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WORKSHOP ON ROADWAY AND STREET DRAINAGE

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1. INTRODUCTION

On the average, 25 percent of all highway construction funds are spent for drainage structures. Maintenance, repair, and reconstruction of those structures consume approximately four billion dollars nationwide each year. Until 1959, Kentucky reportedly had more navigable streams than any other state — and then Alaska became a state. More than likely, Kentucky exceeds the national average in spending for drainage facilities.

The importance of good drainage practices should be obvious. One highway engineering book lists the three most important aspects of pavement performance, in order of significance, as being drainage, drainage, and drainage. Too much surface water may cause cut or fill slopes to erode. Too little water for extended periods may lead to loss of ground cover leading to erosion and dust. Water may saturate soil masses to the extent they may slip or slide. Rapidly moving water can cause severe channel erosion and washouts; whereas slowly moving water can leave deposits of materials and eventually block ditches, channels, and culverts.

Water expands about nine percent when its freezing. As the temperature drops, one gallon of water becomes about 1.09 gallons of ice. As the temperature rises, the ice thaws and the resulting water occupies one gallon. Pressure is generated as confined water expands upon freezing. Pressures are great enough to cause concrete in bridge decks and pavements to disintegrate, pavements to heave, and earth masses to bulge. Frozen subgrades support heavy loads quite well; however, when they thaw, the materials become saturated and soft and do not serve their intended purpose. Freeze-thaw cycles can be devastating in cases where adequate provisions for drainage do not exist.

Essentially, drainage design involves determining quantities of water that may be expected within various portions of the right of way and then sizing channels, culverts, or other structures to adequately handle the flows. Design also involves determining the structures necessary to support imposed earth and wheel loads. Construction naturally involves building the drainage facilities to design standards and insuring that materials meet specifications. Maintenance starts upon completion and acceptance of the constructed facilities. Corrective maintenance may be necessary to take care of situations overlooked during design or created during construction. Preventive maintenance involves work in keeping the facilities in good condition, anticipating things that can go wrong and doing something to keep it from happening, and all other chores that might be involved in keeping the system in tiptop shape.

Highway agencies have a responsibility to motorists and adjoining property owners to maintain the roadways and related accessories in as good a condition as possible with resources available. Anyone, including you, could be the motorist and/or property owner who may be adversely affected by poorly maintained features.

Drainage structures include bridges, culverts, storm sewers, underdrains, edgedrains, shoulders, ditches, energy dissipators, flumes, drop structures, gutters, and several other water-related structures. One of the jobs of maintenance personnel is to make sure that drainage structures serve their intended functions. Other portions of the highway system may be adversely affected by improperly or inadequately drained elements. Various items of the infrastructure are interrelated to the extent that failure of one element within the system may lead to partial or total failure of one or more other items. Maintenance of the entire system is important.

A glossary of terms often used in discussions dealing with drainage is included as an appendix.

2. MAINTENANCE

Maintenance should consist of work that keeps the roadway and related structures in the as-constructed condition -- like new. This assumes the construction was high quality. Maintenance may be corrective or preventative. Sometimes design or construction for a new or improved section of road may not have been adequate and maintenance is performed to correct flaws -- this is corrective maintenance. Other times, corrective work may be necessary because of unusual events or accidents. Preventative maintenance generally includes work done to keep the facilities in good shape and to take care of things that might cause problems later. About one third of all highway funds are spent for maintenance, so it is important that the maximum benefits be obtained from those monies.

2.1 ROUTINE INSPECTIONS AND RECORD KEEPING

Every part of the highway affects drainage in one way or another. In a like manner, all parts of the roadway are affected to some degree by drainage (or the lack of drainage). Drainage is definitely important and things that can be done to improve drainage are generally very cost effective.

Kentucky gets about 44 to 48 inches of rainfall each year on the average. That works out to be about 32 trillion (1 followed by 12 zeros) gallons of water per year statewide. The smallest county (100 square miles) gets about 79 billion (1 followed by 9 zeros) gallons per year and the largest county (782 square miles) gets about 619 billion gallons per year. Naturally, maintenance crews do not have to provide for disposal of all the water in their area, but there is a lot within their work area. Planning, inspection, and record keeping are all a part of a good drainage maintenance management program. Most counties and cities have more work to do than money, equipment, and personnel would allow. The idea is to do the very best possible with what is available.

Some of the suggestions that follow could help counties and cities reduce costs in the long run but may cost more money in the short term. Each will be able to find reasons for not doing some things -- some rightly justified and others may be excuses. Each will have to decide whether the ideas are worth trying.

2.1.1. Map the Facilities

Obtain a large map of your area and spot drainage structures on it with map tacks, write-on tape, or some device that will let you identify each structure. Each structure could be numbered and then identified in a log book. Pertinent information about each structure should be kept in the office for use in planning or emergencies. The data should include size, length, exact location, type of material, general condition as of last inspection, and any other information you might think of that would be helpful. For each route, it would be good practice to include a description of the ditches relative to size, shape, and lining. Also, show locations of edgedrains, underdrains, and other pertinent buried structures.

2.1.2 Inspections

Make routine inspections to see whether the drainage facilities are operating as intended. There probably is not much other work that can be done during a heavy downpour, so that would be an ideal time to make a general inspection and locate problem areas. You should note whether culverts are operating properly and check for unusually high headwater elevations. Check ditches and note locations where they may be overflowing onto the shoulder or driving lanes. Look for inlets and grates that may be restricting flow because of debris. Check cut and fill slopes for erosion.

Sometime after the rain has ended and the pavement begins to dry is a good time to locate low spots that pond water. Also, its a good time to find places where water may be flowing upward through pavement or shoulder joints and cracks. Water also may be retained in raised medians and flow onto the pavement. Check ditch and curblines to see whether there are places that need repairing. Look for debris trapped near or in inlets and grates. Locate channels or culverts that might need cleaning.

More detailed structural inspections should be made during dry periods. When possible, walk-through (or crawl-through) inspections should be made of culverts. Check the headwalls, wingwalls, parapets, and aprons. The interiors should be checked for shear failures, open joints, deflection, open seams, and missing coating and/or paving. Look for indications of undermining and possible seepage along the outside of culverts.

Pay close attention to cut and fill slopes for signs of erosion. If erosion is just beginning, it might be possible a little work now could solve the problem and eliminate the possibility of having to do much more work later. Check underdrains and edgedrains and pay particular attention to see whether the outlets need cleaning. Manhole covers and grates may need to be put back in place and fixed more securely. Look for concrete that may need to be patched or have cracks sealed.

2.1.3 Record Keeping

- Keep good records. Do not try to rely on your memory rather than making a written note of things observed or things that have been done. Keep a daily record of work that was performed: who did what and how much was accomplished? Note weather conditions. You should list the crew by name and position. Make a record of equipment usage and materials used. These type records are valuable later when it comes time to determine how much it may cost to do a job. The daily record should include accurate notations of all work that was performed. Be specific. For instance, you might record that it took one backhoe operator and two laborers five and one-half hours to replace three entrance pipes. Your record should include the type, length, and condition of the pipe removed. The record should indicate the type and length of pipe used for replacement. Include the route number and specific location of where the work was done. List all equipment and materials that were used.

- Keep good inspection records. Ideal records would allow you to conveniently refer to a tabulation and determine the condition, location, size, and type of any drainage structure under your jurisdiction. The dates of the most recent inspection and repairs should be noted. Include records of what needs to be done when a crew is available and what is a best estimate of labor, equipment, and materials needed to do the job?

• Keeping good records leads to greater efficiency. You are also in a much better position to estimate how much money you will need next year. You would be able to project future needs and support those projections with accurate records.

2.2 DRAINAGE FACILITIES

Maintaining drainage facilities involves cleaning and making minor repairs. Extensive repairs may be performed by maintenance crews even though such repairs fall into the category of reconditioning, restoration, rehabilitation, reconstruction, or construction. Regardless of what its called, the jobs should be done thoroughly and properly to save time and money in the long run.

2.2.1 Ditch Maintenance

Ditch maintenance is a form of roadway preventive maintenance. Clogged ditches may overflow the roadway and cause damage to the pavement. Silted ditches may cause the ground-water level to rise to the base or pavement elevation and lead to failures. Roadway damage associated with water is greatly minimized through proper ditch maintenance. The roadway pavement, base, and subbase are placed in layers and each layer slopes down and away from the roadway centerline. Water on the surface or within those layers drains into the ditch as long as the ditch is not filled with debris or silt.

Three goals of ditching are cleaning, reshaping, and restoring the flowline of the ditch to the design grade (slope). Cleaning involves removal of all dirt, debris, and unwanted vegetation to the original flowline. In reshaping, the ditch is shaped to its original cross section. The cross section should be shaped as uniformly as possible. If the ditch widens, the water velocity will decrease and deposit sediment or debris. If the ditch narrows, the velocity will increase and may cause erosion. In the event of erosion, such areas should be restored to original grade with large aggregate or other such materials that will not erode again. Sodding, seeding, or use of jute matting should be considered for some areas.

Cleaning and reshaping ditches to their original flowline elevation usually requires removal of 6 to 10 inches of material. Naturally, it may vary appreciably and will depend upon many factors. Never overdo the job and excavate too deeply -- that could create problems rather than correct them. During those operations and especially when using equipment, always keep a lookout for utility lines -- such as gas lines, water lines, and buried electrical or phone cables -- within or near the ditch.

Ditches should be graded to uniform slopes. Unusual variations in slopes affect the rate of flow of water in the ditch and may create problems. A gradeall is the primary ditching equipment and, when available, can be used very efficiently. It can be operated from the shoulder or roadway and is effective for use in wet ditches and for short sections frequently interrupted by entrance pipe. The gradeall is also useful in areas where a motor grader would damage established sod shoulders. If a gradeall is not available, a backhoe along with a front-end loader could be used.

For long uninterrupted stretches, a motor grader is recommended. The motor grader should not be used in wet ditches because the ditches are not firm enough to support the grader's weight. Ditching operations should proceed in the direction of traffic to minimize conflicts.

Back slopes should never be undercut because they may erode and eventually lead to slides. Also, erosion due to undercut back slopes generally leads to ditches having to be maintained more frequently. If the job is done correctly the first time, less work will be required in that area in the future.

Always strive to do a good job and do it efficiently. Try new procedures in an attempt to increase production. Efforts should be made to utilize equipment to the fullest extent possible -- you may have too many or too few pieces of equipment to do a given job effectively.

> For instance, how many dump trucks should be assigned to a ditching operation? If there are too many, truck drivers remain idle; if there are too few, the gradeall (or other ditching equipment) and its operator may be idle much of the time. To determine how many trucks are needed, first estimate the loading time -- the time in minutes it takes the equipment to load one truck. Then, estimate the trip time -- the time in minutes it takes a truck to make one

round trip to the dump site. Divide the trip time by the loading time. That value plus one provides a good estimate of the trucks needed for the job.

Selection of the dump site is an important factor. A site as close to the job as possible to minimize trip time and reduce the number of trucks required for the job is desirable. It is sometimes possible to find a property owner in the vicinity of the job that could use some fill material.

Efficiency also can be achieved using a good pattern of loading trucks. Try to minimize the necessity for having either the loader or truck make backing, turning, or repositioning movements. The best procedure is to put the truck ahead of the loader -- then, each time a load is placed in the truck, the units simply move forward and unnecessary movements are eliminated.

2.2.2 Cleaning Drainage Structures

Median drop inlets and storm sewer inlets are referred to as catch basins. They catch surface runoff, direct it to the drainage system, and prevent clogging by trapping litter and debris picked up by runoff water. Catch basins seldom need repair, and when they do, normally all that is needed is a good cleaning. Cleaning is no problem, but messy - one man gets in the hole and loads a bucket and another man pulls the bucket up and empties it. Load the debris in a truck and dispose of it some place so it will not wash back into the hole during future storms.

Frequently, debris upstream of a culvert may lodge at the entrance and lead to clogging. If sufficient debris catches on the entrance or in the upstream channel, the velocity of the water flow getting through the culvert will decrease and cause silting along the flowline and may eventually fill the structure. Other times, debris and silt may collect at the outlet and in the downstream channel and cause problems leading to depositions in the culvert. In those cases, debris and vegetation should be removed from the upstream and downstream channels. Those materials should be removed from the site or precautions taken to waste them in an area so they will not wash back into the channel during future storms and create a similar problem again. The flowline of the culvert should match the channel flowline after the cleaning operations are completed -- if they do not match, future problems will be encountered. If the downstream channel is higher than the culvert outlet, silt will begin to deposit at the culvert's outlet and eventually work its way to the inlet. If the upstream channel is too low, water will pond and could lead to undermining at the inlet and subsequent failure of fill over the structure.

If the job of cleaning the upstream and downstream channels is thorough and the culvert is not severely clogged, water flow from future storms might clean the culvert. In such cases, recheck the culvert after the next one or two storms. If the cleaning did not work, a maintenance crew must return and complete the task.

In cases where the fill slope may be washing or eroding at the inlet or outlet, take steps to restore those areas to their original (or design) contours. When soil is used for restoration, the areas should be sodded or seeded and matted to prevent future erosion. An alternative to sodding or seeding would be to place large rocks, boulders, or riprap in the areas to minimize washout. Very steep fill slopes present continuing problems. For such cases, consider the possibility of adding one or more sections to the culvert and then placing additional fill material to flatten the slope.

2.2.3 Cleaning Sewers

Sewer maintenance consists of the use of manpower, equipment, and material to keep the system in good repair and operating smoothly and efficiently at its intended purpose of removing storm runoff. Sewer maintenance may involve the mere removal of a temporary obstruction in a pipe at little cost, or the digging up and replacing of several hundred feet of large diameter pipe costing many thousands of dollars. Between these two extremes lies the area of maintenance involving many problems and their solution.

A sewer system of any size requires a continuous program of maintenance -- in many cases, around the clock. Complaints may range from a rattling manhole cover to a major break in the line. Whatever the complaint, the sewer maintenance staff is expected to have a ready answer -- an answer that will eliminate the complaint quickly enough to satisfy the complainant and cheaply enough to suit governmental officials. To accomplish this feat, the sewer maintenance staff must have abundant knowledge, ample resourcefulness, and infinite patience. In short, the staff is a most valuable asset to the community and does much for the welfare of its citizens -- in all kinds of weather and often under the most adverse conditions.

The number of personnel or the manpower available for sewer maintenance varies considerably with the size of the system and the extent of the area served. In many smaller systems, no full-time sewer maintenance personnel are employed, but instead certain employees are required to perform sewer maintenance work along with other duties such as street maintenance, water main repair, meter reading, pump plant operation, and various other chores in connection with community services. This is not good practice and is not recommended except in extreme cases where the cost of full-time personnel would be prohibitive. The larger systems employ the services of full-time trained maintenance staff to carry on the programs.

There is also a wide variety of tools and equipment available for sewer maintenance depending on the size and scope of the maintenance program. Many sewer maintenance men in smaller communities rely on their own inventiveness and provide their own tools and equipment as necessary, whereas tools and equipment are usually made available in the larger systems.

The same materials for maintenance purposes are available to all systems and care should be exercised in the selection of materials for maintenance and repairs. Due to differences in soils and in the characteristics of the runoff carried, some materials will serve less satisfactorily in one area than in another and care should be taken so as not to choose replacement materials that, for these reasons, have proven unsatisfactory. In large scale repair or replacement, a competent engineer should be consulted in the selection of proper materials.

Generally speaking, sewer maintenance is categorized into two broad classifications -- emergency and routine.

2.2.3.1 Emergency Maintenance

Emergency sewer maintenance may be defined as that action necessary to restore the system or any component part thereof to immediate service, once that service for any reason has been interrupted. This is the most common type of sewer maintenance and in many smaller systems, the entire sewer maintenance program is confined to this.

Stormwater collection systems have several component parts. All of these components are subject to breakdowns or failures that result in interruption of service requiring "emergency" maintenance. Such malfunctions usually can be traced to one of the following causes: stoppages, structural failures, overloading.

2.2.3.1.1 Stoppages -- Stoppages, or stops as they are generally called, result from obstructions in pipes blocking or causing an impediment in the flow. This is probably the most common maintenance problem. An obstruction in the pipe can be the result of foreign objects such as rocks, roots, rags, and sticks; materials such as settled solids, sand, and gravel; or bad joints or a broken pipe.

Many stops are caused by misuse and/or abuse of the system. Probably no other public utility is subject to as much misuse and abuse as is the sewer system. This results from the apparently popular misconception that a sewer is capable of carrying away any unwanted object or material that can be put into it. It has been estimated that the greatest percentage of stops result from this misuse and abuse. A sewer maintenance man is never surprised at what he might find in the pipe.

Stops resulting from foreign objects or materials usually can be corrected without digging into the line. There are special tools on the market for removing stoppages from the surface, through a manhole or other opening. In the past, wooden rods approximately three feet in length and equipped with a more or less flexible metal coupling were used, along with various other tools for removing stops. Although not as efficient nor as mobile as modern equipment, this type rod is still in use for certain types of work.

The flexible steel rod is widely used in today's sewer maintenance program. This type rod is more flexible than the older wooden rod and can be easily coupled together, placed on a reel, and carrier from place to place. The steel rod also is more readily rotated in the sewer, permitting the use of such tools as corkscrews and root saws.

In a system sufficiently large, one or more specially equipped trucks might be required. Considerable thought should go into the planning of such a stop wagon. A 3/4- or 1-ton pickup can be used without extensive modification, but in some communities a special body designed to protect personnel and equipment from weather is preferred.

Certain essential equipment is required on a stop wagon, such as 1) rod-reel and stand with 400- to 600-foot capacity; 2) sufficient rods with assembly tools; 3) rod guides; 4) assortment of various sizes of augers, spear heads, corkscrews, root saws, and other cleaning tools; 5) waterproof tool box with picks, shovels, lanterns, barricades, etc.; 6) small portable power drive for turning rods; and 7) some sort of flood light, running from the truck battery for after-dark operation. A two-way radio, if available, is very valuable in dispatching crews to stoppage locations. Protective clothing such as slicker suits and boots also should be provided as should adequate first aid and safety equipment.

2.2.3.1.2. Structural Failures -- Structural failures causing stoppages are usually the result of some unforeseen force acting adversely on the pipe, resulting in broken pipe, cave-ins, or washouts. This type of trouble is usually more serious than an ordinary stoppage and requires prompt and positive action.

Shifting earth or landslides as a result of unstable soil conditions cause sewer failures by imposing excessive shear loads on the pipe. Pipe installed in trenches of excessive widths or depths without proper support often results in breaks due to poor design. Poor construction, bad joints, and improper backfill also will be responsible for structural failure of a line.

Structural failures can be caused by the failure of certain materials in sewer pipe subject to deterioration from the effects of chemicals and/or acids frequently present. Much work is being done by industry on various types of coatings and liners designed to combat this problem and no doubt an effective and economical solution eventually will be found.

Washouts, resulting from heavy rains, are another type of structural failure. Since sewers are generally designed for gravity flow, their routes, by necessity, are usually along natural drainage courses. During periods of heavy rainfall, where the drainage courses are stream beds, these streams often overflow their banks and cause damage to sewers laid along the course of the stream. Elevated pipe crossings constructed on piers, if not properly anchored, are particularly prone to washouts.

The repair of a sewer damaged as the result of a structural failure frequently requires extensive excavation to uncover the line to repair or replace the broken or damaged pipe. In some cases, it is necessary to reroute or bypass the sewage load to effect the repair.

Before replacing or repairing broken or damaged pipe, special consideration should be given to the cause of the failure. In some situations, the services of a competent engineer may be required before making a repair. A sewer relaid in unstable soil will fail again unless the soil is stabilized or proper pipe support is provided. In extreme cases, the line might need to be relocated to avoid repetition of the failure. Repairs are costly and money spent to avoid a break is money well spent.

Consideration should be given to the type of equipment needed to make a repair on a sewer. A small relatively shallow line located in a city street may be uncovered with a small tractor-mounted backhoe while a large deep sewer situated in an inaccessible river bottom may require a track-mounted dragline; lines located in narrow alleys or in easements may require excavation by a crew using picks and shovels. Besides the unnecessary expense involved in attempting a repair with inadequate or oversized equipment, there is the safety of the men to consider. Equipment unsuited to the task is likely to be dangerous. By providing sufficient and adequate tools and equipment at the beginning of a repair, delay and resultant excessive costs can be avoided.

It is frequently difficult to determine the scope of a repair job before the line is uncovered. However, once a repair job is begun, it should be carried to a successful conclusion, making sure all the damaged pipe is replaced or repaired, that no sand, gravel, etc., remain in the pipe after the repair is completed, and that the line functions properly.

2.2.3.1.3 Overloading -- Overloaded sewers, the result of insufficient capacity in the line to handle the loads imposed by existing conditions, are becoming more and more of a problem due to the rapid growth of many communities. The marked increase in paved areas in cities, such as parking lots, is one reason for a system being taxed beyond the limits of its capacity. Bad joints and the physical condition of the pipe can contribute further to overloaded conditions of the collection system by the admission of ground and surface water into the lines. The solution to this condition is initially a problem of design but ultimately the maintenance staff is called upon to do what can be done to relieve the situation.

The best remedy for excessive infiltration is a tight line. Unfortunately, it is not practical to control infiltration once the line is constructed and put into operation. It is therefore imperative that good materials be used, good design and construction procedures be followed during initial installation, and adequate inspection is undertaken to assure compliance with the specifications. If a sewer overflow is caused by a partial stoppage as a result of foreign material in the line, cleaning would eliminate the problem. The cleaning operation also will help locate any broken pipe or bad joints that may be contributing to the overloaded condition of the line.

If cleaning the line and making the indicated repairs fail to solve the problem, the load may have exceeded the design capacity of the pipe. The overloaded condition should be reported to the superintendent or other responsible official so that a permanent solution may be planned.

2.2.3.2 Routine or Preventative Maintenance

Routine maintenance may be defined as that program of regular inspection, repair, and maintenance work, performed more or less continuously, that is intended to reduce the number of complaints and operational costs and increase the overall efficiency of the system.

One of the most important and useful forms of routine or preventative maintenance is a systematic program of sewer cleaning. This type program involves the periodic cleaning of all sewers in the system on a regularly recurring basis and the keeping of accurate and complete records pertaining thereto.

In addition to the obvious benefits resulting from clean sewers, several other benefits are realized from this type program. Periodic cleaning permits closer inspection of the sewers; thus, repairs can be made on minor trouble spots before they assume the proportions of expensive major repair projects. Frequent inspection reveals the location of chronic trouble areas, such as root penetration and harmful wastes so that proper corrective measures may be taken.

There is a wide variety of sewer cleaning equipment available for such a program. While none of the several items of equipment on the market is considered to be the total solution to all cleaning problems, each has proven to be a valuable tool when used for its intended purpose. Sewer cleaning equipment usually falls into one of three general classifications:

- Rodding machines feed flexible steel rods into the sewer and rotate the tools. Root saws, augers, spear heads, and other tools are attached to the rods and, when rotated, cut roots and other obstructions from the walls of the pipe.

  The most commonly used rodding machine is a portable power drive mounted on a two-wheeled push-type carriage, powered by a gasoline engine of from three to five horsepower. With this machine, the rods are fed into the sewer by hand and the rodder is used to rotate the tool, thereby boring its way through an obstruction.

  Heavy-duty rodding machines, equipped with a rotating reel, power rod drive mechanism, and an engine of approximately 25 horsepower are also available. With this type machine, rods are mechanically fed into the sewer and can be rotated continuously. These machines, mounted on a trailer or on a truck chassis, are very effective against roots. Although one-man operation is possible, a two-man crew is recommended.

- Bucket-type cleaning machines are available in sizes ranging from about 8 to 100 horsepower. These machines are actually nothing more than gasoline powered winches mounted on two-wheeled trailers. Working in pairs by means of a cable threaded between manholes, one machine pulls the bucket into the line and the other pulls it out when full. Buckets, manufactured in different sizes for various sizes of pipe, are designed so that pulling into the sewer opens the jaws to form a sort of scoop. Pulling the bucket out of the line closes the jaws and prevents loss of the material. Bucket-type machines are effective against sand, gravel, and roots. The material may be dumped temporarily onto the street or a specially designed truck loader will dump the material directly into a truck to be hauled away. These machines are capable of removing up to 10 cubic yards of material in a day. A three-man crew is recommended.

- Hydraulic sewer cleaning machines, mounted on a truck or trailer, utilize a high velocity stream of water to wash the inside of the pipe. Components of the machine are a high-pressure pump, a hose reel with from 400 to 600 feet of hose, a specially designed nozzle, a tank for water, and various valves and controls. Pumps are designed to deliver from 30 to 80 gallons per minute at 800 to 1,200 pounds per square inch pressure. The nozzle directs a high-velocity, high-pressure cone of water back toward the hose reel. The jet action of the water propels the hose into the sewer in much the same manner as a jet engine propels an aircraft through the air. When the hose is reeled back in, the pipe is thoroughly washed and the material is flushed back to the manhole where it is trapped and removed. This equipment is very effective against sand and gravel. However, this type machine should not be used in a sewer known to be broken, cracked, or quartered. The high-velocity jet of water will damage such pipe to the extent that it often must be replaced. A two-man crew is required to operate the equipment.

Probably the simplest piece of cleaning equipment is a device known as the sewer ball. The ball is constructed of heavy rubber with a metal bolt through the center. A swivel on the bolt permits a rope or cable to be attached to the ball. Spiral ribs or ridges run around the outside. The ball is inflated to a diameter slightly less than that of the sewer and inserted into the pipe at a manhole. The partial stoppage thus created causes water to back up in the manhole behind it. When sufficient head is built up in the line the ball begins to move downstream. Normally, 2 or 3 feet of head is sufficient to propel the ball. Water pressure forces water out between the ball and the walls of the pipe causing a jet action that scours the line and flushes sand, gravel, and grease ahead as the ball travels through the sewer. The jet action also causes the ball to vibrate up and down and to rotate within the pipe to provide further cleaning action. One man is required to clean the smaller sizes. Two or more men are required for larger lines.

In establishing a cleaning program, the selection of the proper equipment is most important. The type of sewer cleaning problem must be determined. The number of personnel required and the cost of their services is also important. The initial cost of the equipment is often the deciding factor in the purchase of cleaning equipment, but this practice is not recommended because of numerous other considerations that should be taken into account.

In every system, there always seems to be a need for additional manholes and usually as much time, and money as the budget will allow is spent in the construction of additional manholes. These facilities are needed to permit closer inspection and easier cleaning. In some instances, sewer lines have been "wyed" in without a manhole, and a program for the construction of manholes at these points as funds and manpower become available is most desirable.

Repair of manholes also should be included in the routine maintenance program. Manhole covers knocked off during street paving or maintenance should be repaired to prevent the entrance of gravel and dirt into the sewer. Broken or defective steps are a hazard and should be replaced or repaired to prevent injury. Lids that rattle under traffic are a nuisance and should be corrected.

Street paving frequently requires that manholes be adjusted to fit new pavement grades. A manhole that is too high presents a hazard to the traveling public while those that are too low will be paved over and their usefulness thus destroyed.

2.3 EROSION CONTROL

Soil erosion involves detachment, transportation, and then deposition of earth material by moving water. As the velocity and/or depth of flow increase, particles are detached from the channel bed or cut and fill slopes. As the velocity and/or depth of flow decrease, particles carried in suspension will begin to be deposited. Large particles will be deposited first with the smaller particles being carried further downstream or downslope before deposition. Soil erosion may be only minor or it may be devastating. Erosion control serves the purposes of protecting the roadway, ditches, culverts, and slopes. Erosion control helps to minimize damage to adjacent properties, reduces soil loss, and decreases the likelihood of silted ditchlines.

Slope erosion problems may result if the slope is too steep or lacks vegetation. Steep slopes that show signs of erosion should be flattened or serrated (terraced) when possible. If flattening is not feasible, protection could be gained by placing rock on the slope face; increasing vegetation by planting, seeding, and fertilizing; or adding diversion or check devices such as baled hay or straw. Intercepting ditches could be used to collect water and divert flow to suitable channels. Installation of subdrains helps stabilize slopes in some cases.

Ditch erosion can be minimized by a grass lining or other types of lining. For ditches that have established a turf lining, it is important not to destroy the lining when ditches are cleaned. Ditches are generally either V shaped, trapezoidal, or parabolic. V ditches are easily blocked and highly susceptible to erosion. Parabolic sections are the most efficient and most erosion resistant. Changing the ditch shape, cross section, and/or slope are possible ways to solve erosion problems. On steep grades where velocities are high, ditch checks could be installed. Ditch checks may be 6 to 24 inches high and constructed of timber, stone, or sheet metal. The top should be level to distribute flow throughout the channel width. It is also a good idea to place an apron or rubble downstream from the check to prevent scour.

Maintenance crews may do an excellent job in controling erosion and then construction or other operations on property adjacent to the roadway can cause havoc. Maintenance personnel should report such operations and steps should be taken to minimize the adverse effects of those operations. Many cities and counties have guidelines that should be followed that now greatly reduce potential erosion as a result of operations by private agencies.

2.4 DEBRIS CONTROL

Accumulation of debris at the inlets of highway drainage structures is a frequent cause of unsatisfactory performance or malfunction. Debris may reduce capacity of the structure or, in some cases, totally restrict flow. Whenever possible, debris should be removed before it has a chance to clog or block channels and inlets. Removing trash and litter from the roadway and within the right of way helps. Grates and inlets should be cleaned to remove all obstructions. Logs and limbs should be disposed of and hauled from the right of way or at least to a location so they will not eventually clog drainageways.

Debris at a culvert entrance may restrict flow to the extent water will overtop the embankment. Upstream property also might be flooded. In situations where culvert entrances frequently become obstructed, use of a debris control structure should be considered. Debris can be controlled by 1) intercepting it at or above the inlet, 2) deflecting and retaining it near the inlet, or 3) passing it through the culvert. Floods may 1) carry floating objects, 2) force other types of debris along the channel bed, or 3) transport a combination of both.

Large floating objects can be deflected away from the culvert entrance by a V-shaped deflector placed with the apex upstream. Several posts driven into the channel might serve the purpose. Another method is to use a debris rack, which is essentially a structure placed upstream and at right angle to the flow to catch debris. A small dam of logs or posts closely spaced or earth faced with large rocks could be used to trap nonfloating debris carried by the stream. Those type structures would require periodic cleaning to remain effective.

2.5 SUBSURFACE DRAINAGE -- SUBDRAINS AND EDGEDRAINS

Excessive and uncontrolled subsurface water is most likely the cause of much unsatisfactory highway performance and many failures. The adverse effects of subsurface water show up in the form of slope instability and poor pavement performance. Sloughing and sliding of cut slopes and sidehill fills are the predominant forms of slope instability. Premature rutting, cracking, increased roughness, and a generally rapid decrease in level of serviceability are indications of subsurface water problems.

Subsurface water contributes to slope instability in two ways: 1) it adds weight to the soil or rock mass and 2) it reduces the capacity to support loads. Figure 2-1 is an example of how subsurface water may cause cut-slope instability. Embankments, unless properly designed, may act as a dam and lead to collapse as illustrated in Figure 2-2.

Excessive water in the pavement structure and subgrade can cause a variety of problems and result in early distress or failure. Wheel loads on gravel or flexible pavements cause high pore-water pressure and loss of strength in an unbound base, subbase, and subgrade. Without adequate supporting strength in those layers, the surface course fails. That action is illustrated in Figure 2-3. Excess pore pressures also may cause water and fines to be ejected through surface cracks and joints such as those between the riding lanes and shoulders. On gravel roads, fines work their way up through the gravel and gravel is pushed into the spongy base.

Water also may be ejected through joints in portland cement concrete pavements. The water may carry fines with it to the surface and leave voids under the pavement. In such cases, more water may collect and base support is nonexistent. Passing vehicles repeatedly move the slabs up and down and worsen conditions. The action is referred to as pumping and is illustrated in Figure 2-4.

Inadequate control of moisture severely affects pavements as a result of a phenomenon called frost action. Frost action requires a readily available supply of subsurface water, a frost-susceptible soil, and a sustained period of subfreezing temperatures. Water moves upward through the soil (by capillary action) to the freezing zone where growth of ice lenses can cause severe damage to the pavement. Figure 2-5 is an example. Heaving during freezing is damaging and especially noticeable if differential frost action occurs. Even more damage generally occurs when the ice lenses thaw and subgrade support is drastically decreased. That pavement disintegration is generally called the spring breakup. Figure 2-6 shows how water may become trapped during the spring thaw unless provision is made for adequate drainage.

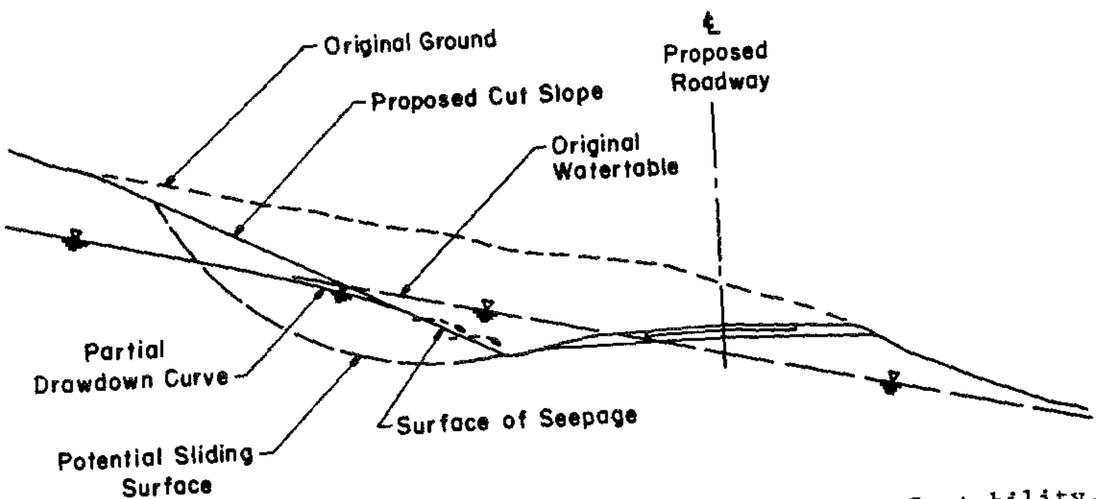


Figure 2-1. Uncontrolled Groundwater Causes Cut Slope Instability.

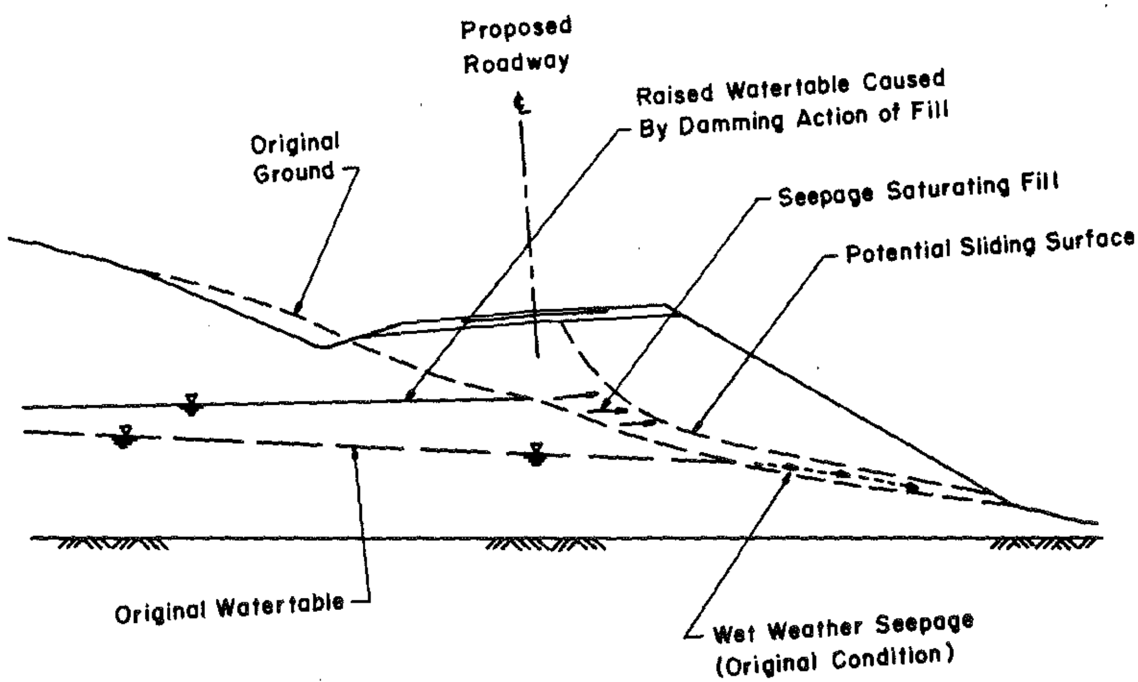


Figure 2-2. Embankment Acts as Dam and Causes Unstable Conditions.

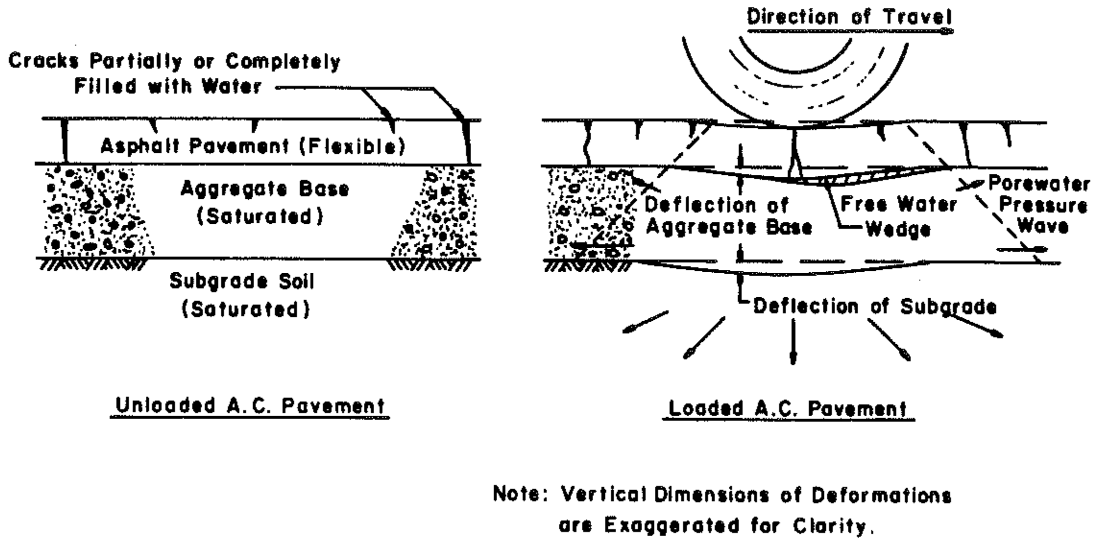


Figure 2-3. Moving Load Causes Water Pressure and Subgrade Deflection.

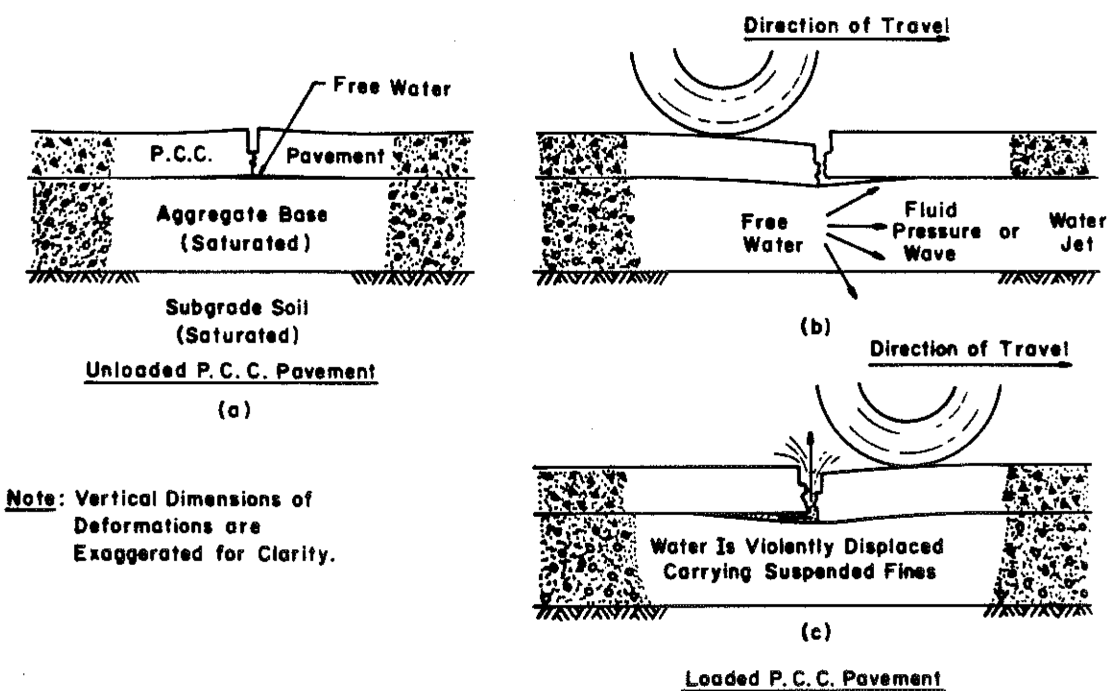


Figure 2-4. Rigid Pavement Pumping as Result of Saturated Base and Moving Load.

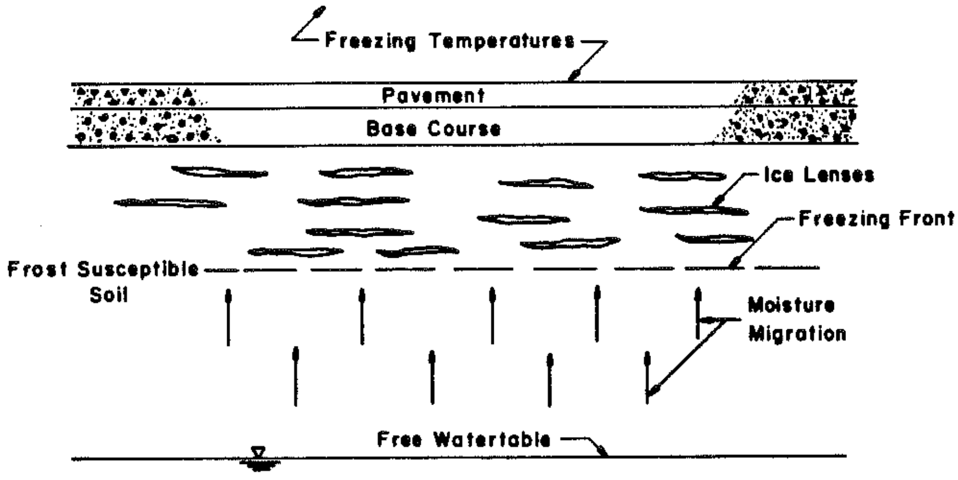


Figure 2-5. Capillary Water Moves to Freezing Zone and Ice Lenses Form.

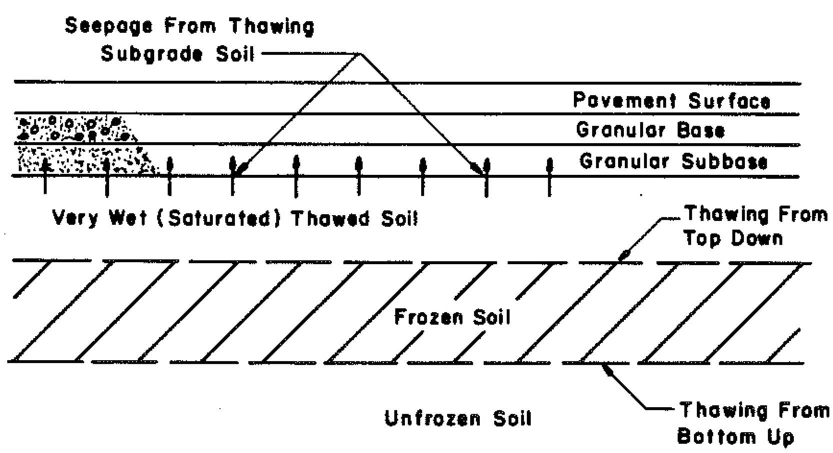


Figure 2-6. Ice Lenses Near Surface Melt and Weaken Subgrade.

Drainable subsurface water may be groundwater, which is water existing in the natural ground in the zone of saturation below the water table, or the water may result from infiltration of surface water through joints, cracks, or pavement voids. Infiltration also may originate from ditches. The ways that precipitation may enter the pavement structure are shown in Figure 2-7. In portland cement concrete pavements, most infiltration probably takes place at the longitudinal and transverse joints. The main sources of infiltration on relatively new bituminous concrete pavements is along the joints between shoulders and the pavement and construction joints. Later, more water may infiltrate through cracks and voids within the mixture of the paving material.

Subsurface drainage systems are classified according to either 1) the source of water they are designed to control, 2) the function they perform, or 3) their location and geometry. Systems may be designed to remove water that seeps into the pavement structure, to remove and control flow of groundwater, or to control both types of flow. Possibilities for classifying subsurface systems by the functions they perform are shown in Figures 2-8, 2-9, and 2-10. Location and geometry classification includes 1) longitudinal drains, 2) transverse and horizontal drains, 3) drainage blankets, and 4) well systems. Examples are shown in Figures 2-11 through 2-14.

Underdrains may be constructed by excavating a trench and filling it with either coarse aggregate or natural sand. Underdrains also are constructed of perforated or nonperforated pipe. In those installations, a trench is excavated to a depth 3 inches below the elevation to which the invert of the pipe is to be placed. The trench width is a least 1 foot wider than the outside diameter of the pipe. A 3-inch bedding layer of coarse aggregate or sand is placed, then the pipe, and then coarse aggregate or sand is placed to a height of at least 12 inches above the top of the pipe.

Perforated pipe generally is placed with the perforations located in the bottom and pipe sections are securely joined. Nonperforated pipe is installed with open joints not to exceed 3/8 inch. The upgrade end of the installations are closed with plugs to keep debris from entering and clogging the pipe. Outlets are equipped with a screen, mainly to keep

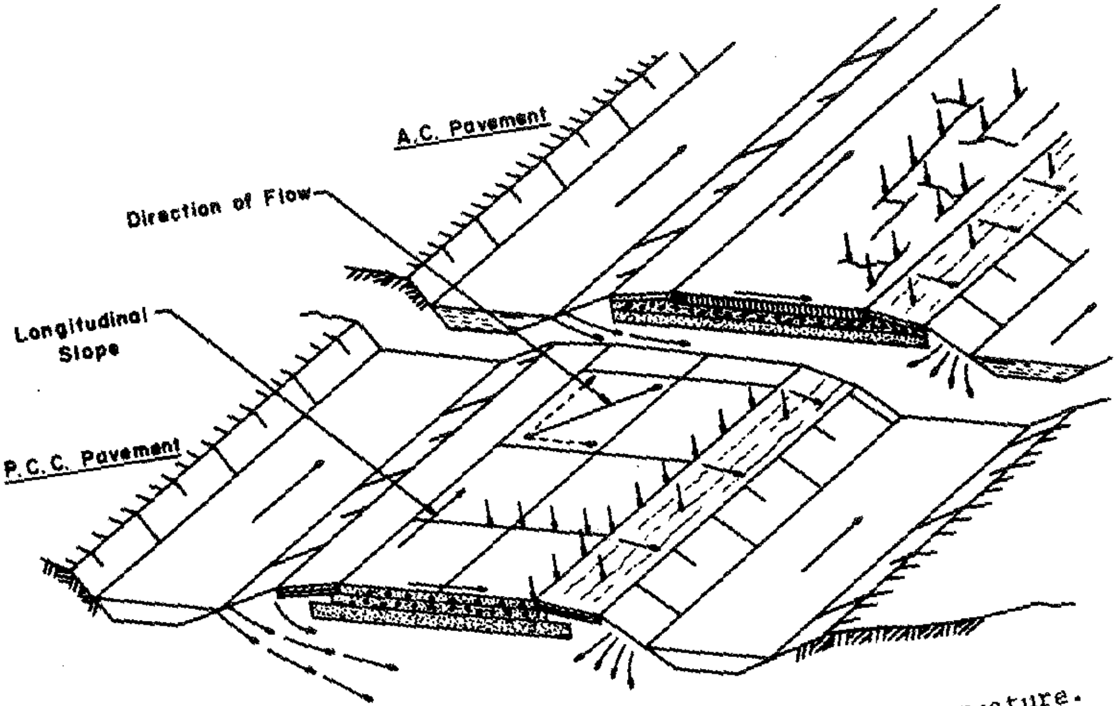


Figure 2-7. Places Water May Get into Pavement Structure.

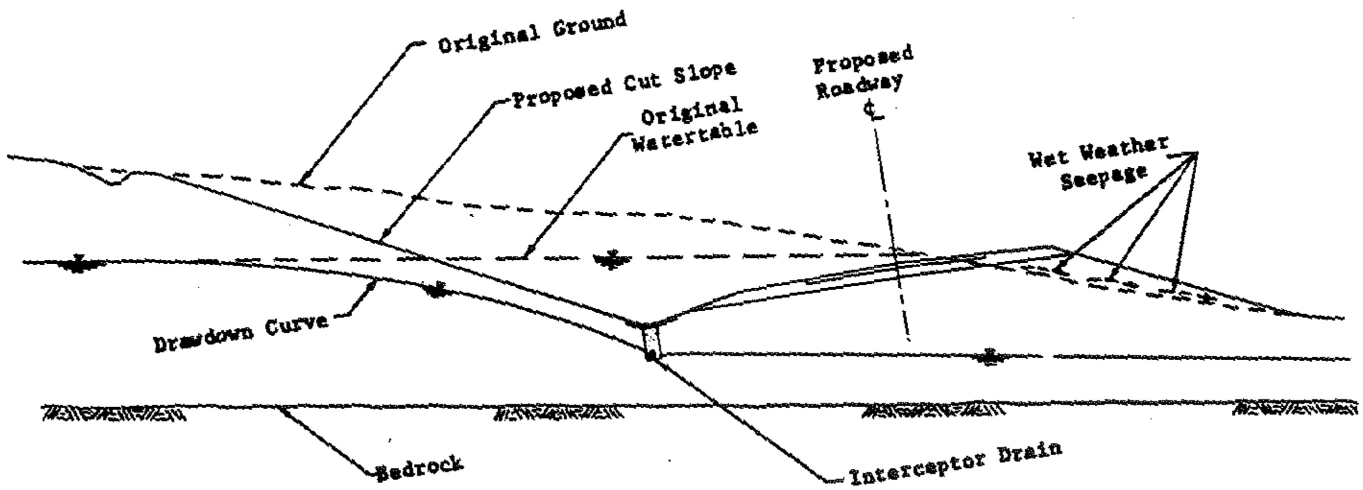


Figure 2-8. Longitudinal Drains Lower Water Table and Cut Off Seepage.

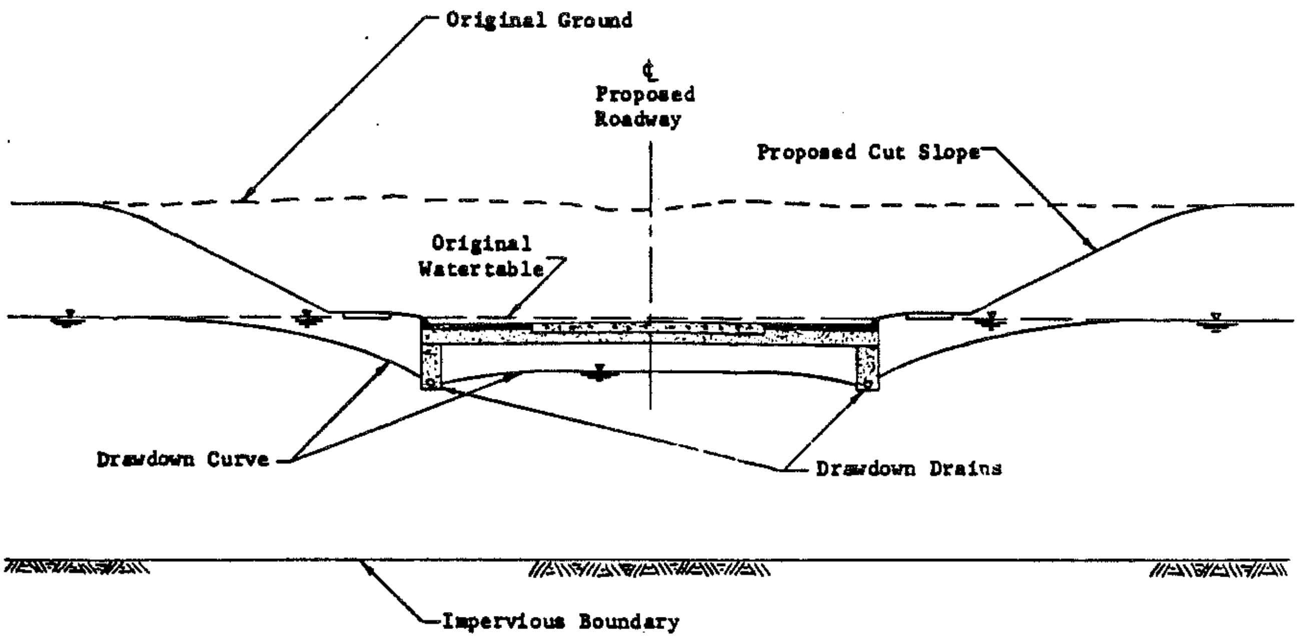


Figure 2-9. Longitudinal Drains at Each Edge of Pavement Lower Water Table.

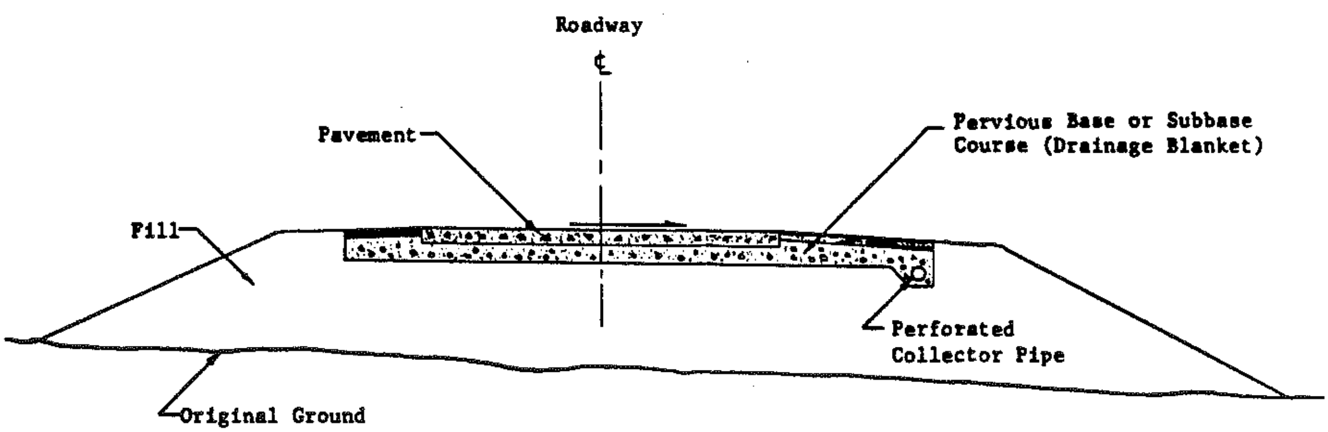


Figure 2-10. Drainage Blanket and Collector Pipe.

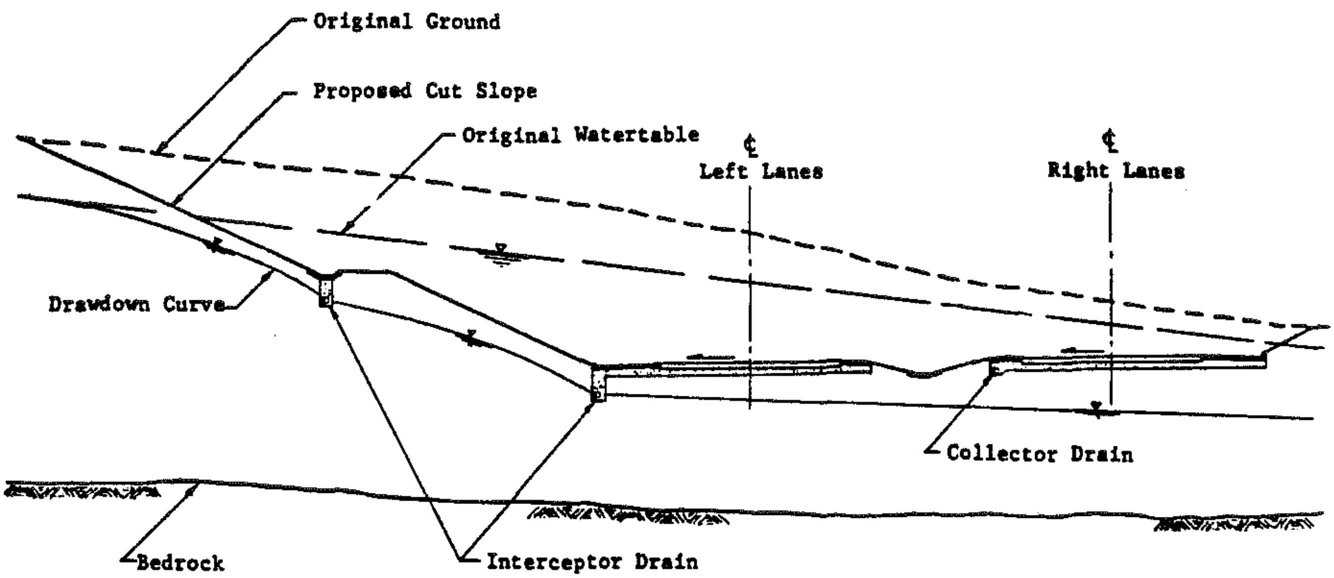


Figure 2-11. Longitudinal Drains Used for Various Purposes.

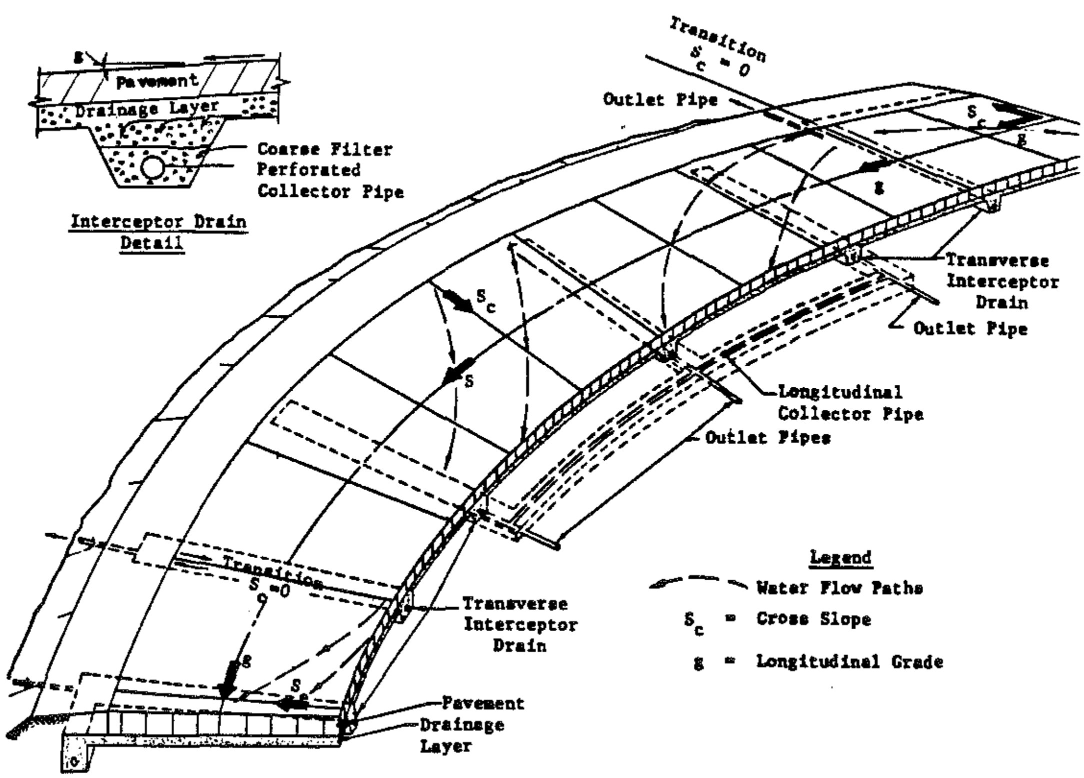
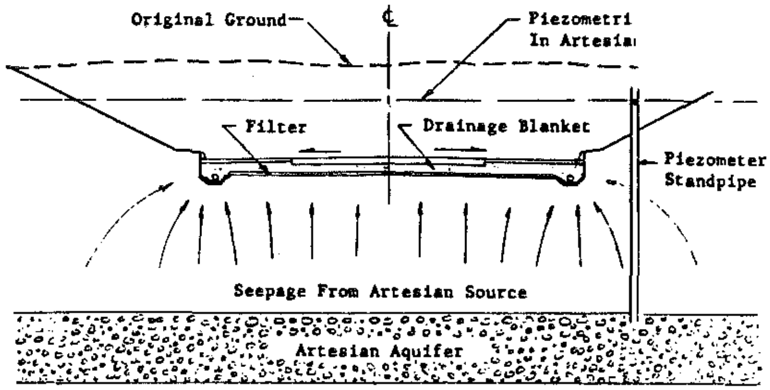
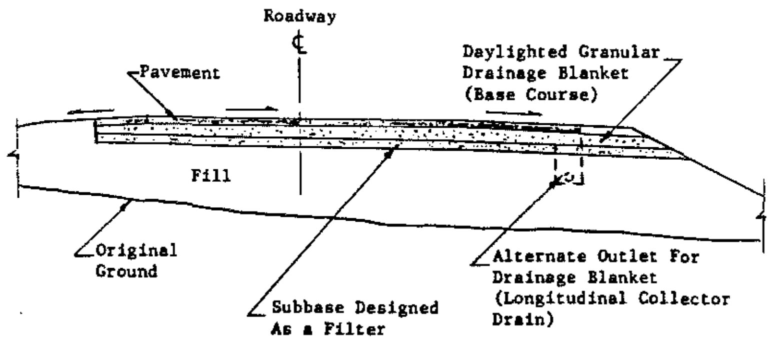


Figure 2-12. Transverse Drains Used in Curve.



(a)

Figure 2-13. Uses of Drainage Blankets.



(b)

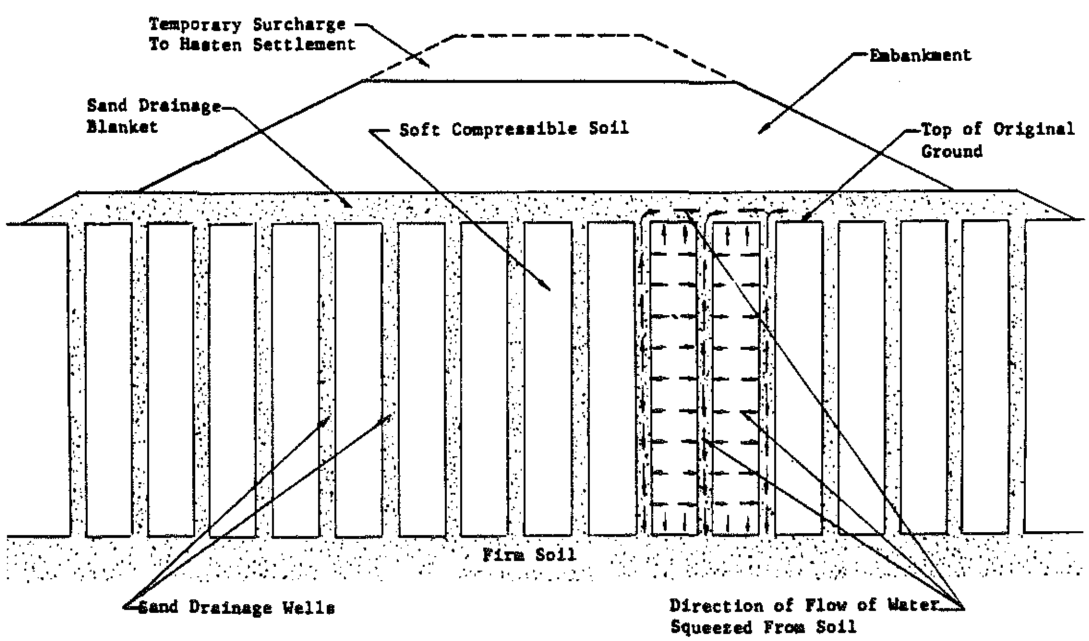


Figure 2-14. Sand Drainage Wells.

animals from building nests in the sections. The minimum slope for smooth pipe is about 1 percent. For corrugated pipe, the slope should not be less than about 2 percent.

A drainage blanket is a very permeable layer whose width and length is large relative to its thickness. Drainage blankets may be placed either beneath the pavement structure or actually be a part of the pavement structure. The material must have adequate thickness, have a high coefficient of permeability (water flows through easily), and have a free outlet.

Underdrain systems should be positioned below the depth of frost penetration. The maximum depth of frost penetration for southern and northern Kentucky is 25 and 30 inches, respectively. Those depths would naturally be for long periods of low temperatures.

2.6 MAINTENANCE REPAIRS

Municipalities vary widely in their capabilities for doing maintenance repairs because of differences in availability of personnel and equipment. As a result, this section may include some things that certain cities or counties may not be able to do with their own crews.

Culvert work may vary from only minor repair to total replacement. Metal culverts may rust, become pitted or perforated, or have sections of the flowline missing. Minor distress might be repaired with a heavy application of asphalt coating. More severe distress could be repaired using an asphalt coating and paving or portland cement concrete paving. In any case, work should be done with the channel dammed or in dry weather.

Wire mesh, 6 inches by 6 inches, should be secured to the bolts of the structure and located so it would be about mid depth of the concrete pavement after placement. In cases when the channel is dry, the concrete should be kept moist for about three days. When there is flow in the channel, flow will have to be diverted until the concrete has set sufficiently so as not to be washed away. Once it has set, let normal flow keep the concrete moist for curing.

Metal culverts are flexible and deflect under loading. Excessive deflection is a sign of a structural problem and should be remedied. Sometimes end sections may be distorted by equipment. Sections may be restored to their original dimensions by jacking. In jacking, place a few wide pieces of wood between the jack and culvert so the metal is not punctured. Apply a slow, gentle force to return the metal to the desired shape. If the structure deflects after releasing the jack, you might consider using struts, vertical supports, to hold the desired shape. Before using struts, be sure to consider the fact that struts will decrease the capacity of the culvert and probably catch debris. Would struts do more harm than good? Maybe they could be used temporarily until more permanent repairs could be undertaken.

A possible solution for the repair of seriously deteriorated culverts would be to place a smaller diameter pipe through the old culvert. The void between the two pipes should be grouted. This type repair would solve the structural problem but would reduce the hydraulic capacity. Will a smaller size pipe be suitable hydraulically? To place the grout, the ends should be sealed, grout holes placed in the top of the new pipe, and grout pumped to hopefully fill the entire void between the two conduits.

Reinforced concrete culverts generally sustain three types of damage -- cracking, spalling, and exposure of the reinforcing steel. Reinforced concrete is designed to provide for cracking and many cracks are not signs of failure. Spalling is a form of disintegration of concrete, sometimes a result of steel near the surface rusting or buckling. Spalls may be patched by a mortar or concrete having small size aggregate.

Exposure of the reinforcing steel could be a result of erosion or abrasion in the culvert invert. In other cases, steel may be exposed because of shear of the pipe walls. Repairs should be made by removing all unsound concrete and then patching with mortar or concrete to restore the culvert to its original dimensions when possible.

Other problems might include missing end sections, leaking joints, or forms of disintegration of headwalls, parapets, aprons, and wingwalls. Missing end sections should be replaced and then something done to prevent future loss of the replaced sections. The original sections may have been lost due to a slide, undermining, seepage, or some other reason. In any event, try to determine what caused the loss of the original section and correct that problem during the replacement operation. Possible remedies might be to lengthen the culvert, add an apron or headwalls, pave a portion of the channel, or seal joints. Leaking joints may be sealed with expanding collars or gaskets, mortar, or one of numerous sealing compounds.

Broken frames, grates, and manhole covers should be replaced or repaired. If damage was done by excessive loads, be sure that replacement items will be strong enough to support the loads. Larger and heavier trucks are now permitted by law and it could be that damage is being done by vehicles for which the facilities were not designed to accommodate.

Many repairs involve flaws in portland cement concrete. Wide cracks that allow excessive movement of water should be cleaned by chipping, sandblasting, or waterblasting and then allowed to dry. Those cracks could then be sealed with conventional sealants forced into the crack under pressure with a caulking gun or other equipment. Silicone seals have been used successfully in recent years.

For other concrete repairs, unsound concrete should be completely removed. During that removal process, be careful not to damage the good concrete. Once the bad material is removed, thoroughly clean surfaces to receive new material and saturate the area with water for at least one hour before new material is placed. Remove accumulations of water and then thoroughly brush or scrub on a grout-bond coat. The grout could be a mixture of cement, sand, and water or concrete that has been screened to remove the coarse aggregate. After placement of the grout-bond coat, place the concrete, being sure to consolidate or vibrate it to remove voids and prevent honeycombing. Finally, cure the new concrete.

Portland cement concrete is frequently, but not always, used in repair work. Latex modified concrete may be used and reportedly provides better durability. For latex concrete, use 3.5 gallons of latex per sack of cement (94 pounds) and about 22 pounds of water (total water, including free water on the fine and coarse aggregate). Latex concrete should be wet cured for 24 hours and then air cured for 72 hours.

Concrete should not be placed in cold weather unless provisions are made to cure it at a temperature not less than 45°F for four days.

Those are minimum temperatures and times. Do not heat to the extent that concrete temperatures during curing would be above 70°F.

There are other admixtures used in concrete to obtain various properties and results. Admixtures may accelerate set, retard set, entrain air, decrease permeability, densify, reduce water requirement, inhibit corrosion of embedded steel, aid in pumping and workability, and so on. When you decide to use an admixture, be sure to select one that has been proven to do what you want and use it strictly according to the directions.

Other materials are available for concrete repairs. Epoxies are available to use straight or to make epoxy grouts and epoxy concretes. Some epoxies may be used under wet or dry conditions and others may work only under dry conditions. Coatings, sealants, penetrants, and various compounds are available. In any situation, be sure you know how to use the materials and find out what they actually will and will not do. It is discouraging to spend considerable time and money to do a job and then have to redo it because the material used did not work like the advertisement said.

3. NEW CONSTRUCTION

3.1 CONTRACT WORK

Work that cannot be performed by municipal or county crews may be let to contract. There may be various reasons why contracting is necessary -- your crews may be too busy and cannot do all that needs to be done, or a contractor may have personnel and special equipment such that the work can be done much cheaper, or the required work is too voluminous. In any event, general steps should be followed for contract work.

For your own well being, you probably should state in writing the reasons that contract work is being considered and obtain written approval to proceed.

Depending on the work required, design may be done by your staff or you may hire a consultant to perform that phase of the work. In any event, municipal personnel must be very specific about the work that is necessary and be able to determine how much money is available for the entire job -- design and construction. If a consulting firm is to do the design work, there should be a complete and signed agreement outlining specifically what is to be required and how payments will be made -- lump sum, periodically, upon completion of each phase, etc. Also, include the total amount to be paid.

Once the plans are complete, reviewed, and accepted, the job should be advertised for bids. You may elect to handle bidding in-house or pay for those services. Some of the things that should be addressed include but may not be limited to the following:

1. LOCATION TO OBTAIN PLANS AND SPECIFICATIONS,
2. IS THERE A CHARGE FOR PLANS, ETC.?
3. QUALIFICATIONS FOR BIDDERS,
4. WHERE AND WHEN ARE BIDS TO BE RECEIVED?
5. DATE OF AWARD,
6. WHEN IS WORK TO COMMENCE?
7. IS THERE A FIRM COMPLETION TIME OR DATE?
8. WHAT ARE COSTS IN CASE OF DELAYS?
9. WHAT ARE BOND REQUIREMENTS?
10. WHEN AND WHAT ARE RULES FOR PAYMENTS?
11. MUST TRAFFIC BE MAINTAINED?

12. WHO IS RESPONSIBLE FOR TRAFFIC CONTROL?

13. WHAT ARE INSURANCE REQUIREMENTS?

14. HOW ARE DISPUTES TO BE RESOLVED?

15. HOW ARE CHANGE ORDERS TO BE HANDLED?

Contractors should be provided all details possible in order that they may make reasonable bids.

You also need to determine whether construction inspection and materials tests are to be done by your staff or others. It might be possible to obtain a package price for design, inspection, and testing that would be less than getting one price for design and then another for inspection and testing. Your staff may be more capable of doing inspection and testing for some jobs than someone from an outside agency.

Be sure you maintain good records during the course of work and thereafter until the job is accepted and final payment has been made.

3.2 FORCE ACCOUNT WORK

Several municipalities have their own capabilities of doing design and construction. In those cases, their personnel are very much aware of current design and construction practices and are generally very progressive. Other agencies may have grown to the point they are ready to begin some design and construction projects. They may, however, have very few design standards or specifications. It is suggested that those agencies consider using manuals, standards, and specifications developed by the Kentucky Department of Highways (KDOH) until such time they can develop their own.

For work performed by your own people, you will have the freedom to make changes during the course of work without being penalized costwise. Sample plans, standards, and specifications could be taken from KDOH documents and modified to suit your specific needs.

Your crews would perform the work in accordance with modified plans or drawings. Materials meeting KDOH specifications would be purchased locally or would be ordered. An advantage of using KDOH documents is the fact they are updated rather frequently and they reference other updated standards of national organizations.

4. DECISION-MAKING PROCESS

4.1 EVALUATIONS

We have already talked about the importance of keeping good records. Of what value are those records? The records are of value to the extent you use them as a basis upon which to make future decisions. Records allow you to plan and make projections or estimates. Records are useful through thorough and proper evaluation.

Most municipalities have some type of budgeting process. You should evaluate your overall operation to determine what has been accomplished and what needs to be done both in the near and distant future. Evaluate your equipment records. How often does equipment need replacing, do you need just to replace some worn equipment, or do you need to replace old equipment and also obtain extra machines? What does each unit cost to operate? It might be possible that you would save money by leasing equipment occasionally (when the need arises) or on a long-term basis rather than buying outright. Check with your counterparts in neighboring areas to see what they are doing.

Evaluate your personnel needs. Are the crew sizes appropriate or do you need changes? Evaluate your training needs. It may be you could let personnel cross train within your own group and increase efficiency. When one person is absent for any reason, things can continue since he has trained someone else to do the job.

Evaluate your materials needs. You may save money by purchasing certain materials in bulk and storing or stockpiling as opposed to making as-needed purchases. Of course, you need to consider your costs for storing or stockpiling and then later loading and hauling to the work site when needed.

Evaluate your overall operation. How much does it actually cost to do various jobs? When all crews are busy and there is still a backlog of work to be done, would it be economical to contract some of the work? You should be in a position to decide which work should be contracted and should have a good idea of a fair price for that work. Your evaluation will allow you to present a good case for a fair share of the budget. Win or lose, your records and evaluation will allow you to determine what work may be done with the money budgeted.

4.2 LISTING AND PRIORITIES

Compile a list of work that currently needs to be done and then another list of work you suspect will need to be done later. Determine those items of work that are essential and list them first. Next, list items that may not be essential but are important. Last, list items of work that would be of benefit but are not absolutely essential. Determine the costs of the three groupings. The cost of performing the work on the essential list would be your bare-bones budget. The costs of the first and second lists combined would probably be more realistic. Some of the items contained on the second list would probably be uneconomical to delay -- that is, further deterioration would be costly. Decide what would be the cost of delaying work.

4.3 TIME FRAMES

Records, evaluations, and listings have been developed and now it is time to decide what to do and when -- this is the time frame. Establish goals based upon what you know needs to be done and what your crews can actually do. You should develop an overall plan to the extent you could tell about when work will be done, what crew will do the work, and about how much it will cost. The time frame or schedule allows you to have a very good idea of what and when things will be accomplished. It also serves to show personnel what is expected. It is also a good public relations tool. People should be able to ask about problem areas and be given a relatively good idea of when repairs may be expected.

Time frames should be realistic. Remember, there will be bad weather, emergencies, crises, and other things that will take crews from the scheduled work. Be flexible. Do not be so rigid that unscheduled events devastate the game plan.

GLOSSARY

ABRASION -- Wear or scour by hydraulic flow.

ABUTMENT -- A wall supporting the end of a bridge and sustaining the pressure of the abutting earth.

BACKFILL -- Earth or other material used to replace material removed during construction, such as in culvert, sewer, and pipeline trenches, and behind bridge abutments and retaining walls. Also refers to material placed in bin-walls or between an old structure and a new lining.

BASE (course) -- A layer of specified or selected material of planned thickness, constructed on the subgrade (natural foundation) or subbase for the purpose of distributing load or providing drainage, or upon which a wearing surface or a drainage structure is placed.

BATTER -- The slope or inclination from a vertical plane (as the face or back of a wall).

BEDDING -- The earth or other material on which a pipe or conduit is supported.

BERM -- The space between the toe of a slope and excavation made for intercepting ditches or borrow pits.

BERM -- An approximately horizontal space introduced in a slope.

BINWALL -- A series of connected bins, generally filled with earth or gravel to serve as a retaining wall, abutment, or pier.

BITUMINOUS (coating) -- Of or containing bitumen; as asphalt or tar.

BORING -- An earth-drilling process used for installing conduits or pipelines.

BRIDGE -- A structure for carrying traffic over a stream or gulley, including the pavement directly on the floor of the structure. (A structure measuring 20 feet or more in clear span.)

CAISSON -- A watertight box or cylinder used in excavating for foundations or tunnel pits to hold out water so concreting or other construction can be carried on.

CAMBER -- Rise or crown of the center of a bridge, or flowline through a culvert, above a straight line through its ends.

CANTILEVER -- The part of a structure that extends beyond its support.

COFFERDAM -- A barrier built in the water so as to form an enclosure from which the water is pumped to permit free access to the area within.

COMBINED SEWER -- A sewer that carries both storm water and sanitary or industrial wastes.

COMPACTION -- The packing together of soil particles by means of mechanical manipulation.

CONDUIT -- A pipe or other opening, buried or above ground, for conveying hydraulic traffic, pipelines, cables or other utilities.

CONSOLIDATION -- The gradual reduction in the volume of a soil mass resulting from an increase in compressive stress.

CUTOFF WALL -- A wall, collar, or apron intended to prevent seepage or undermining. See diaphragm.

DEFLECTION -- Change in shape or decrease in diameter of a conduit, produced without fracture of the material.

DIAPHRAGM -- A metal or other collar at right angles to a drain pipe for the purpose of retarding seepage or the burrowing of rodents.

DESIGN LIFE -- The length of time for which it is economically sound to require a structure to serve without major repairs.

DISCHARGE (Q) -- Flow from a culvert, sewer, channel, in cubic feet per second.

DITCH CHECK -- Barrier placed in a ditch to decrease the slope of the flowline and thereby decrease the velocity of the water.

DRAINAGE -- Interception and removal of groundwater or surface water, by artificial or natural means.

DRAINAGE AREA -- Of a given point, that area of land from which all water drains past that point.

EFFLUENT -- Outflow or discharge from a sewer.

EMBANKMENT -- A bank of earth, rock, or other material constructed above the natural ground surface.

END SECTION -- Flared attachment on inlet and outlet of a culvert to prevent erosion of the roadbed, improve hydraulic efficiency, and improve appearance.

EQUALIZER -- A culvert placed where there is no channel but where it is desirable to have standing water at equal elevations on both sides of a fill.

EROSION -- Wear or scouring caused by hydraulic traffic or by wind.

FILTER -- Granular material placed around a subdrain or edgedrain to facilitate drainage and at the same time strain or prevent the admission of silt or sediment.

FLUME -- An open channel or conduit of metal, concrete, or wood on a prepared grade, trestle, or bridge.

FORD -- A shallow place where a stream may be crossed by traffic.

FOUNDATION -- That portion of a structure (usually below the surface of the ground) which distributes the pressure to the soil or to artificial supports. Footing has a similar meaning.

FREE OUTLET -- Exists when the backwater does not diminish the discharge of a conduit.

FREE WATER -- Water (in soil) free to move under the force of gravity.

FRENCH DRAIN -- A trench loosely backfilled with stones, the largest being placed on the bottom and the size decreasing toward the top.

FROST ACTION -- Freezing and thawing of water in materials and the effects on these materials and on the structure of which they are a part or in contact.

GAGE -- Standard measurement of the thickness of metal sheets or wire (and bearing a relation to the weight of the metal). Thickness of metal is now standardized.

GRADATION -- Sieve analysis (particle-size distribution) of aggregates or soils.

GRADE -- Profile of the center of a roadway or the invert of a culvert or sewer. Also refers to slope, or ratio of rise or fall of the grade line to its length. (Various other meanings.)

GROUND-WATER TABLE (or level) -- Upper surface of the zone of saturation in permeable rock or soil. (When the upper surface is confined by impermeable rock, the water table is absent.)

GROUT -- A fluid mixture of cement, sand, and water that can be poured or pumped easily.

HEADWALL -- A wall (of any material) at the end of a culvert or drain to serve one or more of the following purposes: protect fill from scour or undermining, increase hydraulic efficiency, divert direction of flow, or serve as a retaining wall.

HEIGHT OF COVER (HC) -- Distance from top of a culvert or conduit to the finished road surface or the base of rail.

HYDRAULIC RADIUS -- The cross-sectional area of a stream of water divided by the length of that part of its periphery in contact with its containing conduit; the ratio of area to wetted perimeter.

HYDRAULICS -- That branch of science or engineering which treats of water or other fluid in motion.

INTERCEPTING DRAIN -- A ditch or trench filled with a pervious filter material around a subdrainage pipe.

INVERT -- Generally the lowest point of the internal cross section of a conduit.

JACKING (for conduits) -- A method of providing an underground opening for drainage or other purposes by cutting an opening ahead of the pipe and forcing the pipe into the opening by means of horizontal jacks.

KIP -- A unit equal to 1,000 pounds.

LINER PLATE -- Formed steel unit used to line or reinforce a tunnel or other opening.

LOCK SEAM -- Longitudinal seam in a pipe formed by overlapping or folding the adjacent edges. Seam may be helical.

OUTFALL (or outlet) -- In hydraulics, the discharge end of drains and sewers.

PARAPET -- Wall or rampart, breast high. Also, the wall on top of an abutment extending from the bridge seat to the underside of the bridge floor and designed to hold the backfill.

PAVEMENT, INVERT -- Lower segment of a corrugated metal pipe provided with a smooth bituminous material that completely fills the corrugations, intended to give resistance to scour and erosion and to improve flow.

PERCHED WATER TABLE -- In hydrology, the upper surface of a body of free ground water in a zone of saturation, separated by unsaturated material from an underlying body of ground water in a differing zone of saturation.

PERCOLATION -- The movement of free water through soil.

PERIPHERY -- Circumference or perimeter of a circle, ellipse, pipe-arch, or other closed curvilinear figure.

PERMEABILITY -- A measure of the rate or volume of flow of water through a soil.

PILE, BEARING -- A member driven or jetted into the ground and deriving its support from the underlying strata and/or by the friction of the ground on its surface. (See also sheeting.)

PONDING -- Jetting or the use of water to hasten the settlement of an embankment; requires the judgment of a soils engineer. In hydraulics, ponding refers to water backed up in a channel or ditch as the result of a culvert of inadequate capacity or design to permit the water to flow unrestricted.

PRECIPITATION -- Process by which water in liquid or solid state (rain, sleet, snow) is discharged from the atmosphere upon a land or water surface.

RAINFALL (R) -- Precipitation in the form of water (usage includes snow and hail), generally expressed in inches per hour.

RETAINING WALL -- A wall for sustaining the pressure of earth or filling deposited behind it.

RIPRAP -- Rough stone of various sizes placed compactly or irregularly to prevent scour by water or debris.

ROADWAY (highway) - Portion of the highway included between the outside lines of gutters or side ditches, including all slopes, ditches, channels, and appurtenances necessary for proper drainage, protection, and use.

ROADWAY (railway) -- That part of the right of way prepared to receive the track. (During construction, the roadway is often referred to as the "grade.")

ROUGHNESS COEFFICIENT (n) -- A factor in flow formulas representing the effect of channel (or conduit) roughness upon energy losses in the flowing water.

RUNOFF -- That part of precipitation carried off from the surface of the area upon which it falls. Also, the rate of surface discharge of the above. That part of precipitation reaching a stream, drain, or sewer.

RUNOFF COEFFICIENT -- The percentage of rainfall on a given area that flows off as free water.

SEEPAGE -- Water escaping through or emerging from the ground along some rather extensive line or surface, as contrasted with a spring, the water of which emerges from a single spot.

SHAFT -- A pit or well sunk from the ground surface into a tunnel for the purpose of furnishing ventilation or access to the tunnel.

SHEETING -- A wall of metal plates or wood planking to keep out water or soft or runny materials.

SIPHON (inverted) -- A conduit or culvert with a U- or V-shaped grade line to permit it to pass under an intersecting roadway, stream, or other obstruction.

SLIDE -- Movement of a part of the earth under the force of gravity.

SPAN -- Horizontal distance between supports, or maximum inside distance between the sidewalls of culverts.

SPILLWAY -- A low-level passage serving a dam or reservoir through which surplus water may be discharged; usually an open ditch around the end of a dam, a gateway, or a pipe in a dam.

SPILLWAY -- An outlet pipe, flume, or channel serving to discharge water from a ditch, ditch check, gutter, or embankment protector.

SPRING -- A flow of subsurface water emerging from a limited area.

STRUCTURAL PLATE -- Deeply corrugated steel plates or sheets, bolted together to form large pipes, pipe-arches, arches, and other structures.

SUBDRAIN -- A pervious backfilled trench containing a pipe with perforations or open joints for the purpose of intercepting ground water or seepage.

SUBGRADE -- The surface of a portion of the roadbed on which paving, railroad track ballast, or other structure is placed.

SUBSURFACE DRAINAGE -- Removal of free water from the various structural components of the pavement or the surrounding soil.

SURFACE DRAINAGE -- Collection and removal of water from the surface of the road and the ground.

TAILWATER -- The water just downstream from a structure.

THREADING -- The process of installing a slightly smaller pipe or arch within a failing drainage structure.

TOE DRAIN -- A subdrain installed near the downstream toe of a dam or levee to intercept seepage.

UNDERDRAIN -- A perforated or porous-walled pipe placed with suitable pervious backfill beneath the ground surface to collect and carry away underground water.

WALE -- Guide or brace of steel or timber used in trenches and other construction.

WATER TABLE -- The upper limit of the portion of ground wholly saturated with water.

WATERSHED -- Region or area contributing to the supply of a stream or lake; drainage area, drainage basin, catchment area.

WETTED PERIMETER -- The length of the wetted contact between the water prism and the containing conduit (measured along a plane at right angles to the conduit).