

DRAINAGE AND DRAINAGE STRUCTURES

04.01 EFFECTS OF WATER

04.01.01 IMPORTANCE OF DRAINAGE

This manual is intended for internal guidance only and is not intended to create a legal or moral duty. Supervisors have discretion, based upon their expertise and the particular circumstances, to deviate from this manual and to conduct additional research or receive input from experts in other areas, as needed.

While many factors must be considered in designing, constructing and maintaining a road, the most important requirement is good drainage to permit unwanted water to be carried away.

Rainfall and melting snow and ice are sources of surface water. Drainage of surface water involves three general objectives:

- 1) Rain and water from melted snow on the roadway and shoulders is allowed to run off and is led to a suitable place of discharge
- 2) Where possible, other surface water is prevented from reaching the roadway, shoulders, and side slopes
- 3) Surface water flowing in a natural watercourse is allowed to pass through an embankment, or fill, at suitable locations.

Subsurface water can come from underground springs, seams in rock, and from passages between particles of pervious soil. A soil is said to be pervious if water can pass through it easily. An important purpose of all drainage considerations is to prevent subsurface water from collecting under the roadway.

Although all maintenance operations are of great importance, it is an essential duty of maintenance forces to insure drainage facilities are kept in good working condition.

04.01.02 CONTROLLED WATER

It cannot be said that all water is bad for a road. Controlled water is good for the following reasons:

- 1) It lessens erosion, or wearing away, of soil by the wind.

- 2) It is needed for good maintenance of unpaved roads and shoulders.
- 3) It is needed for good compaction of embankments and surfacing materials of unpaved roads and shoulders.
- 4) It encourages the growth of grass on turf shoulders, and grass and other vegetation on side slopes.
- 5) It helps to keep paved surfaces clean.

04.01.03 UNCONTROLLED WATER

Uncontrolled water is an archenemy of maintenance forces. Some of the bad effects of water are:

- 1) It can erode a side slope of a cut or embankment.
- 2) It can cause a slide, rock fall, or slipout.
- 3) It can change a drainage ditch into a deep gully.
- 4) It can cause scouring at a bridge or culvert and can even wash out the structure.
- 5) It can cause breakup of concrete pavement due to pumping.
- 6) It can cause a shoulder, subgrade, or roadway surface to become unstable.
- 7) It can cause serious damage during freeze-thaw cycles.
- 8) It can cause stripping or removal of the film of asphalt from certain types of aggregate.

04.02 ROUTINE MAINTENANCE SCHEDULE

04.02.01 SPRING OPERATIONS

The operations that are normally performed in the spring are:

- 1) Inspect culverts, flumes, downspouts, drop inlets, catch basins, streams, and ditches for damage that may have occurred during the winter and early spring.
- 2) Remove the most critical obstructions to drainage.

- 3) **Light blading of all unpaved roads and shoulders to improve drainage.**
- 4) **Prepare a schedule of major maintenance of drainage structures on the basis of the inspections.**
- 5) **Make rainy day inspections of drainage.**

04.02.02 SUMMER OPERATIONS

During the summer, the following operations are usually performed:

- 1) **Clean and reshape ditches.**
- 2) **Start annual routine culvert inspections.**
- 3) **Start major drainage maintenance repairs.**
- 4) **Complete emergency repairs and begin permanent repairs.**
- 5) **Routine cleaning of all drainage facilities.**
- 6) **Continue rainy day inspections.**
- 7) **Check and make necessary repairs to rip-rap at end of culverts, on slopes, and on banks of stream channels.**

04.02.03 FALL OPERATIONS

The following operations can be performed in the fall:

- 1) **Complete inspection of all drainage facilities to make sure they are functioning before the snow and ice season begins.**
- 2) **Remove all obstructions.**
- 3) **Complete ditch and culvert cleaning.**
- 4) **Cut tall grass around wooden structures to reduce the fire hazard.**
- 5) **Complete major drainage maintenance projects.**
- 6) **Continue rainy day inspections.**

04.02.04 WINTER OPERATIONS

The following operations are possible during the winter:

- 1) Make emergency repairs to drainage.
- 2) Make advance plans for both routine and major work to be performed during the coming construction season.
- 3) Check the inventory of equipment and materials, and order replacement items and new material.

04.03 SURFACE DRAINAGE

04.03.01 ROADWAY SLOPE

The ease with which water drains from the roadway surface depends on the crown of the roadway, the rate of grade of the road, and the slope of the shoulders. The crown of a roadway is the amount by which the center of the roadway is higher than the edges. A rough surface is given a greater crown, or a steeper slope, than a smooth surface.

The slope of an unpaved road on each side of the centerline is usually between 1/2 in. and 3/4 in. per ft. (13 - 19mm per 300mm) of width. Such a slope makes it possible for the surface water to leave the road surface quickly.

A paved surface on a roadway has a flatter slope. Since the pavement surface is smoother and less porous than the surface of an unpaved road, the slope on each side of the centerline needs to be only be 1/4 or 3/8 in. per ft. (6 or 9 mm per 300mm) to permit the pavement to shed surface water quickly.

04.03.02 SHOULDER SLOPE

An unpaved shoulder will have a slope at least twice that of the pavement and the slope will never be less than 1/2 in. per ft. (13mm per 300mm) of width. A paved shoulder usually has a slope only slightly greater than the pavement slope.

04.03.03 WATERCOURSES

It is desirable that all surface water running from the roadway and shoulders eventually be led to a natural watercourse. For this purpose, man-made watercourses must be provided. These watercourses are of several types. The most important are side ditches, diversion ditches, and gutters.

04.03.03.01 NATURAL WATER COURSES

Surface water flows along the ground in natural watercourses. A natural watercourse may be a running stream or a river, or it may be merely a valley or draw that leads surface water into a stream or river. Keeping water courses free

from sand and gravel bars, trees, branches, boulders, and other obstructions is an important part of drainage maintenance.

04.03.03.02 SIDE DITCHES

A side ditch is a channel that is provided alongside and parallel to the roadway where the road section is in a cut. The ditch is located between the foot of the side slope and the edge of the shoulder.

Original ditch slopes and flow lines should retain a 4:1 or flatter slope. (See Figure 04-9.)

For best results, the rate of grade of a side ditch must be at least 0.5 percent; that is, the fall must be at least 0.5 ft. in 100 ft. (150mm per 30.5m). Ditches having grades that are nearly level need cleaning more often than those with steeper grades. Side ditches in mountainous terrain may have to be so steep that they must either be paved or be fitted with check-dams, to prevent the formation of gullies.

The bottom of a side ditch should always be lower than the top of the subgrade under the pavement base or subbase.

04.03.03.03 DIVERSION DITCHES

A diversion ditch is one dug in the original ground behind and parallel to the top edge of a cut slope. It may be paved or unpaved and its purpose is to keep surface water from flowing over the face of the slope and causing erosion damage. These ditches must be inspected often to make sure that they are kept from becoming clogged by soil, twigs and vegetation washed from higher ground.

04.03.03.04 PAVED GUTTERS

Instead of ordinary side ditches, paved gutters are channels used in cuts on mountain roads. They may be constructed of portland cement concrete, bituminous concrete, one-half culvert pipe sections, hand placed rip-rap, or dumped rock. In an urban area where there are sidewalks, a curb may be installed along the outer edge of the gutter. At the end of a cut in which a gutter is used, the water from the gutter should enter a paved ditch, rock gutter or pipe. The ditch, rock gutter or pipe should lead the water to a nearby stream or draw. A ditch, rock gutter or pipe may also be used at the end of a cut to lead water from a diversion ditch, or a side ditch, to a natural watercourse.

Where there is a long high embankment, a curb or gutter is often built on the outside edge of the shoulder at the top of each side slope to prevent water that flows from the roadway and shoulders from running down the slope. Paved

or rock gutters may be constructed at several points along the embankment to carry the water down the fill slope, thus eliminating possible erosion.

04.03.04 PIPE CULVERTS AND STORM SEWERS

04.03.04.01 TYPES OF PIPES

Pipe of corrugated metal, concrete, vitrified clay, fiber or plastic is used in various ways and for various purposes in the control of surface water. Concrete or clay pipe is either the bell-and-spigot type or the tongue-and-groove type.

Most corrugated metal pipe is galvanized or otherwise coated to protect the base metal from rusting. In many cases the galvanized metal is covered with a bituminous coating. In addition, in sections of the State where the water may contain harmful minerals and chemicals such as mine or industrial wastes, it is considered desirable to use pipe whose invert or lower inside surface is paved with bituminous material.

Headwalls are sometimes needed at the inlet and outlet ends of a pipe culvert, and they may be built of concrete or stone masonry.

04.03.04.02 PIPE CULVERT LOCATION

When a new road is being built, points at which pipe culverts are to be placed are shown on the construction plans. On an existing road it will sometimes be necessary to install a pipe culvert where none was placed during construction. When maintenance crews are to install a pipe at a new location, an easement must be secured by the Right of Way Division and recorded in the Clerk's Office of the County where the work is to be performed.

When it is necessary to replace a broken or worn pipe or to substitute a larger pipe, the new pipe will usually be placed on the same line and grade as the existing pipe. Care must be taken to ensure that the new pipe is located correctly, properly bedded, and on the correct line and grade. Also, when a pipe is placed under an entrance to a side road or driveway, it must be placed to conform to the alignment and grade of the side ditch parallel to the main road. Pipe culverts beneath private driveways, approaches to business establishments, etc., must be furnished by the property owner at no cost to the Division of Highways and must be installed in accordance with a permit approved and issued by the Division (*see Chapter 15 of this Manual for details of permit procedures*).

When a new pipe culvert is needed or an existing pipe requires relocation, a representative of the District will be sent to establish the position and grade of the culvert. A line at the centerline of a pipe on the lowest part of

its inside surface is called the flow line. The grade of a culvert pipe is the grade of its flow line.

04.03.04.03 STORM SEWERS

Some drainage systems also include storm sewers. These are underground pipes which carry large volumes of storm water collected by side ditches or paved gutters. In an urban area, storm sewers receive the water and carry it to larger pipes which in turn lead it into streams or ponds. In rural areas, storm sewers carry the water directly to natural watercourses.

04.03.04.04 CATCH BASINS AND DROP INLETS

These are boxes constructed of concrete, brick or other masonry material at the intersection of pipe lines; at the inlet end of culverts, or various points along a culvert of considerable length. Their purpose is to change the direction of water flow, reduce water velocity, collect sediment in a built-in sump, or to serve as openings for culvert cleaning. Drop inlets used on steep grades are called "hillside drop inlets" and are designed so water is collected from the side ditches through a metal grating into the drop inlet. Grates are used on these inlets to catch boulders and debris and the grate bars must be parallel to the ditch. The entire system should be regularly inspected and cleaned.

04.03.04.05 STORM SEWER MANHOLE

Manholes to provide access for workmen to enter the system are built at suitable intervals along sewers for inspection, cleaning, and repairs. There is usually a manhole at the junction of two or more sewers.

04.03.05 PIPE CULVERT INSTALLATION PROCEDURE

04.03.05.01 GENERAL EXPLANATIONS

The procedure to be followed when installing a pipe culvert is basically the same regardless of its size or whether the pipe passes through an embankment on a major highway or is at an entrance to a side road or driveway. Before a new culvert pipe is placed, the required diameter and proper location will be determined by a representative of the Maintenance Engineer.

When it is necessary to install a new pipe or to replace an existing pipe in a high embankment, either of two methods will be used. One method is to "jack or bore" the pipe through the embankment. In the other method, a trench is dug from the top of the embankment, the pipe is placed in the trench, and the trench is back-filled. Special equipment and skill is needed for either method and the work should always be done by a skilled maintenance crew.

04.03.05.02 STAKEOUT AND ERECTION OF BATTER BOARDS

As previously mentioned, new culverts should be staked by a qualified person. A stake is set at the ends of the pipe giving the cut or fill to the flow line. Reference stakes are then set from the ends far enough (about 10 feet) to allow for excavation. These stakes will show the cut or fill and the offset distance from the end of the culvert.

From these stakes, batter boards can be placed before the excavation is completed to the bottom of the ditch. The best method of setting batter boards is to drive two tall posts on each side of the pipe center line at each end and at about right angles to the center line of the pipe.

These posts should be far enough back (from 5 to 8 feet from centerline depending on size of culvert) to permit working space. A cross board is nailed in a level position between each two posts at the same height above the flow line at each end of the culvert. This height should be 6 feet or more. Then, a nail is partly driven into the cross board at the exact centerline of the culvert. Now, a cord or wire is stretched between the nails in each cross board and the cord or wire will be of equal height above the flow line along the length of the culvert. By use of a measuring stick this same height plus the shell thickness of the pipe, the bottom of the ditch may be checked at any point.

For culverts over 25 feet in length, intermediate batter boards should be placed and the end boards braced to prevent sag in the taut cord or wire.

04.03.05.03 DIGGING TRENCH TO GRADE

Before any pipe is placed in a trench, the bottom of the trench must be fine-graded to the proper grade and shaped so that the pipe can be properly bedded. The worker who is fine-grading the trench will be given a measuring stick equal to the distance from the string line to the flow line of the pipe, plus the thickness of the pipe shell. The point in the bottom of the trench directly under the string line, which is at the centerline of the pipe, will be brought to the proper grade by measuring vertically downward from the line with the grade stick. Grading will start at the outlet end of the trench, so any water in the trench will be drained.

If a pipe for carrying water from a side ditch parallel to a main road is to be placed under an entrance to a side road or a driveway, it is important to check the condition of the bottom of the ditch to be sure that the pipe will be set at the proper grade. The ditch must be at the correct grade for at least 200 feet from the end of the culvert on each side of the side road or driveway. If the bottom of an unpaved ditch is too high, the ditch must be cleaned. If the ditch bottom is too low, enough good material must be spread to obtain proper grade. The flow line of the installed pipe may be a little lower than the bottom of the ditch, but it must never be higher than the ditch bottom. Figures 04-1 and 04-2

show approved methods of placing pipe culverts beneath side road approaches and driveways.

04.03.05.04 BEDDING PIPE

All culvert pipes must be properly bedded on a firm foundation. The bottom of the trench for some distance on each side of the pipe centerline must be shaped with a template to fit the shape of the pipe bottom. Also, when bell-and-spigot pipe is used, holes must be dug at each joint so that the bells do not touch the trench bottom.

The pipe must be supported uniformly. To be satisfactory, the trench bottom must have no hard or soft places. The best material on which to lay pipe is fine soil that has been well compacted. Any pockets of unstable material in the bottom of the trench must be removed and replaced with good material.

Where there is rock at the bottom of the trench, a suitable bed for the pipe must be provided by removing the rock from below the pipe and replacing it with a cushion of granular material well compacted. If there are many large stones at the bottom of the trench, the Supervisor may prefer to make the trench deeper and refill the lower part with fine material that can be easily brought to grade. If there is a thin layer of mud at the bottom of the trench, but the material below it is firm, a satisfactory bed can often be obtained by adding coarse sand to the mud.

04.03.05.05 CRADLE

If the material at the bottom of a trench is very unstable, the pipe culvert may have to be bedded in a concrete cradle. This concrete is placed before the pipe is put in the trench and the surface of the concrete is brought accurately to the grade for the bottom of the pipe. If bell-and-spigot pipe is used, the concrete surface must be at the grade of the line through the bottoms of the bells. After the concrete below the pipe has become hard enough to be worked on, the pipe is laid in its correct position on this concrete. The pipe may be tied in position by placing looped wires in the concrete before it hardens and later passing these wires around the pipe. After the pipe has been placed, wet concrete is used to complete the cradle and encase the pipe.

04.03.05.06 CHECKING PIPE AT JOB SITE

Each load of pipe must be checked upon its arrival at the job site from the storage yard or dealer to make sure that it is of the proper size and type being used. Also, pipe must meet the requirements of the specifications in regard to quality. The pipe will be stamped or marked in some way to show that it comes from a lot which has been inspected and approved at the source. However, as soon as pipe is unloaded at the job, it must be rechecked for any defects. A defective section of pipe must be rejected. Corrugated metal pipe

that has spots where the coating has been damaged or burned by flame cutting or welding is not suitable for use since the exposed steel will rust very quickly. If bituminous-coated pipe has spots where the coating has been damaged, it may be made suitable by coating each spot with bituminous material that is furnished by the pipe manufacturer for this purpose. The manufacturer's directions for applying the coating must be followed.

It is a good practice to store sections of bituminous coated pipe on pallets or timbers so dirt and small stones will not be pressed into the coating. In hot weather, it is desirable to store such pipe in a shady place, or to cover the sections with light colored tarpaulins, so that heat from the sun will not cause the asphalt coating to flow out of place. Each section of pipe with a paved invert must be turned so that the paving is down.

04.03.05.07 HANDLING PIPE

The following precautions must be taken to insure that culvert pipe is handled properly:

- Pipe must always be lowered, not dumped or dropped, from a truck to the ground or from the ground surface to the bottom of a trench.
- Pipe may be lowered from a truck by using any type of crane, or it may be rolled on planks.
- When a crane or excavator is used for lowering sections of concrete or clay pipe into a trench, the pipe can be set in position in the trench easily if a hairpin shaped hook is inserted in one end of each section of pipe. Figure 04-3 shows a sketch of an approved type of pipe hook cut from 3/8 inch sheet steel.
- When pipe must be moved along the ground from one place to another, it must be rolled and never be dragged. If the ground is rocky or stony, it is necessary to place planks in such a way that the pipe will not be damaged.

04.03.05.08 LOWERING PIPE INTO TRENCH

If the pipe is not heavy and the trench is not deep, as at an entrance to a side road or driveway, the pipe may be rolled into the trench. If the pipe is not heavy and the trench is deep and narrow, a rope may be passed through the pipe and the pipe lowered slowly by workers who straddle the trench and "play-out" the rope. For lowering large pipe, a crane or other suitable equipment must be used. Each section of concrete or clay pipe may be supported by a hair-pin shaped hook inserted in one end if it is not constructed with lifting holes or eyes for connecting a crane hook.

If reinforced concrete pipe is oval in shape the point marked "top" must be up. When corrugated metal pipe is lowered into the trench, it must be turned so that the lengthwise joint is at one side. This joint can never be at the top or bottom. If the pipe has a paved invert, it must be turned so that the paving material is at the bottom and the center of the paving is exactly on the vertical centerline of the pipe. Perforated pipe will be placed with the holes down.

04.03.05.09 LAYING PIPE ON BED

Placement of culvert pipe must always begin at the low or discharge end and proceed upward to the inlet end. Concrete or clay pipe will be laid on the bed one section at a time, and the bell or the groove end must be the head or upper end so that the water will enter at this point. The spigot end or tongue end of the next section must be placed in the bell or groove of the section previously placed.

04.03.05.10 FINISHING JOINTS IN CONCRETE

After each joint of the pipe has been placed and checked for line and grade, the joints of concrete must be properly filled with cement mortar. The mortar should consist of one part air-entrained portland cement and two parts masonry sand with only enough water to obtain workability. Any water in the trench should be diverted before placing the mortar. Each joint should first be cleaned and wetted inside and outside. The mortar should be allowed to set for 24 hours.

Outside joints of the bell and spigot type should be well grouted and a bead in the same shape as the bell placed around the entire circumference. The tongue and groove type should be grouted and a semi-circular bead placed around it. The inside joints should be well grouted and left smooth and flush with the inside of the pipe. The joints, when completed, should be watertight. Lifting holes in concrete pipe should be grouted. Curing of the mortar by use of burlap is desirable.

04.03.05.11 JOINTS IN CORRUGATED METAL PIPE

When corrugated metal pipe is shipped to the job site in sections and the sections must be joined when the pipe is being placed, the connections are usually made with standard one piece bands. Two-piece bands are used for larger sizes of pipe and in deep trenches where a joint could not be easily made with a standard band.

To join two sections of corrugated metal pipe with a standard band, the opened band is first slipped over the end of the section of pipe already placed. The end of the next section is then set about 3/4 inch from the pipe in place and the band is tightened. The corrugations of the band must match those of the two sections of pipe.

Care must be taken in placing and assembling corrugated metal pipe to obtain good tight joints. A plain galvanized band may have to be tapped with a mallet or a hammer while the bolts are being tightened to remove the slack and to insure a close fit. However, a tight joint cannot be made on a large pipe by just tapping the band and tightening the bolts. A chain or cable must be placed around the band and cinched so the band will be tight. When corrugated metal pipe has been coated with asphalt, fuel oil may have to be applied to the end of each unit of pipe to permit the band to slip around the pipe while it is being made tight. This lubrication is very necessary in cold weather.

04.03.05.12 INSTALLED CULVERT PIPE INSPECTION

All culvert pipes must be inspected in place before backfilling is started. Each mortar joint of large pipe must be inspected from inside the pipe to make sure that it is properly filled.

04.03.06 BACKFILLING TRENCHES

When backfill is being placed in a trench for a pipe culvert, the backfill material must be shoveled into the trench from a spoil bank or from piles located at least 3 feet from the edge of the trench. Large lumps and large stones must be discarded from material that is used. It is not permissible to push or dump backfill material into the trench around the pipe.

The soil used for backfill must be damp enough to compact well. A rough test can be made by hand squeezing the soil. It is satisfactory if it can be molded into a firm cast which will not break when handled with ordinary care or when tossed in the air. If the soil in a spoil bank is too dry, water must be added by sprinkling the spoil bank and mixing it in before the soil is placed into the trench. If deep ruts remain in the soil after it has been tamped, the soil is probably too wet. Dry soil must then be mixed with the material in the spoil bank.

The backfill must be brought up evenly on both sides of the pipe. It is usually more practical to compact the backfill as the material is being placed, instead of placing the material in definite layers and compacting each layer.

Large diameter corrugated metal pipe must be strutted in accordance with the Division's standard specifications. The struts must remain in place until the trench backfill and embankment are completed.

Bracing and sheeting used for shoring in a deep trench must be raised or removed as the trench is filled, but enough must be left in place to keep the trench safe. If uprights and sheeting are left in place until backfilling has been completed, the void left when they are removed must be filled with dry sand.

04.03.07 INSPECTIONS OF PIPE CULVERTS AND STORM SEWERS

Frequent inspections of facilities for surface drainage are a very important part of preventive maintenance. Signs of potential future trouble must be observed and investigated by maintenance employees. Inspection on rainy days is one of the most effective ways to spot trouble just as it begins. A special inspection should be made after every heavy rainfall or storm.

The ideal time to inspect surface drainage is on a rainy day when no routine field maintenance is being performed. For this inspection, the County Maintenance Superintendent or designated representative will assign specific roads to a truck driver and one or two helpers. These assignments can be based on the County route assignments for snow removal and ice control or they can be made so the same employee does not always check the same roads.

The helpers should be supplied with rubber boots and the crew should be equipped with long handled shovels and potato rakes. Each truck should travel slowly over its assigned roads and stop at every location where minor obstructions to drainage are observed to make proper corrections. Just a few of the many corrections that must be made during rainy day inspections to keep surface drainage functioning smoothly and effectively are as follows:

- 1) Where a turf shoulder or other type of unpaved shoulder is holding water on the traveled way, small trenches must be dug across the shoulder to permit the water to quickly flow to the side ditch.
- 2) Where a false ditch or gutter has developed and is retaining water on the shoulder, openings must be made to allow the water to enter the side ditch.
- 3) Where trash has piled up at the inlet end of a pipe culvert, over or around a catch basin grate, or against a bridge abutment, it must be removed and hauled away.

When a major problem is noted on an inspection, the driver or one of the helpers must make a written report which describes the problem and its exact location. As soon as the crew returns to Headquarters, all such information will be given to the County Maintenance Superintendent or designated representative. If a problem of an emergency nature is discovered, the County Headquarters must be notified by phone or radio as quickly as possible.

04.03.08 MAJOR DEFECT AND CORRECTIONS CHECK LIST

A check list of defects and ways to correct them:

- 1) Scour at inlet end of pipe:

This scour is caused by turbulence that results when more water is collected at the inlet than can be removed rapidly by the pipe. Possible reasons are that the pipe is too small, poorly located, or the entrance is choked by silt, brush, boulders, or trash. The blocking of a culvert entrance by brush, rocks or boulders is one of the most common causes of culvert failure. When water collects at the inlet end of a pipe culvert, the cause must be determined and the necessary correction must be made as soon as possible. If the pipe is too small, a larger pipe must be installed. If the pipe is not properly located, it must be relocated. If the fill surrounding a pipe is not protected, a head-wall or rip-rap should be considered. As a temporary measure, rounding, leveling, or expanding the entrance in almost any way will increase the capacity of the culvert.

2) Scour at outlet end of pipe:

This scour is caused by fast, uncontrolled discharge of a large volume of water into an outlet channel that is easily eroded. Undermining and failure of the outlet headwall can result from such scouring. When scour occurs at the outlet end of a pipe culvert, the proper correction is to build a concrete or stone apron on the spillway beneath the end of the pipe. If there is a headwall, removal of debris from the outlet channel will help. It also may be necessary to pave the bed of the outlet channel.

3) Clogging of the pipe by silt, leaves, or other trash:

Clogging is common where the pipe is too nearly level. A permanent correction is to re-lay the pipe with a steeper slope to make it self-cleaning. The only other thing to do is to clean out the pipe frequently. If a pipe becomes completely plugged, a stream of water under pressure will usually clean it or at least open it enough to permit a pipe cleaner to be forced through. A good piece of equipment for this kind of a job is a culvert cleaner which directs a high pressure stream of water into the outlet end of the culvert.

4) Corrosion or rusting:

This usually occurs along the invert of corrugated metal pipe. Sometimes the galvanized coating is worn through by the scrubbing action of pebbles carried by the water and the base steel is then rusted by action of water and air. In some places, the action of strong chemicals carried by the water caused the corrosion.

If corrosion in a large pipe is detected early, a possible method of delaying serious damage is to paint the invert of the pipe with a heavy coat of asphaltic material obtained from the manufacturer for that purpose, or with hot asphaltic cement. Before any type of pipe is installed in an area where chemical corrosion may be expected, the local soil should be checked for acidity. If the soil is found to contain a high concentration of free sulfuric acid or sulfates, a protective coating must be applied to the pipe before it is installed.

5) Leakage at joints:

Separation of the sections of pipe at the joints is sometimes caused by movement of the embankment material in the general direction of the pipe when the soil becomes saturated with water. Usually, the best procedure is to remove the entire length of pipe and to re-lay it to proper line and grade.

6) Structural failure:

If either concrete or metal pipe is improperly placed, or if the pipe does not have sufficient strength to resist the pressure produced by the earth embankment above, the pipe will break or collapse. When a pipe fails for this reason, it is necessary to install a new pipe of the proper size and strength in the correct position.

7) Clogging of storm sewer grating or catch basin:

This is a defect in the drainage system which can be readily seen in the course of a drainage inspection. The correction is to remove the surface debris and remove the grating to be able to inspect and clean the basin if necessary.

04.03.09 BOX CULVERTS

04.03.09.01 GENERAL

A box culvert is a box-shaped structure of reinforced concrete designed to carry water through or under an embankment. It has a roof, sidewalls, and a floor. The structure may be built as a single unit, or as multiple units side by side.

04.03.09.02 INSPECTION

A box culvert is usually large enough to permit a man to walk or crawl through to inspect the inside for structural defects. The roof, walls, and floor

must be examined for cracks, spalls, and excessive wear which could expose the reinforcing steel to water. Cracks and spalls can be patched with sand-cement mortar; however, a non-shrink additive should be used in this mortar. Deep wear or crumbling of concrete on the roof or a wall can be patched by

"guniting" or some other similar method. Headwalls and wing walls must be checked for cracks, spalls, and settlement.

Scour at the entrance or outlet of a box culvert is common and is likely to be more severe than for pipe culverts because a box culvert usually carries a greater volume of water. For this reason, it is very important to watch for the first small signs of scour. Corrective measures for scour at a box culvert are much the same as those at a pipe culvert though the scope of repairs may be greater and more costly.

04.03.10 SPECIAL CULVERTS FOR STEEP APPROACHES

To prevent surface water from draining down steep side road approaches (5% or greater grades) and across the highway, thus causing a potential safety hazard, a special drainage structure may be used as shown in Figure 04-4, titled "Drainage for Steep Grade Approach." This drainage structure can be a concrete box with open grate (as shown), a slotted pipe, or a prefabricated box with open grate.

04.03.11 CULVERT INSPECTION

Periodic inspection of all pipe and box culverts will be made as directed by the District Engineer or his/her representative. This type of inspection will always be made prior to resurfacing, paving, widening, and similar improvement projects.

04.04 SUBSURFACE DRAINAGE

04.04.01 GENERAL

In addition to providing facilities for draining water from surface areas of the highway, it is highly important to provide drainage for removal of water from beneath the surface. Not all subsurface water can be removed by drainage facilities. Moisture held in the pores of some very fine grained soils cannot be drained easily.

In many ways, subsurface water is more dangerous than surface water. It can cause slips, slides or rock falls. It can soften the subgrade under a pavement or base, thus causing weakness and failure of the roadway. In many cases, the source of subsurface water cannot be easily located.

04.04.02 SUBSURFACE WATER PROBLEMS

A few of the many ways in which subsurface water can create a problem are as follows:

- 1) **Water from rain and melting snow or ice can seep through loose and porous soil. If, in its downward course, the water meets an impervious layer of rock or dense clay, it runs along the upper surface of the layer of rock or clay. If that layer tilts toward any part of the highway, the water can cause trouble. Where the impervious layer lies under the side slope of a cut, the water may act as a lubricant and a slide may occur. Where the impervious layer lies under an embankment built on the side of a hill, there may be a slip. Where a porous layer of loose soil lies between the layers of rock in a cut, there is a strong possibility there will be rock falls. These problems are discussed in detail in the Slides, Slips and Rock Falls chapter of this Manual.**
- 2) **When a road is cut through rock, there may be seams in the rock where water from underground springs can travel upward. This water may collect in the subgrade and soften it. The water may even find its way further upward to cause weakness and failure of the base or surface course.**
- 3) **If the bottom of a side ditch is not low enough, surface water flowing in the ditch may seep into the shoulder, the subgrade and perhaps under and into the base or pavement course.**
- 4) **Unless a system for subsurface drainage is provided, serious trouble is likely to follow if an embankment is placed on wet, marshy natural ground or if a marsh-like condition develops after the fill is placed and the road is in use.**

04.04.03 SUBSURFACE DRAINAGE LOCATIONS

If possible, all underground water must be drained from the highway. In many cases, the sources of subsurface water will have been located before the road was built and proper subsurface drains provided. The locations of these drains will be shown on the original plans. Sketches from these plans will help local crews spot the outlets of the drains and keep the drains in good operating condition.

In many cases, unwanted subsurface water is not discovered until after the road has been built. In such a case, it is a duty of the maintenance forces to find the sources of water and install the proper subsurface drains. Figure 04-5

shows sketches of two locations where seepage frequently occurs after construction.

04.04.04 CLASSES OF SUBSURFACE DRAINS

There are two general classes of subsurface drains which are commonly referred to as interceptor and underdrains. An interceptor drain diverts the ground water before it can reach the roadway. An underdrain is intended to catch and dispose of any water that gets into or under the roadway. Figure 04-6 shows sketches representing places where subsurface drains can be most useful.

04.04.05 TYPES OF SUBSURFACE DRAINS

There are two types of subsurface drains. One type, which is known as a French or a stone drain, is constructed by digging a trench in the soil or rock and filling it with graded aggregate or other material that water can seep through easily. The other type, which is known as a weep drain, consists of a metal, concrete, fiber or plastic pipe with small holes (perforations) in the lower part of its shell. The pipe is placed in a trench filled with granular material with the perforations down. Porous concrete pipe is also available for this type of subsurface drainage. In all subsurface drain installations consideration should be given to the use of a filter fabric to enclose the granular backfill material. Sketches of typical subsurface drains are shown in Figures 04-6 and 04-7.

04.04.06 MATERIAL SELECTION AND INSTALLATION

04.04.06.01 FRENCH DRAIN BACKFILL

It is expected that a subsurface drain will prevent the soil from becoming soaked with water. A properly constructed French drain works well for a long time. If the material used for backfilling the trench is too coarse, muddy soil will move into the large spaces between the particles and plug them in a short time. The drain will then stop working and water will collect in the soil and soften it. For this reason, when there is not a large flow of water and a French drain is suitable, it is best to use a finer backfill material such as a clean concrete sand or a mixture of this sand with gravel, crushed stone, or crushed slag. Also, the use of filter fabric will increase the life of French drain installations. The rate of flow through finer material is about one fiftieth of that through single sized clean stone or gravel, but the openings between the particles are small enough to prevent soil particles from getting into and plugging them and thus the drain constructed with fine material should function well over an extended period of time.

04.04.06.02 PERFORATED-PIPE DRAIN FILTER

If a large flow of water must be taken care of, a perforated pipe drain must be used. Such a drain is constructed as shown in Figure 04-7. The pipe

permits the water to escape, while granular backfill will keep the soil out of the pipe. The granular backfill is then called a filter, since it removes the particles of soil.

04.04.06.03 DRAIN LAYOUT STAKES

After the locations and types of subsurface drains have been determined, layout stakes must be set in the proper places. Before construction of a drain is started, batter boards must be placed at intervals of not more than 25 feet (7.6m) along the line of the drain. They are erected in the manner described in Section 04.03.05.02 for pipe culverts. The desired minimum grade for an underdrain is 2 feet per 100 feet (6mm per 300m). The outlet end should be set at least one foot (300mm) above the ditch to prevent water from flowing back into the underdrain.

04.04.06.04 PLACING BACKFILL MATERIAL

The backfill material used for a subsurface drain must always be clean and be handled so no dirt gets into it while the drain is being built. Even a small amount of mud in the material will greatly reduce the speed with which the drain will carry water.

04.04.06.05 SUBSURFACE DRAIN PRECAUTIONS

It is important to prevent surface water as possible from getting into the roadway base or subbase. Surface water should be prevented from entering the base or subbase with proper maintenance of the roadway surface. Proper crowns, crack filling, joint filling, ditch line maintenance, etc., are examples of proper maintenance of the roadway surface.

The outlet end of each subsurface drain must be marked with a delineator post. Furthermore, they should be accurately recorded by milepost on any as built construction plans or as readily available permanent records kept in the County or District Office.

It must be remembered that a subsurface drain of any type must have an outlet and this outlet must be kept open. Otherwise, the subsurface drain simply acts as a reservoir for water and does more harm than good. Some typical types of blockage include blockage by:

- crushed stone
- siltation
- vegetation
- improper installation elevation

These blockages can occur whether or not the outlet consists of a concrete apron and/or a concrete trough.

04.04.07 INSPECTION OF SUBSURFACE DRAINS

Frequent inspection and routine maintenance of subsurface drains is very important to ensure proper function. If a subsurface drain becomes blocked whether by crushed stone, siltation, or vegetation (including trimmings from mowing operations), it must be cleaned out or, in the case of a French drain, be removed and replaced in a timely manner to prevent possible extensive damage to the roadway. The outlet of every subsurface drain must be so located that the water from it can get to some type of surface waterway such as a side ditch or pipe.

In some cases where sediment is a problem it may be necessary to construct an area below the outlet to collect sediment and permit the underdrain to function. Without such a sediment area the silt would block the outlet and make the drain useless.

Some subsurface drain pipes are fitted with galvanized rodent screens. During inspection and cleaning of these drains, these rodent screens should be removed, cleaned, and reinstalled.

Maintenance personnel should be aware of and have a list of persistent problem areas requiring more frequent inspection and maintenance.

04.05 EROSION CONTROL

04.05.01 GENERAL

Surface water can erode a slope of a cut or fill, an embankment slope under the end of a bridge or overpass, or the soil around a culvert headwall. There are several ways to protect such an area from erosion. The usual procedure is to cover the area with rip-rap, to install ditch checks, or to plant vegetation.

04.05.02 RIP-RAP

Where a blanket of stone in the form of rip-rap can be placed over an area, it will furnish effective protection against erosion. Rip-rap is most useful on a slope. To build a blanket of rip-rap, the first step is to prepare a smooth, firm bed on the slope by using shovels, tampers, and other hand tools. A 4:1 or flatter slope is preferable. Pieces of stone, broken concrete or small boulders should then be carefully placed on the prepared bed. All protruding material should have a maximum dimension of 4 in. (100 mm). The placing of rip-rap must be started at the bottom of the slope and proceed upward. As the area to be protected by rip-rap is covered by "one person" pieces, smaller pieces are placed in the spaces between the large pieces to "chink" these spaces.

Rip-rap is sometimes used along the bank of a stream on a slope that is much steeper than 1 to 1. In such a case, it is a good practice to cover the face of the completed rip-rap with wire fencing to make it stronger.

Rip-rap may be left "dry"; however, where added strength is needed or a smooth face is desired, the spaces between the stones can be filled with a grout consisting of sand, portland cement, and water.

04.05.03 HEADWALLS

As stated previously, a headwall is often needed to protect the area around the end of a pipe or box culvert from erosion by water.

04.05.04 DITCH CHECKS

A ditch check is simply a small dam or obstruction in a ditch, spillway, stream, or other open water channel. The purpose of ditch checks is to slow fast-moving water that could cause severe erosion damage. They are usually thin concrete or stone-masonry walls built at suitable points in the ditch or other drainage channel. In an emergency, a ditch check may simply be a row of boulders or large chunks of concrete that have been taken from pavements or structures in the course of other repair operations.

The relative positions of a pair of typical ditch checks made from cobblestones are shown in Figure 04-8.

04.05.05 VEGETATION

Well-established grass on unpaved shoulders is an effective protection from water and wind erosion. Grass and shrubs afford similar protection to back slopes and embankment slopes. These grass and shrub covers must be mowed and pruned regularly for good appearance and safety of traffic. Slope protection with vegetation and maintenance of the slope and vegetation are discussed in detail in Chapter 10 of this Manual.

FOOTNOTE

As more fully set forth in Section 01.01.01, nothing in this manual is intended to create a legal or moral duty and has been created for internal guidance only.