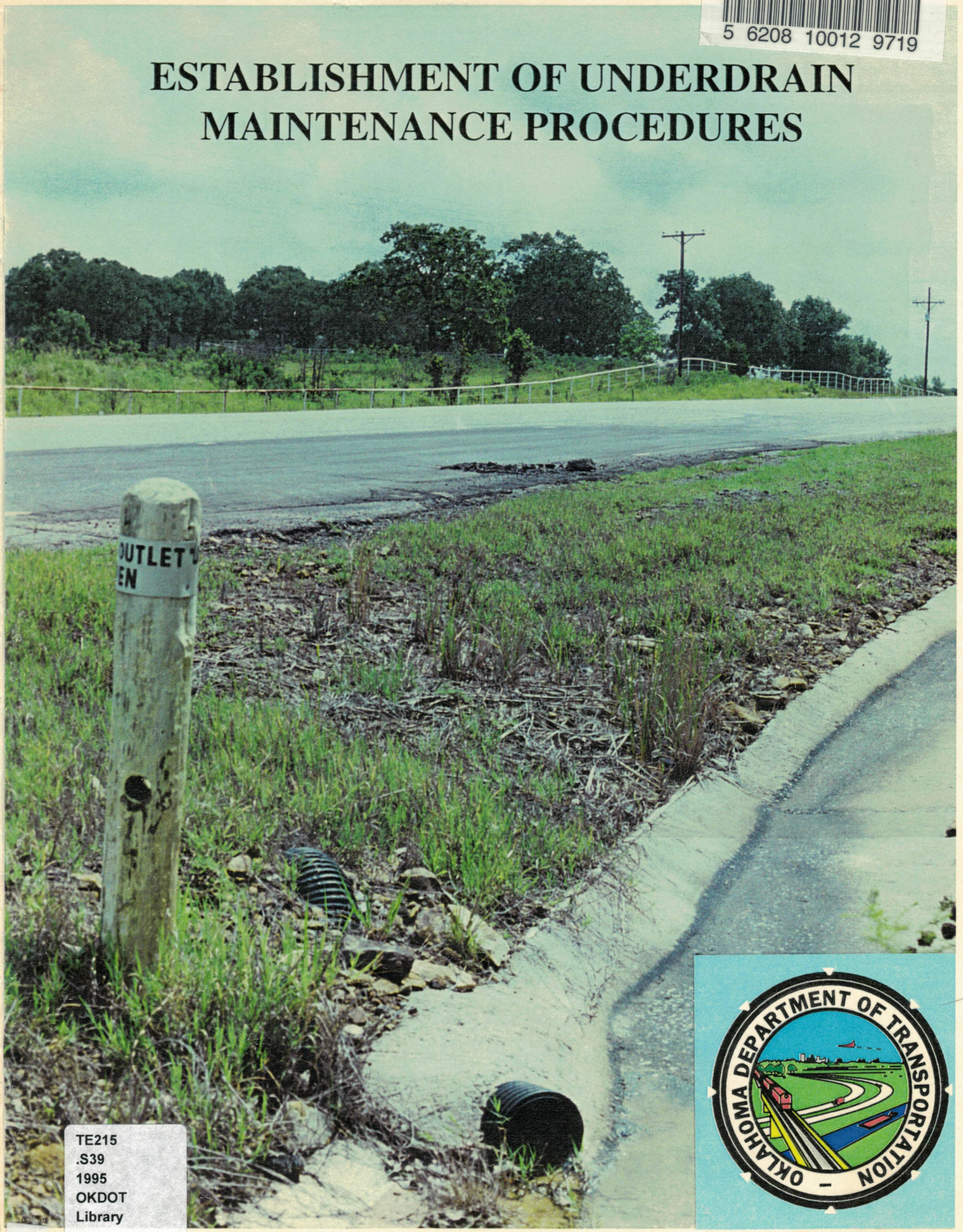
ESTABLISHMENT OF UNDERDRAIN MAINTENANCE PROCEDURES



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16. ABSTRACT

Project #2183 analized the condition of underdrains and developed a method of classifying, maintaining, and, when necessary, replacing underdrain outlets.

The project encompassed every region of Oklahoma and many different climates and geological conditions. The most common seepage conditions occur where a permeable geologic layer, such as sandstone, overlies a relatively impermeable layer, like shale.

Various drain pipe types and sizes were included in the original survey. The outlet maintenance demonstrations were concentrated in those regions where the procedures will be most often applied.

Equipment specially procured for the project included a pipe inspection video package, and a high pressure rodding system (jetter).

The primary focus is on the maintenance of pipe underdrains, although some recommendations regarding design and installation are included.

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The opinions, findings, and conclusions expressed in this report are those of the author(s) and not necessarily those of the Oklahoma Department of Transportation.

ESTABLISHMENT OF UNDERDRAIN MAINTENANCE PROCEDURES

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And especially Curt Hayes, who, in his preponderate perspicacity, allowed me the freedom to choose my own path and, thereby, learn from my own mistakes.

MOVE TO P. BEFORE ToC

INTRODUCTION

The destructive effects of ground water on a roadway system have been documented for many years. (1,2,3) We have approached the problem from a variety of perspectives but the most promising tactic seems to be the most obvious one, i.e., removing the water. Centuries of trial & error and, more recently, research & development, have led to the widespread use of underdrains for lowering ground water levels in roadway cuts. However, underdrain *maintenance* has been conspicuously absent from the typical drainage management plan.

The Oklahoma Department of Transportation spends millions of dollars on pavement rehabilitation each year. Because of underdrain failure, many of these projects are initiated early in the design life of the roadway. And, without a fully functioning underdrain, the rehabilitation is doomed to early failure.

It is safe to assume that the problem lies not in conception but rather in implementation. Therefore, the primary focus of this report is on the installation and maintenance of pipe underdrains, although some recommendations regarding design are included.

The project encompassed every region of Oklahoma and many different climates and soil types were represented. Various drain pipe types and sizes were included in the original survey, but the actual demonstrations were concentrated in those areas where the maintenance procedures will be most often applied.

GEOLOGY

The presence of ground water in a roadway system can stem from a variety of geological conditions. Ten of the more commonly encountered seepage conditions are represented by the cross sections illustrated in Figure 1.

These conditions are comprised of a porous, permeable layer of material overlying a denser, less permeable layer. In Oklahoma, the geology ranges from predominately Pennsylvanian in the east, characterized by thick layers of hardened sandstone and limestone, to predominately Permian in the west, characterized by red clay and soft sandstone. (4)

Annual precipitation, the source of virtually all of Oklahoma's ground water, ranges from 142 cm (56 in) in the east to about 46 cm (18 in) in the west. The conditions in the east are far more favorable for high water tables and one would expect to find a much higher concentration of underdrains in that

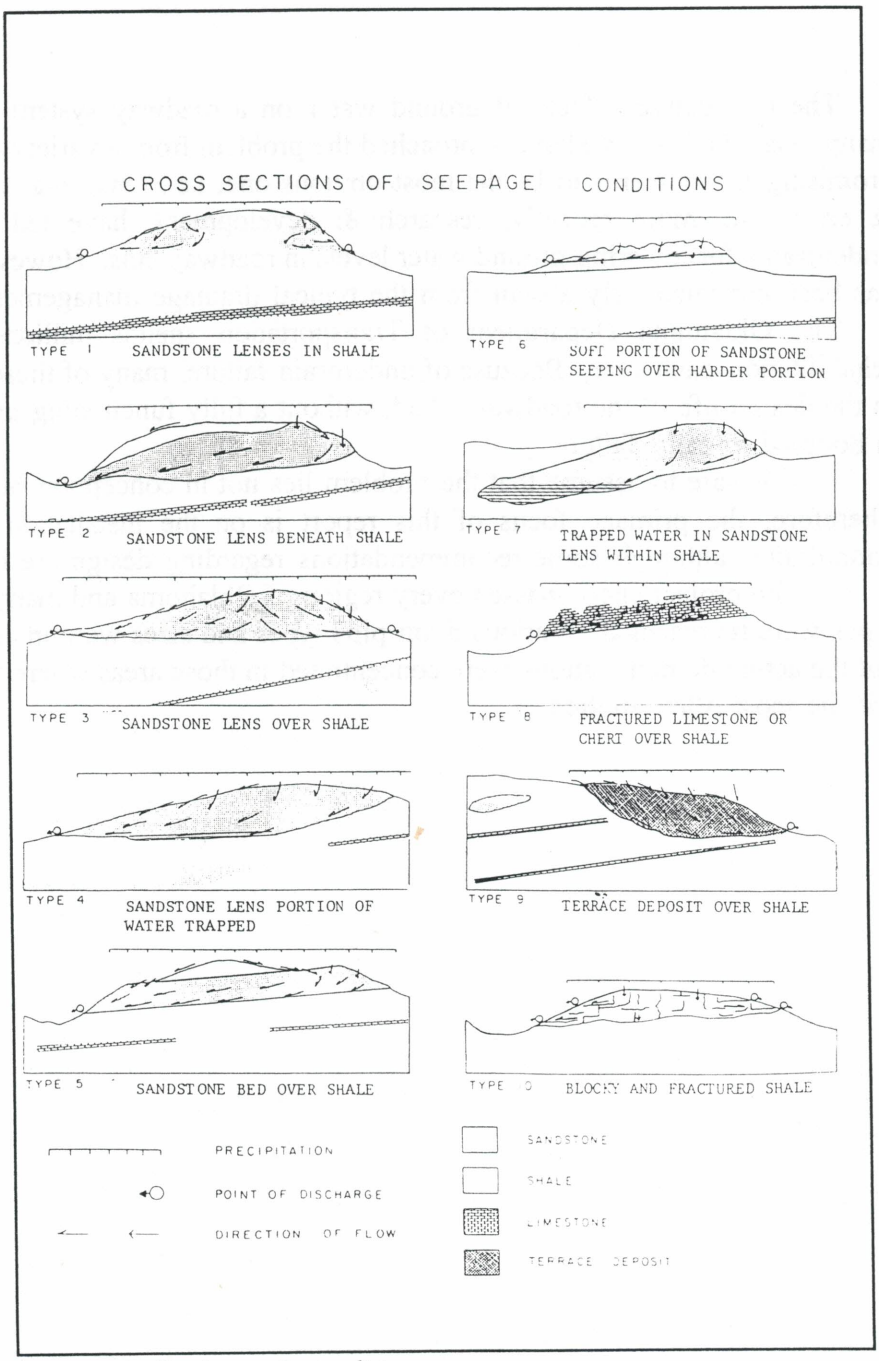


Figure 1 *Geological conditions.*

region, which is indeed the case. In fact, the original survey of one hundred underdrains included only two in the westernmost divisions.

High ground water tables may occur in isolated pockets or vast expanses. They are generally seasonal in nature but can be present throughout the year. Whatever their nature, they have a significant effect on roadways, all of which are designed to function at relatively dry and constant moisture levels.

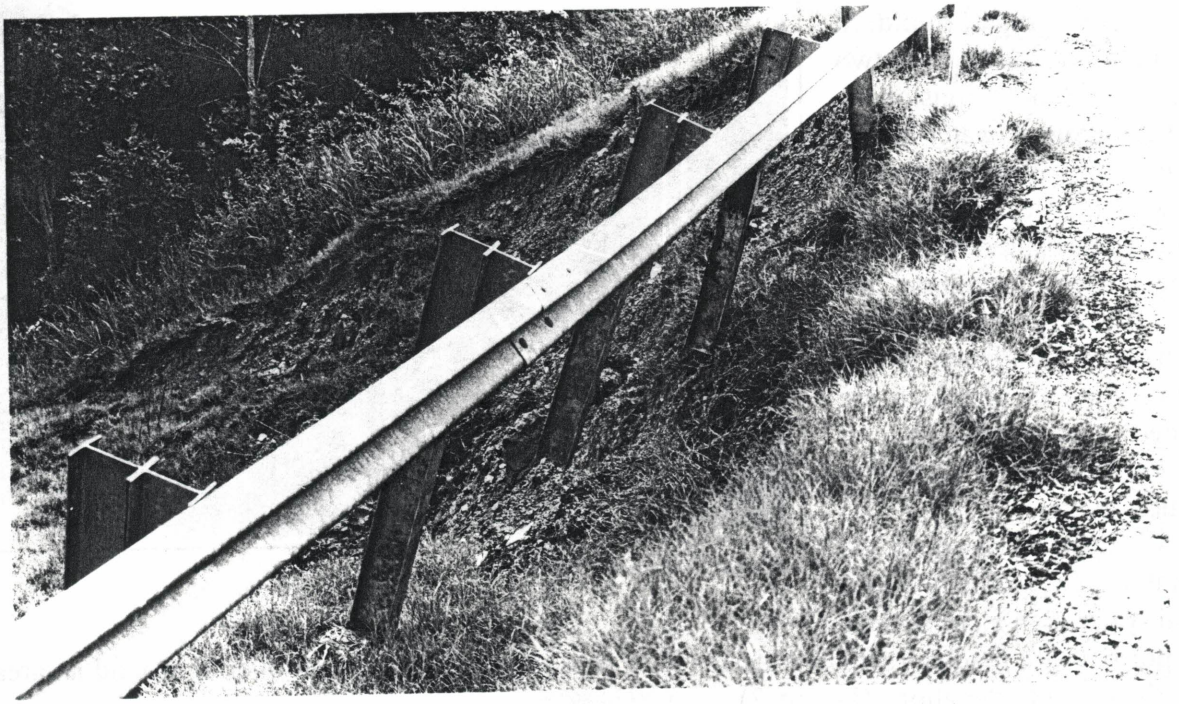
Figure 2 *Cut section.*

The most likely place to encounter a problem with ground water is in a *cut section* - that portion of a roadway which is designed to pass *through*, rather than over or around an area of relatively high elevation. (Figure 2)

When a cut section passes through the upper level of a water table, the water can permeate the sub-base, base, and in some cases, the pavement itself.

The devastating toll exacted by the cyclical and/or continuous presence of water is illustrated in Figure 3. This kind of damage is attributable to such water related processes as pumping, stripping, and erosion of the aggregate fines essential to the strength and integrity of bases and pavements.

Figure 3 *Water related pavement damage.*



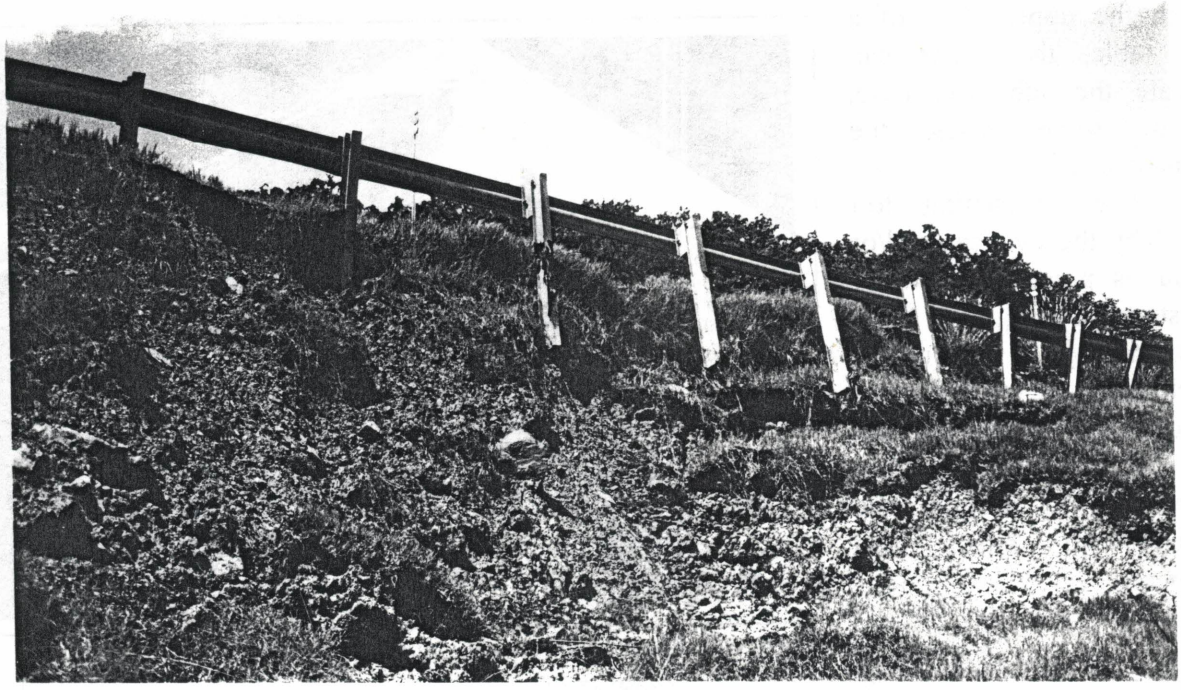


Figure 4 *Landslide.*

If embankments are very steep, excessive moisture may cause the soil material to shear. These troublesome and dangerous *landslides* (Figure 4) are all too common in mountainous terrain.

Whether the problem is deteriorating pavements or sliding embankments, the solution is clearly the removal of the offending water. This arduous task must be accomplished through the development and implementation of a dependable, economical system of internal *drainage*.

DRAINAGE SYSTEMS

The problem of removing unwanted ground water has been grappled with for centuries. The first widely accepted drainage system was the french drain, (Figure 5) a simple but useful design that remains the best choice for many applications even today. The design for the french drain has many variations but the essential elements include a sloping ditch and a layer of drainable (skip graded) aggregate. The water is carried through the ditch to a suitable point of outlet.

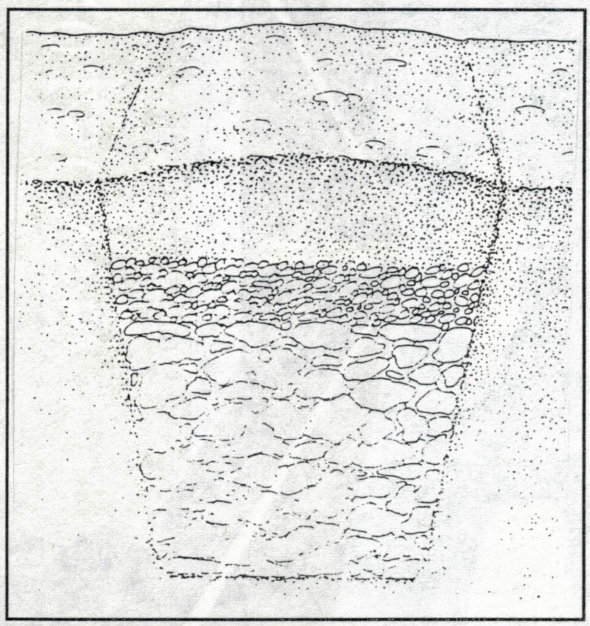


Figure 5 *French drain.*

The next step in the evolution of drains was the introduction of *conduit,* a cylindrical device which carried the water in confinement. The advancements made in design and materials for drainage conduits were varied and many. In May of 1896, Watson and Simpson were granted the first patent for corrugated metal pipe (CMP). The first *perforated* CMP was used by the Southern Railway in 1916. Research and development led to the strong, long lasting metal pipe presently in use throughout the country.

Although metal pipe still has many applications, the need for more economical, corrosion resistant pipe has led to the widespread use of petroleum based materials, i.e., high density polyethylene (HDPE), and polyvinyl chloride (PVC).

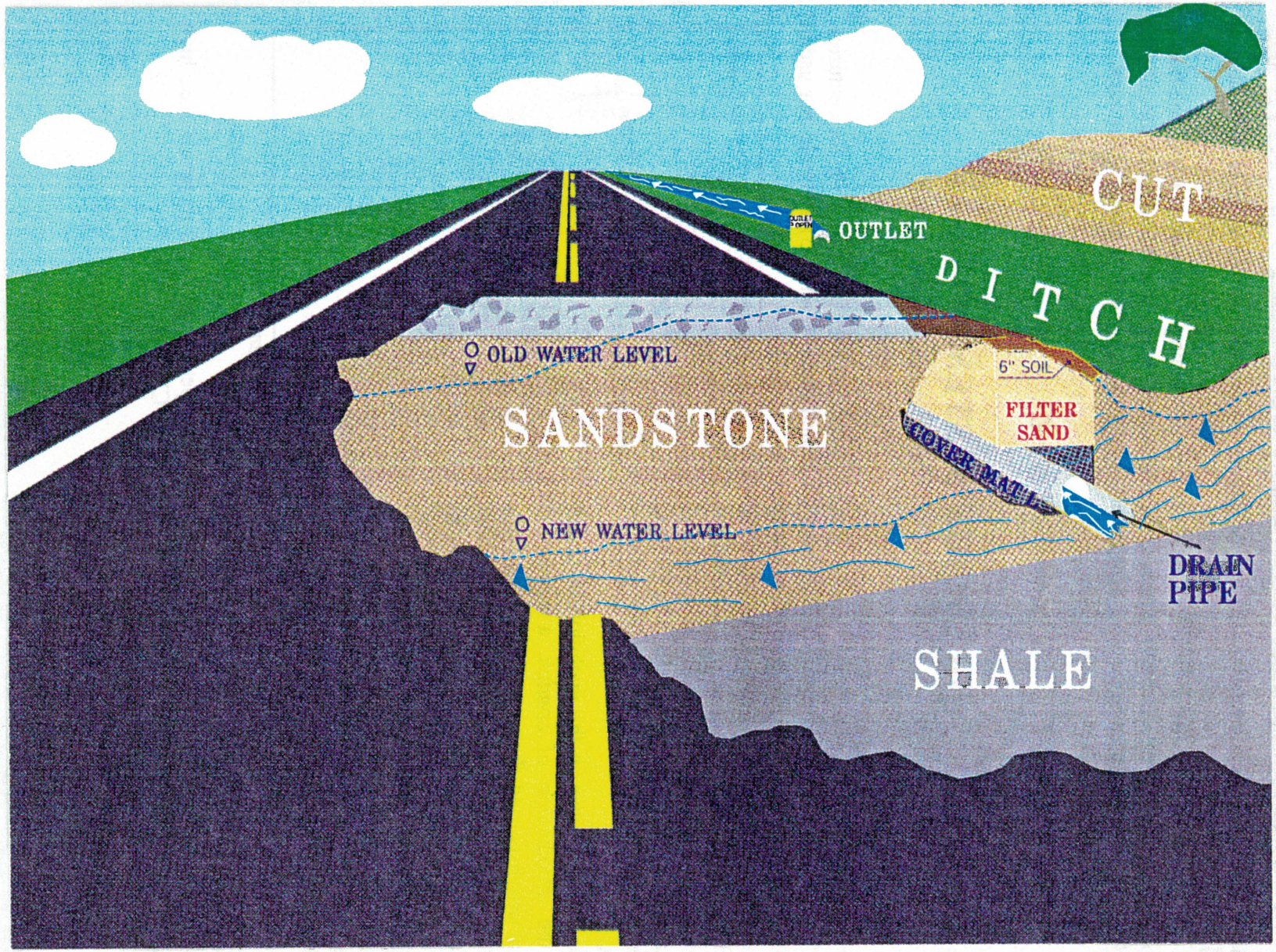


Figure 6 *Cross-section of underdrain.*

The Oklahoma Department of Transportation (ODOT) specifies either metal or plastic pipe for use in underdrains. The metal pipe may be either corrugated galvanized steel (CGMP) or corrugated aluminum alloy, and the plastic either HDPE or PVC. The main conduit must be perforated so as to allow adequate infiltration of ground water per ASSHTO M 252 (5).

The pipe is buried in a trench, usually 1.5 m (5 ft) deep, running parallel to the roadway. It is surrounded by an aggregate meeting standard underdrain cover material specifications spelled out in ODOTs Standard Specifications for Highway Construction. (Detail sheet in appendix A) The trench is then filled with filter sand to within 15 cm (6 in) of the top and capped with a layer of relatively impervious material. (Photos in appendix B) An installed underdrain is represented in the cross-sectional view on the opposite page. The width of the excavation is exaggerated for illustrative purposes.

The simplicity of their design and installation has made underdrains seem almost foolproof. However, ODOT personnel began to notice a troubling incidence of premature pavement failures even where underdrains had been installed. These observations led to the initiation of that research project which is the subject of this report.

CONDITION SURVEY

Ascertaining the condition of our underdrains involved;

◇ Locating underdrains
◇ Inspecting outlets and conduit interiors
◇ Classifying sites according to preestablished criteria

LOCATIONS

Locating underdrain sites proved to be more of a challenge than was initially anticipated. When maintenance engineers were asked to provide a record of underdrain installation sites, it was discovered that the records had been pooled with the locations of edgedrains, culverts, and junction boxes. This meant that each location had to be visited in order to determine which structure was actually present. So, alternatively, a more specific record was sought.

Underdrains are installed at the discretion of the Resident Engineer and a major part of their decision making process usually includes a *seepage investigation*. If the results indicate the presence of ground water, the investigator will recommend an underdrain installation within the affected extent. The Resident Engineer's decision is not made a part of the official record but the results of the seepage investigations are kept on file. It was this file that served as a guide for locating the one hundred sites selected for the project.

Figure 7 displays the apportionment of seepage investigations among the Field Divisions. The bar graph in the upper right corner depicts the number of investigations conducted in each Division over a fifteen year period. The block map (lower right) illustrates their increasing occurrence from west to east. The data was compiled from a total of 234 seepage investigations conducted from 1977 to 1992.

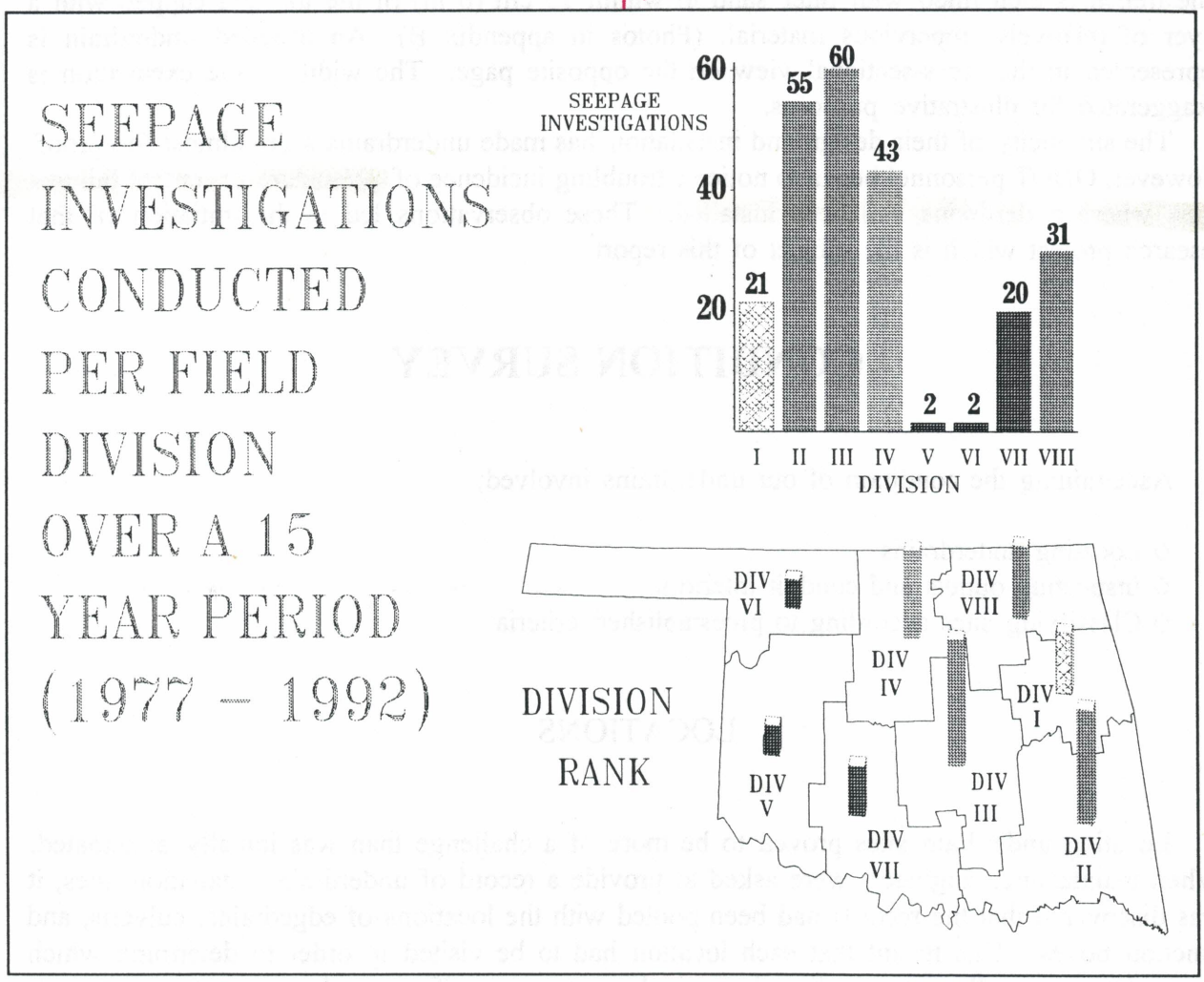


Figure 7 *Apportionment of seepage investigations.*

This distribution was reflected in the one hundred sites chosen for the condition survey. One additional site was eventually selected making the total 101. As was expected, the majority of underdrains were found in the eastern half of the state where the annual rainfall is relatively high. Figure 8 shows the distribution of sites by Field Division. Divisions V and VI, in the more arid western portion of the state, were each represented by only one site, a sum total of just two

percent of the original one hundred. Divisions III, IV, and VII, in the central part of the state, were represented by fifty sites. And Divisions I, II, and VIII represented eastern Oklahoma with the remaining fifty sites.

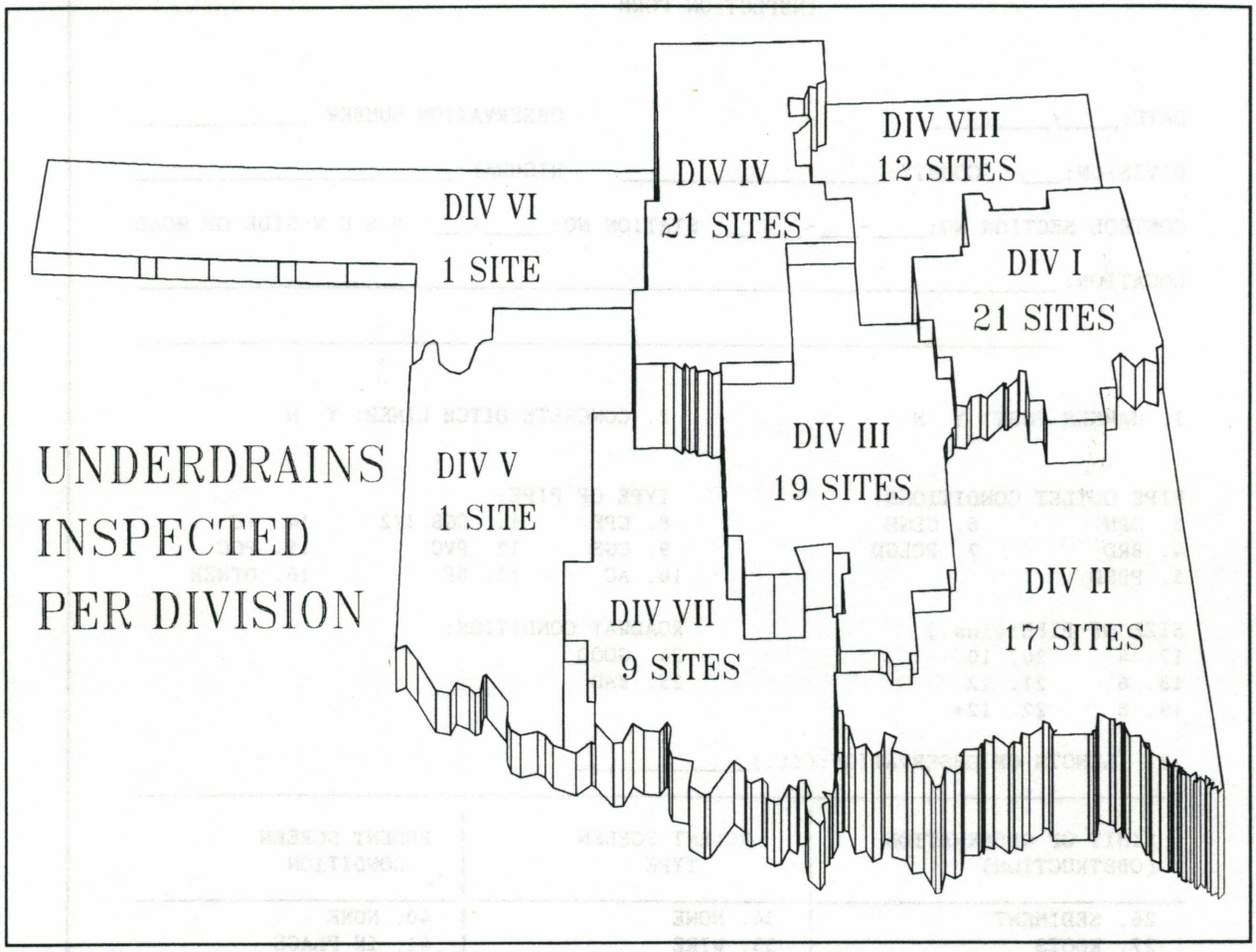


Figure 8 *Sites inspected per Field Division.*

INSPECTIONS

In order to insure uniform assessments of all sites, a form was developed and utilized in a consistent manner. All pertinent data was recorded in multiple choice and fill-in-the-blank formats on the "UNDERDRAIN CONDITION INSPECTION FORM" (Figure 9). The upper portion of the form noted the DATE, OBSERVATION NUMBER (site), and a detailed description of the LOCATION.

The center portion listed specifics about the underdrain and its outlet, any problems encountered, and physical aspects of the design and installation. Abbreviations are interpreted in Figure 10. (Page 11)

UNDERDRAIN CONDITION

INSPECTION FORM

DATE:____/____/____ OBSERVATION NUMBER:_____

DIVISION:___ COUNTY:_____ HIGHWAY:_____

CONTROL SECTION NO:____-___-___.___ STATION NO:_____+___ N S E W SIDE OF ROAD

LOCATION:_____

_____

1. MARKER POST: Y N

2. CONCRETE DITCH LINER: Y N

PIPE OUTLET CONDITIONS:

3. OPN
4. BRD
5. PBRD
6. CLGD
7. PCLGD

TYPE OF PIPE:

8. CPE
9. CGS
10. AC
11. CGS 1/2
12. PVC
13. BF
14. VC
15. PCC
16. OTHER

SIZE OF PIPE:(ins.)

17. 4
18. 6
19. 8
20. 10
21. 12
22. 12+

ROADWAY CONDITION:

24. GOOD
25. BAD

23. LENGTH OF OBSERVATION:(ft.)_____

LIMIT OF OBSERVATION (OBSTRUCTION)	RODENT SCREEN TYPE	RODENT SCREEN CONDITION
26. SEDIMENT	34. NONE	40. NONE
27. ROOTS	35. WIRE	41. IN PLACE
28. NESTS	36. POLYETHYLENE	42. MISSING
29. COLLAPSE	37. OTHER	43. OTHER
30. COVER MATERIAL		
31. CONNECTION	HEADWALL	FLOW
32. FRICTION		
33. OTHER	38. YES 38. PCC	44. YES 45. NO
	39. NO 39. GS	
		45. _____GPM(EST.)

COMMENTS:_____

_____

_____

Figure 9 *Inspection form.*

UNDERDRAIN CONDITION

CLASS DEFINITIONS

PIPE OUTLET CONDITIONS

3. OPN-----OPEN

4. BRD-----BURIED

5. PBRD----PARTIALLY BURIED

6. CLGD----CLOGGED

7. PCLGD---PARTIALLY CLOGGED

TYPE OF PIPE

8. CPE--------CORRUGATED POLYETHYLENE

9. CGS--------CORRUGATED GALVANIZED STEEL

10. AC---------ASBESTOS CEMENT

11. CGSP 1/2---SEMICIRCULAR GALVANIZED STEEL

12. PVC--------POLYVINYL CHLORIDE

13. BF---------BITUMINOUS FIBER

14. VC---------VITRIFIED CLAY

15. PCC--------PORTLAND CEMENT CONCRETE

16. OTHER TYPE

38. PCC--------PORTLAND CEMENT CONCRETE

39. GS---------GALVANIZED STEEL

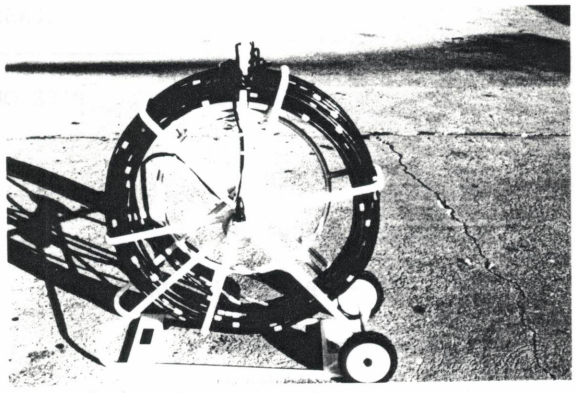
45. GPM--------GALLONS PER MINUTE

Figure 10 *Interpretation of abbreviations.*

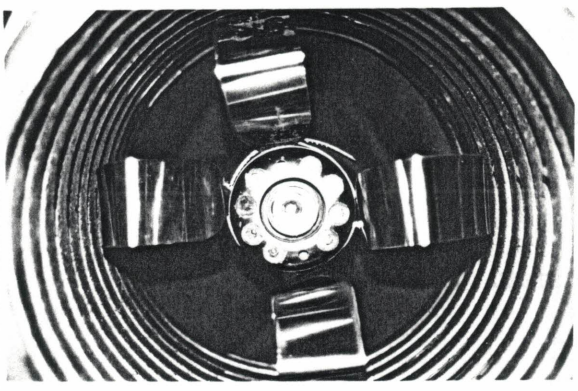
The lower portion provided the researchers with an opportunity to comment on special conditions - such as, the site's suitability for demonstrating a maintenance procedure.

The need for internal pipe examinations prompted the procurement of a televising pipe inspection system. (Figure 11) The pipe inspection package consisted of a small diameter color camera, a control unit with built-in color monitor, a VCR, and a storage reel with 46 m (150 ft) of combination TV cable and push rod. Specifications appear in appendix D.

CONTROL UNIT / MONITOR / VCR



VIDEO CABLE / PUSH ROD



CAMERA HEAD (INSIDE PIPE)

PORTABLE GENERATOR

Figure 11 *Televising pipe inspection system.*

A typical site inspection began with locating an underdrain by either recorded reference or "drive by sighting". Once found, the site was designated by number and its location recorded. The presence (or absence) of a marker post and/or ditch liner was then noted. (A post and liner appear on the front cover photo.) If the outlet condition was BURIED, an attempt was made to uncover the pipe. If the outlet could not be located within a few minutes, the inspection was terminated and the limit of obstruction logged as OTHER.

Photos of outlet conditions appear in figure 12.

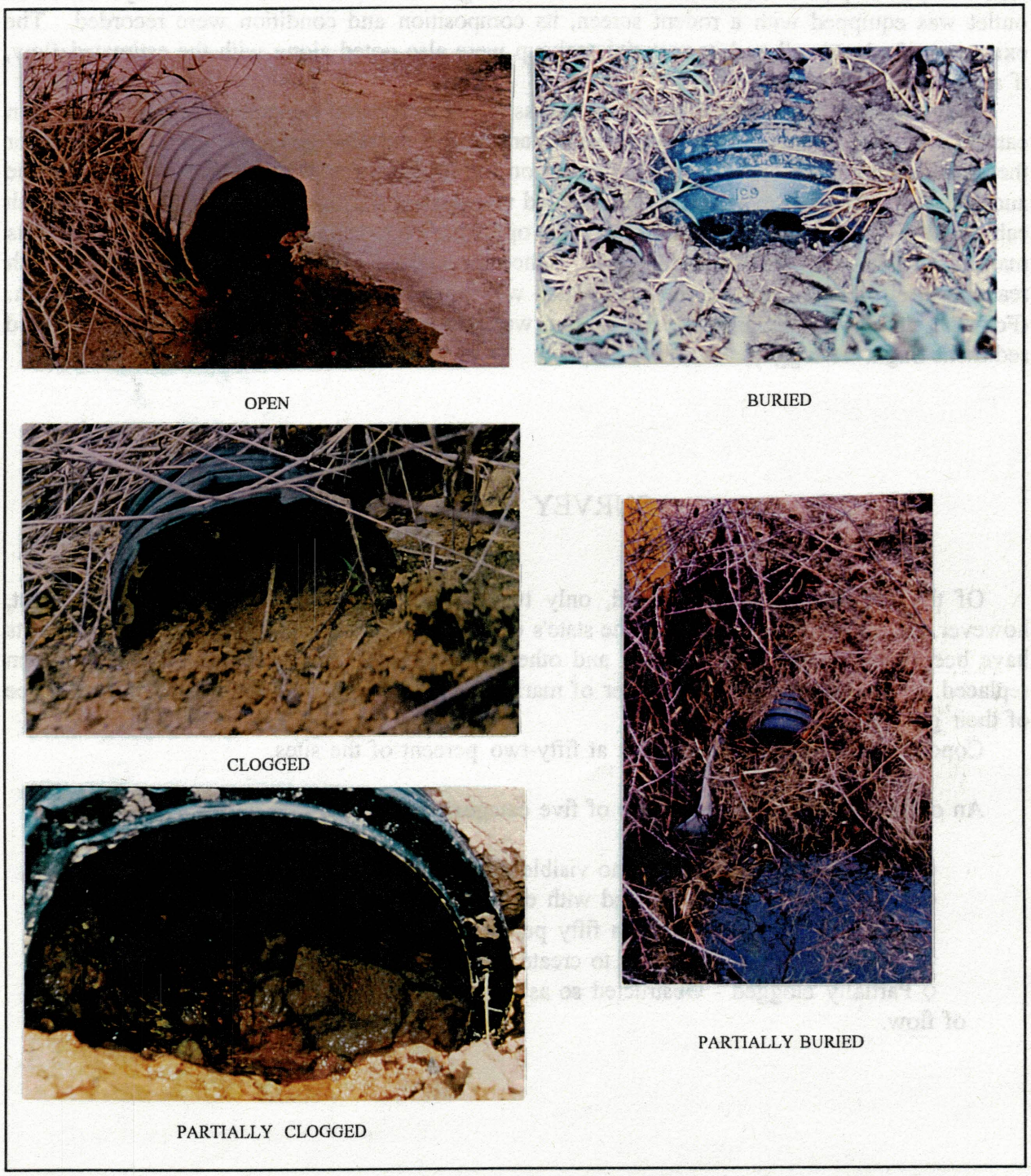


Figure 12 *Outlet conditions.*

If the outlet was successfully uncovered, the inspection continued in a routine fashion. The type and size of pipe were marked down as was the general condition of the roadway. When an outlet was equipped with a rodent screen, its composition and condition were recorded. The existence of a headwall and its material makeup were also noted along with the estimated flow, if any, in gallons per minute.

If the research team was able to gain access to the interior of the outlet, the pipe inspection camera was used to internally examine the underdrain. A portable generator provided power for the camera equipment and VCR. Comments on the internal observation were recorded on the audio track of the VHS tape. The camera head was pushed through the pipe with the stiff push cable and the distance was monitored by the operating technician via 1.5 m (5 ft) increments marked on the cable with reflective tape. Once the camera could be pushed no further with reasonable effort, the length of the observation was indicated as well as the limiting obstruction. (For analytical purposes, only one obstruction was selected as the limiting factor; e.g., roots and sediment might be logged as ROOTS.)

SURVEY RESULTS

Of the 102 underdrains inspected, only two were not marked. This does not suggest, however, that ninety-eight percent of the state's underdrains are marked. Many of the older posts have been knocked down by mowers and other maintenance equipment and have never been replaced. The disproportionate number of marked sites in the survey is a natural consequence of their greater detectability.

Concrete ditch liners were present at fifty-two percent of the sites.

An outlet's condition fell into one of five categories:

◊ Open - Unobstructed with no visible signs of deformation.
◊ Buried - Completely covered with earth.
◊ Partially buried - More than fifty percent covered with earth and/or debris.
◊ Clogged - Obstructed so as to create a major reduction of flow.
◊ Partially clogged - Obstructed so as to create a marginal to significant reduction of flow.

The chart in Figure 13 shows the frequency of each condition.

The need for regular maintenance is emphasized by the alarming ratio of buried to open outlets.

The apportionment of pipe types was more true to prediction. The majority were of the types stipulated in the 1988 standard specifications, CGMP or HDPE. The distribution of all types found is represented by the graph in Figure 14.

The roadway condition was good at all but ten sites. However, the condition was judged strictly by visual inspection and many surfaces had been overlaid.

The majority of underdrain pipe sizes were 15 cm (6 in) and 20 cm (8 in), as indicated by the graph in figure 15 on the following page.

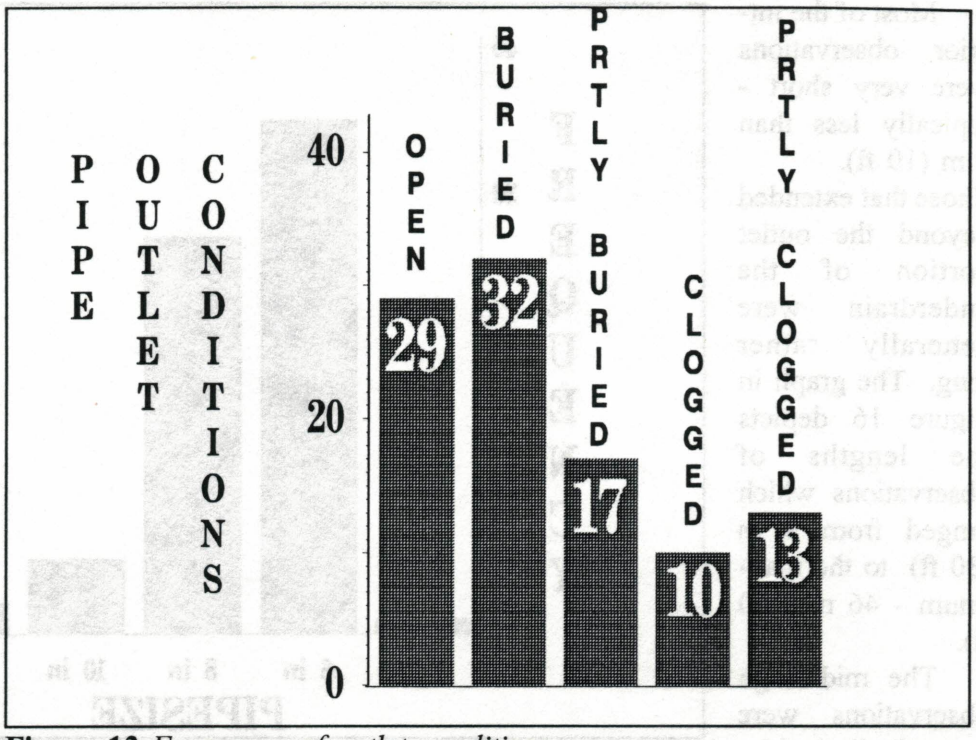


Figure 13 *Frequency of outlet conditions.*

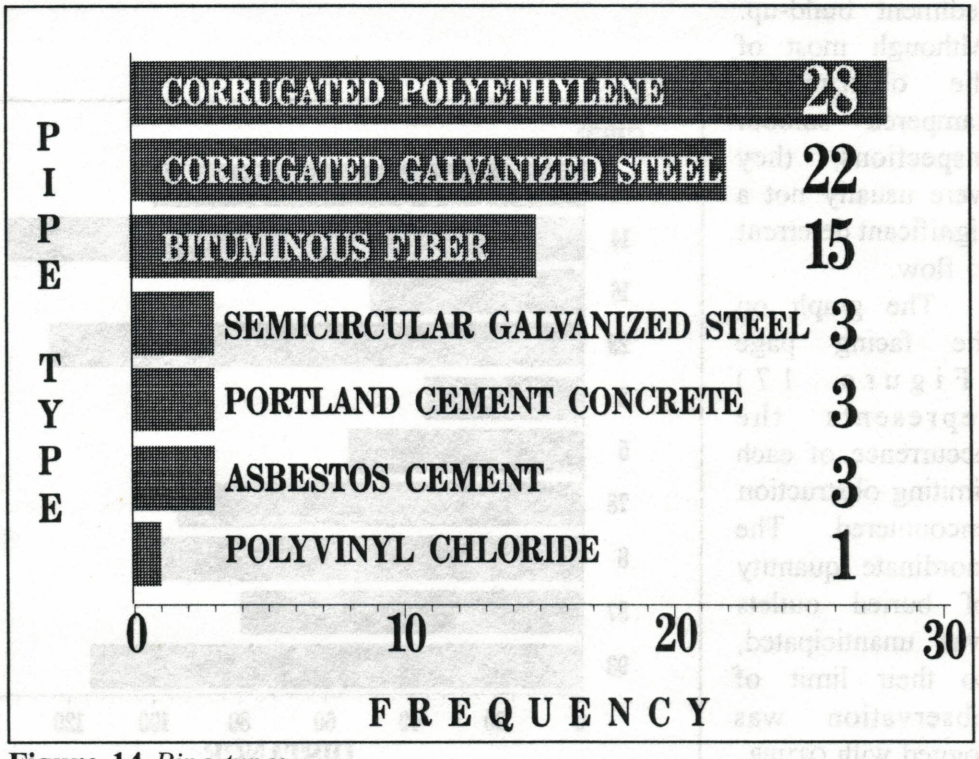


Figure 14 *Pipe types.*

Most of the interior observations were very short - typically less than 3 m (10 ft). Those that extended beyond the outlet portion of the underdrain were generally rather long. The graph in Figure 16 depicts the lengths of observations which ranged from 9 m (30 ft) to the maximum - 46 m (150 ft).

The mid-range observations were generally limited by sediment build-up. Although most of the obstructions hampered smooth inspections, they were usually not a significant deterrent to flow.

The graph on the facing page (Figure 17) represents the occurrence of each limiting obstruction encountered. The inordinate quantity of buried outlets was unanticipated, so their limit of observation was logged with OTHER.

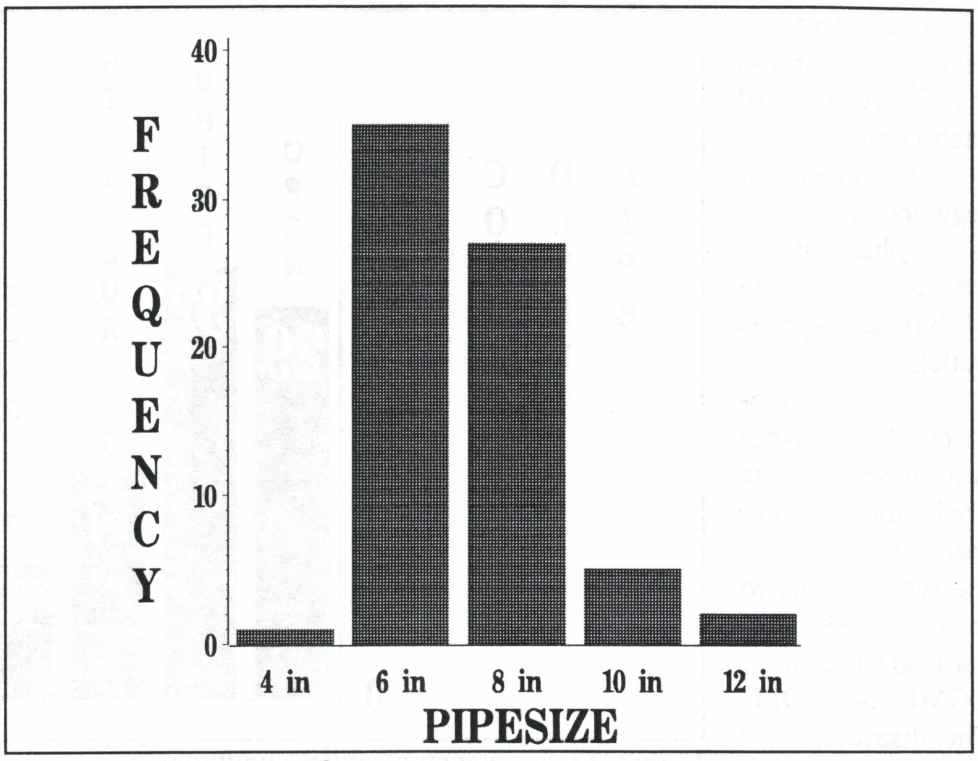


Figure 15 *Frequency of pipe sizes.*

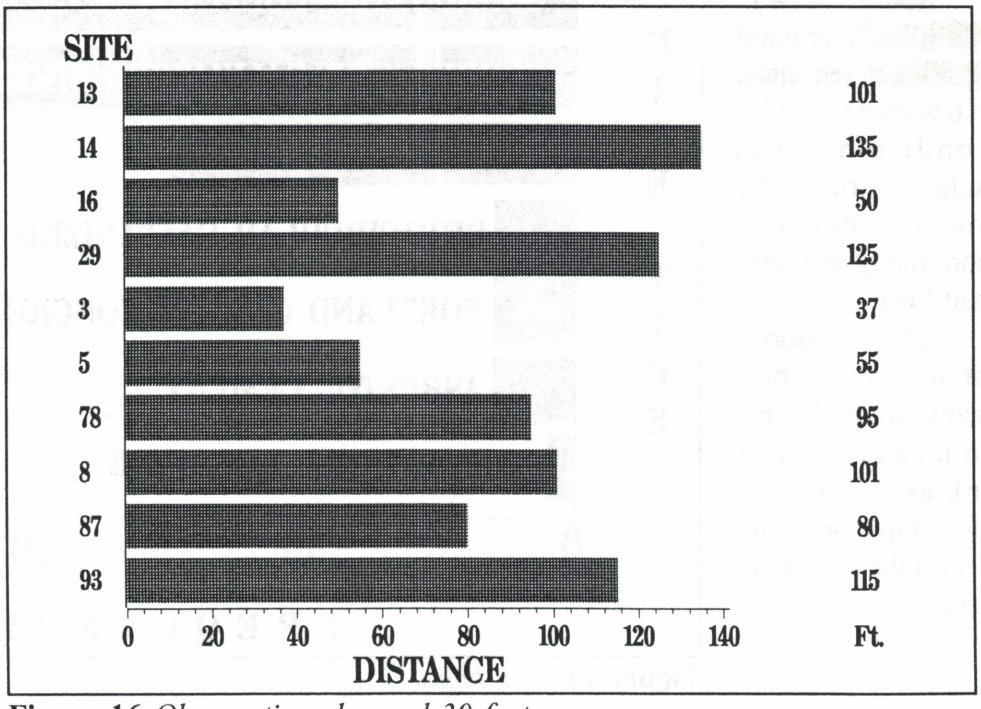


Figure 16 *Observations beyond 30 feet.*

The conditions of twenty-nine of the buried outlets remain unknown because they were not exhumed.

Rodent screens were present at twenty-six sites. The total apportionment of screen types is illustrated in Figure 18.

Of the twenty-six rodent screens found, only three had been detached from the outlet. The remaining screens were secure. (Figure 19)

Twenty-one outlets had headwalls and some perceptible flow was measured at forty-three sites.

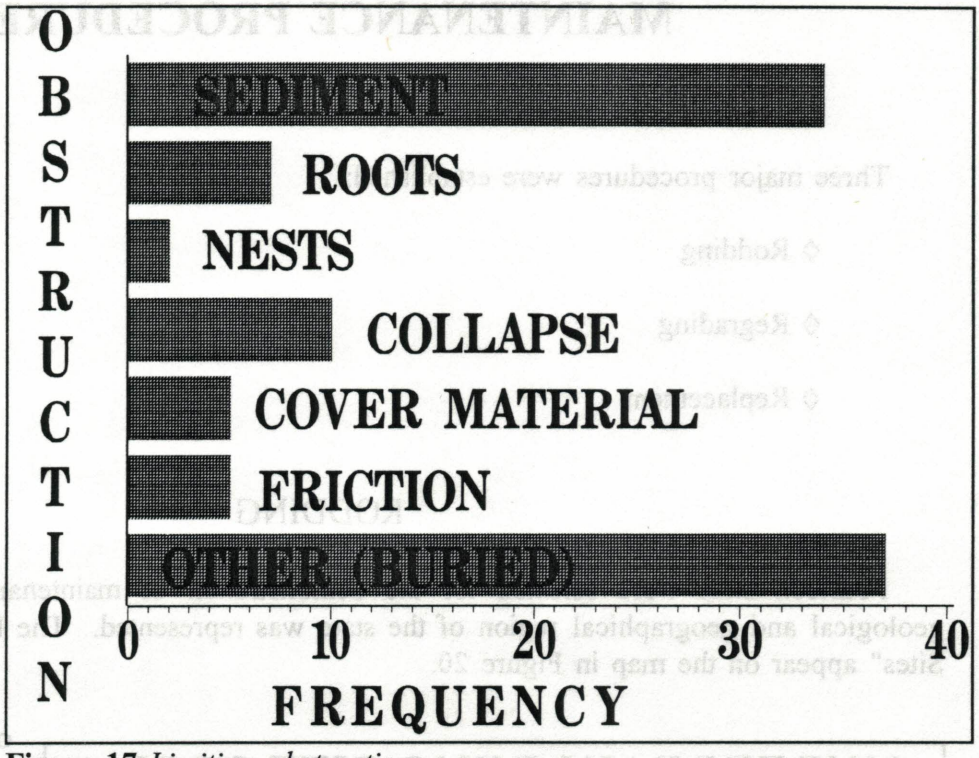


Figure 17 *Limiting obstructions.*

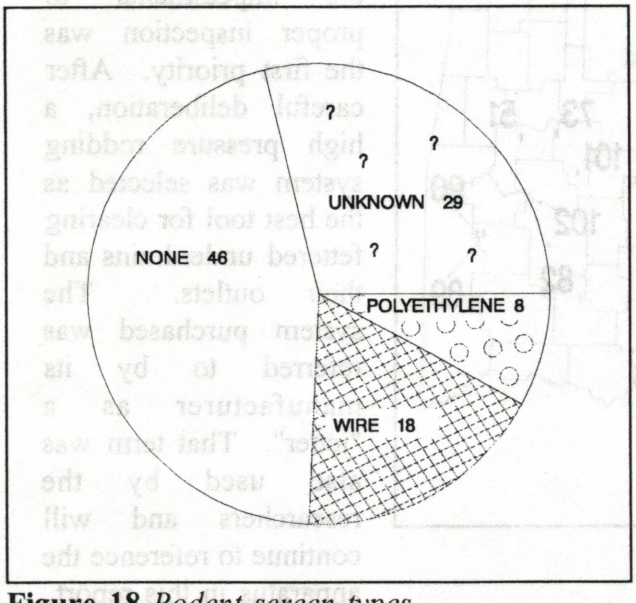


Figure 18 *Rodent screen types.*

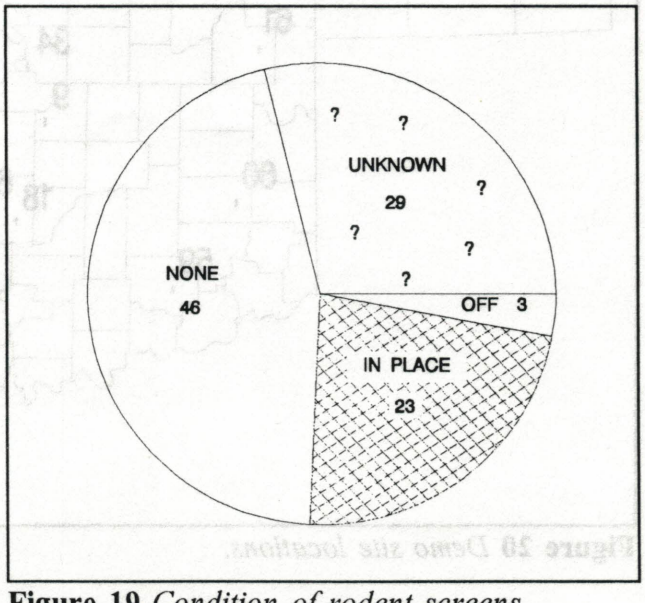


Figure 19 *Condition of rodent screens.*

MAINTENANCE PROCEDURES

Three major procedures were established:

◊ Rodding

◊ Regrading

◊ Replacement

RODDING

Fourteen sites were selected for the demonstration of maintenance procedures. Each geological and geographical region of the state was represented. The locations of the "Demo Sites" appear on the map in Figure 20.

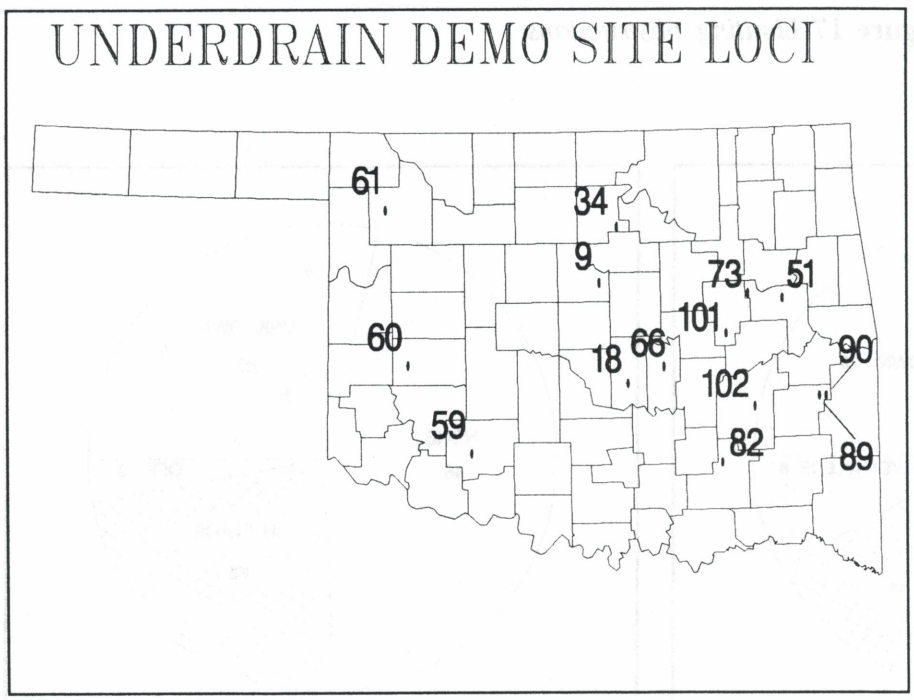


Figure 20 *Demo site locations.*

Since the majority of the outlets were in some way obstructed, the development of methods for removing the impediments to proper inspection was the first priority. After careful deliberation, a high pressure rodding system was selected as the best tool for clearing fettered underdrains and their outlets. The system purchased was referred to by its manufacturer as a "jetter". That term was also used by the researchers and will continue to reference the apparatus in this report.

The jetter (Figure 21) consists of a trailer mounted water pump, 91 m (300 ft) of high pressure hose, and a series of interchangeable thruster heads.

The water pump is capable of generating pressures as high as 20,690 kPa (3000 psi) at a maximum rate of 18.9 L/min (5 gal/min).

Figure 21 *"Jetter" (High pressure rodding system.)*

The jetting action of the most often used thruster head is pictured in Figure 22. One stream thrusts forward to loosen sediment and/or cut through roots while the rearward streams wash out debris and propel the hose through the pipe. The operator swabs the pipe with an oscillating motion until the obstructing material is carried to the outlet opening. (Figure 23)

Figure 22 *Jetting action of a thruster head.*

Figure 23 *Operator clearing obstruction.*

REGRADING

At sites where the outlet was buried, the ditch was regraded and the outlet opening uncovered. For most situations, the consummate implement for regrading is a truck mounted multi-purpose excavator with a hydraulic telescoping boom. (Figure 24) Its versatility allows access to the outlet in many different ditch configurations and a skilled operator can leave the sight in finished condition. (Figure 25) The shape and slope of the regraded ditch was generally left to the discretion of the equipment operator. However, it is recommended that only experienced and highly skilled operators be allowed to make such on-site judgements. If an operator has any doubts about the outcome, the ditch should be surveyed and staked.

Figure 24 *Hydraulic excavator.*

Figure 25 *Finishing site.*

REPLACEMENT

Two sites were selected to demonstrate outlet replacement; one HDPE (actually two sites within sight of each other) and one CGMP. The sites were chosen because the outlets were so badly damaged that the only way to restore acceptable performance was to install new pipe.

The first demonstration was conducted on two 15 cm (6 in) HDPE outlets in Division II.

The pipes had been crushed, bent, and otherwise mutilated (Figure 26), presumably during installation. After estimating the proper size and length of pipe needed, the old outlet was exhumed with a backhoe. The pipe was carefully uncovered in increments of several feet and the severity of the damage examined. When a relatively sound section was exposed, the pipe was severed and inspected internally with the camera. If yet another deformation was encountered, the crew resumed exhumation. In the particular case of this demonstration, the pipe was spliced at the point where the outlet and paved shoulder intersected. Although there was still some deformation beyond this point, it was not deemed a significant deterrent to flow and, therefore, did not warrant the disturbance of the shoulder.

The pipe was easily cut with a small keyhole saw and the trench was layered with chips per ODOT 703.04(a) - Cover Material for Pipe Underdrains - Coarse Cover Aggregate (6) which was worked into a smooth, gentle grade. The new pipe was installed using standard coupling inserts.

Figure 26 *Damaged drain pipe.*

Figure 27 *Chips surrounding new outlet.*

Two 6.1 m (20 ft) joints were needed on each outlet. The new outlet was covered with another layer of chips (Figure 27) before the trench was filled and the site finished.

The second demonstration was conducted on a 15 cm (6 in) CGMP outlet (Figure 28). As with the HDPE, the severely damaged section was uncovered and a suitable splicing point chosen. The pipe was severed with a cutting torch and hacksaw.

Before installing the new pipe, the outlet was examined with the inspection camera. It was necessary to clear the outlet of sediment with the jetter before inspecting the interior. The observation ended at the junction of the outlet and the main underdrain because the connection had been made at too sharp an angle for the camera to negotiate.

Two 6.1 m (20 ft) sections of new pipe were then installed. The joints were fastened with standard band couplings and extended to the existing ditch liner. (Figure 29) The pipe was supported only at the splice and the terminal end. A large rock was used as a center support at the band coupling but no bedding material was used.

Figure 28 *CGMP replacement site.*

Figure 29 *Installing CGMP outlet.*

Figure 30 *Pipe sliding off center support.*

A front-end loader refilled the excavation. The outlet appeared to slide off of the supporting rock when hit by the fill material, leaving the void beneath the pipe unfilled. This problem would most likely have been avoided by stabilizing the pipe with chunks of earth, then bedding and backfilling with aggregate cover material. (See maintenance recommendations on page 24.)

CONCLUSIONS & RECOMMENDATIONS

Several factors were found to contribute to reduced underdrain performance. Those which can be readily treated fell into three main categories: maintenance, design, and installation.

An active maintenance program would extend the lives of existing underdrains. Some new design specifications would reduce the need for maintenance. And close adherence to all new and existing standards would ensure maximum cost effectiveness.

Analysis of the data collected for this project suggests that the most efficient course of action would be to implement the following recommendations for each category.

1) Maintenance

- ◊ Regularly scheduled inspections
- ◊ Regrading ditches
- ◊ Rodding fettered underdrains and outlets
- ◊ Replacing severely damaged outlets

2) Design

- ◊ Outlet-to-underdrain connections (elbows)
- ◊ Mandatory end treatments (headwalls)
- ◊ Type S conduit for HDPE outlets
- ◊ Schedule 40 for PVC outlets

3) Installation (QC/QA)

- ◊ More stringent standards
- ◊ Ardent visual inspections of procedures
- ◊ Internal video pipe inspections
- ◊ Manufacturer (fabricator) assistance clause

MAINTENANCE

Underdrain maintenance should be made an integral part of every drainage management plan. A simple device by which underdrains and their outlets can be properly maintained is the employment of the four 'R' method. The four Rs are; regular inspections, regrading, rodding, and replacement.

Regular inspections can be easily worked into most existing maintenance programs. Field personnel, such as mowing crewmen, encounter underdrains in the performance of their regular duties. It would be a simple matter for them to note outlet locations. If a more aggressive approach is desired, the Maintenance engineer may wish to request a seepage investigation file from the ODOT Materials Division.

Once the outlets have been located, a two-member team can be dispatched to the sites to conduct a thorough investigation utilizing an inspection form and a video pipe inspection package. In many cases the ditch will need regrading and the outlet will be cleared with a narrow spade or 'sharpshooter'. The underdrain can then be inspected internally with the video system.

In other cases, the problem may lie not with the ditch, but with the outlet interior. A high pressure rodding system does a good job of clearing roots and/or sediment from clogged outlets.

Some outlets may need to be replaced. Replacement procedures should conform closely with those discussed in the REPLACEMENT chapter of this report. **Special attention should be paid to the achievement of a smooth, gentle grade of standard bedding material around *all outlets* - plastic and metal.**

Once the Maintenance Engineer is satisfied that all underdrains in his division are functioning properly, the interval between subsequent inspections can be determined based on the type and degree of problems encountered. Those outlets with encroaching roots may need to be reexamined every year, while replacements and regraded sites could be leisurely monitored for aquatic growth in spring but not internally examined for spans of five or even ten years.

While inspecting underdrains it is important to remember that many water tables are *seasonally* high. An outlet may flow in only one season and for a short time. Therefore, it should never be assumed that a dry outlet does not remove ground water - the water table may simply be low at the time of the inspection.

DESIGN

ODOT's current underdrain design standard specifies the use of rodent screens but makes no other reference to outlets or their end treatments. The following recommendations should be seriously considered for inclusion in a revised standard. Illustrations of recommended designs appear in appendix C.

The recommended changes are:

1) All new underdrain outlets should terminate at a ninety degree angle to the roadway with a minimum turning radius of 50 cm (20 in) where joining the main underdrain extent.

2) End treatments (headwalls) should be mandatory on all new outlets. Headwalls should be cast-in-place unless a ditch liner is also installed, in which case, the headwall should be integrated with the ditch liner. If circumstances dictate, the substitution of fabric form for cast-in-place headwalls should be permitted. Partial headwalls should be allowed only in special cases as specified by the Engineer.

3) All new HDPE outlets should be constructed from Type S conduit (AASHTO: M 252-93, 4.1.2) with a minimum pipe stiffness of 317 kPa (46 psi).

INSTALLATION (QC/QA)

1) Procedures for outlet installation should be added to the existing specifications for underdrain construction.

2) Ardent visual inspections should be made during all new installations until the contractor is thoroughly familiar with the procedures.

3) Internal video inspections should be made upon completion of the installation to insure compliance with new and existing specifications.

4) A manufacturer assistance clause should be included in all contracts involving the installation of HDPE conduits.

The inclusion of these specifications in the existing standards will lead to a more cost-effective utilization of pipe underdrains if strict adherence is required and monitored. A televising pipe inspection system will permit post-construction inspections of underdrain interiors in order to insure proper grade, record maximum deformation, and confirm the integrity of joint connections. Manufacturer assistance will insure conformity to designed product application and help to create useful feedback for suppliers, contractors, and the Oklahoma Department of Transportation.

IMPLEMENTATION

The development of an extensive technology transfer program is essential to the practical application of these procedures. Field divisions should be assisted with the integration of underdrain maintenance into their drainage management plans and instructed in the procurement, utilization, and maintenance of the necessary equipment. An effective implementation program will include the following:

◊ An aggressive approach to the dissemination of the pertinent findings of this report.

◊ Presentations to the affected field divisions by personnel qualified to explain the new procedures and answer any questions concerning underdrain maintenance.

◊ On-site demonstrations of the video inspection equipment and the high pressure jetter.

◊ Periodic documentation of the status of each Division's underdrain maintenance program; said documents to include a record of expenditures as data for a long-term study analyzing the cost effectiveness of underdrain maintenance.

Since the implementation program is crucial, a work plan will be developed and submitted within 90 days of the release date of this report.

REFERENCES

1. Drainage of Asphalt Pavement Structures, The Asphalt Institute (MS-15), 1984.

2. Asphalt in Pavement Maintenance, The Asphalt Institute (MS-16), 1983.

3. ASSHTO Guide For Design of Pavement Structures, ASSHTO, 1993.

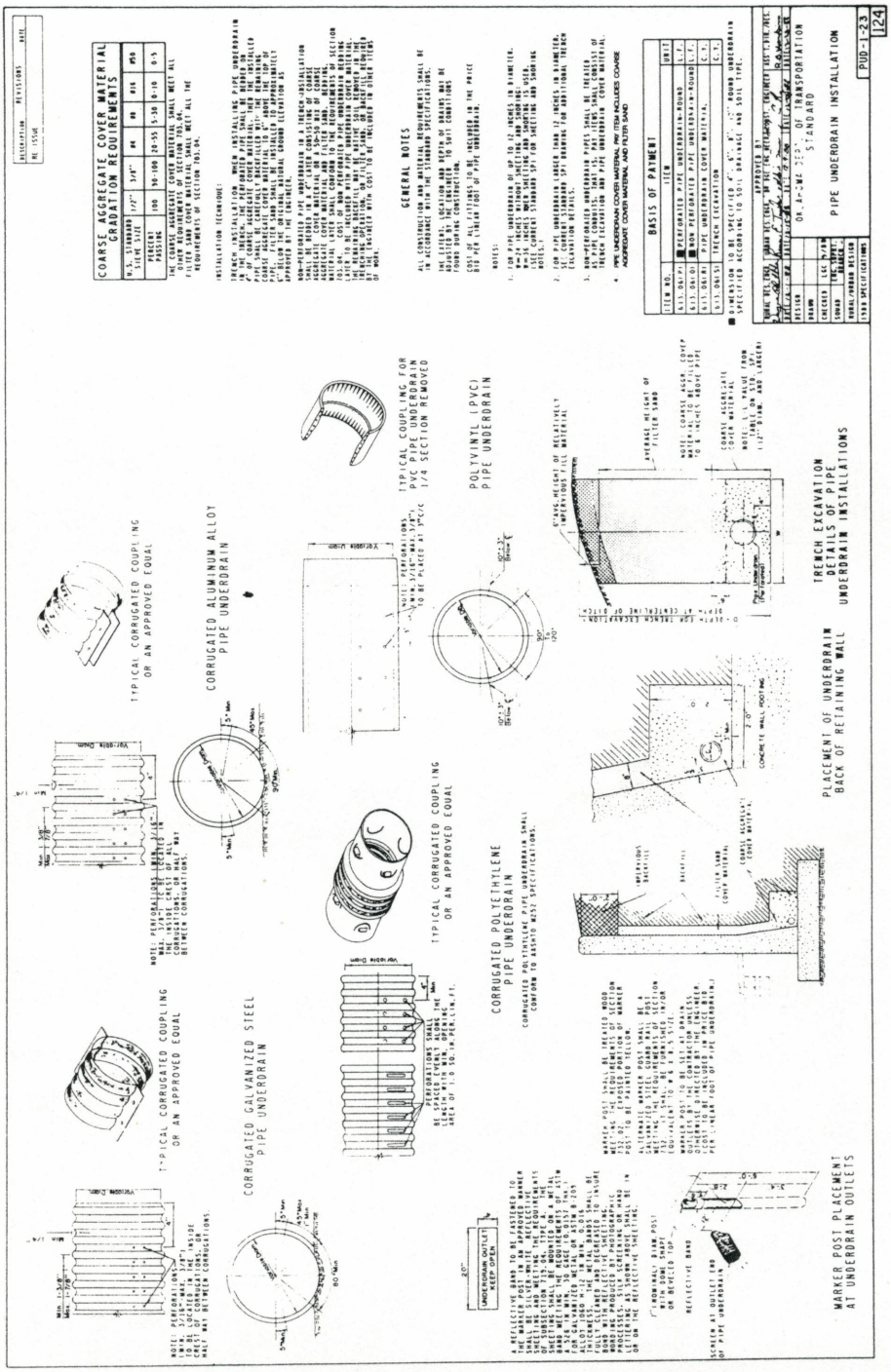
4. Geologic Map of Oklahoma, Hugh D. Miser, 1954.

5. Standard Specifications for Transportation Materials and Methods of Sampling and Testing, ASSHTO, 1993.

6. Standard Specifications for Highway Construction, Oklahoma DOT, 1988.

APPENDIX A

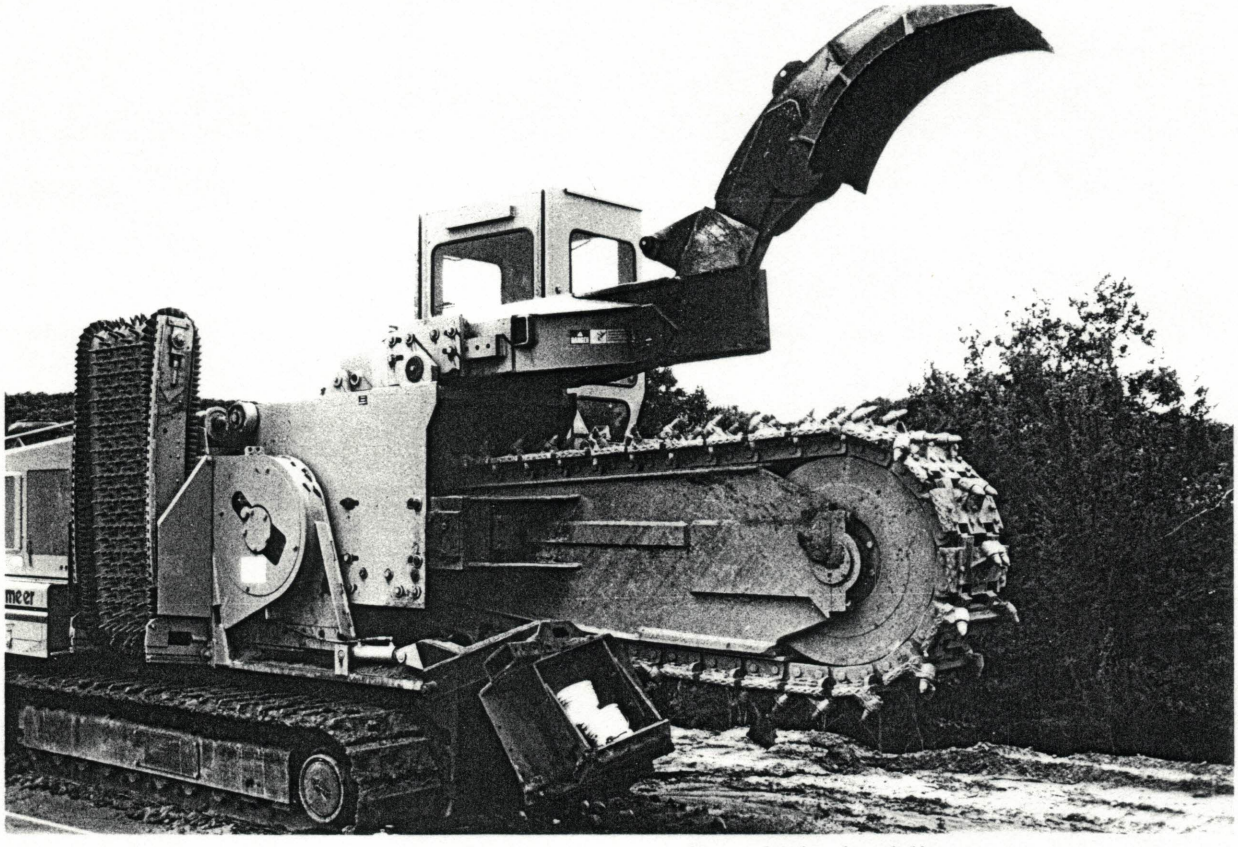
UNDERDRAIN INSTALLATION STANDARD



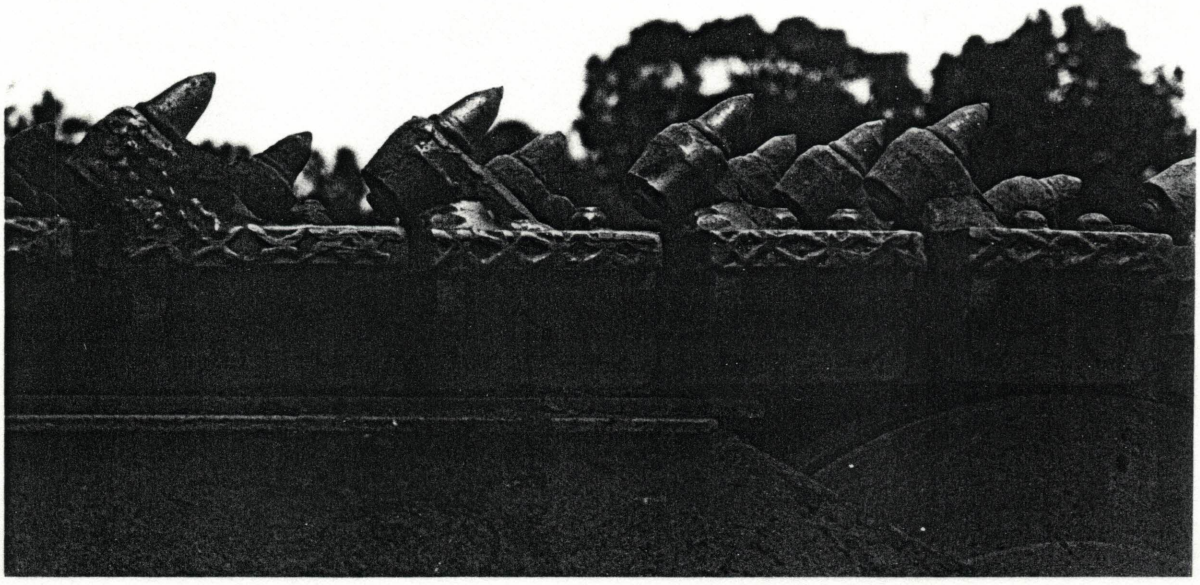
APPENDIX B

UNDERDRAIN INSTALLATION PROCEDURE

A taught string marks this line of construction on US 69 in Pittsburg County.



A large trencher is needed to cut through the hard limestone.



Carbon tipped teeth rip through soil and rock but must be replaced often.

The spoils are ejected via conveyor belt.

The bottom of the trench is layered with bedding material.

The perforated underdrain pipe is laid in.

The pipe is covered with a second layer of bedding material.

Filter sand comes to within 15 cm of the top before the trench is capped with spoils.

APPENDIX C

OUTLET DESIGN RECOMMENDATIONS

APPENDIX D

SPECIFICATIONS FOR PIPE INSPECTION SYSTEM

SPECIFICATION

for

"SMALL DIAMETER (SERVICE CONNECTION) PIPE TELEVISION INSPECTION SYSTEM"

The following Specification is for a complete and functioning small diameter pipe inspection system. This system is to be fully operational by utilizing a portable 2.2 killowatts or greater 115 volt power source.

GENERAL PROVISIONS AND REQUIREMENTS

Equipment to be Furnished:

COLOR SMALL DIAMETER PIPE (SERVICE CONNECTION)
TELEVISION INSPECTION SYSTEM

1. General

It is the intent and purpose of these specifications to secure for the purchaser the necessary equipment and accessories which will comprise and furnish the system described above. A detailed list of components required is included and is the basis on which the suppliers proposal must be made. The system shall be specifically designed to televise small diameter pipe (4"-6" service connections) using a push cable system.

2. Materials and Workmanship

All equipment, materials and workmanship shall be of the highest grade in accordance with modern practice. The equipment supplied will be new and unused except for the necessary testing, calibration and transportation.

3. Warranty

All items furnished in accordance with these specifications shall be covered by the manufacturer's and/or supplier's standard warranty or guarantee on new equipment. The minimum warranty period on new equipment must be one year. Consumable items such as lightbulbs, skids and connector assemblies shall be covered by a limited warranty.

4. Experience

The equipment to be furnished shall be the product of a qualified firm that is regularly engaged in the manufacture and supply of this equipment. A qualified firm shall be defined to mean one which has manufactured and sold 20 of the specified units during the past two years. When required, a list of 20 users will be supplied. Systems listed for other than small pipe inspection systems will not be acceptable.

5. Parts and Service

To best service the requirements of the purchaser, it is the intent of these specifications to secure equipment, which can be properly maintained and serviced without the necessity of stocking an expensive parts inventory or being subjected to long periods of interrupted service due to lack of spare parts.

All suppliers submitting proposals must have available a factory parts and service center. The center shall be staffed with full time technical, as well as order and shipping personnel during regular business hours and days. The factory center must have toll free telephone service and be convenient to air freight, bus or overnight parcel service. The supplier shall list his nearest factory part and service location, plus any other pertinent information requested. The buyer may exercise his right to inspect each bidder's facilities to determine his qualifications to provide parts and service on an acceptable basis.

6. Exceptions

Major exceptions to the component list and specification requirements, or failure to submit requested information will be considered sufficient cause for rejection of a proposal.

SMALL DIAMETER PIPE (SERVICE CONNECTION) TELEVISION INSPECTION SYSTEM COLOR COMPONENT LIST

QTY	DESCRIPTION
1	Small Diameter Solid State Color Camera (Maximum 3" Diameter and 7" Length) w/Built-in Field Replaceable Lighting System
1	Spare Lightring
1	Combination Power Control Unit/Monitor Mounted in a Shock Resistant Case to Include: 1 TV Light Intensity Control W/Meter 1 Video Tape Recorder Input Jack 1 9" 310 Line Resolution Color Television Monitor
1	4-6" Skid Assembly
1	Spare 4 - 6" Skid Assembly
1	Combination TV Cable/Push Cable Assembly 150'
1	Combination TV Cable/Push Cable Storage Reel With a Continuous Contact Gold Plated Slip Ring Assembly
1	Video Tape Recording System to include: 1 Stand Alone Video/Audio Tape Recorder, Industrial Cassette, Black and White or NTSC Color Standard, VHS Format - Front Load 1 Audio Recording Microphone 1 2-Hour 1/2" Recording Tape Cassette 1 Cable Assembly - VTR to Power Control Unit
1	Camera Locator Device
1	Operating Manual

SMALL DIAMETER PIPE INSPECTION CAMERA - COLOR

The small diameter pipe television camera shall be color specifically designed to operate in 4" to 6" pipe. The camera shall be designed to operate through a minimum of 150' of 5/8" multi-conductor cable and shall be waterproof up to 500 PSI to operate in underwater conditions.

Camera construction shall include all solid state circuitry designed to withstand shocks and vibrations while being pushed through the pipe. The image sensing device will be a solid state chip. Cameras incorporating a videcon tube subject to damage will not be acceptable.

SMALL DIAMETER PIPE CAMERA REQUIREMENTS - COLOR

The camera power consumption shall be 425 mA at 12.5 volts DC. The camera shall be capable of providing 300 lines of horizontal resolution, scanning shall be 525 lines, 60 fields, 30 frames and 2:1 interface. Geometrical distortion of the image shall not exceed 2%.

SMALL DIAMETER PIPE CAMERA PROTECTIVE HOUSING - COLOR

The camera shall be enclosed in a high strength, specially machined, stainless steel housing no more than 3" in diameter and 7" in length without the connector assembly. The housing shall be tapered from the center to allow the camera to negotiate multiple sweep 90 degree bends in 4" pipe. The front of the housing shall have a viewport of impact resistant, distortion free optical glass. The front Lightring will include multiple recessed bulbs. The bulbs shall be the low voltage, extended life type designed to provide adequate light in 4" and 6" pipe. The Lightring will be designed to allow easy removal and replacement in the field. The rear of the housing shall be equipped with a sealed connector. The housing shall be fully sealed at the factory to withstand external pressures in excess of 500 PSI without damage or leakage.

SPARE LIGHTRING - COLOR

A spare lightring shall be included with the system. The lightring shall be designed so that it is easily installed in the field with the use of standard hand tools. Lightring systems that require disassembly of the camera shall not be acceptable.

COMBINATION POWER CONTROL/MONITOR UNIT - COLOR

The combination power control and monitor unit for the system shall be contained in a fitted damage resistant case with metal reinforced corners and latches.

The combination power control/monitor unit shall not weigh over 70 pounds.

The combination power control/monitor unit shall operate from a 120 volt AC/60 Hz power source. The camera power supply shall be from a solid state power source. The output of the camera power supply shall be 12.5V DC at 500 mA. It shall not be necessary to vary the camera voltage to accommodate different lengths of TV cable. The lighting for the camera shall be supplied through an isolated power supply and shall regulate the light voltage up to a maximum of 16V AC. The control shall be located on the front panel of the unit.

The monitor shall be color and the screen size shall measure 9". The video response shall be in excess of 310 lines. The front control panel shall contain: off/on switch, vertical hold, tint, color, brightness and contrast controls.

Along with the monitor controls, the power control unit shall have an on/off switch, main power indicator light, video input/output connections, connector for TV transmission cable and all circuit breakers required for proper protection of camera, power supply and monitor. The video input shall be direct from the transmission cable to the control unit through a front panel connector.

SMALL DIAMETER PIPE CAMERA SKID ASSEMBLIES

The unit shall be equipped with 4" and 6" skids that mount directly to the camera housing. They shall be designed for use in both 4" and 6" pipe sizes. They shall be designed for easy removal.

COMBINATION TV CABLE/PUSH CABLE ASSEMBLY

One hundred fifty feet (150') of 5/8" diameter combination TV cable/push cable will be furnished to include the required end connectors. The combination TV cable/push cable will be of sufficient strength to allow the camera to be pushed or pulled a minimum of 150' in the pipe. The cable shall include all the necessary conductors to supply power to the camera and lights and to transmit the video signal along a shielded coaxial cable. The cable shall include a single steel armored wrap which shall provide a minimum of 5000 lbs. breakstrength. The outer jacket shall be constructed of 1/16" abrasive resistant polyethylene and shall be perfectly round to reduce resistance during use in the pipe.

The cable end connector shall be specifically designed to transfer the cable strength to the camera. It shall be equipped with a special flexible coupling to allow the camera to turn and rotate to negotiate 90 degree bends.

COMBINATION TV CABLE/PUSH CABLE STORAGE REEL

A reel will be supplied to store the combination TV cable/push cable and shall include a holder for the TV camera when not in use. It shall have sufficient capacity to hold a minimum of 150' of combination cable. The reel shall be equipped with a disc style continuous contact assembly with gold plated slip rings to allow the camera and cable to be pushed into the pipe without interruption of the video signal. The reel shall be constructed of aluminum and be equipped with a handle and wheels for easy transport.

VIDEO TAPE RECORDING SYSTEM - FRONT LOAD

A video tape recording system shall be provided to permanently record on video tape any transmission from the closed circuit television camera. The recorder shall have four video heads. It shall have a minimum recording time of 120 minutes and shall use 1/2" wide tape contained in a cassette. The recorder shall be capable of providing black and white or color tapes. The video cassette recorder dimensions shall be approximately 14" X 3.5" X 11.5" and the tape transport shall be completely enclosed in a dustproof case.

VIDEO TAPE RECORDING OPERATION REQUIREMENTS

Helical scan recording techniques shall be utilized for recording and playback of the composite video. The composite video signals shall be recorded by two of the four video heads. The video recorder shall reproduce in all the following operating modes: 60 cycles field frequency, random sync, 2 to 1 industrial sync, EIA sync and NTSC color. It shall be equipped with an audio channel for narration of the recorded video. Both video and audio signals may be recorded at the same time, or if desired, the audio may be dubbed in at a later time.

MICROPHONE VIDEO TAPE SYSTEM

A microphone for adding audio to the video tapes shall be provided. The microphone shall have a 150 OHM rating and shall plug directly into the recorder.

CAMERA LOCATOR

The camera must include a transmitter which emits a signal in a frequency that will not interfere with the TV video signal. The signal will be detectable to a depth of 15' and will not require secondary locator observations. A loudspeaker located in the handle of the receiver will provide an audio response to variable signal strengths. The receiver must also include a meter to indicate peak signal strength when unit is located directly over the camera.

OPERATING INSTRUCTIONS

Operating instructions for the small diameter pipe inspection system will be furnished with the unit.

Trouble shooting and maintenance service information will be provided.

A qualified technician will assist with setting up and testing the assembly. Such technician shall be available within 30 days of the delivery date.

DEVIATIONS

Bidder must itemize all deviations to the specifications here. If this is not sufficient space, attach additional sheets as required. A statement referring to manufacturer's literature or specifications without stating the actual deviation hereon will be cause for disqualification.

NONE

Unless otherwise stated by the bidder in the space provided above, the proposal will be considered as being in strict accordance with the specifications outlined herein, even though the manufacturer's literature indicated deviations from the city's specifications.

APPENDIX E

COST ESTIMATES

Cost estimates are based on average ODOT wages and equipment rates for the 1996 fiscal year. Actual costs will vary depending on the personnel and equipment used.

At Site #9 a CGMP outlet was replaced by the Guthrie maintenance crew, Division IV.

SITE #	EQUIPMENT	$/HR[1]	PERSONNEL	$/HR[2]	HOURS	TOTALS
9	PRO SCOUT	43.56	Maint. Wrkr. II (2)	17.31	0.25	**$15.22**
	JETTER	38.9	Maint. Wrkr. II (2)	17.31	0.33	**$18.55**
	EXCAVATOR	34.72	Equipment Operator	11.25	0	**$0.00**
	BACKHOE	15.78	Equipment Operator	10.38	1.35	**$35.32**
	HAND TOOLS	0	Maint. Wrkr. II (2)	17.31	1.1	**$19.04**
MILES	**VEHICLES**	**$/Mile**				
40	CREW CAB	0.326	Maint. Wrkr. II	8.66	1.2	**$23.43**
	VAN	0.29	Maint. Wrkr. II	8.66	1.2	**$21.99**
	DUMP TRUCK	0.69	Maint. Wrkr. II	8.66	1.2	**$37.99**
	MATERIALS[3]					**$104.00**
					COST	**$275.54**

[1]Estimated rates for 1996.

[2]Estimated average wage.

[3]Forty feet of 6" CGMP.

At Site #90 the ditch was regraded by maintenance personnel from Division I.

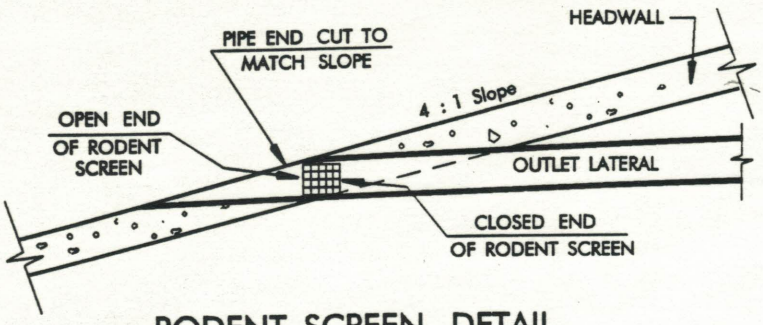
SITE #	EQUIPMENT	$/HR[1]	PERSONNEL	$/HR[2]	HOURS	TOTALS
90	PRO SCOUT	43.56	Maint. Wrkr. II (2)	17.31	0.2	**$12.17**
	JETTER	38.9	Maint. Wrkr. II (2)	17.31	0	**$0.00**
	EXCAVATOR	34.72	Equipment Operator	11.25	2.5	**$114.93**
	BACKHOE	15.78	Equipment Operator	10.38	0	**$0.00**
	HAND TOOLS	0	Maint. Wrkr. II (2)	17.31	0.25	**$4.33**
MILES	**VEHICLES**	**$/Mile**				
109	CREW CAB	0.326	Maint. Wrkr. II	8.66	2.725	**$59.13**
	VAN	0.29	Maint. Wrkr. II	8.66	2.725	**$55.21**
	DUMP TRUCK	0.69	Maint. Wrkr. II	8.66	2.725	**$98.81**
					COST	**$344.58**

At site #66 Reserch Technicians uncovered, jetted, and internally inspected a CGMP outlet.

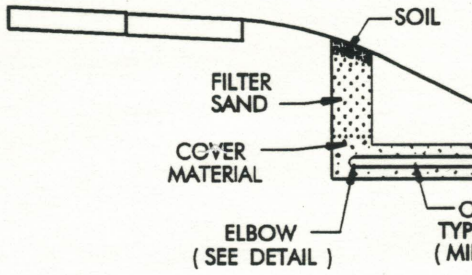
SITE #	EQUIPMENT	$/HR	PERSONNEL	$/HR	HOURS	TOTALS
66	PRO SCOUT	43.56	Maint. Wrkr. II (2)	17.31	0.17	**$10.35**
	JETTER	38.9	Maint. Wrkr. II (2)	17.31	0.13	**$7.31**
	EXCAVATOR	34.72	Equipment Operator	11.25	1.2	**$55.17**
	BACKHOE	15.78	Equipment Operator	10.38	0	**$0.00**
	HAND TOOLS	0	Maint. Wrkr. II (2)	17.31	0.17	**$2.94**
MILES	**VEHICLES**	**$/Mile**				
86	CREW CAB	0.326	Maint. Wrkr. II	8.66	2.15	**$46.66**
	VAN	0.29	Maint. Wrkr. II	8.66	2.15	**$43.56**
	DUMP TRUCK	0.69	Maint. Wrkr. II	8.66	2.15	**$77.96**
					COST	**$246.88**

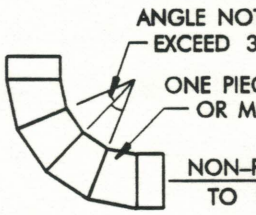
[1]Estimated rates for 1996.

[2]Estimated average wage.



RODENT SCREEN DETAIL AT OUTLET





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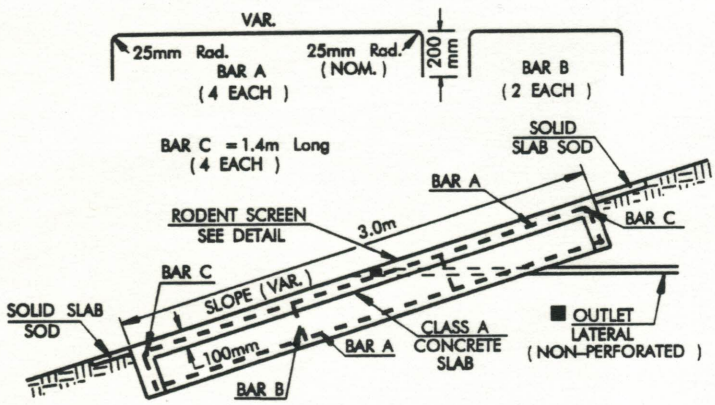
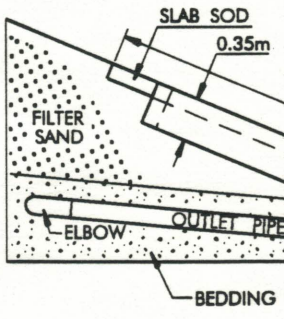
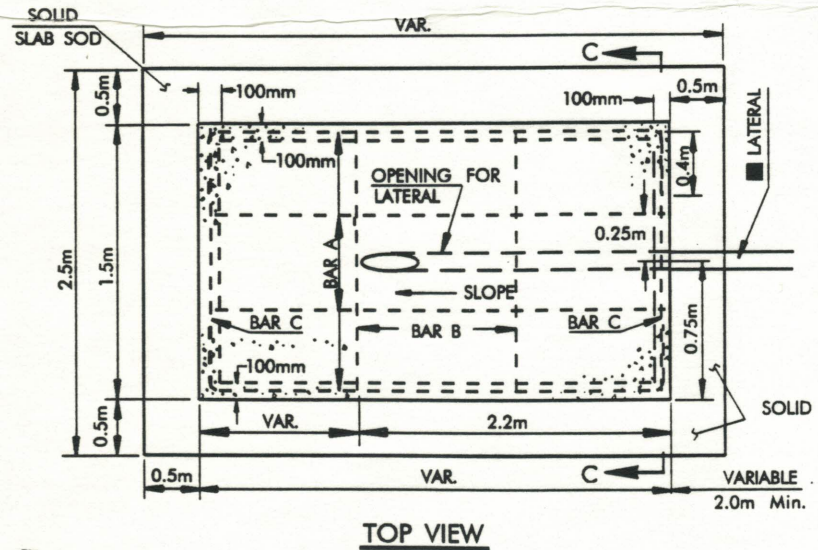
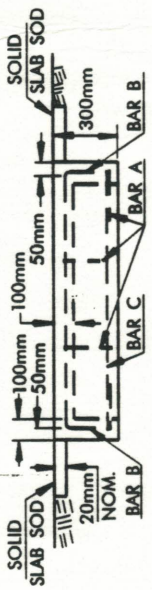


TYPICAL SECTION - (HEADWALL)



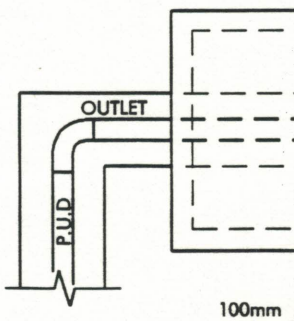


TOP VIEW



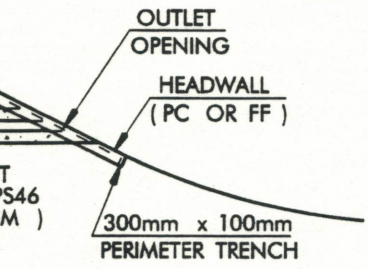
SEC C-C

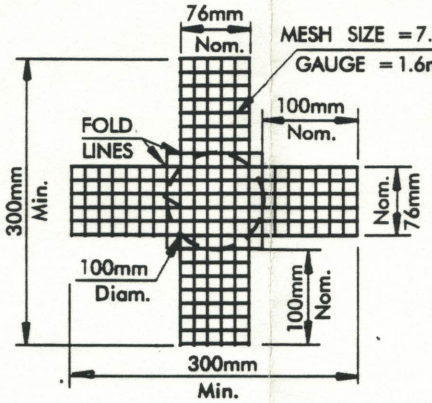
UNDERDRAIN/LATERAL NOT SHOWN



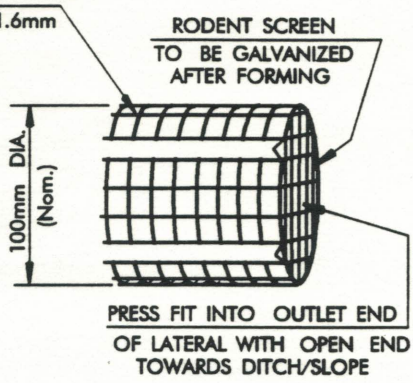
CAST-IN-PLACE CONCRETE OUTLET HEADWALL

VARIATION





TYPICAL LAYOUT



RODENT SCREEN DETAIL

THIS RODENT SCREEN DETAIL IS TYPICAL ONLY AND OTHER DESIGN LAYOUT PATTERNS MAY BE ALLOWED IF APPROVED BY THE ENGINEER. NO TOLERANCE SHALL BE ALLOWED ON MATERIAL SPECIFICATIONS. RODENT SCREEN DIMENSIONS WILL CHANGE PROPORTIONATELY FOR ALTERNATE SIZE OUTLET LATERAL CONDUIT.

ONSTRUCTION
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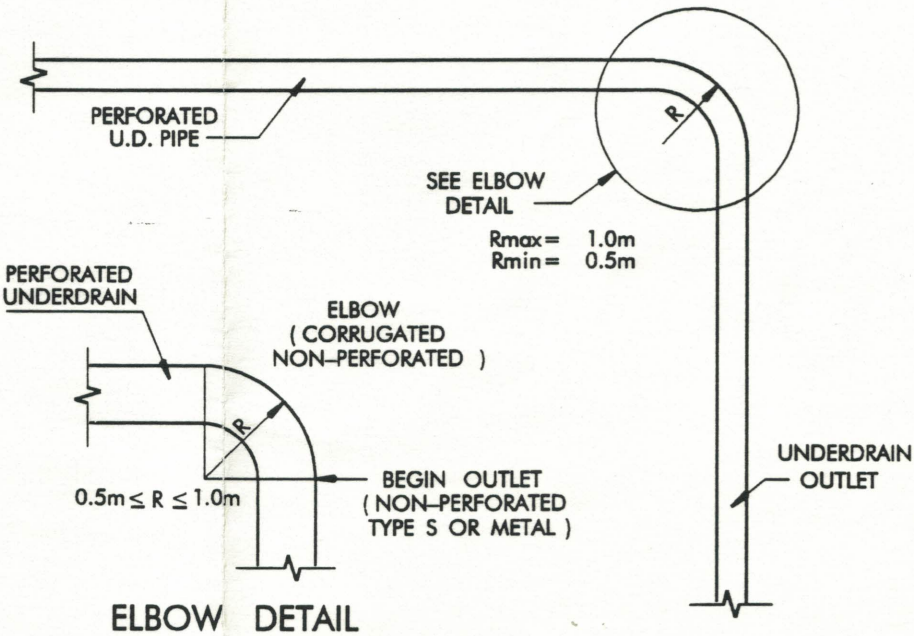
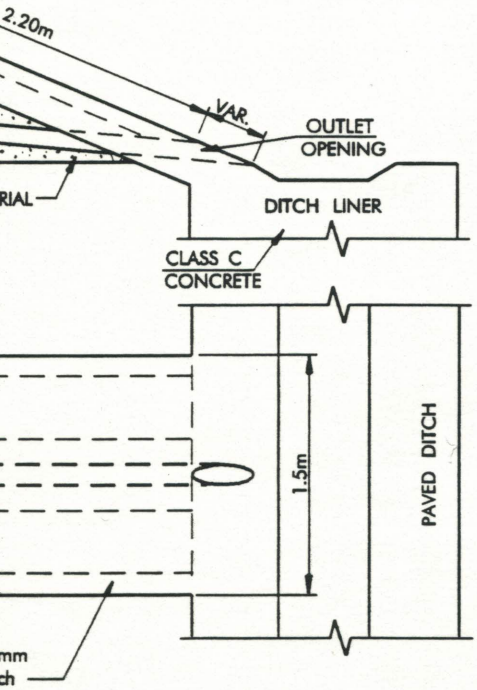
RATED
ET

IL



ELBOW DETAIL



OR PAVED DITCH

Design		
Drawn		
Checked		
Approved		
Issued		

DETAIL
UNDERDRAIN OUTLET
W/HEADWALL

PROJECT _____ SHEET NO ____