7
CHAPTER

Chapter 7: Maintenance Guidelines

7.0 General

A good maintenance program will protect a dam against deterioration and prolong its life. A poorly maintained dam will deteriorate, and may fail. Nearly all the components of a dam and the materials used for its construction are susceptible to damaging deterioration if not properly maintained. A good maintenance program protects not only you, the owner, but the general public as well. Moreover, the cost of a proper maintenance program is small compared to the costs of major repairs, loss of life and property, and litigation.

Develop a basic maintenance program based primarily on systematic and frequent inspections. Inspections, as noted in Chapter 5, should be performed at least monthly and after major floods or earthquakes. During each inspection, refer to a checklist of items that call for maintenance.

7.1 Maintenance Priorities

Maintenance should never be neglected. The following outline lists, by relative priority, the various problems or conditions that might be encountered in a dam that has deteriorated from lack of maintenance.

7.1.1 Immediate Maintenance

The following conditions are critical and call for immediate attention:

- A dam about to be overtopped or being overtopped.
- A dam about to be breached (by progressive erosion, slope failure, or other circumstances).
- A dam showing signs of piping or internal erosion indicated by increasingly cloudy seepage or other symptoms.
- A spillway being blocked or otherwise rendered inoperable, or having normal discharge restricted.
- Evidence of excessive seepage appearing anywhere at the dam site (an embankment becoming saturated, seepage exiting on the downstream face of a dam) increasing in volume.

Although the remedy for some critical problems may be obvious (such as clearing a blocked spillway), the problems listed above generally require the services of a professional engineer familiar with the construction and maintenance of dams. The emergency action plan (discussed in Chapter 8) should be activated when any of the above conditions are noted.

7.1.2 Required Maintenance at Earliest Possible Date

The following maintenance should be completed as soon as possible after the defective condition is noted:

- Remove all underbrush and trees from the dam, and establish a good grass cover.
- Fill animal burrows.
- Restore and reseed eroded areas and gullies on embankment dams.
- Repair defective spillways, gates, valves, and other appurtenant features.
- Repair any concrete or metal components that have deteriorated, as soon as weather permits.

7.1.3 Continuing Maintenance

Several tasks should be performed continually:

- routine mowing and general maintenance
- maintenance and filling of any cracks and joints on concrete dams and in concrete spillways
- observation of any springs or areas of seepage, comparing quantity and quality (clarity) with prior observations
- inspection of the dam (as discussed in Chapter 5)
- monitoring of development in the watershed which would materially increase runoff from storms
- monitoring of development downstream and updating the emergency notification plan to include new houses or other occupied structures within the area

7.2 Specific Maintenance Items

7.2.1 Earthwork Maintenance and Repair

The surfaces of an earthen dam may deteriorate for several reasons. For example, wave action may cut into the upstream slope, vehicles may cause ruts in the crest or slopes, or runoff waters may leave erosion gullies on the downstream slope. Other special problems, such as shrinkage cracks or rodent damage, may also occur. Damage of this nature must be repaired continually. The maintenance procedures described below are effective in repairing minor earthwork problems. However, this section is not intended to be a technical guide, and the methods discussed should not be used to solve serious problems. Conditions such as embankment slides, structural cracking, and sinkholes threaten the immediate safety of a dam and require immediate repair under the direction of an engineer.

The material selected for repairing embankments depends upon the purpose of the earthwork. Generally, earth should be free from vegetation, organic materials, trash, and large rocks. Most of the earth should be fine-grained soils or earth clods that easily break down when worked with compaction equipment. The intent is to use a material which, when compacted, forms a firm, solid mass, free from excessive voids.

If flow-resistant portions of an embankment are being repaired, materials that are high in clay or silt content should be used. If the area is to be free draining or highly permeable (riprap bedding, etc.), the material should have a higher percentage of sand and gravel. It is usually satisfactory to replace or repair damaged areas with soils similar to those originally in place.

An important soil property affecting compaction is moisture content. Soils that are too dry or too wet do not compact well. One may roughly test repair material by squeezing it into a tight ball. If the sample maintains its shape without cracking and falling apart (which means it is too dry), and without depositing excess water onto the hand (which means it is too wet), the moisture content is probably near the proper level.

Before placement of earth, prepare the repair area by removing all inappropriate material. Clear vegetation such as brush, roots, and tree stumps, along with any large rocks or trash removed. Also, unsuitable earth, such as organic or loose soils, should be removed, so that the work surface consists of exposed, firm, clean embankment material.

Following cleanup, shape and dress the affected area so that the new fill can be compacted and will properly tie into the existing fill. If possible, trim slopes and roughen surfaces by scarifying or plowing to improve the bond between the new and existing fill and to provide a good base to compact against. Grade the slopes in a direction such that the soil ridges are parallel to the length of the dam—this will help to minimize or reduce rill erosion. Roughening in the wrong direction will likely increase rill erosion.

Place soils in loose layers up to eight inches thick and compacted manually or mechanically to form a dense mass free from large rock or organic material. Maintain soil moisture in the proper range. The fill should be watered and mixed to the proper wetness or scarified and allowed to dry if too wet.

During backfilling, take care that the fill does not become too wet from rainstorm runoff. Direct runoff away from the work area and overfill repair areas so that the fill maintains a crown that will shed water.

As mentioned earlier, occasionally minor cracks will form in an earthen dam because of surface drying. These are called *desiccation* (drying) cracks and should not be confused with *structural* or *settlement* cracks. Drying cracks are usually parallel to the main axis of the dam, typically near the upstream or downstream shoulders of the crest. These cracks often run intermittently along the length of the dam and may be up to four feet deep. Drying cracks can be distinguished from more serious structural cracks because the former are usually no wider than a few inches and have edges that are not offset vertically.

As a precaution, initially monitor suspected desiccation cracks with the same care used for other types of cracks. The problem area should be marked with survey stakes, and monitoring pins should be installed on either side of the crack to allow recording of any changes in width or vertical offset. Once you are satisfied that observed cracking is the result of shrinkage or drying, you may stop monitoring.

These cracks should close as climatic or soil moisture conditions change. If they do not, it may be necessary to backfill the cracks to prevent entry of surface moisture, which could result in saturation of the dam. The cracks may be simply filled with earth that is tamped in place with hand or tools. It is also recommended that the crest of a dam be graded to direct runoff waters away from areas damaged by drying cracks.

As Chapter 5 suggests, erosion is one of the most common maintenance problems at embankment structures. Erosion is a natural process and its continuous forces will eventually wear down almost any surface or structure. Periodic and timely maintenance is essential to prevent continuous deterioration and possible failure.

Sturdy sod, free from weeds and brush, is an effective means of preventing erosion. Embankment slopes are normally designed and constructed so that surface drainage will be spread out in thin layers (sheet flow) on the grassy cover. When embankment sod is in poor condition or flows are concentrated at any location, the resulting erosion will leave rills and gullies in the embankment slope. An owner should look for such areas and be aware of the problems that may develop. Eroded areas must be promptly repaired to prevent more serious damage to the embankment. Rills and gullies should be filled with suitable soil (the upper four inches should be topsoil, if possible), compacted, and then seeded. The local Natural Resources Conservation Service office can help select the types of grass to use for protecting dam surfaces. Erosion in large gullies can be slowed by stacking bales of hay or straw across the gully until permanent repairs can be made.

Not only should eroded areas be repaired, but the cause of the erosion should be found to prevent a continuing maintenance problem. Erosion might be caused or aggravated by improper drainage, settlement, pedestrian traffic, animal burrows, or other factors. The cause of the erosion will have a direct bearing on the type of repair needed.

Paths due to pedestrian, livestock, or vehicular traffic (two- and four-wheeled) are a problem on many embankments. If a path has become established, vegetation will not provide adequate protection and more durable cover will be required unless traffic is eliminated. Small stones, asphalt, or concrete may be used effectively to cover footpaths. In addition, railroad ties or other beams of treated wood can be embedded into an embankment slope to form an inexpensive stairway. All vehicular traffic, except for maintenance, should be prohibited from the dam.

Erosion is also common at the point where an embankment and the concrete walls of a spillway or other structure meet. Poor compaction adjacent to such a wall during construction and subsequent settlement can result in an area along the wall that is lower than the grade of the embankment. Runoff, therefore, often concentrates along these structures, resulting in erosion. People also frequently walk along these walls, wearing down the vegetative cover. Possible solutions include regrading the area so that it slopes away from the wall, adding more resistant surface protection, or constructing wooden steps.

Adequate protection against erosion is also needed along the contact between the downstream face of an embankment and the abutments. Runoff from rainfall can concentrate in gutters constructed in these areas and can reach erosive velocities because of relatively steep slopes. Berms on the downstream face that collect surface water and empty into these gutters add to the runoff volume. Sod-surfaced gutters may not adequately prevent erosion in these areas. Paved concrete gutters may not be desirable either because they do not slow the water and can be undermined by erosion. Also, small animals often construct burrows underneath these gutters, adding to the erosion potential.

A well-graded mixture of rocks up to 9–12" in diameter (or larger), placed on a layer of sand (which serves as a filter), generally is the best protection for these gutters on small dams. Riprap covered with a thin concrete slurry has also been successful in preventing erosion on larger dams, and should be used if large stone is not available.

As with erosion around spillways, erosion adjacent to gutters results from improper construction or a poor design in which the finished gutter is too high with respect to adjacent ground—preventing much of the runoff from entering the gutter. Instead, the flow concentrates along the side of the gutter, eroding and potentially undermining it.

Care should be taken when replacing failed gutters or designing new gutters to assure that:

- The channel has adequate capacity.
- Adequate erosion protection and a satisfactory filter have been provided.
- Surface runoff can easily enter the gutter.
- The outlet is adequately protected from erosion.

7.2.2 Riprap Maintenance and Repair

A serious erosion problem called *benching* can develop on the upstream slope of a dam. Waves caused by high winds or high-speed boats can erode the exposed face of an embankment by repeatedly striking the surface just above the pool elevation, rushing up the slope, then tumbling back into the pool. This action erodes material from the face of the embankment and displaces it down the slope, creating a “bench.” Erosion of unprotected soil can be rapid and, during a severe storm, could lead to complete failure of a dam.

The upstream face of a dam is commonly protected against wave erosion and resultant benching by placement on the face of a layer of rock riprap over a layer of filter material. Sometimes, materials such as bituminous or concrete facing, bricks, or concrete blocks are used for this upstream slope protection. Protective benches are sometimes actually built into small dams by placing a berm (8–10 ft wide) along the upstream face a short distance below the normal pool level, supplying a surface on which wave energy can dissipate. Generally, however, rock riprap offers the most economical and effective protection.

Nonetheless, benching can occur in existing riprap if the embankment surface is not properly protected by a filter. Water running down the slope under the riprap can erode the embankment. Sections of riprap that have slumped downward are often signs of this kind of benching. Similarly, concrete facing used to protect slopes may fail because waves wash soil from beneath the slabs through joints and cracks. Detection is difficult because the voids are hidden, and failure may be sudden and extensive. Effective slope protection must prevent soil from being removed from the embankment.

When erosion occurs and benching develops on the upstream slope of a dam, repairs should be made as soon as possible. Lower the pool level and prepare the surface of the dam for repair. Have a small berm built across the face of the dam at the base of the new layer of protection to help hold the layer in place. The size of the berm needed depends on the thickness of the protective layer.

A riprap layer should extend a minimum of 3 ft below the lowest expected normal pool level. Otherwise, wave action during periods of low lake level will undermine and destroy the protection.

If rock riprap is used, it should consist of a heterogeneous mixture of irregular shaped stone placed over a sand and gravel filter. The biggest rock must be large and heavy enough to break up the energy of the maximum expected waves and hold smaller stones in place. (An engineer may have to be consulted to determine the proper size.) The smaller rocks help to fill the spaces between the larger pieces and to form a stable mass. The filter prevents soil particles on the embankment surface from being washed out through the spaces between the rocks in the riprap. If the filter material itself can be washed out through these voids and benching develops, two layers of filters may be required. The lower layer should be composed of sand or filter fabric to protect the soil surface and the upper layer should be composed of coarser materials.

A dam owner should expect some riprap deterioration because of weathering. Freezing and thawing, wetting and drying, abrasive wave action and other natural processes will eventually break down the material. Therefore, allocate sufficient funds for the regular replacement of riprap.

The useful life of riprap varies depending on the characteristics of the stone used. Thus, stone for riprap should be rock that is dense and well cemented. When riprap breaks down, and erosion and beaching occur more often than once every three to five years, professional advice should be sought to design more effective slope protection.

7.2.3 Controlling Vegetation

Keep the entire dam clear of unwanted vegetation such as brush or trees. Excessive growth may cause several problems:

- It can obscure the surface of an embankment and prevent a thorough inspection of the dam.
- Large trees can be uprooted by high wind or erosion and leave large holes that can lead to breaching of the dam.
- Some root systems can decay and rot, creating passageways for water, and thus causing erosion.
- Growing root systems can lift concrete slabs or structures.
- Trees, brush, and weeds can prevent the growth of desirable grasses.
- Rodent habitats can develop.

When brush is cut down, it should be removed to permit a clear view of the embankment. Following removal of large brush or trees, also remove their leftover root systems, if possible, and properly fill and compact the resulting holes. In cases where they cannot be removed, treat root systems with herbicide (properly selected and applied) to retard further growth.

TCEQ personnel have consulted with the Texas Parks and Wildlife Department regarding effective herbicides for control of vegetation on dam structures. Appendix C recommends which herbicides to use and not to use, offers guidelines for applying them, and addresses concerns about endangered and threatened species.

According to the TPWD, the herbicides triclopyr (Remedy) and clopyralid (Reclaim) are effective in control of mesquite trees. Although these are listed in the appendix as herbicides to avoid on dam structures, they are not considered toxic to fish and wildlife. The problems are high mobility in soil and concerns about water quality. Consequently, use extreme caution when applying these herbicides. Treatments should be localized (applications on individual plants), and every effort made to prevent overspraying.

The Brush Busters Program is a cooperative program of Texas Cooperative Extension and the Texas Agricultural Experiment Station for the development of brush-management technology. Specific guidance on the methods of treatment and spraying, equipment, equipment preparation, and herbicide mixtures related to mesquite trees are available online at <http://texnat.tamu.edu/BrushBusters/Mesquite.htm>.

After the removal of brush, cuttings may need to be burned, in which case you should notify the local fire department, forest service, or other agencies responsible for fire control. Also contact the TCEQ regional office for the area both to ascertain any burn notifications, authorizations, or requirements and to inform the agency of your inent to burn.

If properly maintained, grass is not only an effective means of controlling erosion—it also enhances the appearance of a dam and provides a surface that can be easily inspected. Grass roots and stems tend to trap fine sand and soil particles, forming an erosion-resistant layer once the plants are well established. Grass is least effective in areas of concentrated runoff or in areas subjected to wave action.

7.2.4 Controlling Livestock

Livestock should not be allowed to graze on an embankment surface. When soil is wet, stock can damage vegetation and disrupt the uniformity of the surface.

Moreover, livestock tend to walk in established paths and thus can promote severe erosion. Such paths should be regraded and seeded, and the livestock permanently fenced out of the area.

7.2.5 Controlling Animal Damage

Burrowing animals (beaver, nutria, muskrat, badgers, and otters) are naturally attracted to the habitats created by dams and reservoirs and can endanger the structural integrity and proper performance of embankments and spillways. The burrows and tunnels of these animals generally weaken earthen embankments and serve as pathways for seepage from the reservoir. This kind of damage has resulted in several failures of dams; therefore, controlling burrows is essential to their preservation.

The beaver is the most common source of burrowing damage to earthen embankments in Texas. Beavers usually construct their tunnels and dens in the banks surrounding the reservoir or in the dam. The main entrance to a beaver's den is generally 4–10 ft below the normal water level of the lake. The tunnel systems become very extensive as the colony grows, and embankment material located above these systems will eventually settle or collapse. Tunnels occasionally extend through a dam where pools of water are allowed to collect along its toe, and provide pathways for water to pass through the embankment.

Common signs of the presence of beaver include gnawed or cut vegetation around the waterline; burrows or sunken or collapsed areas in the crest or slopes of the embankment; and obstructions across spillways and inlets that produce unusual changes in the water level of the reservoir.

Barriers such as properly constructed riprap and filter layers offer the most practical protection from these animals. When an animal tries to construct a burrow, the sand and gravel of a filter layer will cave in and discourage den building. Filter layers and riprap should extend at least three feet below the waterline. Heavy wire fencing laid flat against a slope and extending above and below the waterline can also be effective. Eliminating or reducing aquatic vegetation along a shoreline will also discourage habitation.

For assistance in removing the animals from your property, contact the nearest office of the Texas Wildlife Damage Management Service, whose personnel will assist the owner or will provide the name of a local trapper who will remove the animals, sometimes for little or no charge.

Methods of repairing rodent damage depend upon the nature of the damage but, in any case, extermination of the rodent population is the required first step. If the damage consists mostly of shallow holes scattered across an embankment, repair may be necessary to maintain the appearance of the dam, to keep runoff waters from infiltrating the dam, or to discourage rodents from subsequently returning to the embankment. In these cases, tamping of earth into the rodent hole should be sufficient repair. Soil should be placed as deeply as possible and compacted with a pole or shovel handle.

Large burrows on an embankment should be filled by mud packing. This simple, inexpensive method involves placing one or two lengths of metal stove or vent pipe vertically over the entrance of the den with a tight seal between the pipe and den. A mud-pack mixture is then poured into the pipe until the burrow and pipe are filled with the earth-water mixture. The pipe is removed and more dry earth is tamped into the den. The mud-pack mixture is made by adding water to a mixture of 90 percent earth and 10 percent cement until a slurry of thin cement is obtained. Plug all entrances with well-compacted earth and reestablish vegetation. Eliminate dens promptly—one burrow can lead to failure of a dam.

Different repair measures are necessary if a dam has been damaged by extensive small rodent tunneling or by beaver, nutria, or muskrat activity. In these cases, it may be necessary to excavate the damaged area down to competent soil and repair as described in Section 7.2.1.

Occasionally, rodents will dig passages all the way through the embankment that could result in leakage of reservoir water, piping, and ultimate failure. In those cases, do not plug the downstream end of the tunnel since that will add to the saturation of the dam. Tunnels of rodents or ground squirrels will normally be above the phreatic surface with primary entrance on the downstream side of the dam, while those of beaver, nutria, and muskrat normally exist below or at the water surface with entrance on the upstream slope. If a rodent hole extends through the dam, first locate its upstream end. Excavate the area around the entrance and then backfill it with impervious material, plugging the passage entrance so that reservoir water is prevented from saturating the dam's interior. This should be considered a temporary repair. Excavation and backfilling of the entire tunnel or filling of the tunnel with cement grout are possible long-term solutions, but pressure cement grouting is an expensive and sometimes dangerous procedure. Indeed, pressure exerted during grouting can cause further damage to the embankment via hydraulic fracturing (an opening of cracks by high-pressure grouting). Thus, grouting should be performed only under the direction of an engineer.

7.2.6 Controlling Fire Ants

Fire ants have become one of the most serious pests in Texas. Fire ants require water to survive and have been found on dams throughout much of the eastern two-thirds of Texas. These ants can create problems in the dam itself and with any of its electrical components.

In some habitats, fire ants can move as much or more soil as earthworms, thereby reducing soil compaction. Nest galleries can penetrate in a V-shaped pattern below the nest, penetrating as much as four feet deep in the soil. These galleries can create pathways for surface water to penetrate the dam, possibly resulting in internal erosion and collapse of the surface. The ants could also create pathways for water from the reservoir to flow through the dam when the reservoir level is high.

Fire ants left undisturbed can build mounds that become very large (10–12" in diameter) and tall (12–14 inches high). These can create problems for mowing. However, frequent mowing can induce the colonies to migrate to neighboring, undisturbed areas.

Fire ants often infest electrical equipment and utility housings, in which whole colonies will move at certain times of the year. Worker ants will import soil for nesting. This material can cause corrosion and interfere with maintenance operations. Ants chew on insulation and can cause short circuits or interfere with switching mechanisms, resulting in electrical components for operating gates and valves not working properly when needed. Ants nesting in these units are highly defensive of their colony and can be a medical threat to maintenance personnel.

Worker ants, which have an affinity for oscillating magnetic fields, can cause a particular problem when they enter switching mechanisms of electrical equipment. Once ants in a switching mechanism bridge the gap across an open switch, they are electrocuted. The shocked ants release communication chemicals or other signals that attract more worker ants. The result is that switching units can become tightly packed with the bodies of dead worker ants, causing a failure of the mechanism.

There are many options for managing fire ants. Use only pesticides labeled as suitable for the location you want to treat. Make every effort to avoid contaminating water with pesticides. For information on managing fire ants, contact:

Texas Imported Fire Ant
Applied Research and Education

412 Minnie Belle Heep Center
Attn: Bart Drees
Texas A&M University
College Station, Texas 77843-2475
979/845-7026
<http://fireants.tamu.edu>

7.2.7 Controlling Damage From Traffic

As mentioned earlier, vehicles driving across an embankment dam can create ruts in the crest if it is not surfaced with roadway material. The ruts can then collect water and cause saturation and softening of the dam. Other ruts may be formed by vehicles driving up and down a dam face; these can collect runoff and cause severe erosion. Vehicles, except for maintenance, should be banned from dam slopes and kept out by fences or barricades. Repair any ruts as soon as possible using the methods outlined in Section 7.2.1. Maintenance vehicles should only travel on the soil and grass portions of the dam when the surface is dry unless necessitated by an emergency.

7.2.8 Mechanical Maintenance

The safe and satisfactory operation of a dam depends on proper operation of its outlet works. Release of water from a dam is normally a frequent or ongoing function. However, at some reservoirs used for recreation, fish propagation, or other purposes that do not require continual release of water, an operable outlet provides the only means for the emergency lowering of the reservoir and is therefore essential for safety.

If routine inspection of the outlet works indicates the need for maintenance, the work should be completed as soon as access can be gained. Postponing maintenance could result in damage to the installation, significantly reduce the useful life of the structure, and result in more extensive and more costly repairs when finally carried out. More importantly, failure to maintain an outlet system can lead directly to dam failure.

The simplest procedure to ensure the smooth operation of outlet gates is to operate all gates through their full range at least once—and preferably twice—annually. In fact, many manufacturers recommend operating gates as often as four times a year. Because operating gates under full reservoir pressure can result in large outlet discharges, schedule gate testing during periods of low storage, if possible, or else operate them during periods of low stream flow. If you expect large releases, only have the outlets tested after coordinating releases with the local floodplain administrator and other dam owners located downstream and after notifying downstream residents and water users.

Operation of the gates minimizes the buildup of rust in the operating mechanism and therefore the likelihood of its seizure. During this procedure:

- Check the mechanical parts of the hoisting mechanism—including drive gears, bearings, and wear plates—for adverse or excessive wear.
- Check all bolts, including anchor bolts, for tightness.
- Replace worn and corroded parts.
- Make mechanical and alignment adjustments as necessary.

The way the gate actually operates should also be noted. Rough, noisy, or erratic movement could be the first signs of a developing problem. The causes of operational problems should be investigated and corrected immediately.

Excessive force should be neither needed nor applied to either raise or lower a gate. Most hoisting mechanisms are designed to operate satisfactorily with a maximum force of 40 pounds on the operating handle or wheel. If excessive force seems necessary, something may be binding the mechanical system. Excessive force may result in increased binding of the gate or damage to the outlet works. If there does seem to be undue resistance, the gate should be worked up and down repeatedly in short strokes until the binding ceases or the cause of the problem should be investigated. Of course, you should correct the problem as soon as possible to assure the continued operability of the gate.

If a gate does not properly seal when closed, debris may be lodged under or around the gate leaf or frame. Raise the gate at least two to three inches to flush the debris; then have the operator attempt to reclose the gate. This procedure should be repeated until proper sealing is achieved. However, if this problem or any other problem persists, consult a manufacturer's representative or engineer experienced in gate design and operation.

An outlet gate's operating mechanism should always be well-lubricated in accordance with the manufacturer's specifications. Proper lubrication will not only reduce wear in the mechanism, but also protect it against adverse weather. Gates with oil-filled stems (i.e., stems encased in a larger surrounding pipe) should be checked semiannually to assure the proper oil level is maintained. If such mechanisms are neglected, water could enter the encasement pipe through the lower oil seal and could cause failure of the upper or lower seals, which in turn could lead to the corrosion of both the gate stem and the interior of the encasement pipe.

The metal used in gate seats is usually brass, stainless steel, bronze, or other rust-resistant alloys. Older or smaller gates may not be fitted with seats, making them susceptible to rusting at the contact surfaces between the gate leaf and gate frame. Operation of gates should prevent excessive rust buildup or seizure.

For satisfactory operation, a gate stem must be maintained in proper alignment with the gate and hoisting mechanism. Proper alignment and support are supplied by stem guides in sufficient number and properly spaced along the stem. Stem guides are brackets or bearings through which a stem passes. They both prevent lateral movement of the stem and bending or buckling when a stem is subjected to compression as a gate is closing.

Check the alignment of a stem should be checked during routine inspections by sighting along the length of the stem, or more accurately by dropping a plumb line from a point near the top of the stem to the other end. The stem should be checked in both an upstream–downstream direction as well as in a lateral direction to ensure straightness. While checking alignment, all gate stem guide anchors and adjusting bolts should be checked for tightness. A loose guide provides no support to the stem and could cause it to buckle at that point.

If, during normal inspection, the stem appears out of alignment, the cause should be remedied. Completely lower the gate and take all tension or compression off the stem. Loosen any misaligned stem guides and make them move freely. Then operate the hoisting mechanism so as to put tension on the stem, thereby straightening it, but do not open the gate. Then align and fasten the affected guides so that the stem passes exactly through their centers.

Many outlet gates are equipped with wedges that hold the gate leaf tightly against the gate frame as the gate is closed, thus ensuring a tight seal. Through years of use, gate seats may become worn, causing the gate to leak increasingly. If an installation has a wedge system, the leakage may be substantially reduced or eliminated by readjusting the wedges.

Because adjustment of these gates is complicated, inexperienced personnel can cause extensive damage to one. Improper adjustment could cause premature seating of the gate, possible scoring of the seats, binding, vibration, leakage, uneven closing, or damage to wedges or gate guides. Thus, only experienced personnel should perform adjustments; consult a gate supplier or manufacturer to obtain names of persons experienced in such work.

Ice can exert great force on and cause significant damage to an outlet gate leaf. Storage levels in a reservoir during winter should be low enough that ice cannot form behind a gate. To prevent ice damage, the winter water level should be significantly higher than the gate if storage is maintained through the winter months, or, if the reservoir is to remain empty over the winter, the outlet should be fully open. If operations call for the water level to move across the gate during the winter, a bubbler or other anti-icing system may be needed.

7.2.9 Electrical Maintenance

Electricity is typically used at a dam for lighting and to operate outlet gates, spillway gates, recording equipment, and other miscellaneous equipment.

It is important that an electrical system be well maintained, including a thorough check of fuses and a test of the system to ensure that all parts are properly functioning. The system should be free from moisture and dirt, and wiring should be checked for corrosion and mineral deposits. Carry out any necessary repairs immediately, and keep records of the work. Maintain generators used for auxiliary emergency power—change the oil, check the batteries and antifreeze and make sure fuel is readily available.

7.2.10 Cleaning

As already suggested, the proper operation of spillways, sluiceways, approach channels, inlet and outlet structures, stilling basins, discharge conduit, dam slopes, trashracks, and debris-control devices require regular and thorough cleaning and removal of debris. Cleaning is especially important after upstream storms, which tend to send more debris into the reservoir.

7.1.11 Concrete Maintenance

Also as mentioned, periodic maintenance should be performed on all concrete surfaces to repair deteriorated areas. Repair deteriorated concrete immediately when noted; it is most easily repaired in its early stages. Deterioration can accelerate and, if left unattended, can result in serious problems or dam failure. Consult an experienced engineer to determine both the extent of deterioration and the proper method of repair. Seal joints and cracks in concrete structures to avoid damage beneath the concrete.

7.2.12 Metal Component Maintenance

All exposed, bare ferrous metal on an outlet installation, whether submerged or exposed to air, will tend to rust. To prevent corrosion, exposed ferrous metals must be either appropriately painted (following the paint manufacturer's directions) or heavily greased.

When areas are repainted, ensure that paint does not get on gate seats, wedges, or stems (where they pass through the stem guides), or on other friction surfaces where paint could cause binding. Use heavy grease on surfaces where binding can occur. Because rust is especially damaging to contact surfaces, remove existing rust before the periodic application of grease.