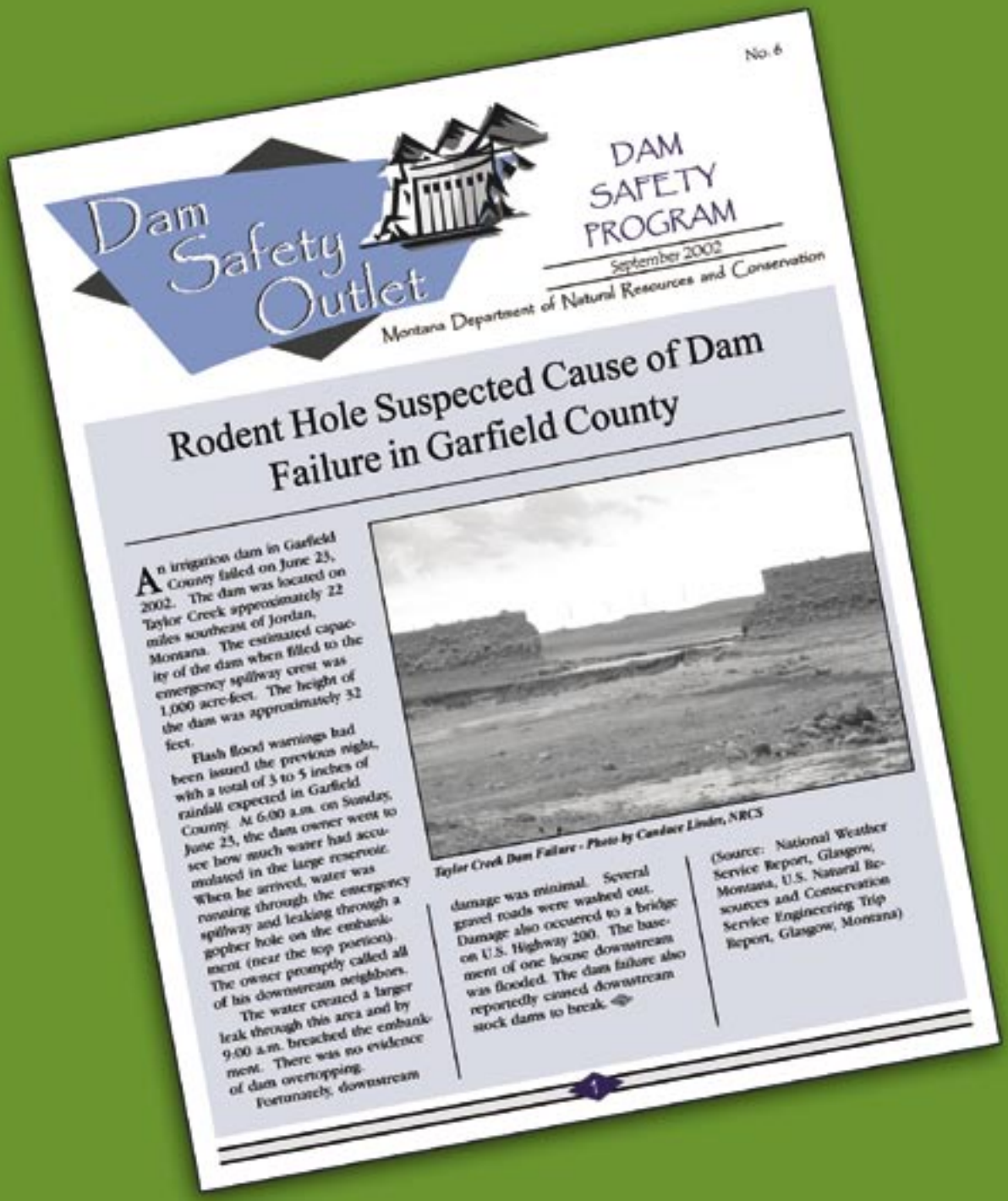
Technical Manual for Dam Owners

Impacts of Animals on Earthen Dams

FEMA 473 / September 2005

FEMA

Twenty-five states across the U.S. can write headlines of dam failure caused by nuisance wildlife intrusions, and many dam owners find the struggle to adequately manage nuisance wildlife at their dams a never-ending story. The Federal Emergency Management Agency (FEMA) has funded the development of this manual with the understanding that safe dam operation includes comprehensive, state-of-practice guidance on timely inspection and observation of wildlife damages, accurate wildlife identification and mitigation, and appropriate dam design, repair, and preventive measures. It is hoped that the information and methods contained in this manual will compose the core of dam management routines practiced by dam specialists across the country. Armed with education and diligence, dam specialists can prevent animal intrusion dam failure from becoming headline news.



No. 6

Dam Safety Outlet

DAM SAFETY PROGRAM

September 2002

Montana Department of Natural Resources and Conservation

Rodent Hole Suspected Cause of Dam Failure in Garfield County

An irrigation dam in Garfield County failed on June 23, 2002. The dam was located on Taylor Creek approximately 22 miles southeast of Jordan, Montana. The estimated capacity of the dam when filled to the emergency spillway crest was 1,000 acre-feet. The height of the dam was approximately 32 feet.

Flash flood warnings had been issued the previous night, with a total of 3 to 5 inches of rainfall expected in Garfield County. At 6:00 a.m. on Sunday, June 23, the dam owner went to see how much water had accumulated in the large reservoir. When he arrived, water was running through the emergency spillway and leaking through a gopher hole on the embankment (near the top portion). The owner promptly called all of his downstream neighbors.

The water created a larger leak through this area and by 9:00 a.m. breached the embankment. There was no evidence of dam overtopping.

Fortunately, downstream damage was minimal. Several gravel roads were washed out. Damage also occurred to a bridge on U.S. Highway 200. The basement of one house downstream was flooded. The dam failure also reportedly caused downstream stock dams to break.

Taylor Creek Dam Failure - Photo by Candace Linder, NRCS

(Source: National Weather Service Report, Glasgow, Montana, U.S. Natural Resources and Conservation Service Engineering Trip Report, Glasgow, Montana)

1

Technical Manual for Dam Owners

Impacts of Animals on Earthen Dams

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Table of Contents

1.0 Introduction and Purpose of Manual 1
1.1 Background 1
1.2 Target Audience, Purpose, and Application of This Manual 2
1.3 Technical Resources Cited 3
2.0 Impacts of Wildlife on Earthen Dams 4
2.1 Background 4
2.2 Hydraulic Alteration 5
2.3 Structural Integrity Losses 6
2.4 Surface Erosion 6
3.0 Dam Inspection From Two Perspectives: Engineering Function and Biological Potential 8
3.1 Wildlife and the Earthen Dam 8
3.2 Two-Perspective Dam Inspection Methodology 9
3.2.1 Zone 1: Upstream Slope Area 9
3.2.2 Zone 2: Dam Crest Area 10
3.2.3 Zone 3: Upper Downstream Slope Area 12
3.2.4 Zone 4: Lower Downstream Slope Area 13
3.2.5 Zone 5: Downstream Toe Area 13
3.2.6 Zone 6: Spillway, Outlets, and General Areas 14
4.0 Overview and Identification of Nuisance Wildlife 15
4.1 The Importance of Accurate Wildlife Identification 15
4.2 Identifying Nuisance Wildlife 17
4.2.1 Muskrat Overview 17
4.2.2 Beaver Overview 19
4.2.3 Mountain Beaver Overview 22
4.2.4 Groundhog Overview 24
4.2.5 Pocket Gopher Overview 26
4.2.6 North American Badger Overview 29
4.2.7 Nutria Overview 31
4.2.8 Prairie Dog Overview 33
4.2.9 Ground Squirrel Overview 35
4.2.10 Armadillo Overview 37
4.2.11 Livestock Overview 39
4.2.12 Crayfish Overview 41
4.2.13 Coyote Overview 42
4.2.14 Moles and Voles Overview 44
4.2.15 River Otter Overview 47
4.2.16 Gopher Tortoise Overview 48
4.2.17 Red Fox and Gray Fox Overview 50
4.2.18 Canada Goose Overview 52
4.2.19 American Alligator Overview 54
4.2.20 Ants Overview 55
5.0 Dam Repair and Intrusion Prevention Through Design 57
5.1 Conformity to the Clean Water Act of 1972 57
5.2 The Role of Vegetation Management 58
5.3 Burrow Repair Procedures 58
5.3.1 Restoration Measures 58
5.3.2 Preventive Measures 59

5.4 Dam Repair Zones 59
5.4.1 Dam Repair Zone 1 60
5.4.2 Dam Repair Zone 2 62
5.4.3 Dam Repair Zone 3 62
5.4.4 Dam Repair Zone 4 63
5.4.5 Dam Repair Zone 5 63
5.5 Professional Dam Safety Review 64
5.6 Sequenced Repair Program 64
5.7 Mitigation Through Design 64
5.7.1 Muskrat 64
5.7.2 Beaver 66
5.7.3 Mountain Beaver 68
5.7.4 Groundhog 68
5.7.5 Pocket Gopher 68
5.7.6 North American Badger 68
5.7.7 Nutria 68
5.7.8 Prairie Dog 68
5.7.9 Ground Squirrel 68
5.7.10 Armadillo 69
5.7.11 Livestock 69
5.7.12 Crayfish 69
5.7.13 Coyote 69
5.7.14 Mole and Vole 69
5.7.15 River Otter 69
5.7.16 Gopher Tortoise 70
5.7.17 Red and Gray Fox 70
5.7.18 Canada Goose 70
5.7.19 American Alligator 70
5.7.20 Ants 70
5.8 Monitoring 70
6.0 Mitigating Damaging Wildlife 71
6.1 Compliance with State and Federal Regulations 71
6.1.1 Conformity to Federal Regulations 71
6.1.2 Conformity to State Regulations 72
6.2 Muskrat Management Methods 73
6.2.1 Muskrat Control Through Habitat Modification 73
6.2.2 Muskrat Control Through Trapping 73
6.2.3 Muskrat Control Through Fumigants 75
6.2.4 Muskrat Control Through Toxicants 75
6.2.5 Muskrat Control Though Frightening 76
6.2.6 Muskrat Control Through Repellents 76
6.2.7 Muskrat Control Through Shooting 76
6.3 Beaver Management Methods 76
6.3.1 Beaver Control Through Habitat Modification 76
6.3.2 Beaver Control Through Trapping 76
6.3.3 Beaver Control Through Fumigants 77
6.3.4 Beaver Control Through Toxicants 77
6.3.5 Beaver Control Through Frightening 77
6.3.6 Beaver Control Through Repellents 77
6.3.7 Beaver Control Through Shooting 77

6.4 Mountain Beaver Management Methods 77
6.4.1 Mountain Beaver Control Through Habitat Modification 77
6.4.2 Mountain Beaver Control Through Trapping 77
6.4.3 Mountain Beaver Control Through Fumigants 77
6.4.4 Mountain Beaver Control Through Toxicants 78
6.4.5 Mountain Beaver Control Through Frightening 78
6.4.6 Mountain Beaver Control Through Repellents 78
6.4.7 Mountain Beaver Control Through Shooting 78
6.5 Groundhog Management Methods 78
6.5.1 Groundhog Control Through Habitat Modification 78
6.5.2 Groundhog Control Through Trapping 78
6.5.3 Groundhog Control Through Fumigants 78
6.5.4 Groundhog Control Through Toxicants 78
6.5.5 Groundhog Control Though Frightening 78
6.5.6 Groundhog Control Through Repellents 79
6.5.7 Groundhog Control Through Shooting 79
6.6 Pocket Gopher Management Methods 79
6.6.1 Pocket Gopher Control Through Habitat Modification 79
6.6.2 Pocket Gopher Control Through Trapping 79
6.6.3 Pocket Gopher Control Through Fumigants 80
6.6.4 Pocket Gopher Control Through Toxicants 80
6.6.5 Pocket Gopher Control Through Frightening 81
6.6.6 Pocket Gopher Control Through Repellents 81
6.6.7 Pocket Gopher Control Through Shooting 82
6.7 North American Badger Management Methods 82
6.7.1 North American Badger Control Through Habitat Modification 82
6.7.2 North American Badger Control Through Trapping 82
6.7.3 North American Badger Control Through Fumigants 82
6.7.4 North American Badger Control Through Toxicants 82
6.7.5 North American Badger Control Through Frightening 82
6.7.6 North American Badger Control Through Repellents 82
6.7.7 North American Badger Control Through Shooting 82
6.8 Nutria Management Methods 82
6.8.1 Nutria Control Through Habitat Modification 82
6.8.2 Nutria Control Through Trapping 83
6.8.3 Nutria Control Through Fumigants 83
6.8.4 Nutria Control Through Toxicants 83
6.8.5 Nutria Control Through Frightening 83
6.8.6 Nutria Control Through Repellents 83
6.8.7 Nutria Control Through Shooting 84
6.9 Prairie Dog Management Methods 84
6.9.1 Prairie Dog Control Through Habitat Modification 84
6.9.2 Prairie Dog Control Through Trapping 84
6.9.3 Prairie Dog Control Through Fumigants 84
6.9.4 Prairie Dog Control Through Toxicants 85
6.9.5 Prairie Dog Control Through Frightening 85
6.9.6 Prairie Dog Control Though Repellents 85
6.9.7 Prairie Dog Control Through Shooting 85
6.10 Ground Squirrel Management Methods 85

6.10.1 Ground Squirrel Control Through Habitat Modification 86
6.10.2 Ground Squirrel Control Through Trapping 86
6.10.3 Ground Squirrel Control Through Fumigants 86
6.10.4 Ground Squirrel Control Through Toxicants 86
6.10.5 Ground Squirrel Control Through Frightening 87
6.10.6 Ground Squirrel Control Through Repellents 87
6.10.7 Ground Squirrel Control Through Shooting 87
6.11 Armadillo Management Methods 87
6.11.1 Armadillo Control Through Habitat Modification 87
6.11.2 Armadillo Control Through Trapping 87
6.11.3 Armadillo Control Through Fumigants 88
6.11.4 Armadillo Control Through Toxicants 88
6.11.5 Armadillo Control Through Frightening..... 88
6.11.6 Armadillo Control Through Repellents 88
6.11.7 Armadillo Control Through Shooting 88
6.12 Livestock (Cow, Sheep, Horse, Pig, and Wild Pig) Management Methods 88
6.12.1 Livestock Control Through Habitat Modification 88
6.12.2 Livestock Control Through Trapping 88
6.12.3 Livestock Control Through Fumigants 89
6.12.4 Livestock Control Through Toxicants 89
6.12.5 Livestock Control Through Frightening 89
6.12.6 Livestock Control Through Repellents 89
6.12.7 Livestock Control Through Shooting 89
6.13 Crayfish Management Methods 89
6.13.1 Crayfish Control Through Habitat Modification 89
6.13.2 Crayfish Control Through Trapping 89
6.13.3 Crayfish Control Through Fumigants 89
6.13.4 Crayfish Control Through Toxicants 89
6.13.5 Crayfish Control Through Frightening..... 89
6.13.6 Crayfish Control Through Repellents 89
6.13.7 Crayfish Control Through Shooting 89
6.14 Coyote Management Methods..... 89
6.14.1 Coyote Control Through Habitat Modification 89
6.14.2 Coyote Control Through Trapping 89
6.14.3 Coyote Control Through Fumigants 90
6.14.4 Coyote Control Through Toxicants 90
6.14.5 Coyote Control Through Frightening 90
6.14.6 Coyote Control Through Repellents 90
6.14.7 Coyote Control Through Shooting 90
6.15 Mole and Vole Management Methods 90
6.15.1 Mole and Vole Control Through Habitat Modification 90
6.15.2 Mole and Vole Control Through Trapping 90
6.15.3 Mole and Vole Control Through Fumigants 91
6.15.4 Mole and Vole Control Through Toxicants 91
6.15.5 Mole and Vole Control Through Frightening 91
6.15.6 Mole and Vole Control Through Repellents 91
6.15.7 Mole and Vole Control Through Shooting 91
6.16 River Otter Management Methods 91

6.16.1 River Otter Control Through Habitat Modification 91
6.16.2 River Otter Control Through Trapping 92
6.16.3 River Otter Control Through Fumigants 92
6.16.4 River Otter Control Through Toxicants 92
6.16.5 River Otter Control Through Frightening 92
6.16.6 River Otter Control Through Repellents 92
6.16.7 River Otter Control Through Shooting 92
6.17 Gopher Tortoise Management Methods 92
6.17.1 Gopher Tortoise Control Through Habitat Modification 92
6.17.2 Gopher Tortoise Control Through Trapping 92
6.17.3 Gopher Tortoise Control Through Fumigants 92
6.17.4 Gopher Tortoise Control Through Toxicants 92
6.17.5 Gopher Tortoise Control Through Frightening 92
6.17.6 Gopher Tortoise Control Through Repellents 92
6.17.7 Gopher Tortoise Control Through Shooting 92
6.18 Red Fox and Gray Fox Management Methods 93
6.18.1 Red Fox and Gray Fox Control Through Habitat Modification 93
6.18.2 Red Fox and Gray Fox Control Through Trapping 93
6.18.3 Red Fox and Gray Fox Control Through Fumigants 93
6.18.4 Red Fox and Gray Fox Control Through Toxicants 93
6.18.5 Red Fox and Gray Fox Control Through Frightening 93
6.18.6 Red Fox and Gray Fox Control Through Repellents 93
6.18.7 Red Fox and Gray Fox Control Through Shooting 93
6.19 Canada Goose Management Methods 93
6.19.1 Canada Goose Control Through Habitat Modification 93
6.19.2 Canada Goose Control Through Trapping 94
6.19.3 Canada Goose Control Through Fumigants 94
6.19.4 Canada Goose Control Through Toxicants 94
6.19.5 Canada Goose Control Through Frightening 94
6.19.6 Canada Goose Control Through Repellents 95
6.19.7 Canada Goose Control Through Shooting 95
6.19.8 Other Methods of Canada Goose Control 95
6.20 American Alligator Management Methods 95
6.20.1 American Alligator Control Through Habitat Modification 95
6.20.2 American Alligator Control Through Trapping 95
6.20.3 American Alligator Control Through Fumigants 95
6.20.4 American Alligator Control Through Toxicants 95
6.20.5 American Alligator Control Through Frightening 95
6.20.6 American Alligator Control Through Repellents 95
6.20.7 American Alligator Control Through Shooting 96
6.21 Ant Management Methods 96
6.21.1 Ant Control Through Habitat Modification 96
6.21.2 Ant Control Through Trapping 96
6.21.3 Ant Control Through Fumigants 96
6.21.4 Ant Control Through Toxicants 96
6.21.5 Ant Control Through Frightening 96
6.21.6 Ant Control Through Repellents 96
6.21.7 Ant Control Through Shooting 96

7.0 Fiscal Considerations for Managing Animal Damage on Earthen Dams 97
7.1 Fiscal Considerations for the Reluctant Dam Owner 97
7.2 Fiscal Considerations of the Willing Dam Owner 97
7.3 Overcoming the Economic Hurdles 98
8.0 References 102
Appendix A 105
Appendix B 109

1.0 Introduction and Purpose of Manual

1.1 Background

In 1999, the Federal Emergency Management Agency (FEMA) and the Association of State Dam Safety Officials (ASDSO) jointly conducted research and a workshop to shed light on the national problem of animal intrusion damage to earthen dams and the resulting safety issues. The FEMA/ASDSO survey and workshop united dam owners, engineers, state and federal regulators, wildlife managers, foresters, and academia to form an educated and experienced front against the growing problem of earthen dam damage and failures due to animal intrusion. The information generated by roundtable discussions and survey answers indicates that while most states recognize animal intrusion as a problem, only a handful know of guidance on dams and wildlife management practices available to the dam professionals and owners. Based on input from the dam communities, FEMA/ASDSO's mission to develop a guidance manual on the proper management of nuisance wildlife in the earthen dam environment became clear.

To determine the information needs of the dam community—and therefore the most appropriate focus of this manual—FEMA/ASDSO issued a survey in 1999 and used the survey input from the 48 state dam safety officials representatives and 11 federal agencies representing the Interagency Committee on Dam Safety (ICODS). Additionally, a second survey was issued in 2003 to identify the current needs of each state, determine what nuisance wildlife and damages the states encounter, and understand which mitigation methods are being used with success or failure. Four main ideas emerged from the two survey efforts; these ideas consequently steered the direction of this manual:

- Cumulatively, the states indicated a range of problems caused by numerous wildlife species relative to the operation of dams. This manual discusses 23 species with regard to their habitat, behavior, threat to dams, food habits, identifying characteristics, and management options: Muskrat, Beaver, Mountain Beaver, Groundhog, Pocket Gopher, North American Badger, Nutria, Prairie Dog, Ground Squirrel, Armadillo, Livestock (cow, sheep, horse, pig and wild pig), Crayfish, Coyote, Moles and Voles, River Otter, Gopher Tortoise, Red Fox and Gray Fox, Canada Goose, American Alligator, and Ants.

- While the states are fully aware of the potential adverse impacts wildlife activity can have on earthen dams (such as failure), private dam owners and local dam operators are often not aware of potential problems, and thus may

25: number of states that indicate animal activity has caused or contributed to unsafe dam operation or outright failure within the state.

9: number of states aware of information or guidance on the effects of animal activity on dams.

not conduct inspections with wildlife damage in mind. Local dam owners may not typically mitigate existing wildlife intrusion problems or prevent them in the future.

- States want to know how other states are successfully mitigating wildlife damages. Further, mitigation and prevention guidance should be developed and conveyed to the dam communities.

- Guidance booklets for local dam owners are needed to assist dam inspectors in identifying and mitigating animal intrusion issues.

Out of 48 states that responded to FEMA and ASDSO surveys, 25 document nuisance animals as the cause of dam failures or unsafe dam operations in their states. The U.S. Bureau of Reclamation, the National Park Service, and the U.S. Department of Agriculture document several similar cases at the federal level. State dam safety officials and federal agencies agree that animal burrows within dams can cause substantial and costly damage if left unmitigated and are consequently a major concern.

1.2 Target Audience, Purpose, and Application of This Manual

This manual provides technical guidance to dam specialists (including dam owners, operators, inspectors, state dam officials, and consulting engineers) in areas of focus identified through the two survey efforts and workshop. The purposes of this manual are to:

- Assist dam specialists in understanding the impacts wildlife can have on earthen dams.

- Provide dam specialists with basic information on habitat, range, description, and behavior of common nuisance wildlife to aid in their proper identification at the dam.

- Describe state-of-practice methods to prevent and mitigate adverse wildlife impacts on earthen dams.

- Provide state-of-practice design guidance for repair and preventive design associated with nuisance wildlife intrusion.

It is envisioned that the entire dam specialist community will use this manual to augment their routine duties in earthen dam management. This manual is presented as a process toward dam inspection and management that includes wildlife damage identification and control. This manual provides technical information and guidance on:

- How wildlife damage adversely affects the safe operation of earthen dams; specifically, hydraulic alteration, internal and external erosion, and structural integrity losses (Chapter 2.0).

- Dam inspections that incorporate a biological component to sensitize dam specialists to the aspects of their dams that attract wildlife and to understand where nuisance wildlife are likely to occur on the dam (Chapter 3.0).

- Biological data for specific nuisance wildlife to assist the dam specialist in identifying which nuisance wildlife inhabits the dam. Biological data will also assist in controlling nuisance wildlife (e.g., listed food sources can be removed to encourage the animal to leave the area) (Chapter 4.0).

- Dam design specifications and methods that can be incorporated into repair of existing dams or new dam designs to prevent wildlife intrusions (Chapter 5.0).

- Guidelines to determine when wildlife management should occur at a dam (beyond dam repair and prevention actions) and wildlife management methods that can be implemented when control of specific nuisance wildlife populations is deemed necessary. Specific methods discussed include habitat modification, use of toxicants and fumigants, trapping, and shooting (Chapter 6.0).

- The fiscal issues related to appropriate and timely wildlife management at earthen dams (Chapter 7.0).

1.3 Technical Resources Cited

The technical information provided in this manual represents the most current practices in the areas of wildlife data and management and engineering inspection and repair, as they relate to nuisance wildlife and their effects on safe dam operations. While numerous technical sources are cited throughout the document, three main sources form the backbone of this manual's technical understanding and recommendations. The first source is a manual titled *Prevention and Control of Wildlife Damage* (University of Nebraska, 1994). The data contained in the 1994 manual are considered the industry standard for pest control, and the manual is used as the handbook for those testing for licensure as pest control managers. It should be noted that the 1994 manual is under revision and a revised version will be completed February 2005. Until the release of the revised manual, the 1994 edition remains the leading guidance literature in this field and is accepted as the most current practice in nuisance wildlife management (Smith, Pers. comm., 2003; 2004). The second source is a booklet called *Prevention and Control of Animal Damage to Hydraulic Structures* (USDA, 1991). The 1991 booklet adapts some of the 1994 manual data for application to the dam environment. The last source is technical data on remedial dam repair design by Dr. B. Dan Marks, as presented in the 2001 ASDSO West Region Seminar on Plant and Animal Penetrations for Earthen Dams (ASDSO, 2001). Many other sources are also used throughout this manual to provide a cross-reference of data as well as a broad spectrum of information.

2.0 Impacts of Wildlife on Earthen Dams

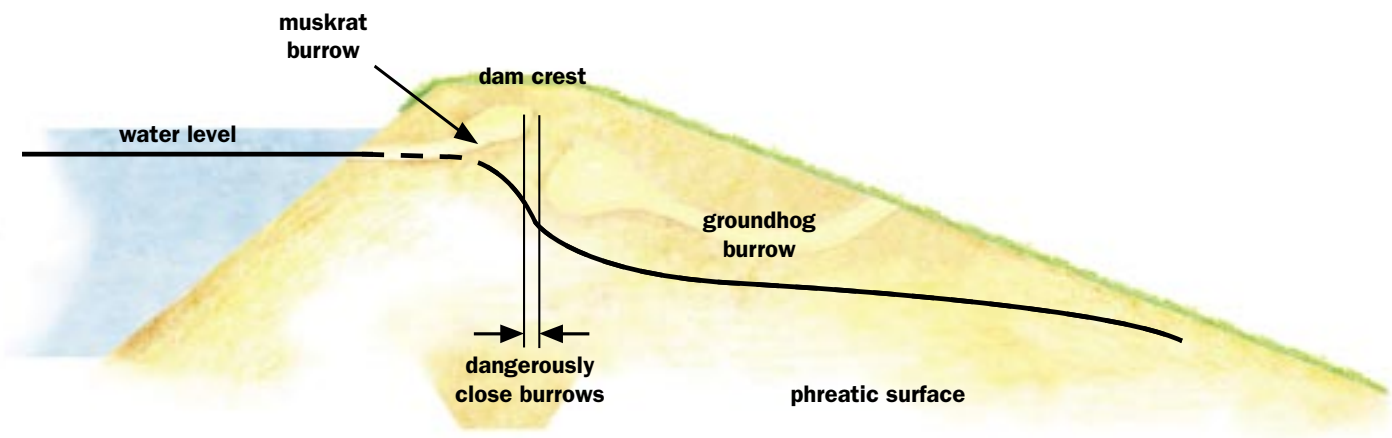


Figure 2-1. Upstream and downstream burrows can become dangerously close, causing internal erosion that may lead to dam failure.

Earthen embankment dams are used by private landowners and state and federal agencies to store farm water supplies, city water supplies, recreational waters, flood waters, and wastewater lagoons. Earthen dams rely on a thick placement of compacted soils to withstand the water pressure of the pool contained behind the embankment. Often constructed outside of developed areas, the earthen dam environment is usually near a water source and can contain a variety of vegetation; given these characteristics, earthen dam environments can be naturally conducive to use by wildlife. Wildlife inhabiting the dam can alter the dam environment through habitat establishment and use—beaver build dams, muskrat excavate dens, livestock feed on stabilizing vegetation. The natural instincts of wildlife to adapt and use their environment toward their survival can compromise the balance of engineered functions that maintain the viability of an earthen dam.

The first step in fortifying a dam against unsafe operations caused by wildlife damage is to understand what could go wrong if wildlife damage is left unchecked. While a dam owner may observe a few small burrows on the upstream and downstream slopes, it is important to understand that potential problems, like those burrows, often run deep below the surface. As such, the purpose of this Chapter is to discuss adverse engineering effects stemming from nuisance wildlife activity. Adverse effects caused by specific wildlife (as well as their identification and mitigation) are discussed in Chapters 4.0, 5.0, and 6.0.

2.1 Background

Embankment dams are vulnerable to damage from wildlife intrusions. Twenty-five states indicate that animal activity has caused or contributed to unsafe operation or outright failure of an embankment dam. Several animal species excavate burrows, tunnels, and den entrances for shelter, while other predatory animals will enlarge these structures via digging in search of prey. Similarly, herbivorous species will forage on vegetation growing on embankment dams. All of these occurrences create open areas in the embankment fill which are detrimental to the safety and performance of embankment dams. Some of these effects can be easily identified, such as surface erosion; other effects such as internal erosion may not become visible until dam safety is jeopardized.

Homogeneous and zoned embankment dams are equally susceptible to damage from animal intrusions. The ultimate consequence from the intrusions depends on the specific engineering and biological characteristics of an individual dam.

Embankment dams can be generally categorized as either homogeneous (containing one material) or zoned (containing multiple materials). Zoned embankment dams usually contain a central core designed to produce a lower phreatic surface (static water level within a dam embankment) within the downstream slope than the theoretical surface often assumed for homogeneous embankments. Due to the variability of zoned embankments, this manual discusses only homogeneous embankments.

2.2 Hydraulic Alteration

The most significant and often least obvious impact of wildlife intrusions on embankment dams is hydraulic alteration. Hydraulic alteration and its effects can manifest in different ways depending on the type and location of intrusion, including flownet distortion and physical barriers to flow.

A distorted flownet may not be a visible problem but it can have the most dramatic impact. Flownet is a term referring to the theoretical description of water flow through and under an embankment dam. The phreatic surface, equal potential lines and flow lines associated with a flownet are defined by the physical dimensions of the dam, classification of soils in the dam, and variability of the reservoir normal pool. As such, each dam has a unique flownet. The presence of animal burrows, either on the upstream or downstream slope, can distort the established phreatic surface and impact the flownet. As illustrated on Figure 2-2, upstream burrows can allow the normal pool elevation to extend into the dam embankment, forcing the phreatic surface further into the embankment. Likewise, downstream intrusions can allow the phreatic surface to day-light higher on the downstream slope. The overall effect can be a significant alteration to the phreatic surface. Dramatic changes to the phreatic surface can shorten seepage paths, increase seepage volumes, decrease the factor of safety against slope failure, and cause internal erosion of embankment materials (piping).

Of these impacts, piping is most often cited as the greatest concern among dam safety professionals because it is progressive and can rapidly lead to failure of the dam. Piping is the uncontrolled movement of soil particles caused by flowing water. As shown on Figure 2-3, piping will often start in a burrow on the downstream slope. Flowing water moves soil particles from the embankment to the burrow, leaving a void that is quickly filled with soil particles from deeper within the embankment. Because water pressure and flow generally increase further into the dam embankment, the rate of movement of soil particles will also increase. A pipe is rapidly formed extending from the downstream slope to the upstream slope. A dam breach is almost certain to develop in these instances.

External problems can also arise from wildlife activity around an embankment dam. Though hydraulic barriers can result from the activities of several species, beaver cause perhaps the largest array of adverse effects. To create deep waters in which to hide from predators, beavers compact felled tree trunks, limbs, and other materials into a mound to restrict the natural flow of a water source. As a result, the hydraulic function of the dam is altered in several ways. First, beaver mounds may block principal and emergency spillways and riser outlets, resulting in increased normal pool levels and reduced spillway discharge capacity. Second, sudden high discharges from the dam could occur if the beaver dam fails. Third, beaver dams located upstream of the embankment dam can clog water control structures as debris from the beaver dam floats downstream. Finally, erosion of the downstream toe of the dam can occur as a result of elevated tailwater caused by beaver activity.

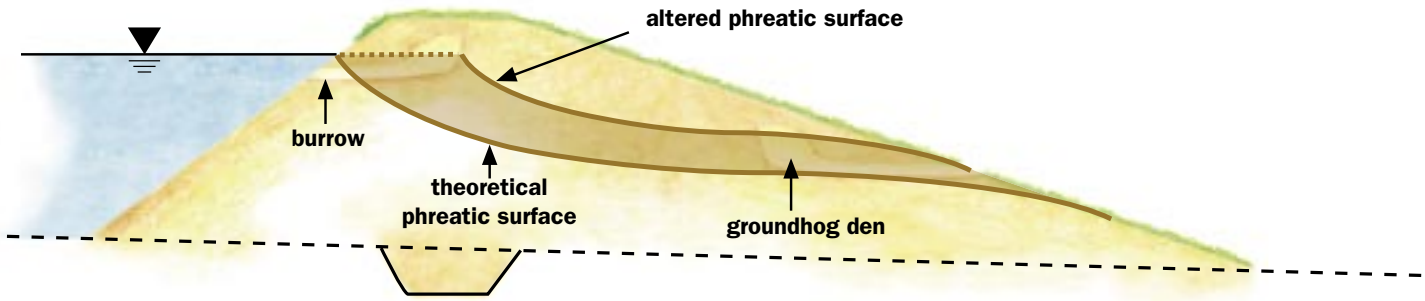


Figure 2-2. Burrows can alter dam hydraulics by shortening seepage paths.

2.3 Structural Integrity Losses

Wildlife excavate dens, burrows, and tunnels within embankment dams, causing large voids that weaken the structural integrity of the dam. Typical voids can range from the size of a bowling ball to a beach ball and much larger. Heavy rain and snow melt loosen soils surrounding a burrow, causing a localized collapse inside the burrow. In addition, a burrowing animal may encounter loose zones in the embankment (due to variability of constructed embankments) during burrow excavation, leading to a localized collapse. Animal dens also erode and collapse under the load of heavy equipment and other vehicles that use the crest of the dam as a throughway.

The collapsing soils will progressively lead to sinkholes or depressions appearing on the embankment surface. Because burrows can be under several feet of soil, the deformation or sinkhole visible at the surface could be several times the size of the original burrow. As illustrated on Figure 2-4, the collapsed soils can represent a significant portion of the dam embankment. Under the right circumstances, localized slope instability can result from a collapsed animal burrow. Depending on the location and number of collapsed burrows, dam safety or operation could be jeopardized. If portions of the crest are affected, a loss of freeboard can result, thus endangering the dam during storm events. Downstream slope failures, regardless of their extent, weaken embankment soils and reduce confinement of surrounding soils, thereby resulting in further weakening of embankment soils. Depending upon site and weather conditions, the process can progress slowly or rapidly, potentially leading to massive slope instability.

2.4 Surface Erosion

The foraging behavior of some animals on open area vegetation associated with dam embankments can reduce or eliminate vegetative cover on a dam. This increased feeding pressure on the dam's vegetative groundcover can lead to erosion paths and decreased soil retention on the dam's crest and slope. In addition, dams that are grazed by live-

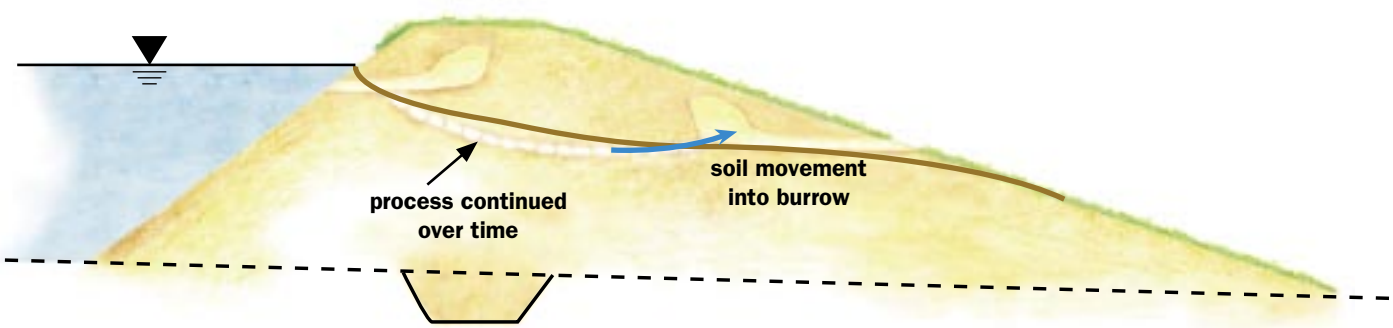


Figure 2-3. Burrows can lead to piping within an embankment.

stock often show increased rates of soil erosion because of the lack of stabilizing vegetation from grazing and trafficking, which can lead to irregular surface erosion and the formation of rills and gullies.

With continued neglect, these areas will require more than simple maintenance. In fact, given enough time, external erosion can lead to a reduction in freeboard and loss of cross section. In turn, these impacts can increase the dam's vulnerability to damage from high water during large storm events.

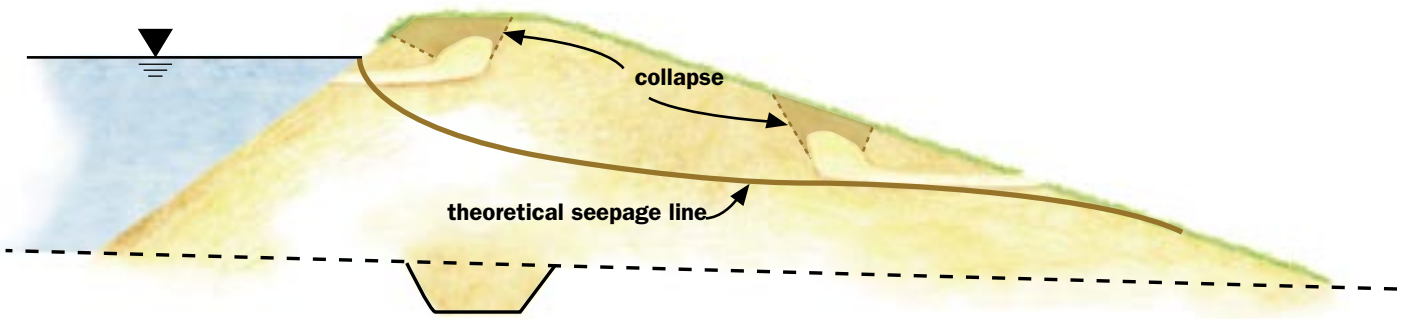


Figure 2-4. Burrows can collapse, leading to formation of sinkholes and loss of structural integrity.

3.0 Dam Inspection From Two Perspectives: Engineering Function and Biological Potential

The second step toward fortifying a dam against the effects of nuisance wildlife damage is the observation of clues left by wildlife in the dam environment. As such, regular inspection of the dam that incorporates wildlife activity recognition must be conducted by the dam owner, who is the first line of defense in protecting earthen dams. While the dam inspection is focused primarily on seepage, deformation, and structural deficiencies, the inspectors must also perceive wildlife clues left behind by dam inhabitants whose presence could cause trouble down the road. Toward this goal, this Chapter details an inspection procedure that pairs engineering inspection with key biological considerations to assist the dam specialist in viewing the dam from both perspectives (this methodology should be applied using the specific wildlife clues data presented in Chapter 4.0 of this manual).

3.1 Wildlife And The Earthen Dam

Through their natural desire to create dens, search for food, or escape predators, wildlife can cause a host of adverse impacts to an earthen dam which can lead to dam failure (refer to Chapter 2.0 of this manual for detail on the adverse impacts of wildlife activities). Though earthen dams are manmade, wildlife interacts with the earthen dam environment as if it were natural field or forest. To protect their dams, dam owners should know the biological potential of their dams—can wildlife find a suitable environment at the dam, and if so, which kind of wildlife will inhabit which locations of the dam? In answering these questions, it is helpful to know the characteristics that compose favorable habitat, and to realize that dams with diverse vegetation and site features often support a wide variety of wildlife. In assessing the dam for its biological potential, review the following relative to the dam area and surrounding areas (adapted from Benyus, 1989):

- **Vegetation Vitality:** Do the dam and adjacent areas contain dense vegetation at all levels (e.g., grass, shrub, and tree)? In general, greater variety of dense vegetation at levels ranging from groundcover to understory to canopy (regardless of vegetation type) allows for a greater variety of wildlife to inhabit the area. Small mammals, such as those discussed in this manual, prefer sites with adequate vegetation cover to hide from predators (see Chapter 5.2 for a discussion on appropriate vegetation at a dam).

- **Mini-habitats:** Do the dam and surrounding area offer vegetative diversity? Different landscapes such as prairie and forest? Sun and shade? Deep and shallow water? An environment with a mosaic landscape provides several habitat types in one area, which can support a wider variety of wildlife.

- **Transition Zones:** Is there a clear edge between one habitat type and another? At the dam environment, the dam area (a lake/pond environment) may be surrounded by a grassy field environment, a shrub edge, or a forested environment. The junction where two environments meet is called an edge, and edges are the most heavily trafficked areas in an environment (a good place to view the wildlife in and around the dam area) because they provide safe travel corridors between the two habitat types and create a more diverse habitat than either of the two habitat types.

- **Size:** Does the dam environment provide a large land area that allows wildlife to meander without having to cross roadways or come into contact with people? Most species of wildlife prefer large parcels of land that provide habitat variety without human influence.

- **Unique Characteristics:** Does the dam contain unique land features? By its very nature, the dam environment is unique because it contains a water source. Wildlife prefers a constant water source, so dams with a permanent pool will be preferable to those with a fluctuating pool, such as those used for flood control or irrigation. However, any water source will attract wildlife to some degree.

3.2 Two-Perspective Dam Inspection Methodology

The typical dam safety inspection checklist requires observation of every dam feature. The checklist is developed by an individual state's dam safety program or federal organization such as the U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, or the Federal Energy Regulatory Commission. All inspections focus on distinct physical regions, although the inspection checklists vary in length, listed inspection items, and required observations. Generally, the features are divided into clear components including:

- Upstream Slope
- Downstream Slope
- Crest
- Embankment-Abutment Contact (Groin)
- Principal Spillway
- Emergency Spillway
- Lake Drain or Outlet Works

Although inspection for animal intrusions is a facet of most if not all state inspection checklists, it is certainly not a major part of the inspection. Specific guidance on identifying animal intrusions or the typical intrusion locations of specific animals is not provided on the checklists. An inspector lacking this information may be unable to adequately inspect their dam for animal intrusions, much less adequately identify and mitigate the nuisance animal. As such, this manual presents an inspection methodology that combines engineering and biological considerations, which when viewed together, allow a dam specialist to view the dam comprehensively.

For the purposes of this manual, the dam is divided into six zones: Upstream Slope, Dam Crest, Upper Downstream Slope, Lower Downstream Slope, Downstream Toe, and Spillway, Outlets, and General Areas (Figure 3-1). The risk posed by animal intrusions is greater in some zones than in others. As such, the zones are overlapped to emphasize the critical nature of the area and to require inspection of the area twice to ensure that biological clues are sighted (ASDSO, 2001). Further discussion of the six zones relative to risk, restoration, and repair of animal intrusions is provided in Chapters 5.3 and 5.4.

When considering animal intrusions, inspection of each zone should consider not only physical evidence of an animal presence (e.g., burrow entrance), but also the habitat and biological factors that attract wildlife to the dam and sustain them once they have become established (Figure 3-2). Understanding both the engineering and biological aspects of animal intrusions into embankment dams is critical in eliminating or at least controlling the intrusions.

3.2.1 Zone 1: Upstream Slope Area

Engineering Perspective: The goal of inspecting the upstream slope of the earthen dam is to see the entire surface clearly. To ensure the inspector views the entire slope surface, the inspector must walk back and forth across the slope utilizing one of two patterns: zig-zag or parallel. In general, the zig-zag method is best for small dams and mild slopes (Figure 3-3, shown on page 17). It may prove difficult to move in a zig-zag pattern on large dams and steeper slopes, and in these cases the parallel pattern is suggested (Figure 3-4, shown on page 17).

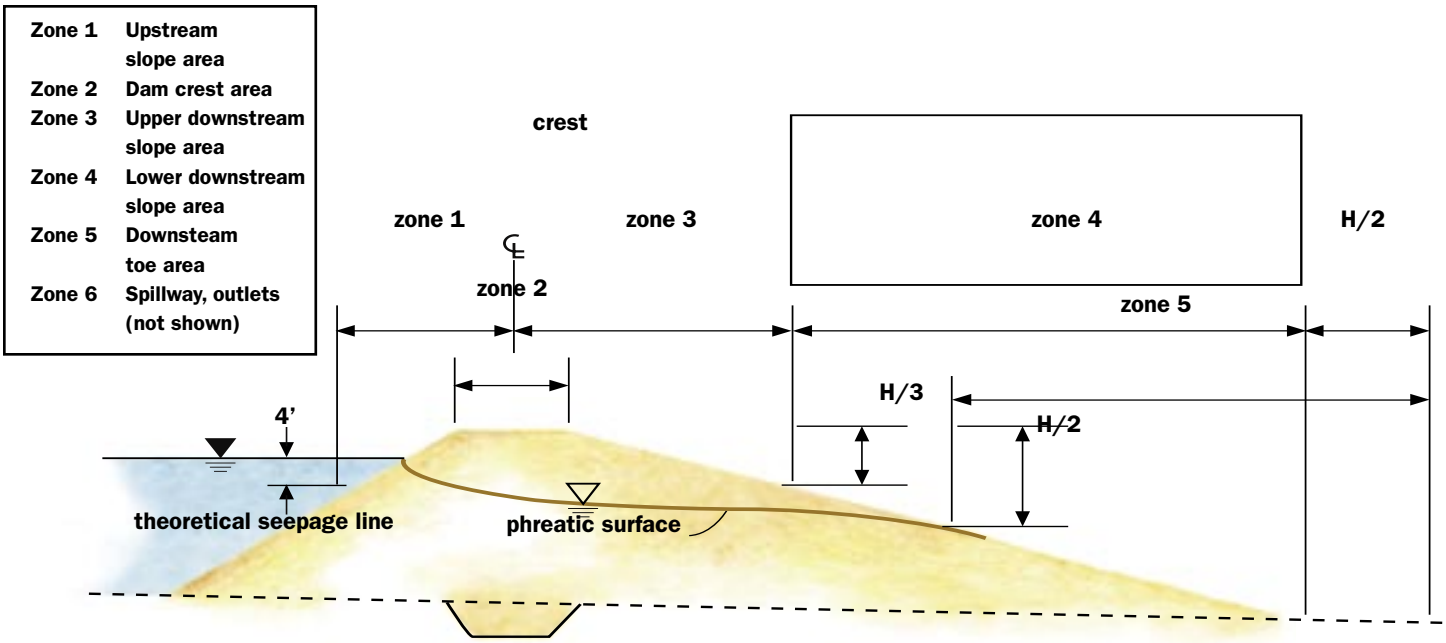


Figure 3-1. Dam Inspection Zones.

While walking the slope, the inspectors should routinely stop and view the alignment of the surface by turning their gaze a full 360 degrees. Checking the slope frequently and from many viewpoints and distances can reveal deficiencies and distortions (such as surface distortions or vegetation changes) that might otherwise go undetected. The inspectors should observe berms on the upstream slope by centering their eyes on the line being viewed and moving their body from side to side to view the line from several angles. This approach will help the inspector identify misalignments.

A typical dam safety inspection report should comment on vegetation, slope protection, erosion, instabilities, and animal burrows observed in Zone 1. When specifically considering animal burrows and other deficiencies resulting from animal activity, the inspector should look for the following: animal burrow entrances, mounds of excavated soil, debris (evidence of beaver activity), cracks, depressions, erosion, sinkholes, paths and ruts, sloughs, slides, and scarps. These conditions often indicate damaging animal activity. The inspection report should note whether the deficiencies warrant monitoring, repair, or further investigation.

Biological Perspective: This zone is primary habitat for aquatic burrowers such as muskrat and beaver, which generally burrow from 6 inches to 4 feet below the water line upward toward the crest. Nutria prefer to dig dens in the zone where land and water meet, which could be dominated by aquatic vegetation. River otters are often found living in abandoned muskrat, beaver, and nutria burrows, and can construct slides on slopes and bare areas where they repeatedly enter and exit the water. Livestock often traverse the upstream slope area—look for hoof tracks, rills, and eroded pathways. Canada geese and livestock feed on embankment slopes causing eroded areas and ruts. Crayfish and alligator may inhabit the banks and shallows of the upstream slope area. Ants may dig tunnels in the slope, loosening existing cracks. Mountain beaver or armadillo may be found along the wet edge of the pond, especially if a forest fringe or wooded area is nearby. Moles may hunt in the moist soils near the reservoir.

3.2.2 Zone 2: Dam Crest Area

Engineering Perspective: Similar to inspecting the upstream slope, the crest can be viewed using either a zig-zag or parallel pattern, with the primary goal being to view the

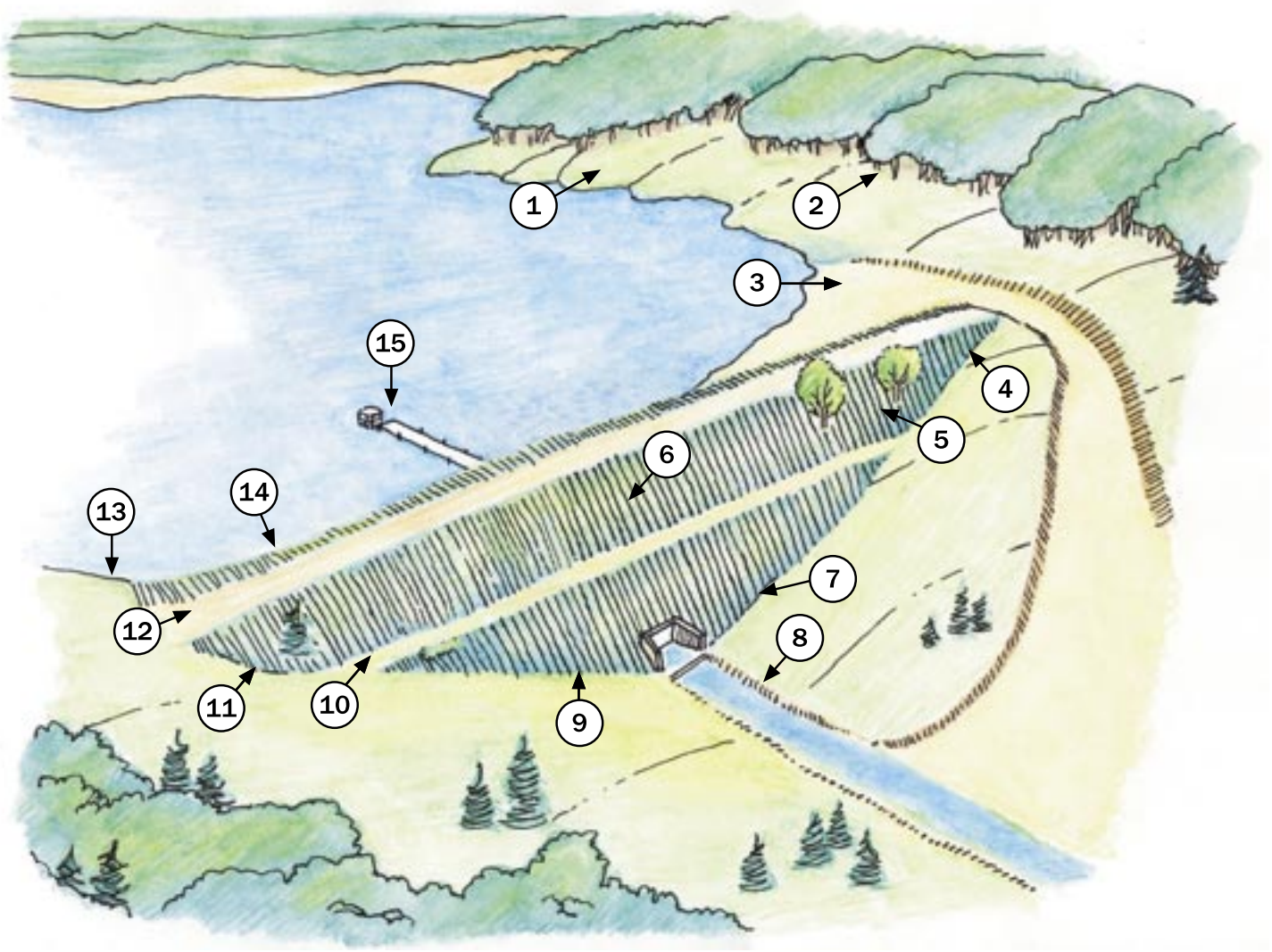
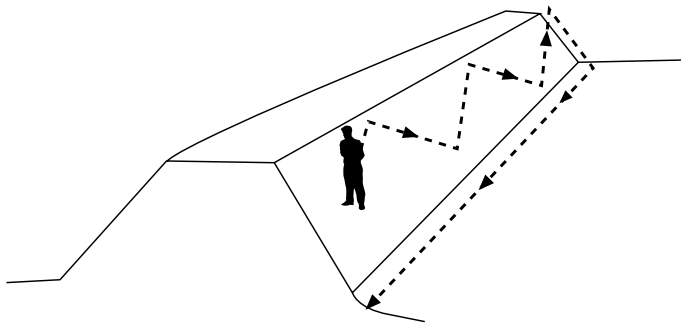


Figure 3-2. The Earthen Dam from Biological and Engineering Perspectives.

1. **Upland Areas.** Many species live in the upland areas, away from the water. Even the downstream slope, abutments, and groin areas of the dam can be considered upland in terms of habitat.
2. **Forest Fringe.** The zone between two environments (the edge) is the best place to observe those species living at and around the dam. The more habitat types at the dam, the greater number of species likely to inhabit the dam. Mountain beaver or armadillo prefer forested/wooded areas.
3. **Emergency Spillway.** Beaver often dam the spillway, causing the pond water levels to rise.
4. **Left Abutment contact.**
5. **Inappropriate Vegetation on Embankment.** Many dams contain vegetation other than mowed grass. Improper vegetation provides cover and food supply, which encourage animals to inhabit the dam.
6. **Downstream Slope.** This area is often the location where groundhogs, coyote, and fox excavate burrows. Canada geese will feed on the downstream slope, which could cause loss of protective vegetative cover and associated erosion. Species that prefer upland areas could be found in this area.
7. **Left Groin.**
8. **Discharge Conduit and Outlet Channel.** Beaver can dam the outlet structure. Aquatic species may inhabit this area depending on water flow and availability of vegetation.
9. **Toe of Embankment and right groin.**
10. **Erosion Pathways on the Embankment.** Livestock traverse the embankment creating erosion pathways.
11. **Right abutment contact.**
12. **Crest.** Livestock traverse the crest which creates ruts. The ceilings of beaver and muskrat burrows in the upstream slope are often just below the dam crest.
13. **Aquatic Fringe.** The zone where the bank meets the pond usually contains aquatic vegetation preferred by many animals such as nutria.
14. **Upstream Slope.** Beaver, muskrat, and nutria prefer the upstream slope for burrow excavation. Alligators, otters, and turtles usually live in the shallow waters near the upstream slope.
15. **Principal Spillway (with riser and trash rack).** Beavers can block principal spillways by constructing dams.



entire crest from several perspectives and distances. Similar to the upstream slope inspection, the inspectors should center their eyes on the crest line, moving their body from side to side to view the line from several angles. Fixed features that can mark horizontal and vertical points along a dam can be used as reference lines; guardrails, a row of posts, or parapet walls are good reference lines (use caution when using man-made reference lines which can be moved). The reference line must be viewed from several different perspectives; first, the inspectors should sight directly on the reference line and then move their body to either side. This method will assist the inspector in detecting a change in the uniformity of the crest. Zone 2 overlaps Zone 1 on one-half of the crest width. This is intentional, and is meant to em-