



TRC9207

Performance of Pavement Drainage Systems

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Final Report

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**TRC-9207
Performance of Pavement Drainage Systems**

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INTRODUCTION

It has been widely recognized that water is one of the contributing factors associated with pavement deterioration. Pavements tend to be a barrier to the encroachment of water into the pavement and sub grade strata. In the past, attempts have been made to seal pavements in order to inhibit this intrusion of water, thereby, reducing damage caused by water. In more recent times, it has been accepted that the absolute prevention of water intruding into a pavement's strata is not achievable. Therefore, in many instances, emphasis has shifted to providing adequate pavement drainage in order to aerate the strata to avoid damage caused by saturated pavements.

The increased use of open graded pavement materials and the implementation of rubblizing to refurbish highway roadbeds require the installation of pavement edge drains to vent the open graded materials and allow moisture to flow freely from the pavement strata. If these drains are not installed and maintained properly, water will collect under the pavement and the result is increased, rather than reduced, causing more damage to the pavement structure.

Currently, the Arkansas State Highway and Transportation Department (AHTD) installs 4" pipe edge drains on highway projects within the State. In the past, both the conventional round collector pipe drain (see Picture 1 in Appendix A) and geo-composite edge drains (see Picture 2 in Appendix A) have been used. This project, TRC-9207, Performance of Pavement Drainage Systems, was intended to compare the performance of both of these type edge drains and to

investigate the overall performance of edge drains throughout the State. By studying these drains in operation, problems associated with these systems can be documented and solutions determined which would prevent premature failure of future systems, thereby maximizing the State's return on its investment.

The TRC project "Performance of Pavement Drainage Systems" was implemented in 1992 with three objectives.

1. Evaluate the pavement section (surface, base, sub base) in terms of type, design, and materials involved in the pavement section,
2. Investigate the performance of both types of subsurface drainage systems used in Arkansas in terms of pavement distress, and
3. Determine the factor or factors influencing the performance of each subsurface drainage system.

Since the initiation of this project, investigations and observations have been made and resulted in two additional secondary objectives.

4. Sample the condition of pavement edge drain installations statewide and assess and report on their condition and
5. Prepare recommendations on the repair and maintenance of existing pavement drains including recommendations for future design, construction, and inspection procedures.

PROJECT HISTORY

Experimental Project No. 608, Pavement Rehabilitation Techniques, was initiated in 1983. The edge drains to be studied were installed with Job 4826, I-40 Pavement Restoration, which was completed in 1986. A section of Monsanto Drainage Mat (MDM) geo-composite drain was installed in the westbound lanes at approximately log mile 42.00 of Interstate 40 in Franklin County near Ozark (see Pictures 3 and 4 in Appendix A). The conventional round collector pipe was installed in the eastbound lanes of I-40 in the same location for comparison. The presence of both a geo-composite edge drain and a pipe edge drain on opposite sides of I-40 at this location, made these sites ideal for comparing their performance for this project. In addition to these sites, drains were selected on U.S. 65 (now I-530, Sections 4 and 5; I-30, Section 14; and on S. H. 540 (now I-540, Section 3) to analyze their performance.

Flow monitoring equipment systems were installed and measurements made on I-40, Franklin County, as part of an earlier project, *Experimental Project No. 608*, in 1987 (see Pictures 5 & 6 in Appendix A). In 1996, updated, more reliable flow monitoring equipment was installed and inspections were made (see Pictures 7 and 8 in Appendix A).

The Department has been installing pavement edge drains for decades with the assumption that the edge drains were in operating condition following their installation. Since the Department, at that time, had no means of inspecting the drains without excavating them, this seemed to be a reasonable assumption. The

major problem with the operation of these drains has always seemed to be vegetation and silt control at the drain outlets.

During a FHWA sponsored demonstration project, *Demonstration Project No. 87*, video inspections were performed across the State on November 7 through November 9, 1995, which revealed various other problems occurring with the edge drain's performance capabilities. Brent Rauhut Engineers from Austin, Texas acted as consultant for FHWA, and supplied the video equipment and technician for the demonstrations.

The Pearpoint video inspection camera system was used for this demonstration. See Picture 9 in Appendix A. It was mounted on the end of a flexible rod fed from a cage type coiler. A camera control unit allowed the technician to adjust the camera and view the drain during operation. A video recorder and video printer were also interfaced with the control unit to record the demonstration and provide still photographs during the inspections.

In 1996, the Department purchased, under Job #60592, a waterproof video camera system capable of inspecting 4" diameter edge drains pipes (see Picture 10 in Appendix A). This camera system was used initially to check the condition of existing edge drains. But additionally, this system has been used to inspect drains that are under construction.

During the inspections, it was noted that video inspections were limited by the access to the structures being viewed. Often adequate access is only made possible by flushing of the edge drains.

In 1998, the Department purchased a flushing trailer to be able to perform a more thorough inspection of these edge drains by flushing them out and inserting a rod through the pipe. See Picture 11 in Appendix A.

PROJECT RESULTS

Monitoring of the outflow of one edge drain on each type of drainage system (MDM versus flexible pipe) was conducted in the late 1980's using tipping buckets and counters. The outflow monitoring was inconsistent due to the unreliable nature of the equipment. However, early data seemed to indicate that the total volume of flow from each edge drain was similar except that the MDM site drained at a much faster rate than the standard pipe under drain. This observance was upheld with the more reliable monitoring equipment that was installed in 1996. This equipment utilized electronic data collectors and also recorded rainfall.

Results from a typical series of rainfall events are shown in Charts 1, 2, and 3 (pages 7, 8, and 9). During the storm event from September 23 – 25, 1997, the data collected indicated that the MDM site produced the highest peak discharges within one (1) hour of the storm event while the flexible pipe site recorded the highest peak discharges approximately 5-6 hours after the storm event.

During the first rainfall event on September 23 beginning at 11:00 a.m., approximately 0.3 inches of rainfall was recorded during the next 5 hours. See

Chart 1. The outflow collected on the flexible pipe edge drain site during this 5-hour time period was 17.75 gallons with the MDM site data recording a ten-fold increase of volume with 190.11 gallons.

The data retrieved on September 25 from 1:00 a.m. to 5:00 a.m. showed approximately 0.32 inches of rainfall was collected. See Chart 3. During that rainfall event, the flexible pipe edge drain recorded an outflow of approximately 47 gallons with the MDM site recording approximately 235 gallons of outflow. Comparison of the two figures indicates that the MDM site had almost five (5) times the outflow of the flexible edge drain.

These examples of the rainfall and runoff event characteristics reveal that the MDM site moves water faster than the flexible edge drain even though the volume of the total outflow is almost the same.

The storm event data during September 1997 also revealed that the total volume of flow was similar when comparing the two drainage systems. The flexible pipe edge drain recorded an outflow of approximately 907 gallons and the MDM drain system recorded approximately 847 gallons during the three-day time period. These results indicated that the flexible pipe outflow measurements were approximately 7% greater than the MDM site.

In spite of the installation of these pavement edge drains on I-40, pumping continued and resulted in the multiple slab replacements during the following years (see Picture 12 in Appendix A). During this same time period in

Chart 1
September 23, 1997 Storm-TRC9207

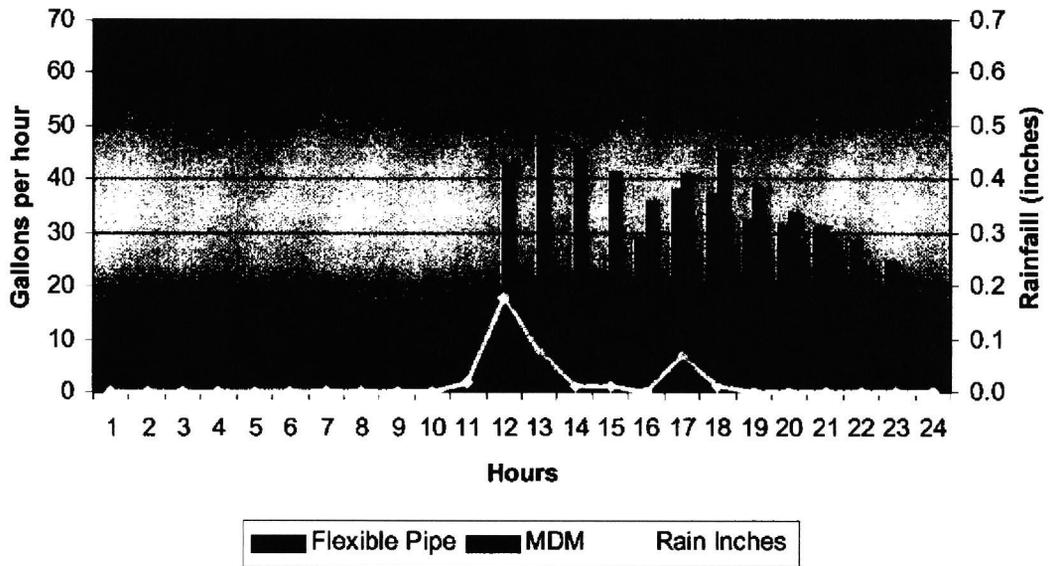


Chart 2
September 24, 1997 Storm-TRC9207

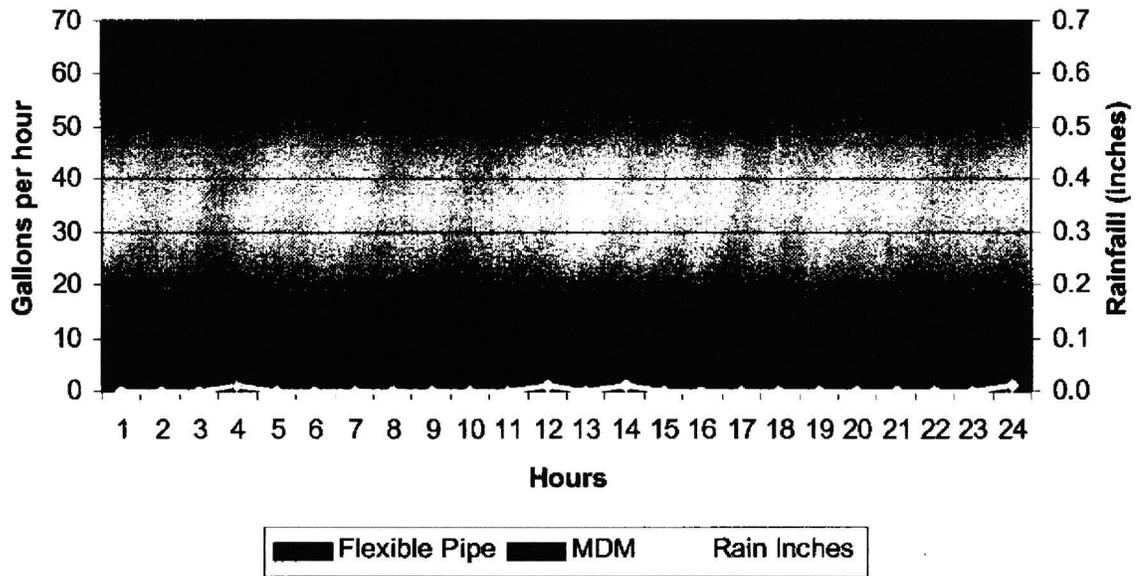
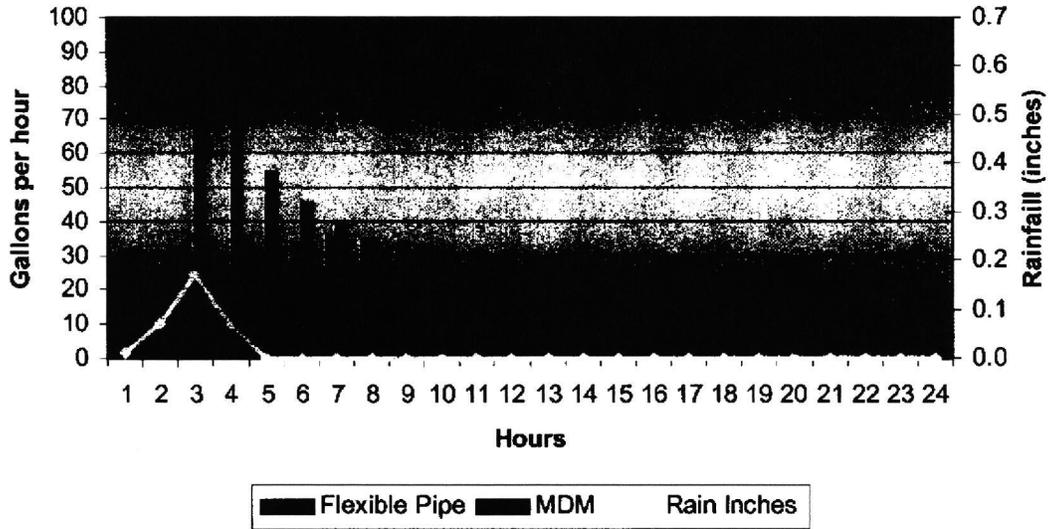


Chart 3
September 25, 1997 Storm-TRC9207



1996, a strip of asphalt shoulder along the pavement edge was milled and several inches of asphalt was laid to repair deteriorated asphalt and settling of the shoulders. Despite this effort, severe asphalt pavement stripping and settling reoccurred in a relatively short period of time (see Pictures 13 and 14 in Appendix A).

During the first day of the FHWA Demonstration Project on November 7, 1995, video inspections were performed along I-40 in Pulaski, Faulkner, and Franklin Counties. See Picture 9 in Appendix A. These edge drains were installed in 1984 and 1985 during rehabilitation work performed with Jobs 60284, 8845, and 4826. Many of the drains appeared to be either crushed, (see Picture 15 in Appendix A), so that the camera could not gain access, or had sags, (see Picture 16 in Appendix A), causing the drains to hold water and debris. All of the drains inspected on that day contained various restrictions preventing complete access by the video inspection camera.

On the second day of the demonstration project, edge drain inspections were performed along I-540 in Crawford County. These edge drains were installed along this highway between one and two years of the inspection date under Job R40036. Only one of the outlet pipes checked with these edge drains allowed full access to its' end cap. See Picture 17 in Appendix A. The other drains checked either had outlet pipes partially crushed, (see Picture 18 in Appendix A), or were crushed and filled with debris. See Picture 19 in Appendix A.

During the final day of the demonstration project, edge drain inspections were performed in Hempstead and Nevada Counties along I-30. The edge drains along this highway were constructed either in 1980 with Job 3854 or in 1987 with Job 3906. Most of these drains could only be inspected in the first few feet of the outlet pipe, (see Picture 20 in Appendix A). Most of the outlet pipes inspected was blocked either by crushed pipes, see Picture 21 in Appendix A, or debris, preventing inspection with the video camera.

From inspection of the interiors of the pavement edge drains, it was determined that the condition of the outlet pipes limit access to the edge drains for inspection and potentially reduce their effectiveness. The blocked or damaged edge drain outlet pipes appeared to be more prevalent in drains which have been in service for several years; however, blocked and damaged edge drains were also discovered on I-540 which at the time of investigation was only recently opened to traffic (August 1995) in Crawford County.

The types of blockages discovered in this initial inspection include crushed or deformed pipes, gravel and sediment blockages, vegetation infiltration, wasp nests, and ant nests. It was noted that no rodent nests were discovered during these demonstrations, which may be a result of the rodent screens being maintained by the Districts on most of the drains. During these inspections, it was found that the AHTD District personnel have a regular program of outlet maintenance, including the replacement of worn or missing rodent screens. Some of the edge drains had clean openings with rodent screens in tact; however, they

were not functioning properly due to blockages in the outlet pipes beyond the head walls. If the District did suspect any problems at this time, their only option would be to uncover the edge drainpipe and replace any damaged or blocked sections.

In 1996, the Department purchased, under Job #60592, a waterproof video camera system capable of inspecting 4" diameter edge drains pipes. See Picture 22 in Appendix A. This video inspection system enabled District personnel to further investigate existing edge drain pipes being repaired on I-540 in Crawford County and edge drains under construction with Jobs R20138, I-530, Section 4 and 5 (see Picture 23 in Appendix A) and 070061, I-30, Section 14. The inspection showed that in new construction many of the edge drains were being damaged during or slightly after installation by trucks and heavy equipment during the construction phase. These drains were installed along the highway equipped with a pavement over an open graded base. Trucks hauling roadbed material from quarries located along the right of way crushed many of the edge drain laterals installed on the project. Many of the edge drains replaced after the hauling was complete, were subsequently crushed a second time by heavy equipment working along the shoulders. The flexible pipe or light wall PVC pipe used to construct these laterals provided inadequate strength at shallow depths along the shoulder to withstand heavy loads. If the installation of the laterals had been delayed until the road bed construction was completed and heavier rigid pipe had been used for the

lateral construction, it is likely that very little of this damaged would have occurred.

During the inspection of Job 70061, I-30, Section 14, in Clark County particular attention was made to the edge drain radii and main drain lines. The inspection confirmed that many of the radii, constructed from 4" flexible pipe, had been crushed by the weight of heavy equipment on the gravel filled trench. See Pictures 24 and 25 in Appendix A. Also, many of the drains were found to contain tailings from the joint sawing of the main lanes. The saw water, which drained into the gravel filled trench and subsequently into the edge drains, caused tailings to settle out in the drainpipe and laterals. As a result, these drains had to be flushed with a sewer cleaning truck in order to remove this material. The laterals on this job were constructed of 4" Schedule 40 PVC pipe. None of the Schedule 40 PVC pipe laterals found were crushed or deformed.

On September 1996, a construction review inspection was conducted on the edge drain system under Job 70061, I-30 at Arkadelphia. Gra-Co, Inc., a company specializing in sewer cleaning equipment and accessories, was contracted to flush out edge drains using high-pressure water jetting equipment. The AHTD video camera inspection van was at the site to inspect the edge drain system after the slurry was flushed out.

The first location that was cleaned out was in the eastbound lanes near the Caddo River Bridges. The hose and nozzle were fed into the outlet all the way through the mainline and around the bend of the cleanout lateral on the upper end

of that edge drain section. Camera inspection was then attempted but was hampered by the silty water that had not yet drained from the system.

Slurry material was flushed from all of the edge drain sections. Several locations showed considerable slurry removal. At two locations well into the mainline, accumulated slurry stopped forward progress of the flushing head. After stopping the hose at these locations for a short period of time, the slurry was blown free and forward progress was resumed. Subsequent camera inspection proved the flushing to be very effective at removing slurry from the pipes. There were, however, at least two locations where the flushing equipment was obstructed by crushed lateral bends. See Picture 26 in Appendix A. After all edge drain sections were cleaned, further camera inspection revealed the extent of the crushing problems. At two locations, the camera verified that the flexible polyethylene pipes were crushed at the connection was schedule 40 PVC lateral. Also, some deformation of nearly the entire length of mainline edge drain inspected was noted.

Upon conclusion of the inspection, several criteria were established to repair and prevent deformations and crushing problems with the edge drains. Concerning the crushed flexible polyethylene **at the connection to the lateral**, if some deformation was present but the flushing equipment could easily negotiate the system, and shoulder paving is complete, the edge drain would remain as is. If the deformation was extensive enough that the flushing equipment was obstructed, this connection must be excavated and repaired regardless of whether shoulder

pavement is already in place. Any significant deformation, even where the flushing head and camera were still able to pass, would be repaired in locations where the paved shoulder was not yet in place. See Picture 27 in Appendix A.

For the crushed or deformed **mainline flexible polyethylene**, extensive length of minor deformation would be allowed to remain in place if, at a very minimum, the opening is large enough for the cleaning equipment to pass the entire distance. It was believed that excavation and replacement in this scenario would likely cause considerable damage to the area and not result in any significant improvement of the system. Crushing of occasional locations that are found to be isolated and of short distance (e.g. one foot) and were under completed shoulder pavement would be allowed to remain in place. In this scenario, drainage would still occur some through the pipe and what could not go through would go through the pea gravel trench outside the slotted pipe. All locations which were deformed enough to prohibit the cleaning equipment from passing and the shoulder pavement was not yet placed, would have to be repaired. There was, however, no serious crushing of mainline pipe during this inspection.

The repairs that were to be made are at the connection of the mainline to the lateral. These locations will be repaired using solid schedule 40 long sweep elbows. The Resident Engineer of the AHTD attending the inspection proposed to also place a seal over any patched shoulder areas to provide a uniform appearance when completed.

Possible changes in construction practices at this inspection review site were as follows. The Contractor prefers the solid elbows and will use them to construct the westbound lanes. The Contractor will also widen the tracks of the paver to run outside the Open-Grated Base Course (OGBC). This will require placement and set up of shoulder gravel to provide a track line for good grade control. The Contractor was also agreeable to take steps to protect the open graded base course on remaining sawing and grinding operations by covering the exposed 2 feet of OGBC using visqueen or plywood.

Video inspections were made during the construction of Job R20138 on I-530 near Redfield (See Pictures 28 and 29 in Appendix A). Several crushed radii were discovered. The reasons appear to be caused by installation practices and heavy equipment. The trench cut for the lateral installation creates a relatively large trench at the radius point of the drains. Pressure on the gravel from heavy construction equipment and trucks appear to be sufficient to crush the flexible pipe radii below the gravel. Also, inadequate bedding and the dumping of gravel over the pipe appears to have crushed and/or misaligned many of the radii. None of the Schedule 40 PVC lateral pipes were crushed. A few were misaligned during installation, causing water to pond above the outlet protectors. The majority of problems on this job involve the flexible pipe radii being in use.

SUMMARY

Excess water is the cause of many types of pavement failures and an improved sub drainage system is needed to minimize its damaging effects. The performance of these pavement drainage systems was analyzed for this study.

Over the years, a great deal has been learned regarding the physical processes involved with pavement drains. Precipitation is the primary source of free water present under pavements. Since Arkansas has relatively high annual rainfall, any area over the State, which has silty or clayey soils, and significant heavy truck traffic, may be subject to pavement pumping and the associated damage.

It has been known for some time that many laterals to pavement edge drains are damaged or obstructed, from construction activities, environmental factors, and maintenance activities, to the extent of becoming dysfunctional during their design life. In past observations, the majority of laterals inspected were blocked either by structural damage or debris. Those drains, which could be inspected above their laterals, were mostly found to be open and operating to some extent. As a result of these inspections it is known that flexible pipe laterals buried at shallow depths are vulnerable to damage from tractors, vehicles, and equipment. Therefore, schedule 40 PVC pipe is now specified for laterals on newly constructed edge drains, and schedule 40 PVC pipe, fixtures, and rubber sleeves have been recommended by Research for rehabilitation and repairs to existing pavement edge drain laterals.

The implementation of the flushing trailer and video camera system has added to the knowledge of the Department regarding the construction and operation of pipe under drains. It has been discovered that many flexible under drainpipes are damaged during construction by improper bedding and the weight of heavy equipment. Frequent alignment problems are created when the flexible pipe at the radius above the lateral is raised to attach it to the lateral itself. Flexible pipe couplings that are inserted inside the pipe are often crushed by backfill. Rocks in the trenches often push the bottom of the drain up during back fill trapping water inside the drain. Flexible pipe used for drain laterals are frequently crushed between the shoulder and the headwall by the weight of construction equipment, and often this is left undetected prior to final acceptance of construction.

Pavement edge drains, which function normally following construction often, sustain damage and blockages from environmental factors or maintenance activities. Insects and rodents occasionally try to occupy drains, placing debris that plugs the drain. Vegetation often infiltrates drains seeking the most direct path to nutrients and water and thereby, plugging the drain. Flexible pipe under drain laterals often sustain damage from the weight of maintenance vehicles operating beyond the highway shoulders. Mowers throw debris over the lateral outfalls occasionally blocking drainage and encouraging the propagation of vegetation that also blocks drainage.

Sufficient care must be exercised in the installation of pavement edge drains to insure that they have an adequate outfall to operate. Since these are gravity systems, their outlets must be installed below the grades of the collector pipe in order to drain. Also care must be exercised during construction to insure that the collector pipe is not crushed or damaged to avoid restrictions in the system and aggravate the accumulation of debris in the pipes. The laterals extending from the collector pipe should be constructed with rigid pipe with sufficient strength to prevent misalignment and damage during installation and damage from maintenance operations during the life of the system.

It has already been determined that a large portion of restrictions in pipe under drains are limited to the pipe laterals. The video inspection camera can be used to verify the structural integrity of these pipe sections, thereby, allowing the rehabilitation of them by repairing the pipe laterals and avoiding excavation of the shoulder. This can save significant time and money during highway rehabilitation projects. Periodic inspection, cleaning, maintenance, and repair must be performed if adequate drainage of free water from the pavement is to be achieved. If the drains do not remain open and operating efficiently, they may actually increase damage to pavements by acting as a reservoir to hold water under the pavement for long periods of time.

APPENDIX A
PHOTOGRAPHS



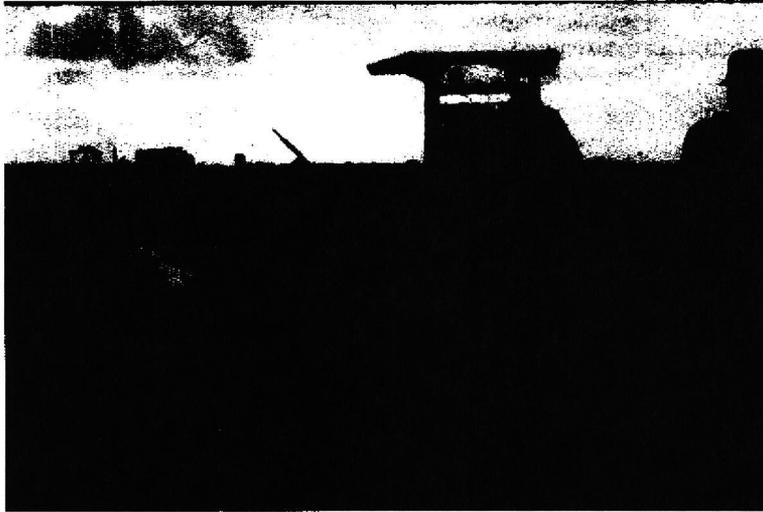
Picture 1. Traditional Flexible Pipe



Picture 2. Monsanto Drainage Mat



Picture 3. Site Location of Project on I-40 near Ozark



Picture 4. Installation of MDM Drainage System



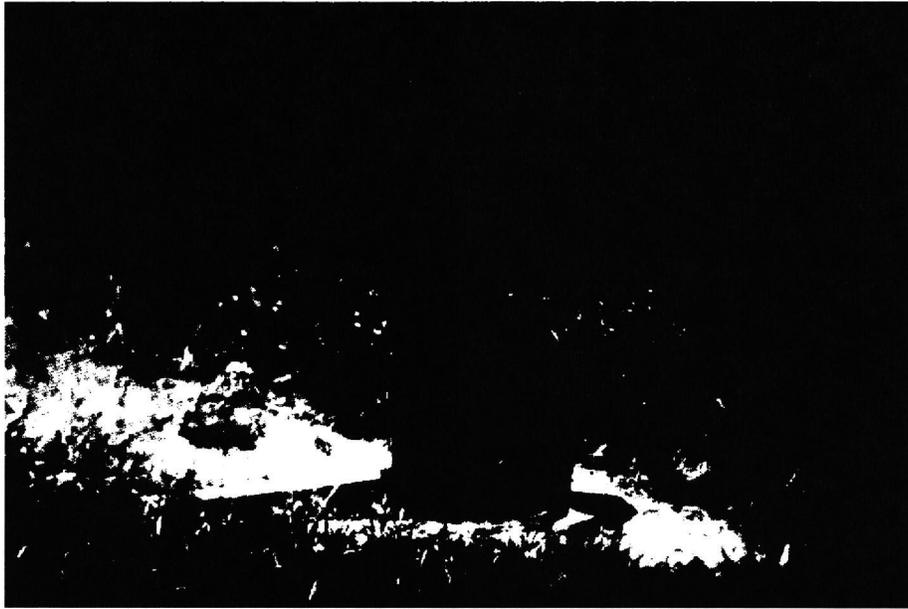
Picture 5. Flow Monitoring Equipment



Picture 6. Flow Monitoring Equipment with Tipping Bucket



Picture 7. Updated Flow Monitoring Equipment on I-40



Picture 8. Edge Drain Gage Site on I-40 near Ozark.



Picture 9. Pearpoint Video Edge Drain Inspection System



Picture 10. Video Inspection of Edge Drain



Picture 11. Flushing Trailer



Picture 12. Pumping Evidence on I-40



Picture 13. Shoulder Staining Along East Bound I-40



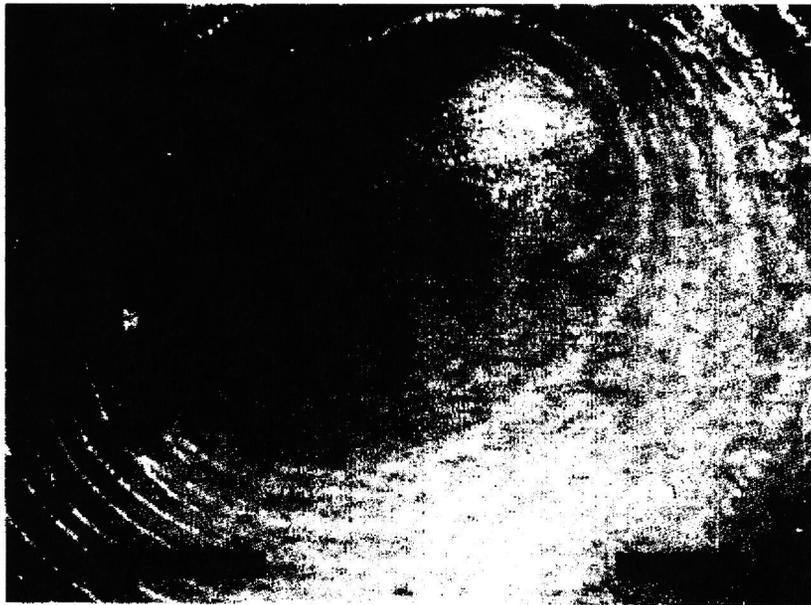
Picture 14. Asphalt Stripping on Rehabilitated Shoulder



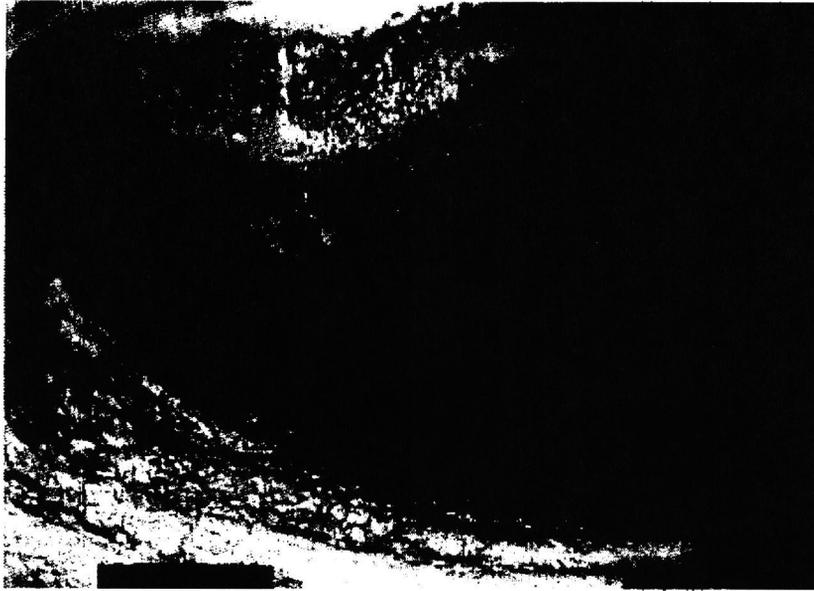
Picture 15. Crushed Outlet Pipe at Headwall on I-40 in Pulaski County



Picture 16. Edge Drain Outlet Pipe with Sag Behind Headwall Holding Water



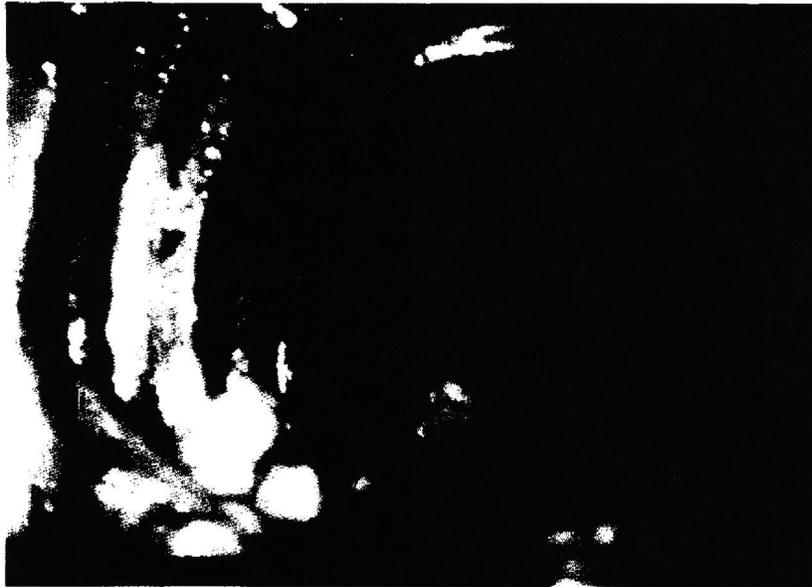
Picture 17. End Cap in Edge Drain on I-540 in Crawford County



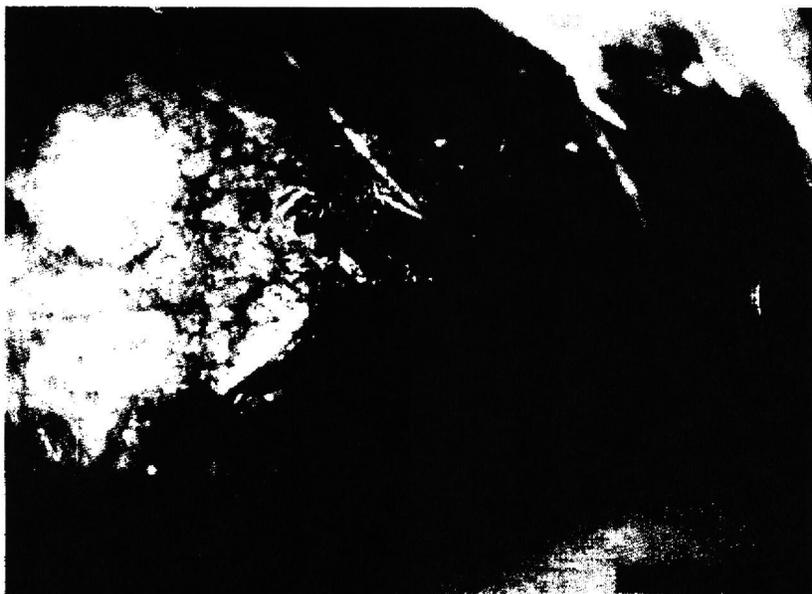
Picture 18. Crushed Edge Drain Outlet Pipe on I-540 in Crawford County



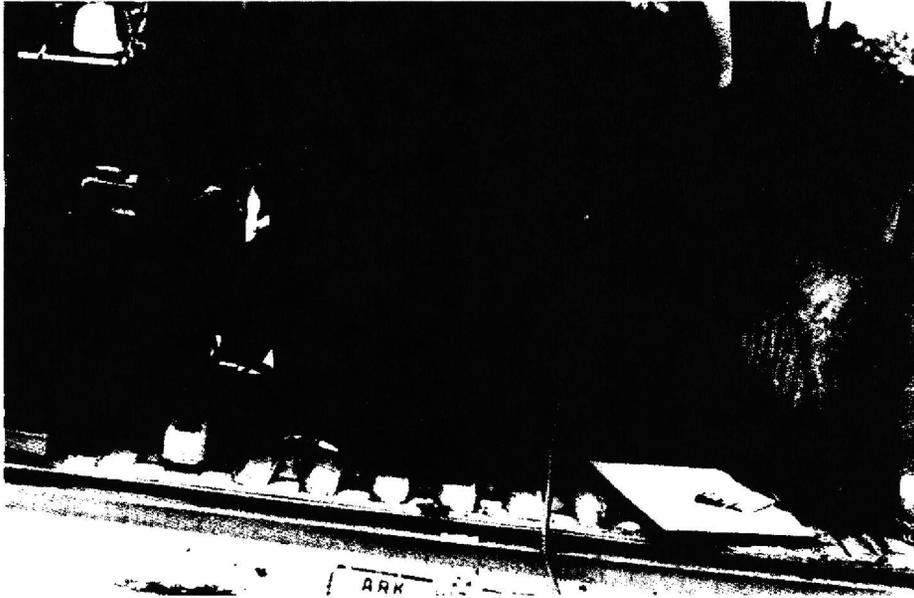
Picture 19. Edge Drain Outlet Pipe Damaged and Full of Material



Picture 20. Damaged Edge Drain Outlet Pipe with Gravel and Debris



Picture 21. Crushed Edge Drain Outlet Pipe Just Inside Headwall



Picture 22. Camera Control Unit and Generator for Video Inspection System Operated from Pickup Truck



Picture 23. Video Inspection System on I-530 near Redfield



Picture 24. Damaged Radius Discovered with Video Camera on Job #070061 in Clark County



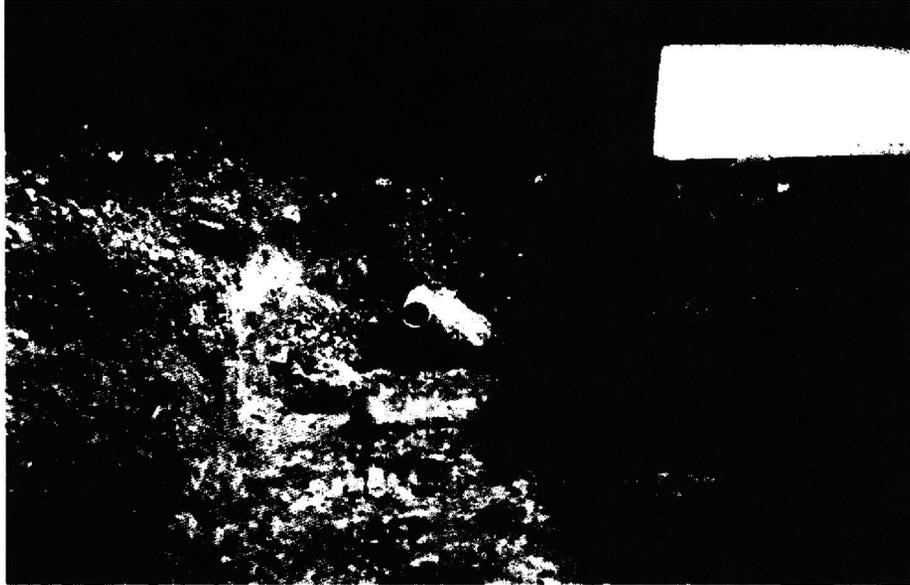
Picture 25. Silt in Edge Drain on Job #070061 on I-30



Picture 26. Collapsed Edge Drain Lateral Discovered During Inspection



Picture 27. Schedule 40 Lateral Pipe Repair to Damaged Edge Drain



Picture 28. Newly Installed Schedule 40 Lateral Pipe on I-530 - Job #020138



Picture 29. New Edge Drain Outlet on I-530