rodenticides work in different ways. For details on various rodenticides, their properties, and their cautions, see the Rodenticides Appendix from the National Pesticide Information Center (NPIC).

Before using a rodenticide, first contact your County Extension Office at npic.orst.edu/pest/countyext.htm to identify the species and determine potential products that may be most effective and appropriate for your situation. They can also provide lists and explanations of active ingredients.

You can also contact the NPIC at npic.orst.edu/contactus.html. A Pesticide Specialist can provide more specific information once you have a product in mind.

See the U.S. Environmental Protection Agency's (EPA) website for more information on rodenticides at www.epa.gov/rodenticides.

5.2.5.2. Follow All Regulatory and Permitting Requirements

Research and follow all Federal, State, and local requirements and plan rodenticide operations accordingly, and work with Reclamation.

- **Always read and follow the label**. Rodenticide labels and material safety data sheets (MSDS) should be kept in a convenient location for reference or in case of emergencies. The label is a legal document. Application of rodenticides outside of labeled directives or restrictions is a violation of law. Use products only as directed and follow precautions. Only certified rodenticide applicators can use Restricted Use rodenticides, which could cause adverse effects to the user or the environment even when used correctly.

- **Use approved products only.** All rodenticides must be registered with the U.S. Environmental Protection Agency (EPA). Always use registered products that are labeled for use in your particular site and for control of the target species. If you are not familiar with rodenticide use directions or

if the label information is unclear, check with the EPA or other experts on site-specific information. Always consult with the appropriate agencies and stakeholders with interests in the application areas and review all available information before using rodenticides within the range of any federally listed species. County-level bulletins may be issued for specific rodenticide materials and are available through the EPA, the USFWS, USDA, county agricultural extension offices, and rodenticide point-of-sale outlets. The county bulletins include habitat maps and possible rodenticide use limits. If a product is classified as restricted, it will not be available for purchase or use unless by a certified rodenticide applicator or under their direct supervision.

- **Understand permits and other requirements.** Contact your local Reclamation IPM coordinator or natural resources manager. Legal use of specific toxicants and fumigants varies from State to State, so coordinate with your State Wildlife Agency or county agent to determine which substances are allowed for use in each State. Necessary approval and/or permits should be obtained in States where required. In addition, certain Federal requirements apply as well that may not be listed on the rodenticide product label.

Follow the law. The Federal Insecticide Fungicide and Rodenticide Act (FIFRA), as amended established a system of examination and certification both at the private level and at the commercial level for applicators who wish to purchase and use restricted use rodenticides.

- **Documentation**. All rodenticide treatments should be documented in a standardized format and archived. Reclamation offices should have an up-to-date IPM plan on hand that describes the documentation requirements and protocol.

Pesticide Labeling Questions and Answers are at www.epa.gov/pesticide-labels/pesticide-labeling-questions-answers.

The National Institute for Occupational Safety and Health (NIOSH) and OSHA have compiled summary safety-related information and data for many hazardous chemicals, published in *Occupational Safety and Health Guidelines* bulletins. Each bulletin is devoted to a specific material or materials.

In addition, pesticide experts at land-grant colleges or your State's Cooperative Extension Service can provide valuable information on State and local pesticide laws and regulations, as well as serve as sources of current pesticide research and practical information.

5.2.5.3. Apply and Time Rodenticides Effectively

Plan rodenticide treatments to get the most out of the product, avoid and minimize potential environmental impacts, and ensure the safety of staff and the public from exposure to the rodenticide as well as to dead and live rodents. It is important to:

- Monitor and evaluate the rodenticide treatment regularly to determine whether it has been effective. Re-treat an infested area only if monitoring shows the rodent population is remaining the same or is increasing.

- Continue other non-chemical methods when using rodenticides for spot treatments, unless they conflict with the rodenticide.

- Work with local experts to determine the best time to control animals, as timing and methods depend on the life cycle, food availability, and behavior of the animal you are controlling—as well as other species that may be in the area. For example, it might be more effective to use bait early in the spring when animals are emerging from hibernation and there are few other supplies of food. If needed, consult with experts on the species in question to determine the most effective timing for that animal's life cycle and rodenticide. The University of California IPM Program advises using fumigation in the spring and summer and baiting in the late spring through early fall for California ground squirrel control, based on their activity periods and food sources (University of California 2017).

5.2.5.4. Keep Safe

Safety to both the general public and workers is a key element to Reclamation chemical control activities. Reducing mishaps and employee exposure to herbicides is key to applying the substance safely and not endangering humans, livestock, crops, beneficial wildlife, or water supply, or leaving illegal residues. Safety for handling herbicides comprises a wide range of actions, including:

- Preplanning
    - Obtain permits
    - Coordinate with all required entities (local, State, and Federal)
    - Read, understand, and follow current labels
- Protecting workers
    - Train employees in rodenticide safety and applicable anticipation, recognition, evaluation, and control of herbicide hazards in accordance with applicable Federal, State, and local regulations
    - Use safe work practices

  - Use personal protective equipment
  - Conduct medical surveillance programs
  - Keep all poison in a closed container
  - Before smoking or eating, wash hands with detergent and water
  - Watch your step on uneven ground—watch out for snakes.
  - Understand the MSDS' specific information about the health effects associated with their products and observing the listed safety precautions
  - Prepare Job Hazard Analysis (JHA) to anticipate, recognize, evaluate, and control potentially unsafe acts and conditions associated with each step of a job

- Post notices and coordinate with local agencies to protect the public
- Protect transport
  - Ensure the driver is trained to transport chemicals
  - Use appropriate markings
  - Coordinate with the State Department of Transportation
- Proper storage to prevent spills and leaking containers
  - Limit stockpiles of chemicals
  - Conduct regular inspections
  - Post proper notices
- Spills and emergencies
  - Have contact information and ways to communicate on site
  - Prepare spill response and containment plans
  - Prepare emergency and evacuation plans
  - Maintain emergency kits to address spills, fires, or first aid
  - Maintain an emergency eyewash and shower

If good work practices are followed, even the most toxic rodenticides may be used safely without creating a health hazard. Conversely, improper handling and application of low-toxicity rodenticides may result in serious injury. These chemicals can enter humans through the skin, lungs, mouth, and eyes. Precautions must be taken against both acute and chronic exposures.

5.2.5.5. Use the Correct Rodenticide for Your Situation

5.2.5.5.1. Bait

Baits are mixtures of rodenticides with edible material, usually grain or dried fruit. Some are encased in wax blocks to increase their useful life. Baits are used extensively on Reclamation projects to control pocket gophers, ground squirrels, and other rodents. Usually, they are applied without further dilution or mixing.

General tips for bait include:

- Determine what other animals will be affected, including whether threatened or endangered species or pets are using the treatment area. Evaluate which, and to what extent, non-target species will be harmed. For example, burrowing owls commonly use ground squirrel burrows and would also eat the bait.

- Determine whether the bait could enter the water system and impact human health or the environment.

- Be particularly cautious with the use of bait in urban areas. For example, an irrigation district placed bait along some of their urban canals. The bait spilled onto land bordering the embankment and was consumed by pet dogs (Guerra 2014).

Probe to find the animal's main burrow and dispense bait or toxicants into the burrow. To locate the main tunnel, probe around the mound or burrow. This probe may depend on the type of burrow and animal, and local experts should be consulted. For example, for a gopher mound, probe in an 8-to-12-inch radius, poking into the ground about 4 inches. When the probe goes into the main tunnel, it readily drops about 2 more inches. Open the container to dispense the correct amount of bait into the tunnel and close the hole afterward. Mark the burrow to repair once the animals are gone.

Ensure that domesticated animals and children that may be in the canal system cannot reach the bait. A polyvinyl chloride (PVC) pipe bait station may work to ensure that only the burrowing animals reach the bait. A sample bait station could be adapted to other burrowing animals (Figure 10). Bait stations can be made from 2- to 3- inch PVC pipe constructed in an L-shape or upside-down T-shape. The horizontal pipe should be at least 12 inches long. Bait stations can also be made from rolled tar paper, mailing tubes, or similar durable materials.

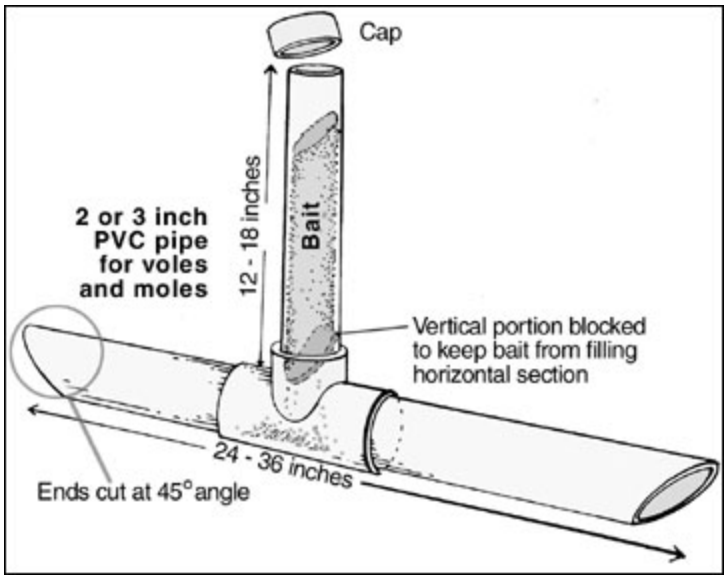

Figure 10. Sample bait station.

5.2.5.5.2. Fumigants

Fumigants, such as gas cartridges, carbon monoxide, or smoke bombs may work. To work, the gases build up in the burrow to lethal concentrations. Insert the fumigant and then seal the burrow. Many burrows have multiple entrances, so work with a local expert to determine the species and number and extent of burrow entrances to properly seal the burrow. Make sure there is adequate volume and pressure within the animal burrow.

Only persons properly trained or under direction of certified applicators may perform pest control activities including gassing, gopher bombs, and poisoning.

Carbon Monoxide

Carbon monoxide has long been used as a fumigant. In 1917, Harding reported that "Suffocation with the exhaust fumes of an automobile is reported to have been effective on the Klamath Project" (Harding 1917). Today, carbon monoxide can be injected into the burrow of a rodent using more modern technology (Figure 11). Two industry carbon monoxide systems are discussed below as examples, but there are others. Please note that Reclamation does not endorse specific products.

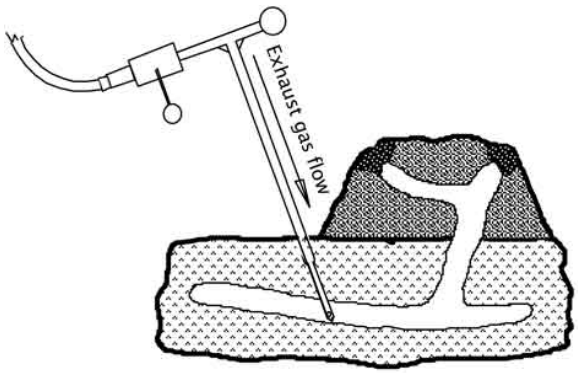

Figure 11. Gas injected into a gopher burrow.

The Pressurized Exhaust Rodent Controller (PERC) system uses a probe with an exhaust flow: "To treat open burrows, such as ground squirrels, prairie dogs and ground hogs, the probe or the $^{3}/_{8}$" short air hose (furnished with the machine and replaces the ¼" probe on the end of the T bar hand piece) is inserted into the open burrow. Dirt is then shoveled to close the opening and direct the gas flow down

into the burrow. Treat all live holes. It is impossible to tell if one mound or hole is connected to a nearby mound or hole. If gas is coming out of the adjacent hole, then it is obvious that they are connected and the adjacent hole should be plugged and need not be treated." (PERC 2017)

"The Cheetah rodent control machine quickly kills burrowing rodents by capturing carbon monoxide produced by a self-contained two-cycle gasoline engine and blowing the fumigant, under low pressure, into rodent tunnels, asphyxiating the pests. The fast acting carbon monoxide will quickly fill a large burrow system. Four minutes for squirrels and seven minutes for prairie dogs and groundhogs." (Cheetah Industries 2017)

Other Gases

Buckle and Smith (2010) also suggest phosphine and notes other gases which are not used often, including methyl bromide, chloropicrin, carbon dioxide, and carbon disulfide. They report that the European Union is examining the use of hydrogen cyanide.

5.2.6. Shooting

Shooting may provide some control in rural areas but should not be used as the primary method of control. Shooting is not a recommended method of rodent control as it may be ineffective and there are safety concerns. This method is only mentioned here because people often ask about it. If this method is used:

- Comply with all State and Federal regulations for firearms. Consult with your local Reclamation Area Office for interpretations of these laws on **Reclamation property, rights-of-way, and easements**. For example, 43 Code of Federal Regulations (CFR) 423.30, which prohibits firearms at or in a Reclamation facility, allows deviations by permit or contract (such as an irrigation district). Firearms and hunting are allowed in Reclamation lands. 18 United States Code 930 prohibits the possession of firearms at Federal facilities. Section (d)(3) provides an exception for firearms in a Federal facility for hunting or other lawful purposes.

- Follow all **safety** guidelines and precautions. When using any projectile weapon, always wear eye protection such as shooting glasses or goggles.

- Check to determine if **licenses**, such as a valid hunting license, are required.

- Ensure that shots will not affect **neighbors**. A .22 caliber bullet can travel over a mile and can easily penetrate corrugated metal walls and roofs, so always be sure of your backstop when using a firearm.

- Find the **best time** to shoot. For example, rats are nocturnal, so the best hunting is at dusk and after dark. Rodents do not see in color and do not

seem to see in the red or amber wavelengths, so use a red or amber filter over your flashlight to help spot your targets without alarming them.

6. Repair Damage

6.1.1. Determine the Extent of the Damage

Before making repairs to Reclamation canals, you must consult Reclamation and receive formal approval. An investigation should be conducted to determine the extent of the animal burrow damage. The investigation should begin with counting the number of burrow entrances per unit area. Areas with a higher density of animal burrow entrances should be prioritized for repair over areas where there are just a few burrows. Flexible probes should be used to measure the distance the burrows extend into the embankment. Surface depressions, gullies along the burrow alignment or sloughing should be noted. Methods such as ground penetrating radar may be used to estimate the extent of the burrow networks or locate larger nest chambers. In one case, polystyrene grout was injected through a series of small diameter auger holes to form a cast of the burrow network (Figure 12). The burrows were then carefully exhumed. While there were only a few entrances at the surface, the burrow network extended almost completely through the embankment section. When using this investigation method, the area that was grouted needs to be completely removed and reconstructed.

Figure 12. Marking and filling burrows with polystyrene grout.

A test pit program may also be used to determine the extent of the burrow network. Starting at the burrow entrance, carefully excavate along the burrow until you have reached its limit. A number of burrows will need to be excavated to better understand their extent, as each burrow is different. With the collected information a plan for filling, removing or, cutting off the animal burrows can be developed.

6.1.2. Embankment Reconstruction

The preferred repair method is to reconstruct the affected embankment areas. The operating entity must work with Reclamation for additional support to develop an embankment reconstruction plan. See Reclamation’s Canal Operation and

Maintenance: Embankment (Reclamation 2017 [Embankment]) for more information on embankment reconstruction.

With the information collected during the investigation, the horizontal width of the excavation should be selected. The excavation width should be at least 8 feet wide to facilitate riding compaction equipment during fill placement (Figure 13). Where the canal embankment is narrow or the burrow extend is large, complete removal may be required. The excavation face should be carefully examined. If the burrow network continues further laterally into the embankment, the excavation should be widened.

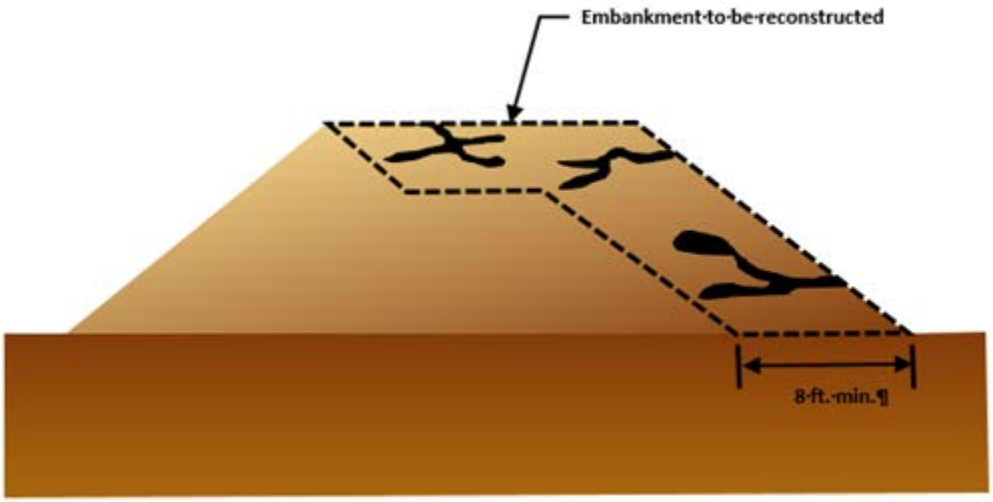

Figure 13. Schematic of embankment with burrows.

Side slopes and terminal ends of the excavation should be 3H:1V (horizontal:vertical) or flatter. Periodic benches should be formed in the excavation side slopes to avoid slip surfaces following fill placement.

6.1.3. Cutoff Methods

Animal burrows can be "cutoff" from the canal water by using a robust lining or cutoff wall system. Lining or cutoff wall systems do not eliminate the need for a Burrowing Animal Control Program but can greatly reduce the risk of seepage and erosion along existing burrow networks. Lining must be able to span existing animal burrows and be resistant to future burrowing. Acceptable lining systems include geomembrane with a concrete or shotcrete cover[1]. The lining is only required against the affected slope but should be anchored into the canal invert. Canal lining also minimizes vegetation and reduces the ability of wildlife to burrow.

[1] See Reclamation's Canal Operation and Maintenance: Concrete (Reclamation 2017 [Concrete]) for more information on concrete design and considerations.

Cutoff walls may also be used. Technologies include: steel sheet piling, synthetic sheet piling, soil-cement slurry walls, and augered concrete secant walls. Driven sheet piles are more appropriate for loose fine grained soils. Dense granular soils containing cobbles may require trenching or auger construction methods. The cutoff wall material must be resistant to future burrowing. Some synthetic sheet pile vendors can add a chemical rodent deterrent to the plastic resin when forming the sheets.

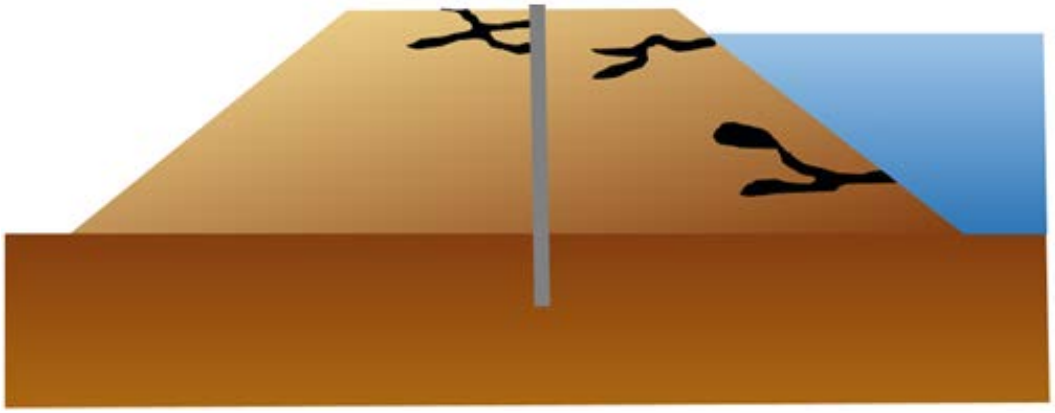

Figure 14. Schematic of embankment cutoff wall.

For detailed instructions on compaction, see Reclamation's Earth Manual Part 1, 1990 and Design of Small Canal Structures, 1978. at www.usbr.gov/tsc/techreferences/mands/manuals.html.

The Soil Compaction Handbook from Multiquip provides a simple layout and graphics to understand basic compaction processes at www.multiquip.com/multiquip/pdfs/Soil_Compaction_Handbook_low_res_0212_DataId_59525_Version_1.pdf

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Appendix A: NPIC Rodenticide Fact Sheet

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RODENTICIDES
TOPIC FACT SHEET

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What are rodenticides?

Rodenticides are pesticides that kill ***rodents***. Rodents include not only rats and mice, but also squirrels, woodchucks, chipmunks, and other animals. Although rodents play important roles in nature, they may sometimes require control. They can damage crops, violate housing codes, transmit disease, and in some cases cause ecological damage.[1]

Rodents, humans, dogs and cats are all mammals, so our bodies work in very similar ways. Rodenticides may have the same type of effect when eaten by any mammal. They can also affect birds. Rodenticides are usually formulated as baits, which are designed to attract animals. Flavorings may include fish oil, molasses or peanut butter. Baits used in agriculture and natural areas may contain ground meat, vegetables, grains, or fruits.[2] These may be attractive to ***children*** and ***pets***, so they should never be used or stored within their reach. Tamper-resistant bait stations make it even more difficult for accidents to happen. For ways to prevent exposures to children, pets, and wildlife, see the information below about what you can do to reduce risks.

How many kinds of rodenticides are there?

There are many different ***active ingredients*** registered as rodenticides in the United States. They can be grouped together according to how they work. Many rodenticides stop normal blood clotting; these are called anticoagulants. Bromadiolone, chlorophacinone, difethialone, diphacinone, brodifacoum, and warfarin are all anticoagulants. There are a number of rodenticides that are not anticoagulants, and these work in different ways. This fact sheet will discuss ***zinc phosphide***, bromethalin, cholecalciferol, and strychnine.

How toxic are rodenticides?

All rodenticides can be toxic when eaten.[3,4,5,6] See Table 1 on page 2. Most rodenticides are also toxic when inhaled and when they come into contact with skin. The exceptions include warfarin, which is low in toxicity when inhaled or if skin contact occurs.[6] Strychnine, cholecalciferol, and zinc phosphide are relatively low in toxicity upon skin contact.[3,5,7] Bromethalin is moderately toxic for dermal exposure.[4]

How do anticoagulants work?

Our livers make a special enzyme that allows our bodies to recycle Vitamin K. Our bodies need Vitamin K to make the blood clotting agents that protect us from bleeding too much. Anticoagulants stop this enzyme from doing its job. Our bodies store an extra supply, but if we are exposed to enough anticoagulant, the supply will run out and internal bleeding may begin.[8]

NPIC fact sheets are designed to answer questions that are commonly asked by the general public about pesticides that are regulated by the U.S. Environmental Protection Agency (US EPA). This document is intended to be educational in nature and helpful to consumers for making decisions about pesticide use.

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Table 1. ACUTE TOXICITY CLASSIFICATION - RODENTICIDES

	Oral	Inhalation	Dermal	Primary Eye Irritation	Primary Skin Irritation
Warfarin[3,6]	Moderate - High toxicity	Not significant	Not significant	**No data**	**No data**
Chlorphacinone[4]	High toxicity	High toxicity	High toxicity	**Non-irritating**	**Non-irritating**
Diphacinone[4]	High toxicity	High toxicity	High toxicity	**Moderate irritation**	**Slight irritation**
Bromadiolone[4]	High toxicity	High toxicity	High toxicity	**Low irritation**	**Minimally irritating**
Difethialone[3]	High toxicity	High toxicity	High toxicity	Mild irritant	Non-irritating
Brodifacoum[4]	High toxicity	High toxicity	High toxicity	Minor irritation	Mild irritant
Bromethalin[4]	High toxicity	High toxicity	**Moderate toxicity**	Slight irritation	Non-irritating
Cholecalciferol[3]	High toxicity	Very low toxicity	**Low toxicity**	No data	No data
Zinc phosphide[5]	High toxicity	High toxicity	**Low toxicity**	Slight irritation	Non-irritating
Strychnine[7]	High toxicity	High toxicity	**Low toxicity**	Highly irritating	Non-irritating

Classification categories were modeled after the U.S. Environmental Protection Agency, Office of Pesticide Programs, Label Review Manual, Chapter 7: Precautionary Labeling. http://www.epa.gov/oppfead1/labeling/lrm/chap-07.pdf

Warfarin was the first anticoagulant rodenticide.[1] It was registered for use in 1950.[4] Warfarin was discovered in moldy sweet clover that had made a herd of cattle sick. Researchers found that a fungus had converted a chemical that occurs naturally in the clover to a more toxic chemical.[9] Warfarin was the most widely used rodenticide until many rodents began to become resistant to it. This led to the development of new rodenticides.[9]

Which anticoagulants require more feedings to work?

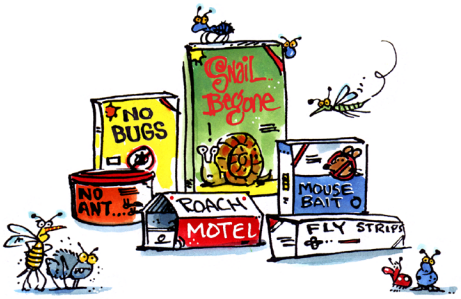
Warfarin, chlorophacinone, and diphacinone generally require that an animal eat multiple doses of the bait over several days. These are known as multiple-dose anticoagulants. Single-dose anticoagulants, such as brodifacoum, bromadiolone, and difethialone are more toxic. One day's feeding can deliver a toxic dose.[4]

Table 2. Summary of common rodenticides

Rodenticide	Type	Chemical class	Days of feeding needed
Warfarin	Anticoagulant	Hydroxycoumarin	multiple
Chlorphacinone	Anticoagulant	Indandione	multiple
Diphacinone	Anticoagulant	Indandione	multiple
Bromadiolone	Anticoagulant	Hydroxycoumarin	single
Difethialone	Anticoagulant	Hydroxycoumarin	single
Brodifacoum	Anticoagulant	Hydroxycoumarin	single
Bromethalin	Non-anticoagulant	other	single
Cholecalciferol	Non-anticoagulant	Vitamin D3	multiple or single
Zinc phosphide	Non-anticoagulant	other	single
Strychnine	Non-anticoagulant	other	single

Single-dose anticoagulants are more toxic because they bind more tightly to the enzyme that makes blood-clotting agents. They can also interfere with other steps in Vitamin K recycling. Second-generation, or single-dose anticoagulants, are not easily excreted from the body, and they can be stored in the liver.[10] Most of these rodenticides are not allowed to be marketed to non-licensed applicators for residential use.[11] Instead of classifying anticoagulants into "first generation" or "second generation", many sources refer to them as multiple-dose or single-dose rodenticides because it is less confusing.

What are some of the other rodenticides?



There are a number of rodenticides that work differently than anticoagulants. These are currently used within the United States: bromethalin, cholecalciferol, zinc phosphide, and strychnine. Each of these pesticides works in a different way.

Bromethalin was first registered by the U.S. Environmental Protection Agency (EPA) in 1984.[4] It stops the cells in the central nervous system from producing energy. The nerve cells swell, this puts pressure on the brain, and paralysis and death soon follow.[12] The major breakdown product of bromethalin is more toxic than bromethalin itself. The varying ability of different species to break down bromethalin may explain why it is more toxic to some animals than others. [12] Bromethalin is considered a single-dose rodenticide.[4]

Cholecalciferol was first registered as a rodenticide in the United States in 1984.[4] Cholecalciferol is vitamin D_3.[13] Vitamin D helps the body maintain calcium balance by enhancing absorption of calcium from the gut and kidneys.[13] Toxic doses of cholecalciferol lead to too much calcium in the blood, which can affect the central nervous system, muscles, the gastrointestinal tract, cardiovascular system, and the kidneys.[13] The body's ability to maintain proper calcium levels must be overwhelmed before cholecalciferol becomes toxic. Rodents must eat several doses of this rodenticide.[4] This causes a time lag between exposure and signs of toxicity.[13] Although pets have gotten sick from eating cholecalciferol, poisonings of people are very rare.[14]

Zinc phosphide was first registered in 1947.[1] It changes into phosphine gas in the presence of water and acid. The phosphine gas is very toxic; it blocks the body's cells from making energy, and the cells die.[15] Phosphine exposure is particularly damaging to the heart, brain, kidney, and liver.[15]

Strychnine was first registered in 1947, but it was used for many years before then.[16] It can only be used below ground. Products with more than 0.5% strychnine are restricted; they are only sold to certified applicators.[16] Strychnine comes from the seeds of certain plants, *Strychnos nux-vomica* and *Strychnos ignatii*.[17] It affects the cells in the spinal cord by causing nerve cells to fire more readily, which leads to muscle spasms. Given a sufficient dose, the spasms cause breathing paralysis and death.[17]

What are signs of rodenticide poisoning?

Always follow label instructions and take steps to minimize exposure. If any exposure occurs, be sure to follow the First Aid instructions on the product label carefully. Some products contain blue or green dye that helps determine whether a child or pet has handled or eaten the product.[4,18] For additional treatment advice, contact the Poison Control Center at 1-800-222-1222. If you wish to report an incident to the ***National Pesticide Information Center***, please call 1-800-858-7378.

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Anticoagulant rodenticide exposure can lead to uncontrolled bleeding in any part of the body, but this is not always obvious. Difficulty breathing, weakness, and lethargy have been seen in animals poisoned with anticoagulant rodenticides. Less common signs include coughing, vomiting, stools marked with blackened, tarry blood, paleness, bleeding from the gums, seizures, bruising, shaking, abdominal distention and pain.[9] Because the stored clotting agents have to run out, signs may be delayed for up to five days following exposure.[8] Children usually eat small amounts and may never show signs of poisoning. Signs in people include sudden bleeding from the nose, gums, or skin. Internal bleeding can also occur.[10]

Bromethalin ingestion causes muscle tremors, seizures, heightened sensitivity to light or noise, and hyperexcitability if the animal eats more than a lethal dose. The onset of signs depends on the dose. If a lethal dose is eaten, signs may develop 8 to 12 hours or several days after ingestion and progress over a period of a week or longer. In this case, animals lose their ability to control their hind legs or sense where their hind legs are. Animals may also vomit, lose interest in food, or adopt strange postures. They may fall into a coma.[12,19] People may also have altered mental status.[20]

Cholecalciferol can be toxic from routine or one-time exposure.[13] Signs in animals include weakness, depression, and loss of appetite. Signs progress to include vomiting, increased thirst, more frequent urination, dehydration, and constipation.[13] Vomiting, diarrhea, loss of appetite, and depression may develop within 12 to 36 hours after exposure and the kidneys may fail within one or two days. Survivors may have permanent damage to kidneys and muscles. Signs of poisoning may last for weeks because cholecalciferol can be stored in the body and its breakdown products are removed slowly.[21] Exposed people experience unusual thirst and increased urination. They may suffer heart and kidney damage if the increase in calcium levels lasts long enough.[14]

Zinc phosphide may cause vomiting within an hour of ingestion. However, signs of toxicity may be delayed for 4 hours and in some cases longer than 18 hours. The vomit may smell like garlic and may contain blood. Other signs of toxicity include anxiety, discomfort leading to frantic pacing, staggering and weakness, difficulty breathing, and convulsions.[15,22] Humans also experience vomiting, excitement, chills, shortness of breath and coughing, delirium, convulsions, and coma. Breathing in zinc phosphide dust or phosphine gas given off by zinc phosphide may cause anxiousness and extreme difficulty breathing.[14]

Strychnine poisoning causes involuntary muscle spasms in both people and animals. These spasms can be severe, and include extreme extension of the limbs. Signs can begin within 15 minutes in people and within two hours in animals after eating strychnine. Death is caused by impaired breathing.[14,17]

What if pets and wildlife eat rodents that have been poisoned?

Rodenticide baits are made to attract animals. Pets and wildlife may take the bait if they find it. When an animal eats the bait directly, it is called primary poisoning. Secondary poisoning is caused by eating poisoned prey. It may also be called relay toxicosis. See the fact sheet on ***Ecotoxicology***. For ways to prevent exposures, see the information about what you can do to reduce risks.

The rodenticides with high secondary poisoning risks to birds such as hawks and owls include difethialone and brodifacoum (see Table 2).[23] The rodenticides that pose the greatest secondary poisoning risks for wild mammals, dogs and cats include chlorophacinone, diphacinone, and all of the single dose rodenticides. Bromethalin and cholecalciferol may pose secondary risks but these risks have not been studied as extensively.[2]

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Table 3. Secondary poisoning risks to birds and mammals[2]		
Rodenticide	**Secondary risk to birds**	**Secondary risk to mammals**
Warfarin	slight risk	low risk
Chlorophacinone	slight risk	high risk
Diphacinone	moderate risk	high risk
Bromadiolone	moderate risk	high risk
Difethialone	high risk	high risk
Brodifacoum	high risk	high risk
Bromethalin	possible (insufficient data)	low risk
Cholecalciferol	low risk	low risk
Zinc phosphide	low risk	slight risk
Strychnine[17,24]	possible (insufficient data)	possible (insufficient data)

Single-dose anticoagulants pose a greater risk to animals that eat poisoned rodents.[25] If the rodent continues to feed on the single-dose anticoagulant after it eats a toxic dose during the first day, it may build up more than a lethal dose in its body before the clotting factors run out and the animal dies. Residues of single-dose anticoagulants may remain in liver tissue for many weeks, so a predator that eats many poisoned rodents may build up a toxic dose over time.[26] However, even the multiple-dose anticoagulants may be poisonous to animals who eat poisoned rodents.[2]

Strychnine has caused secondary poisoning in pets that ate poisoned rodents.[17] Zinc phosphide may cause secondary poisoning in pets, but only when the stomach of the rodent still contains intact pellets of the rodenticide. Zinc phosphide breaks down quickly so the rodent must be very recently dead or just dying in order for the zinc phosphide to pose a secondary poisoning risk.[15]

What can I do to reduce the risks?

Always follow label instructions and take steps to avoid exposure. Keep all rodenticides out of the reach of children and pets, whether they are in use or in storage. Because of the flavorings and attractive odors in these products, dogs may ***dig them up***, working hard to get to them. ***Choose the right bait station*** for your needs around the home. Some of them are resistant only to children. Some are resistant to children and pets; others are resistant to children, pets and the weather. The EPA has been taking action to reduce risk by requiring bait stations in sensitive areas and by limiting the most toxic active ingredients available on the homeowner market.[11]

Many rodenticide baits can be toxic to wildlife if they are eaten, or if an animal eats a rodent that was recently poisoned. If you choose to use a rodenticide outdoors, always follow label instructions. To reduce risks of secondary poisoning for pets and wildlife, search for, collect, and dispose of poisoned rodents. Use gloves when disposing of dead rodents to avoid contact and secure trashcan lids to minimize pet or wildlife access to poisoned rodents. If you suspect an ***animal may have been poisoned***, please contact NPIC at 1-800-858-7378 to talk with a Pesticide Specialist.

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You may find that there are other things you can do to control rodents, in addition to using rodenticides. Find out what kind of rodent you have and ***learn*** about its habits, abilities, likes and dislikes. Consider trapping, try to block entry points, and remove any food and water sources. This is called ***Integrated Pest Management (IPM)***.

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