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VIDEO EVALUATION OF HIGHWAY DRAINAGE SYSTEMS

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DISCLAIMER

ABSTRACT

Since 1978, the concept of longitudinal edge drains along Iowa primary and interstate highways has been accepted as a cost effective way of prolonging pavement life. Edge drain installations increased over the years since 1978 reaching a total of nearly 3,000 miles by 1989. With so many miles of edge drain installed, the development of a system for inspection and evaluation of the drains became essential. Equipment was purchased to evaluate 4 inch diameter and geocomposite edge drains.

Initial evaluations at various sites supported the need for a post construction inspection program to ensure that edge drain installations were in accord with plans and specifications.

Information disclosed by video inspections in edge drains and in culverts was compiled on videotape to be used as an informative tool for personnel in the design, construction and maintenance departments.

Video evaluations have influenced changes in maintenance, design and construction inspection for highway drainage systems in Iowa.

INTRODUCTION

Longitudinal edge drains were determined to be cost effective in removal of underslab moisture and prevention of premature pavement failures by the Iowa Department of Transportation. Prior to 1978 a minimal amount of longitudinal edge drain was installed in severe moisture problem areas.

In 1978, approximately 167,000 feet of 4 inch diameter longitudinal drain was installed along primary and interstate highways in Iowa. Since then, the annual installation has increased to a peak of approximately 3.5 million feet in 1988 (Figure 1). By 1989, a total of over 14 million feet of longitudinal edge drain was installed (Figure 2).

The average cost for installation of edge drains has decreased, in general, since 1987. Some cost fluctuations were due to changes in specifications. The average cost per foot installed over the years is shown in Figure 3 with a current cost of approximately $4.00.

Even though a very large amount of edge drain was in place by 1989 (Table 1), there was no inspection program or positive method to evaluate the condition of drains other than the visual inspection of the outlets.

OBJECTIVE

The objective of this report was to describe the benefit of a video evaluation of highway drainage systems and to present the results of the evaluation.

HISTORY OF EDGE DRAINS IN IOWA

An initial 1978 edge drain installation was placed as a rehabilitation effort for 28 miles of deteriorating 10 inch portland cement concrete (PCC) pavement on I-80 in Poweshiek County. At that time, this roadway carried approximately 6500 heavy trucks per day and pavement pumping was an extreme problem. The drain design used a 6 inch polyethylene slotted pipe placed at the pavement edge, in a 24 inch deep trench measured from the top of the pavement. Slot size and porous backfill were designed according to Federal Highway Administration implementation package 76-9. Filter criteria assumed a sandy silt AASHTO A-4-3 soil classification. The trench was 12 inches wide and the porous backfill was placed in contact with and 2 inches above the bottom of the pavement. A 3 inch bedding was placed under the pipe and flow lines were controlled by the grade line of existing pavement to minimize costs. The entire system was designed to be constructed using a "one pass" mechanical system. Drain outlets at approximately 1000 foot intervals were constructed using earth backfill and metal pipe aprons.

This drain system rapidly developed problems. Considerable localized plugging of the backfill and drain pipe occurred. During the first winter, a near disastrous outlet freeze up occurred which resulted in substantial water flowing from the top of the drain trench and freezing on the pavement. To eliminate that problem, the outlets were reconstructed the following spring by placing full depth porous backfill so it would daylight on the foreslope and the metal aprons were removed. No further winter freeze up problems have occurred using this design.

The 1979 designs utilized a 30 inch trench depth for similar interstate highways and our nondestructive pavement deflection testing (Road Rater) program indicated that there was a small but significant subgrade strength improvement. Localized backfill plugging also decreased significantly. Of most significance was the discovery that most outflow was now occurring thru the porous backfill bedding and the pipe functioned only during heavy rain periods. This alleviated many concerns for poor pipe flow line control and failures due to poor construction which have been verified by excavation.

Based on the improvements from early design changes, 1981 designs increased the trench depths to 48 inches, reduced the pipe size to 4 inches and the trench width to 10 inches, as shown in Figure 4. It was discovered that subgrade strengths again increased and localized porous backfill plugging was reduced to areas of complete pavement failure. Subsequently, it was determined by excavation and laboratory testing that the material which plugged the backfill consisted primarily of cement dust. It was typical to find less than 10% clay in these extracted fines. This meant that permeability in excess of 200 feet per day remained and that the plugging material would flush through the system after the pavement problem was corrected. It also proved that the system could accommodate recycled crushed PCC and provided the emphasis for the development of the present drainable base system which uses crushed recycled PCC almost exclusively.

The deeper drain trench made continual maintenance inspection necessary and the Maintenance Department responded by establishing an annual inspection policy for all drain outlets. A Standard Road Plan for various types of installations of longitudinal subdrains is shown in Figure 5.

During 1985, there were numerous plugging problems on an interstate project which had been surface corrected by diamond grinding. Investigation revealed that cement fines were again the problem and they were present in sufficient quantities to plug the pipe as well as the porous backfill. This problem was solved by retrofitting additional outlets at 400 to 500 foot spacing compared to the 1000 feet maximum as used originally. The water would then wash the fines out of the drains as verified by recent video inspections. Design policy was changed to require an outlet spacing of 500 feet for all grades less than 2% and again changed during 1988 to require a 500 foot spacing for all outlets.

The 1989 video inspections soon showed that much of the outlet problem was caused by disconnected "Y" pipe couplers at the main line outlet junction. It also showed us that fines accumulation in the pipe was practically nonexistent even when the pipe was completely ponded, separated or blocked by porous backfill aggregate. Although numerous sites had been excavated in the past, these conditions had not been readily identifiable until the camera equipment became available. Design changes have been made to eliminate the outlet coupler and the standard deep drain has been raised to 42 inches to assure that the outlet occurs above the ditch bottom.

Although numerous changes have been required to improve system performance, the original implementation package design for porous backfill and pipe slot design has performed satisfactorily under all conditions and has provided the porous aggregate alternative drainage necessary for long term highway edge drain operation.

VIDEO INSPECTION PROJECT INITIATION

From 1978 through 1988, the Iowa Department of Transportation installed, under contract, approximately 12 million feet of longitudinal edge drain along primary and interstate highways.

In areas where no subgrade related problems were present, subdrains were placed on one side of the pavement only. The side of placement was determined by major traffic volume, relative low side elevation or primary water source. After construction inspection, there was no post construction evaluation or internal visual inspection of these drains. In 1989 a proposal was presented to the Highway Research Advisory Board for the Iowa Department of Transportation to initiate a research project on evaluation of edge drains.

Information was obtained from ten suppliers of evaluation equipment. Eight demonstrated their equipment in laboratory and/or field conditions. In addition, product information was obtained through contacts with organizations that were using similar video equipment for other than highway edge drain purposes. It was determined that two types of video evaluation equipment would be required to inspect the two types of Iowa edge drains. Most edge drain pipe used in Iowa is 4 inch diameter corrugated, slotted polyethylene. Three brands of geocomposite edge drain have been used experimentally since 1987 for a total installation of approximately 60,000 feet.

EQUIPMENT

For the 4 inch diameter edge drain, a camera system of 3 inch diameter or less with a cable length of 300 feet was considered desirable. The geocomposite edge drain required a camera probe of maximum 1/2 inch diameter and a minimum of 3 foot length. A video recording unit was required to record the inspections and a small portable electric generator was needed for the power supply in the field.

Several product suppliers offered equipment which met the project needs. For the 4 inch diameter drains, they offered cameras from 2 inch to 3 inch diameter on a cable which could be pushed to approximately 150 feet. Some systems used a heavy semirigid push/conductor cable to enter the drains. Other systems used a light weight flexible conductor cable in parallel with a fiberglass push rod. Either of these video camera systems was adaptable to being used for evaluation of small diameter culverts also. The mini crawler tractor mobile camera systems offered by some suppliers for deep probes were considered unsuitable for 4 inch diameter drains. The option to have color and/or black and white pictures was available. The cost with the color option was considerably more and the color camera was longer; therefore, the black and white option was selected for the larger diameter camera.

From several suppliers who offered suitable video evaluation equipment for the 4 inch diameter drain, the Cues®, Inc. Mini Scout™ system was finally selected. This system has a 2 3/4 inch diameter camera, including a headlight on a 150 foot semirigid push/conductor cable which connects to a black and white 9 inch video monitor. The system was competitively priced and well packaged for field conditions. The equipment cost with some accessories was approximately $12,000. A photo of the Cues Mini Scout video camera system and accessories is shown in Figure 6. The cost estimates for other basic video units considered for small drains started around $11,000. As options are added, such as footage counter, additional cable length, pull system, 35mm camera accessories, optional lighting head, etc., the system cost may be doubled.

For geocomposite (1 inch wide) edge drain evaluation, several sets of suitable video probe equipment were considered. For this application, the colored picture and the 50 feet of 1/2 inch diameter video probe options were preferred. The probe length is far beyond the 3 foot requirement for geocomposite edge drain evaluation. However, this probe length and diameter could also be used for entering 4 inch diameter drains when they are partially plugged, such that the 2 3/4 inch Cues camera cannot pass. A 50 foot video probe with an articulating tip was selected so that the equipment would have more potential in adapting to other possible uses within the Iowa Department of Transportation. From several choices of suitable equipment offered for mainly geocomposite edge drain evaluation, the Welch Allyn VideoProbe™ 2000 system was selected. The cost of the equipment was approximately $45,000. A photo of the Welch Allyn VideoProbe 2000 system and accessories is shown in Figure 7.

Some accessory equipment items were purchased for the project:

- small portable electric generator
- video tape recorder
- 300 feet of 3/8 inch fiberglass push rod

The total project expenditure was approximately $60,000.

MODIFICATIONS

Cues Inc. 2 3/4 Inch Mini Scout Video Camera System

The standard Cues Mini Scout system has a 150 feet of semirigid push/conductor cable. A modification of cable length to 300 feet was made at the time of purchase. Under normal conditions, the camera could be pushed approximately 125 feet into 4 inch diameter drain before cable buckling would occur. With the addition of a 3/8 inch diameter fiberglass push rod, the camera can be pushed 300 feet into a drain.

The option to replace the semirigid push/conductor cable with a flexible conductor cable also exists. That would reduce cable weight from 100 lbs to 30 lbs and reduce friction and manpower required to push the camera. With that option, the fiberglass push rod is required.

For small culvert evaluations a skid assembly with battery powered, waterproof lights is added to the camera. This modification raises the camera off the culvert floor and the extra lights assist in illuminating culvert walls. For evaluations beyond 75 feet, a push rod consisting of 10 foot sections of 1 inch diameter poly-vinyl-chloride pipes is assembled and used to push the camera.

For bridge pier evaluation a camera position holder and a guide pole are required.

Welch Allyn VideoProbe 2000

To improve visibility of a picture on the video monitor in outdoor sunlight conditions a sun shield was required.

The addition of a 1/16 inch fiberglass push rod attached parallel to the 50 foot video probe was essential for probe rigidity. The fiberglass rod changed the length that could be utilized in 4 inch diameter drain from 15 to 50 feet

VIDEO EVALUATION/OBSERVATIONS

Initially, the sites for video evaluation of edge drains were selected on a random basis. As the research project and the use of the equipment became more publicized, requests were received for evaluation of specific problems or suspected problem areas.

Both types of equipment were transported to each evaluation site. The 2 3/4 inch diameter camera was used in most cases. When a partially buried outlet was encountered, the 1/2 inch diameter video probe was used. In some cases, the outlet pipe was found completely plugged or buried. With the porous backfill extending to the outlet, as in a french drain, water can still flow around any plugged or buried outlet pipe.

The random drain inspections did expose some problems. They were:

1. Rodent nests in the drain
2. Vertical sag - mainline/outlet
3. Polyethylene tubing and connector failures
4. Break from stretch or puncture
5. Geocomposite drain J buckling

<u>Rodent Nests</u>

Drought conditions prevailed across Iowa in 1989. With little or no water flow through the 4 inch diameter edge drain pipe, the conditions were favorable for rodent nesting in the drains. The rodent guards used were a hanging finger type and they did not prevent small rodents from entering. The video evaluations in the fall of 1989 showed rodent nests in approximately 50% of the drains inspected.

No rodent nests were encountered by video evaluations during the rainy spring of 1990. There was evidence of rodent nest material, i.e., grass and fur around the outlet of the drain. From these observations, it appears that water flows in the drains were sufficiently high or turbulent to flush out the rodent nests. A rodent guard made from 1/2 inch mesh is more suitable to prevent small rodents from passing.

Vertical Sag - Mainline/Outlet

Longitudinal edge drains are installed by a trencher/installer which follows the grade of the pavement. Drain outlets are spaced at 500 feet. Occasionally, a vertical sag full of water is observed in the mainline when no water is flowing at the outlet.

The outlet section through the shoulder is excavated by a trencher or a backhoe. Even though plans show a continual downgrade, it is common to find the shoulder outlet section high and retaining standing water in the edge drain.

Polyethylene Tubing And Connector Failures

It is often assumed that anytime the main line of an edge drain is disrupted by a coupler, Y, T, elbow or other device there is an increased risk of failure at that point. Through video evaluations, that assumption can be, to some degree, confirmed. Occasionally, a blockage from porous backfill is found inside the drain at the point of a connection.

Break From Stretch or Puncture

Excessive tension applied to the polyethylene corrugated pipe during installation can, in the worst case, cause it to tear and leave an opening. The opening is likely to allow backfill to enter and a cavity may develop above the opening. Pipe opening can also be caused by an oversized sharp stone, 3" diameter or larger, in the backfill which may puncture the pipe during compaction. The pipe could also be stretched which reduces its stiffness, resulting in collapse. If a drain is collapsed or plugged completely, the water flow will travel outside of the pipe through the porous backfill.

Geocomposite Drain J Buckling

Some brands of geocomposite drains are designed with one side being covered by only filter fabric, and therefore, quite flexible and weak under vertical load. During installation, the drain is fed downward to the bottom of the trench and is forced to bend in a vertical plane. The force causes the drain to "buckle under" along its bottom edge, leaving it in a "J" configuration as backfill is compacted beside it. Video evaluations have identified "J" buckling in soft-sided geocomposite drains.

The video evaluation equipment has been used as a post construction inspection tool in finding stretch breaks and collapsed or damaged drains. The most common video sights of special interest, in their descending order of frequency in 4" diameter plastic drain pipes were:

1. Vertical sags
2. Rodent nests (decreasing after specification change)
3. Collapse from stretch
4. Connector failures (decreasing after specification change)
5. Break from stretch
6. Puncture by oversized sharp stone

Two representative photos taken from the videotape are shown in Figures 8 and 9.

IMPROVED INSPECTION AND INSTALLATION

The use of the video evaluation equipment for post construction inspection can provide valuable information and detect problems. The internal view of an edge drain may show the drain pipe to be parted at a coupler or collapsed from being stretched. These problems could occur in a trench during installation and not be detected by an operator or inspector. Within its limits of travel, the video evaluation equipment can clearly detect some construction or material quality problems. Normally, any water found in an edge drain is quite clear, therefore, a good video picture can be obtained even under water.

The exposure of one "buried" edge drain problem through the use of video evaluation equipment increases the effort to produce quality workmanship. The end result is an overall improvement in quality of edge drain installation and performance.

Preliminary findings from edge drain evaluations demonstrated the need for post construction inspection immediately following installation for all projects. This program has been initiated in Iowa and any problems found by this "spot check" are corrected immediately by the contractor.

BENEFITS FROM RESEARCH

Video evaluation equipment applied to highway drainage systems can provide valuable information for design, construction and maintenance engineers. Through the visual feedback given by a video evaluation, some design changes have been made to improve drain performance.

The video evaluation equipment used as a post construction inspection tool has disclosed a variety of construction problems or damaged drain. The exposure of problems through the use of video evaluations provides information which can assist the construction inspector and the contractor to insure that the drains are being installed properly and will function as intended.

Maintenance personnel also found a variety of uses for video evaluation equipment. It can provide valuable information on culvert replacement requirements and answers for surface depressions or underground cavities around culverts and drains. The video camera can help find the exact location where a culvert or drain may be plugged or damaged and where excessive corrosion or joint separation has occurred. This information will help the maintenance engineer to make cost effective, intelligent decisions for repairs based on accurate visual information through the video system.

The use of the video evaluation equipment for underwater inspection of bridge piers is very limited. The visibility of the underwater view from one trial was encouraging. The water pressure limitation of the camera used (Cues Inc.) was 15 psi or approximately 35 feet of depth.

Specific benefits derived from this research in terms of exact dollars cannot be calculated. Information obtained from the video inspections and evaluations has played a part in changes in design and improvements in installation of edge drains. As a result, there is some improvement expected in the overall performance and effective life of the edge drains and in turn, extended pavement life. Evaluations of culverts, 14 inch to 30 inch diameter, have influenced maintenance and replacement decisions. It can be stated that the research project was cost effective. The video evaluation equipment has more than paid for itself through internal views and information it provided concerning highway drainage systems. Some of these views were compiled into a 10 minute videotape which is being used as an educational tool for design, construction, maintenance and inspection personnel involved in highway drainage systems.

CONCLUSIONS

The research on video evaluation of highway drainage systems supports the following conclusions:

1. The video evaluation equipment can be used as an effective tool to obtain internal views in 4 inch diameter edge drain pipes, geocomposite edge drains and small diameter culverts.

2. Information obtained through video inspection of highway drainage systems aids the design, construction and maintenance engineers with engineering decisions based upon visual observations.

3. Video evaluations of edge drains have resulted in design modifications and improved construction inspection.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the Highway Research Advisory Board for their recommendation of the research and to the Iowa Department of Transportation Highway Division for funding the project. Appreciation is also expressed to Richard Smith, Todde Folkerts and Gary Harris for their assistance with field evaluations. Kathy Davis and Todde Folkerts were very helpful in preparing the report.

TABLE TITLES

1. Summary of 4 Inch Diameter Longitudinal Subdrain Installation

TABLE 1

Summary of 4 Inch Diameter Longitudinal Subdrain Installation

Year	Qty. (ft) Installed	Ft. Installed Accumulated	$Cost/Ft Installed	Total $ Cost
1978	167,122	167,122	4.85	810,256
1979	177,273	344,395	5.88	1,043,176
1980	95,289	439,684	6.08	579,119
1981	178,669	618,353	5.05	903,118
1982	441,959	1,060,312	4.65	2,053,779
1983	763,556	1,823,868	5.14	3,924,366
1984	503,126	2,326,994	5.24	2,638,368
1985	1,234,213	3,561,207	4.26	5,263,676
1986	2,676,745	6,237,952	4.04	10,824,118
1987	2,686,218	8,924,170	3.50	9,410,118
1988	3,452,414	12,376,584	4.14	14,294,100
1989	1,884,281	14,260,865	3.58	6,751,087

Total Accumulated Feet Installed	14,260,865.00
Average Cost per Foot	$4.10
	=============
Total Cost	$58,495,281.00

FIGURE CAPTIONS

FIGURE 1
ANNUAL FOUR INCH DRAIN INSTALLATION

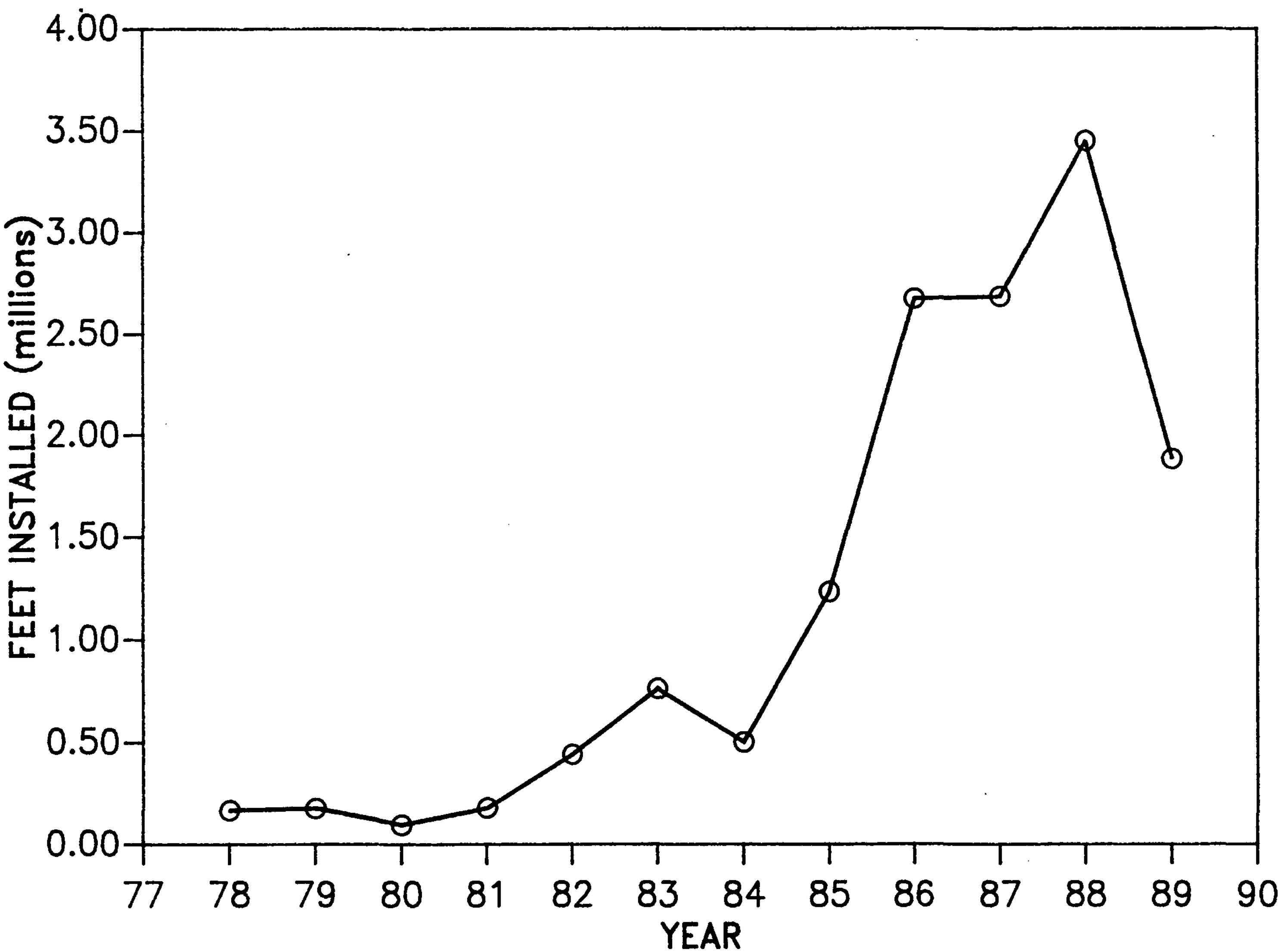


FIGURE 2
ACCUMULATED FEET OF 4" DIAMETER DRAIN INSTALLED

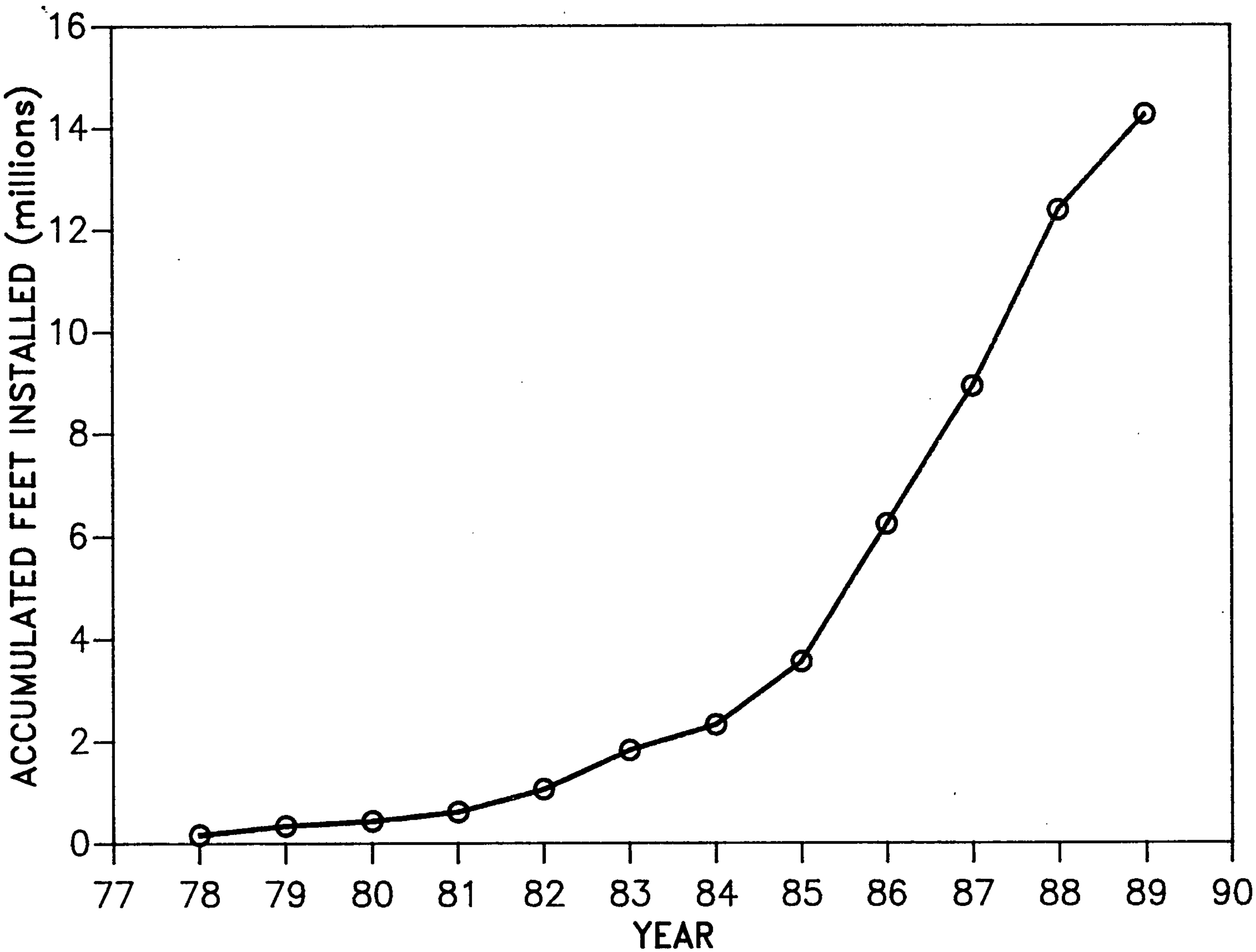
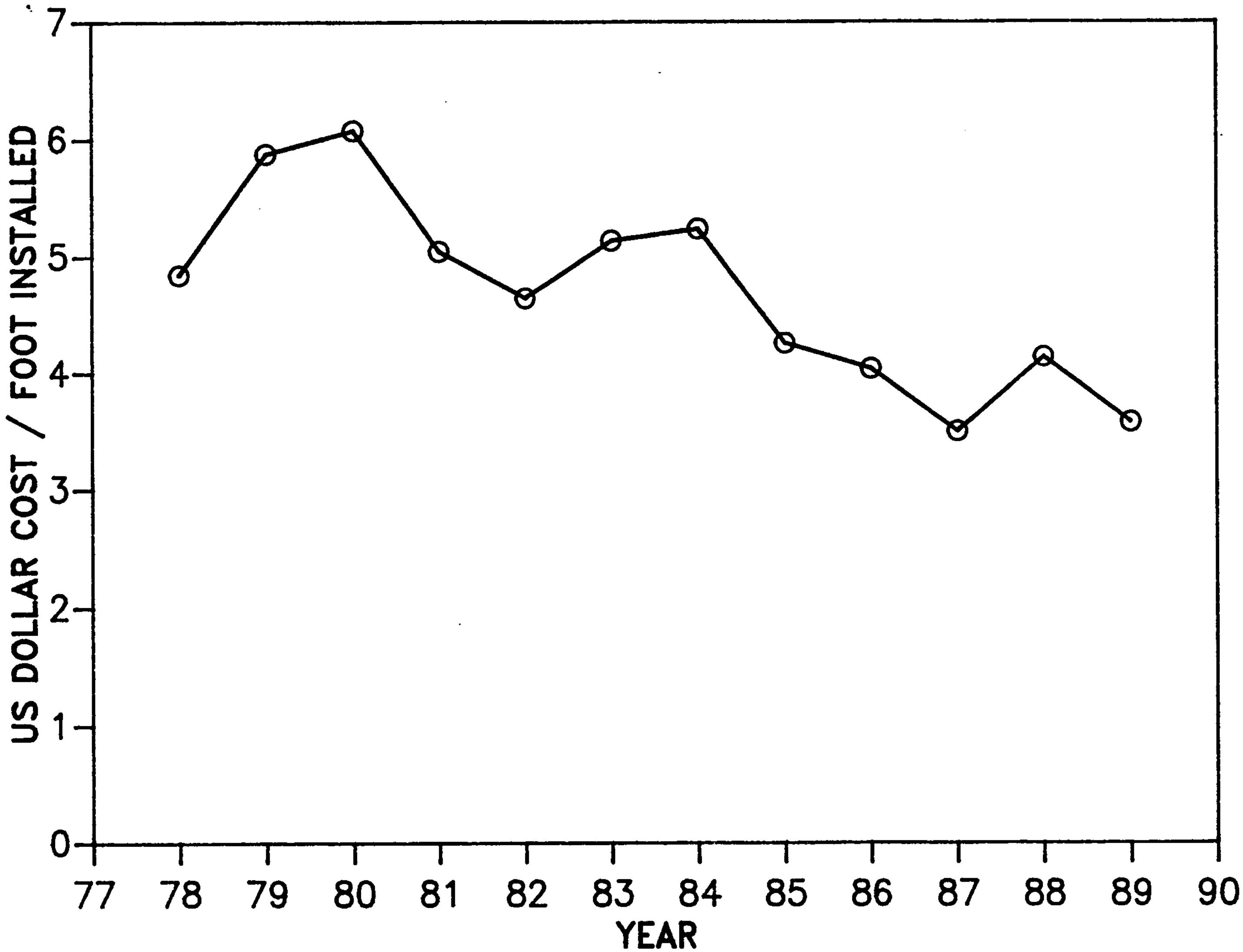


FIGURE 3
AVERAGE COST OF EDGE DRAINS



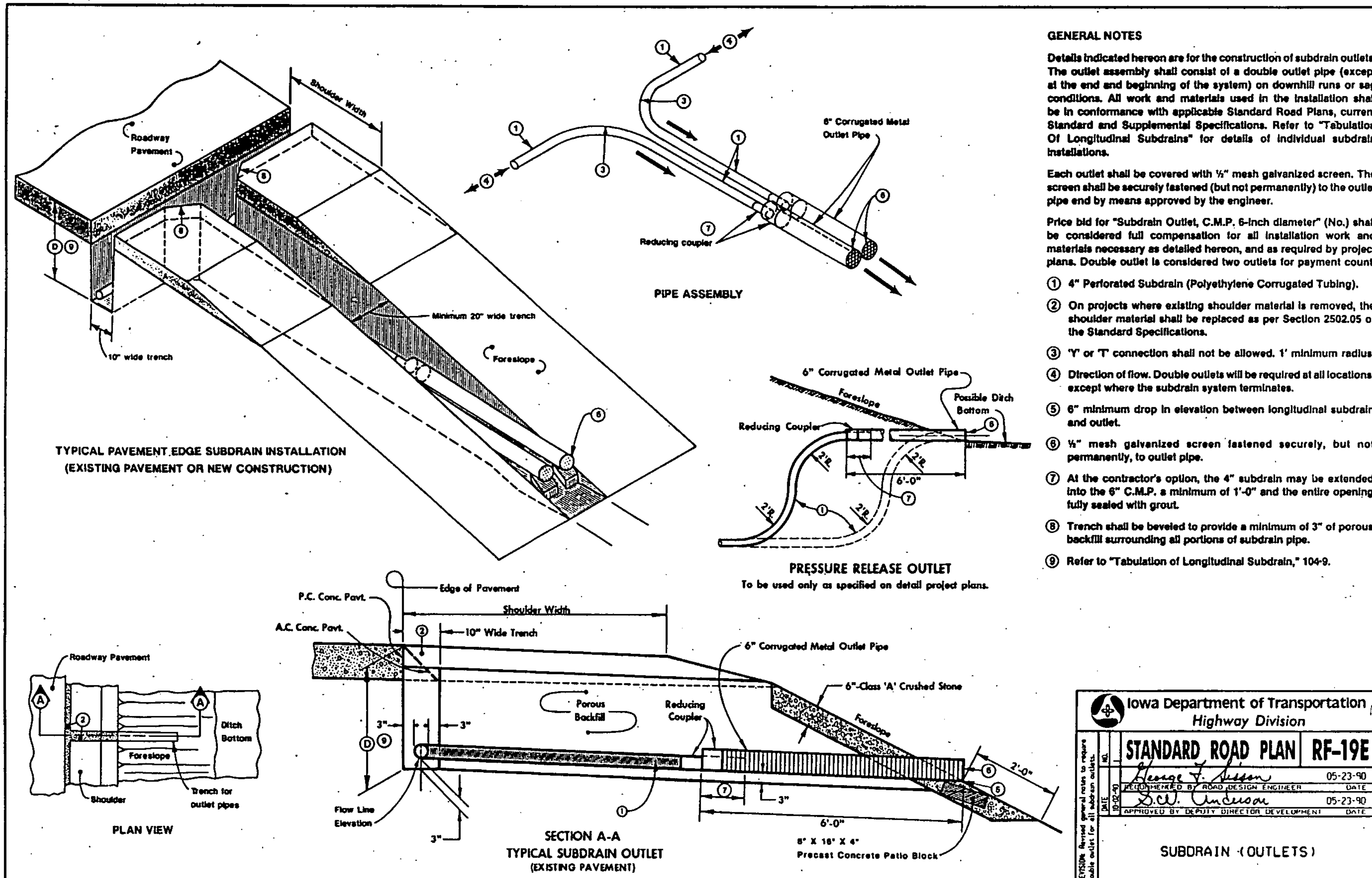


Figure 4
Standard Road Plan for Subdrain Outlets

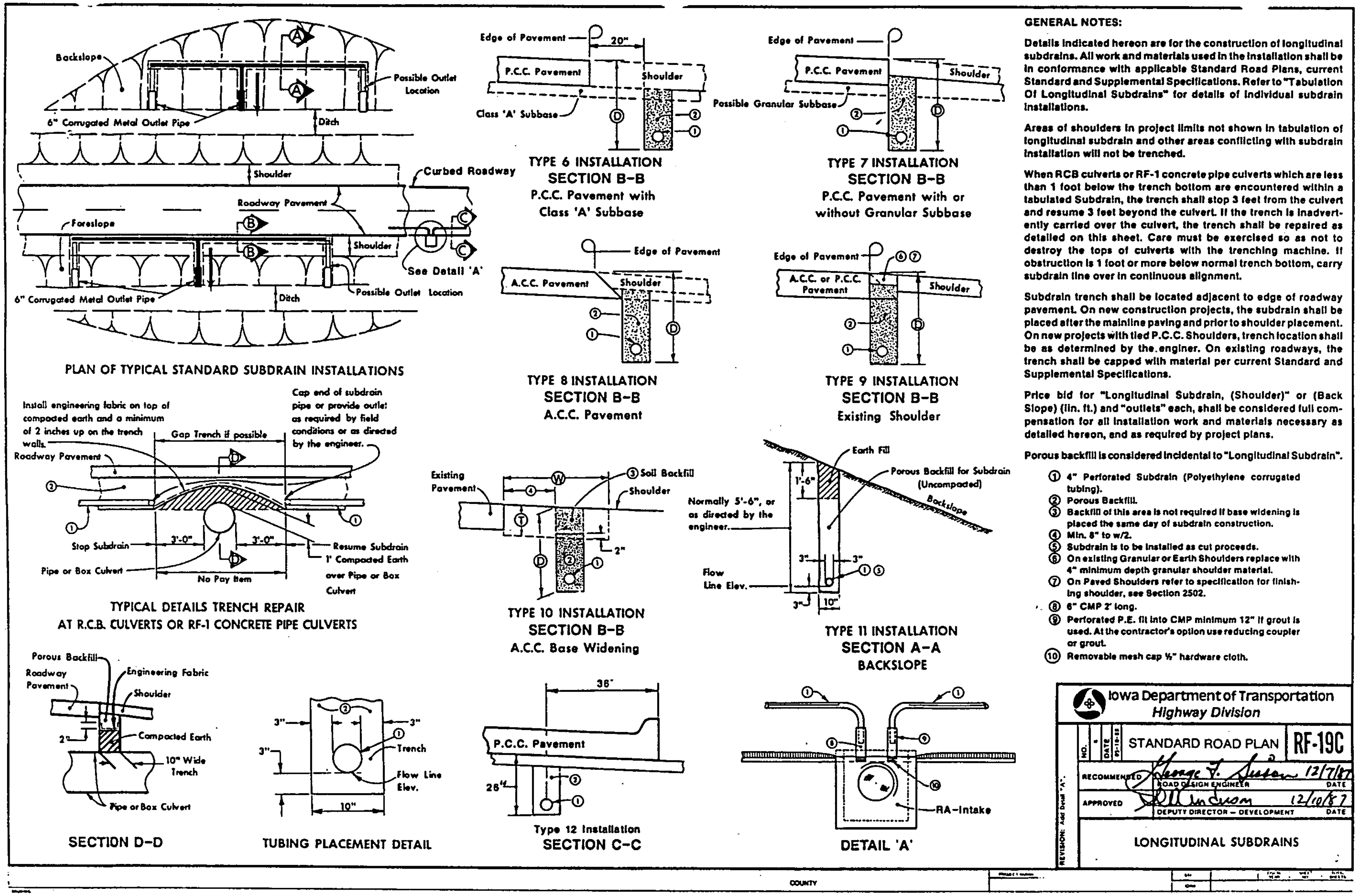
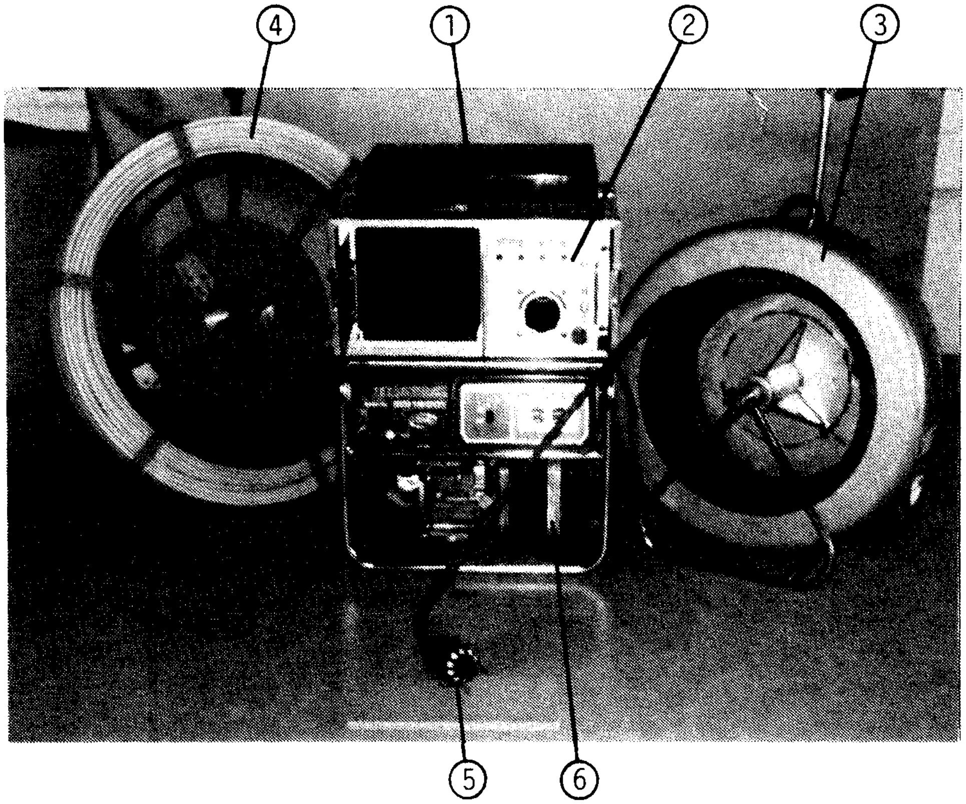
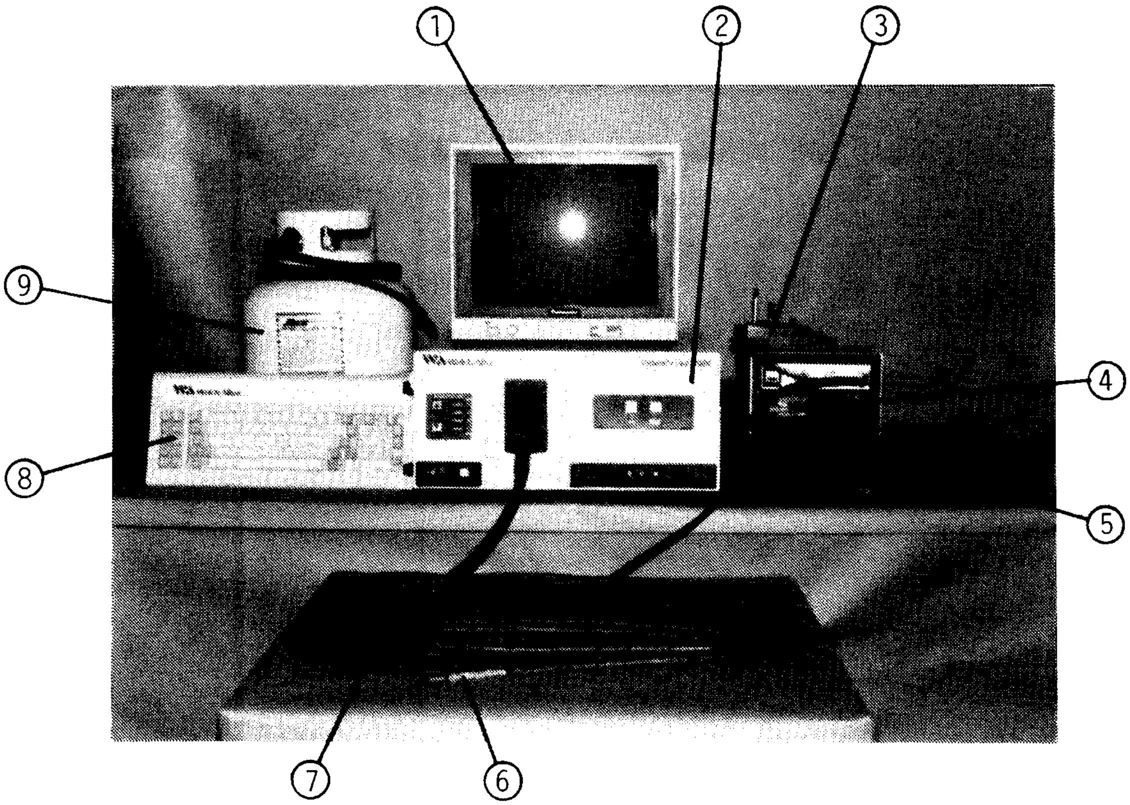


Figure 5
Standard Road Plan for Longitudinal Subdrains



1. Video Recorder
2. Cues Monitor/Power Control
3. Cues push/conductor cable with camera and storage reel (300')
4. Fiberglass push rod 3/8" dia. and storage cage (300')
5. Cues Camera
6. Portable Generator

Figure 6: Cues® Mini Scout™ Video Camera System and Accessories



1. Monitor
2. Videoprocessor
3. Articulation Control Stick
4. Pneumatic Controller
5. Video Recorder
6. Articulating VideoProbe
7. VideoProbe Cable 1/2" Dia. (50')
8. Data Input Keyboard
9. Air Supply for Camera Head Articulation

Figure 7: Welch Allyn VideoProbe™ 2000 System and Accessories

Figure 8

Rodent Nests in Subdrains

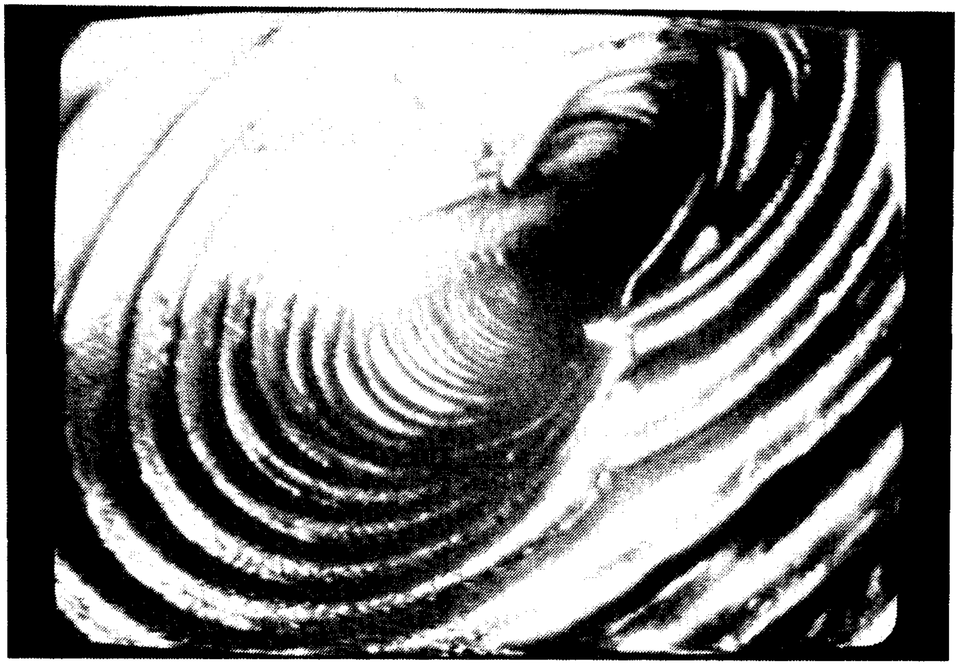


Figure 9

Collapsed Subdrain