Research Report
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FIELD PERFORMANCE REPORT ON CORRUGATED POLYETHYLENE PIPE

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16. Abstract

This report documents the installation and performance of corrugated smooth lined polyethylene pipe installed during construction of South Forbes Road in Fayette County, KY 54 in Daviess County, US 62 in McCracken County, Nicholasville Road in Fayette County, US 68/KY 80 in Warren County, KY 127 in Franklin County, US 62 in Hardin County, Donaldson Road and KY 236 in Kenton County, KY 17 in Kenton County, and Anderson Road in Kenton County. The majority of the pipe installed was N-12 pipe manufactured by Advanced Drainage Systems, Inc., and is designated as ADS N-12. ADS N-12 is a corrugated high-density polyethylene (HDPE) pipe. The pipe has a corrugated exterior for increased strength and a smooth interior to provide maximum flow capacity. A similar product, Hi-Q manufactured by Hancor, was also installed on portions of the project on Anderson Road.

This report makes recommendation on the usage of polyethylene pipe in Kentucky.

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EXECUTIVE SUMMARY

This report documents the installation and performance of corrugated smooth lined polyethylene pipe installed during construction of South Forbes Road in Fayette County, KY 54 in Daviess County, US 62 in McCracken County, Nicholasville Road in Fayette County, US 68/KY 80 in Warren County, KY 127 in Franklin County, US 62 in Hardin County, Donaldson Road and KY 236 in Kenton County, KY 17 in Kenton County, and Anderson Road in Kenton County. The majority of the pipe installed was N-12 pipe manufactured by Advanced Drainage Systems, Inc., and is designated as ADS N-12. ADS N-12 is a corrugated high-density polyethylene (HDPE) pipe. The pipe has a corrugated exterior for increased strength and a smooth interior to provide maximum flow capacity. A similar product, Hi-Q manufactured by Hancor, was also installed on portions of the project on Anderson Road.

Polyethylene pipe appears to perform satisfactorily as cross drains, storm drains, and entrance pipe when properly bedded and backfilled with a high shear strength material. From observations obtained in this study, long-term deflections do not appear to be a problem when pipe are properly installed. Flammability of polyethylene pipe was beyond the scope of this study and no conclusions can be made. Most problems with pipe damage, such as rips, delamination, or punctures appear to be traceable to improper handling and/or construction procedures. Sags in grade, misalignment, and poor coupling do not appear to be a material related problem but are largely due to poor construction techniques.

It is recommended that polyethylene pipe be approved for use as storm sewers, cross drains, and entrance pipe subject to the following limitations: 1) All polyethylene pipe should be installed according to Kentucky Standard Drawing No. RDI-20-04, with the addition of granular backfill. Granular backfill should be used to a minimum height of one foot above the crown of the pipe. 2) An ASTM Class I or Class II type backfill should be used for polyethylene pipe. 3) Entrance pipe should have a minimum of one foot of cover. More aggressive inspection of all pipe installations should be implemented. 4) Continued long-term inspections of selected installations using various materials are suggested.

Further research is recommended to determine the minimum shear strength needed to provide adequate side support for flexible pipe.

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INTRODUCTION

Smooth-lined, corrugated, high-density polyethylene (HDPE) pipe is a relatively new product developed within the last five years. The pipe has a corrugated exterior for increased strength and a smooth interior to provide maximum flow capacity. As with any new product, questions have been raised about short-term and long-term performance, installation procedures, durability, flammability, and other performance characteristics.

Polyethylene pipe has been used in Kentucky on an experimental basis since 1987. Most of the pipe that has been installed was manufactured by Advanced Drainage Systems, Incorporated, and is designated as ADS N-12. A similar product, Hi-Q manufactured by Hancor, was also installed on portions of a project in Kenton County. The projects that have used polyethylene pipe are distributed throughout the state.

The Kentucky Transportation Center was requested by the Kentucky Transportation Cabinet to monitor the field performance of polyethylene pipe. No laboratory strength tests, durability tests, or flammability tests were conducted by this agency. This report documents the installation and performance of corrugated smooth lined polyethylene pipe on South Forbes Road in Fayette County, KY 54 in Daviess County, US 62 in McCracken County, Nicholasville Road in Fayette County, US 68/KY 80 in Warren County, KY 127 in Franklin County, US 62 in Hardin County, Donaldson Road and KY 236 in Kenton County, KY 17 in Kenton County, and Anderson Road in Kenton County. The product Hi-Q was installed on portions of the project on Anderson Road.

The purpose of the study was to evaluate the field performance of the pipe during construction and after placement, and to determine the extent of use of this product in other states, as well as its performance in other states.

The conclusions and recommendations in this report are based largely on the observed field performance, and to a lesser extent, on information and experience of other agencies and states.

BACKGROUND

The current AASHTO design methodology for conduit considers the composite performance of the structure and the soil in which it is to be buried. The structural phenomenon of the composite system is generally referred to as soil-structure interaction. The structures are classified as either flexible or rigid and the soils are classified as either compressible or incompressible. The conduit ring and the surrounding soil envelop play a vital role in the structural design and performance of the culvert. Design considerations include strength properties of the conduit material and soil parameters of the foundation, bedding, side fill, and embankment materials. The adequacy of any soil- structure system may be nullified by poor installation practices such as improper bedding, inadequate compaction of the side fill and embankment, non uniformity of foundation, as well as other factors.

Permissible fill-height tables based upon the AASHTO design guidelines have been developed.

Designs are based upon material parameters designated by AASHTO materials specifications for the various types of conduit and current bedding details included in the Kentucky Department of Highways' Standard Specifications for Road and Bridge Construction and Standard Drawings. Current bedding details were developed during the late 1950's with nominal modifications throughout the years. It should be noted that structural performances of conduits which have been installed in strict conformance with existing guidelines have been excellent.

The majority of structural distresses which have been observed throughout the years, for the most part, have been traced to poor installation practices. Distresses have been observed in rigid and flexible conduit. Thorough investigations of those distresses nearly always revealed nonconformance to installation guidelines. Conduit which meet AASHTO materials requirements and which are installed in strict conformance with current bedding details may realistically be expected to provide many years of service.

The American Society for Testing and Materials (ASTM) has a standard practice for installation of thermoplastic pipe (ASTM D 2321). One of the most important portions of that standard practice is the description of the recommended backfill materials for thermoplastic pipe. In that document, Class IVB soils (fine-grained soils with high plasticity) and Class V soils (organic soils) are not recommended as backfill materials. Class III soils (coarse-grained soils with fines present) and Class IVA soils (fine-grained soils with low plasticity) are recommended with severe restrictions. Soil Classes IA, IB, II are generally recommended for backfill assuming migration of fines into the backfill is not a problem. Sharff and Chambers (1), in their commentary on this ASTM standard, emphasize the "soil-structure" interaction problem and the need for long-term support for the pipe. In addition, they state that "Class I materials, which include all manufactured aggregates such as crushed stone, will generally provide maximum stability and pipe support for a minimum amount of installation effort." They state further that "Classes II through V, which include all naturally occurring soils from coarse-grained gravel and sands to fine grained silts, clays, and organics, generally require increasing installation effort with decreased reliability of performance."

The American Association of State Highway and Transportation Officials (AASHTO) has published recommended design procedures for soil-thermoplastic interaction systems (Section 18) in their Standard Specifications for Highway Bridges (2). This design standard indicates the performance of flexible culvert pipe is dependent on soil-structure interaction and soil stiffness. AASHTO also recommends side fill soils that classify as A-1, A-2, or A-3 soils according to the AASHTO soil classification system. These soils are generally regarded as granular soils (Section 18.1.6.1).

The long-term performance of the pipe during a long service life is also a matter of concern. An expected, service-life of 50 years is often referenced in the literature. A report (3) published by the Subcommittee on New Highway Materials (sponsored jointly by AASHTO, AGC and ARTBA) indicates that 92 percent of respondents to a survey that they conducted considered a service life of 25 to 50 years as appropriate. Eight percent of respondents in that same survey indicated polyethylene pipe should have a service life of greater than 50 years. AASHTO (Reference 2) also indicates a minimum 50-year life expectancy (Section 18.4.3). AASHTO limits the deformation of the pipe during the 50-year life to five percent (Section

18.4.3.1.1).

SURVEY OF POLYETHYLENE PIPE USAGE

From information obtained by research personnel, it appears that approximately 46 states use polyethylene pipe on a limited basis. Four states were contacted by telephone for an in-depth interview concerning their practices for using polyethylene pipe.

The state of New York has been using polyethylene pipe for approximately four years. The pipe is backfilled with a granular material. Designs are for a 70-year life span. The maximum permissible fill height is 15 feet. A mandrel test is not required since the average deflection is in the range of 2 to 3 percent. The use of the pipe for entrances is limited since it is difficult to obtain the required one foot of cover. Use of the pipe is left to the discretion of the designer.

The Michigan Department of Transportation has currently used up to 24-inch diameter pipe. The use of a granular backfill is required. Maximum permissible fill height is 18 feet. A mandrel test may be performed at the inspector's discretion. It is being used for entrance pipe with extra precautions taken to ensure a minimum of one foot of cover over the pipe. Metal end sections are required on some of the pipe installations.

The Ohio Department of Transportation uses the pipe for storms drains, cross drains, and entrance pipes. Problems have developed with the pipe when it is not properly backfilled. The trench is excavated to twice the diameter of the pipe and backfilled with a dense-graded aggregate base material to a height of one foot over the crown of the pipe. They do not require a mandrel test.

The California Department of Transportation has been using polyethylene pipe for approximately 3 years. All sizes up to a 36-inch diameter pipe is approved for use. The pipe is used for storm drains and cross drains. The maximum permissible fill height is 12 feet. A mandrel test is not required. The use of existing soils for backfill is permitted; however, a compaction requirement of 95 percent of maximum dry density is a part of the specification.

According to a research report by the North Carolina Department of Transportation on polyethylene pipe, the pipe will perform satisfactorily if it is properly installed according to ASTM D 2321 (4).

FIELD OBSERVATIONS

It should be noted that some of the projects that were inspected by research personnel for this study were not inspected during construction; therefore, the nature of the backfill material could not be ascertained on every project. The projects that the researchers inspected during construction are indicated in the discussion below.

Forbes Road, Fayette County

In November 1987, the first section of N-12 pipe installed in Kentucky was along Forbes Road

in Fayette County. The pipe was installed in two locations. The first was 15 inches in diameter and was installed 28 feet right of Station 6+54. The 15-inch N-12 was used as an entrance pipe (very seldom loaded). The entrance pipe was backfilled with approximately one foot of material.The second location starts at a storm sewer inlet and runs 240 feet north to a manhole; this N-12 is used as a 15-inch culvert. The pipe was backfilled with No. 9 stone to approximately one foot above the top of the pipe. The remainder of the trench was backfilled to grade elevation with excavated material. The maximum fill height was approximately 6 feet.

The pipe was visually inspected on November 19, 1987, September 21, 1989, and in October 1991. Random measurements were taken of the internal diameter of both pipes. Measurements indicated there had been little to no distortion of the pipe since construction. Table 1 summarizes the results of the inspections of this site.

The pipes also were inspected for chemical or physical deterioration or defects. The inlet, outlet, and manholes were examined and photographed. There were no signs of deterioration of the N-12 pipe.

KY 54, Daviess County

During the relocation of KY 54, in Daviess County, approximately 468 feet of 15-inch N-12, and 592 feet of 18-inch N-12 were installed. The project begins at Station 93+81.17 and ends at Station 152+00. The first section of N-12 pipe was placed May 18, 1988, at Station 137+88. The pipe was installed as a cross drain. Approximately 104 feet of 18-inch N-12 were placed at that location. The trench was backfilled with a coarse and clean sand approximately midway up the pipe and compacted with a vibratory tamper. The remainder of the trench was backfilled with excavated material. The excavated material was alluvial by nature (sandy silt).

Prior to installation, it was observed that a number of the pipe sections had been cut during construction. It appeared that the sections had been damaged during transport with a backhoe. The damaged sections were returned to the manufacturer for inspection.

Two sets of monitoring points were placed in the 18-inch pipe at Station 137+88 prior to installation. The monitoring points were placed at 41 feet and 61 feet from the outlet. The points were monitored three times during 1988, once in 1989, once in 1990 and on October 3, 1991. Since installation, the interior of the pipe at 41 feet had deflected approximately 0.32 inch (Figure 1), and approximately 0.22 inch at 61 feet (Figure 2). The fill height above the 61-foot monitoring point was 6 feet, and the fill height at the 41-foot monitoring point was 8 feet. During the inspection of the cross drain on October 3, 1991, noticeable deflection appeared to be occurring at the upgradient end of the pipe. After further inspection, it was found that the pipe had deflected 18-percent in the vertical direction and 12.7 percent in the horizontal plane. This compressed area is occurring approximately 55-inches from the junction box. This is occurring under the right wheel path of the overlaying road. The pipe is covered by approximately 28-inches of fill. No surface distress was noticeable. No distress had been noticed until this date. Overall, approximately 3 percent of the total amount of 18-inch pipe that was installed had deflected over 10 percent. Table 2 is a summary of deflections at this

site.

All pipes, including the 18-inch and 15-inch pipe were inspected and photographed. All appeared to be symmetrical. On June 18, 1988 during the inspection of the 104-foot, 18-inch pipe at Station 137+88, a rip or cut was noted in the smooth interior lining of the pipe. The rip follows one of the corrugations and is approximately 7 inches in length. The rip was closely inspected again on September 18, 1989. The rip appeared to be approximately the same length and had bulged approximately 0.5 inch. The pipe was inspected again in October 1991 and there had been no noticeable change since September 1989.

The interior of a 216-foot, 18-inch pipe was inspected in detail on September 19, 1989, from Station 126+00 to 128+20. Each 20-foot section was photographed and visually inspected. The pipe appeared to be clean and symmetrical. A 4-inch gap was discovered between the first and second section south of Station 128+20. It was apparent that the sections were not completely butted together at the time of installation. All other joints were inspected and their conditions were recorded. The next largest separation was one inch. A 0.5 inch separation at joints was fairly common throughout the pipe section.

US 62, McCracken County

During 1989-1990, approximately 652 feet of N-12 pipe was installed during reconstruction of US 62 from two lane to four lane. As shown in Table 3, the sizes of pipe installed were 15, 18, 24, and 30 inches. The majority of the pipe is being used as entrance pipes for local residences. On September 18, 1989, all entrance and culvert pipes were visually inspected and photographed. Several of the pipes showed signs of deflection. It appears the pipes had deformed during backfill operations. Appendix A is an inspection log for each pipe.

On March 13, 1990, all pipes were visually inspected, photographed, and deflection measurements were taken. Contained in Appendix B is an inspection log of each pipe. Through further observation, it appears that culvert pipes (cross drains) are functioning well with little notable deflection. The N-12 pipe used as entrance pipe appears to be deflecting considerably more than pipe used for culverts. It appears that the entrance pipes are deflecting due to shallow fill heights, weak backfill material, and traffic loading. A 9-inch deep, 1.5-foot long compression failure was observed in an 18-inch pipe located under a concrete driveway. As shown in Table 3, approximately 50 percent of the 15-inch pipe and the 24-inch pipe had deflected over 10 percent. Approximately 40 percent of the 18-inch pipe had deflected over 10 percent.

US 68/KY 80, Warren County

In 1989, a contract was awarded for the widening of US 68/KY 80. Included in this contract was the installation of N-12 pipe. Approximately 7,080 feet of N-12 pipe was installed. The pipe was used predominately as storm drains and cross drains. Monitoring points were marked inside the pipes on November 28, 1989 while the pipes were stockpiled. A puncture was observed inside one of the 36-inch pipes. The puncture passed through the outside corrugations

and through the smooth interior lining.

A construction and monitoring inspection was performed on December 12, 1989, January 11, and February 21, 1990. The pipe was being backfilled with No. 11 stone to an elevation approximately 3/4 up the height of the pipe. The material was being compacted with vibratory compactors. On December 12, 1989, the remaining trench was backfilled with the excavated material which consisted of frozen red to brown clay and rock. According to Section 612.05 of the Kentucky Standard Specifications For Road And Bridge Construction, the fill material should be free of rocks larger than 3 inches and is not to contain frozen clods of soil. A large 36-inch storm drain was visually inspected and deflection measurements were obtained. The pipe appeared to be symmetrical and well within the maximum allowable 5-percent deflection.

On April 18, 1990, a tear approximately 6 inches long was observed in a 24-inch pipe. The pipe had deflected 3 inches, approximately 45 degrees off vertical. The tear had occurred in one of the inside spiral corrugations. It appears to have been caused by a rock in the backfill. Five tears were observed inside the N-12 pipe in Warren County. It appears the tears are occurring where the sections of plastic are wrapped together to form the pipe. The tears may have occurred due to improper backfilling and unequal loading of the pipe. It appears that large rocks or large clods become lodged against the pipe during backfilling operations.

On December 20, 1990, further inspections were conducted on US 68/KY 80. A significant amount of deflection occurred in a 24-inch lateral outfall pipe which discharges collected water from the storm drains on the east end of the project. The pipe had deflected approximately 12 percent (approximately 24 feet south of the junction box). Similar deflections appeared to be occurring in several of the other pipe sections in the outfall. A 6.75-inch gap was noted at a junction of the pipe during construction, approximately 2 feet from box. A crack in the enter line had occurred in the invert of the first section of pipe. On the average, approximately 10 percent of the 24-inch pipe installed had deflected over 10 percent.

In October of 1991, KTC investigators conducted a final visual inspection of the US 68/KY 80 installation. No visible deflection was apparent on any of the 15-inch to 24-inch pipe sections. Deflection measurements were taken on 24-inch and 36-inch pipe (Figure 3 - 4). Approximately 4 percent deflection was recorded in a 36-inch storm drain. All of the deflections taken on the 36-inch pipe were less than 5 percent. Maximum deflection recorded for a 24-inch storm drain was 3 percent. The 24-inch outfall pipe was also inspected and deflections were approximately 12 percent, showing no change since December of 1990. Table 4 summarizes deflections at this site.

In general, other than the 24-inch outfall pipe draining the east end of the project, very little deflection was observed in the remainder of the pipe sections. The pipes appeared to be to grade and had very little horizontal or vertical distortion. The several rips and tears observed in five locations appeared to be due to improper bedding and/or backfill.

US 27 (Nicholasville Road), Fayette County

Approximately one mile of N-12 pipe was installed during a widening project on the Nicholasville Road in Fayette County. The pipe is being used as cross and storm drains. The trench around the pipe was backfilled with No. 9 stone to an elevation approximately 1 foot above the pipe. The remainder of the trench was backfilled with excavated material (red/brown clay). The entire project was inspected on November 4, 1991. The pipe appeared to be in excellent condition. All the pipes appeared to be symmetrical. A 6-inch change in grade (sag) of a 24-inch pipe was observed on the north end of the project. There was no apparent stress in the walls of the pipe. A 15-inch separation at a coupling was observed. The coupling connected to the pipe that was sagged. It appears that the pipe was not installed properly and that the sagging in the pipe did not create the separation at the coupling. It is apparent the pipe was not laid to a proper grade. No surface distress was apparent.

During an inspection of a 36-inch lateral outlet pipe in 1990, a 2 x 4-inch raised area in the inner liner was observed in the downstream pipe at a coupling. It was apparent that a small rock had been wedge in the pipe during construction. On November 4, 1991, a large limestone slab approximately one foot in diameter had been wedge in this same area. A 4-inch wide strip of the inner liner has been pealed up approximately 2 or 3 inches up on the haunches of the pipe. During inspection of the upgrade junction box, several rocks had been wedged around the pipes in order to fit the precast holes. It is apparent the boxes were not properly manufactured to fit the pipe and not enough grout was used to properly fill this space. Other than the sag and the tear in the inner liner observed during the last inspection, the pipe is in excellent condition. No significant deflection had been noted in any of the pipe sections (Table 5).

KY 207, Greenup County

In October, 1991, approximately 10 to 20 percent of the 11,220 feet of storm and cross drains were inspected. The pipe appeared to be in excellent condition other than some significant deflections in some areas. Approximately 20 percent of 30-inch storm drain that was inspected had deflected over 5 percent. The maximum recorded was 5.5 percent. Several sections of a 36-inch outfall pipe had deflected over 5 percent. The highest deflection was 7.3 percent (Table 6).

US 62, Hardin County

By October 14, 1991, approximately half of the pipe had been installed on the US 62 project. The majority of the pipe appeared to have been placed properly and was performing satisfactory. At the time of the inspection, the pipes contained heavy layers of silt due to construction runoff. It appeared that the pipes had been backfilled with No. 9 stone. One cross drain showed significant deflections. The pipe had deflected approximately 8.0 percent. Approximately 19 percent of the 18-inch pipe that was installed had deflected over 5.0 percent (Table 7). The inspector indicated that a portion of the 18-inch pipe had failed compression test but had been installed.

US 127, Franklin County

On October 15, 1991, 18 entrance pipes were inspected on the US 127 construction project. It appeared that most of the pipes had been backfilled with the excavated trench material. Sixteen 15-inch entrance pipes were inspected, 40 percent had deflected over 10 percent. One 18-inch entrance pipe and it had deflected approximately 15 percent (Table 8). Most of the 15-inch entrance pipe were installed under shallow fill heights of approximately 6-inches to 1-foot. A large majority of the entrance pipes appeared to have had heavy construction equipment passing over them. Under the shallow fill heights and marginal backfill, the pipes appear to be performing satisfactory.

Anderson Road, Cresent Springs, Kenton County

On October 31, 1991, personnel from the Kentucky DOT, ADS, and KTC visited several sites in Northern Kentucky. Anderson Road was the first site visited. An 18-inch storm sewer was inspected. The pipe had several sagged areas and vertical miss alignments (vertical offset) at the joints. Vertical deflection of 8.3 percent was recorded. Approximately 16 percent of the 18-inch pipe that was installed had deflected more than 5 percent. A 24-inch cross drain was also inspected. Vertical offset of 2.75 inches was observed at the junction of two pipes. The pipe had deflected approximately 10.5 percent. Approximately 12.5 percent of the 24-inch pipe that was inspected had deflected more than 5 percent (Table 9).

On November 14, 1991 an 18-inch storm sewer which discharges into a 20-foot X 10-foot concrete box culvert was inspected. The pipe appeared to be symmetrical. Vertical offsets at the joints of 1.5 inches were recorded. There was also a large amount of lateral movement in the pipe. Three other pipes discharge into the culvert, two 18-inch pipes, and one 24-inch pipe. The 24-inch pipe had one long noticeable sag in its grade. The pipe had been longitudinally compressed where it ties into the box culvert. The smooth inner liner had wrinkled. The two other 18-inch pipes had also been longitudinally compressed at the box culvert. The pipes are connecting to the box at a fairly step grade. The pipes are likely compressing due to the angle of installation and compaction and settlement of the backfill. One of the pipes had a 2-inch buckle or hump in the bottom where it had not been properly bedded. The other 18-inch pipe had several vertical and horizontal offsets at the joints, several sagged areas, and considerable lateral movement. In addition, two 24-inch storm drains were inspected. One was approximately 100 feet long the other was approximately 165 feet long. The 100-foot long drain had noticeable dips in its grade approximately every 5 feet. The 165-foot storm drain was fairly symmetrical. The pipe had one large sag in one of the pipe sections and a 1-inch vertical offset was observed at a joint.

In general, the pipes appeared to be critically stressed at the connection with the concrete box culverts. Most of the pipes appeared not to be properly bedded due to the number of sags. A large majority of the pipes varied laterally. Due to the lightness of the polyethylene, the N-12 pipe has a tendency to rise or drift during backfilling. To eliminate this, the contractors should bed each side equally to approximately 1/2 to 3/4 of the pipe height before compacting (depends greatly on the backfill material).

Donaldson Road and KY 236, Kenton County

Donaldson road was inspected on October 31, 1991 and November 14, 1991. Significant deflection was observed in several 15-inch and 24-inch pipe sections. A large majority of the pipe had noticeable dips in the grade. As shown in Table 10, 20.0 percent of the 15-inch pipe inspected had greater than 10 percent deflection, and 15 percent of the 24-inch pipe had greater than 10 percent deflection. Some lateral drifting was present in some of the pipe sections. The inspector on site indicated that all the pipes were being backfilled with sand to approximately 1 foot over the crown of the pipe. Due to the number of noticeable dips in the grade of the pipes, it appears that the pipes may have not been substantially bedded for the poor soils that exist in the northern portion of the state.

Entrance pipes were also inspected on KY 236. The entrance pipes that were inspected were 15 inch in diameter. The pipes appeared to be backfilled with No. 57 stone and appeared to be in relatively good shape. Four entrances were inspected and no vertical deflection was apparent, a change in grade (dip) was present in one of the entrances (Table 11).

KY 17, Kenton County

KY 17 was inspected on October 31, 1991 and several times in November, 1991. The last inspection was on November 14, 1991. Approximately 12.5 percent deflection was noted in a 24-inch outfall storm drain pipe which discharges into a large box culvert on the north end of the project (Table 12). The pipe is approximately 125 feet long. It appears that the majority of the pipe is deflected. The pipe is egg shaped and is listing at a 45 degree angle. Numerous changes in grade (sags) were observed in approximately 80 percent of the 24-inch pipes that were inspected. An additional section of 24-inch storm drain was also inspected. The section was approximately 180 feet long. There was no noticeable vertical or horizontal deflection. Sagging was apparent in several areas and a 0.5 inch to 1.5 inch vertical offsets at several joints was recorded.

Four entrance pipes had been installed. A 15-inch entrance pipe had been deflected approximately 6.0 percent (Table 13). An 18-inch entrance pipe had been compressed horizontal at one end. It was apparent a piece of heavy equipment had damaged the end of the pipe. The remainder of the pipe appeared to be in satisfactory condition.

DISCUSSION AND ANALYSIS

Backfill

As stated earlier in this report, the importance of the interaction between the flexible pipe and the soil backfill cannot be overstressed. To keep the pipe in ring compression, it is critical to provide high shear resistance at the springline of the pipe. This implies that a material having a high angle of internal friction would provide the best side support for the pipe. Granular natural soils and manufactured aggregates are the most appropriate materials to provide and maintain high side resistance. The results listed in Table 14 appear to confirm

this. All of the pipe listed in that table were backfilled with No. 57 or No. 9 crushed limestone aggregate. Only two projects out of the 11 that were inspected used crushed stone throughout the project for backfill to a height one foot above the pipe. These projects were Nicholasville Road and Forbes Road. As shown in Table 14, there was no apparent deflection in any of the pipes that were inspected. In addition, a number of cross drains on US 68/KY 80 which were backfilled with a crushed stone to a height of one foot above the pipe. There was no apparent deflection in any of these pipes. Four entrance pipes that were installed along KY 236 in Kenton County were backfilled with No. 57 stone and were under shallow fill heights. None of these pipes exhibited any apparent deflection. In one case, it was apparent that a medium-sized bulldozer had made several passes over the entrance with no apparent damage to the drainage structure.

Table 15 summarizes the remaining pipes that were inspected where the backfill material was not known, or was suspected of being a fine-grained soil, or where compaction efforts were suspected of being inadequate. It is noted that the percentage of pipe having deflections greater than five percent is significant. This appears to point out the importance of using high-quality, high-strength backfill material.

Data obtained from the Division of Materials of the Kentucky Highway Department also illustrate the importance of a high-strength backfill for polyethylene pipe. Table 16 shows that polyethylene pipe supported less stress at five percent strain than steel pipe. (However, it supported more than aluminum pipe.)

Long-Term Deflections

The vertical deflections from Figures 1 and 2, and the largest vertical deflections from Figures 3 and 4 (locations 1T and 2L, respectively) are plotted semi-logarithmically in Figures 5 through 8. A straight line has been constructed through the data to estimate magnitude of deflections in 50 years. It appears this may overestimate the deflection somewhat because the deflection appears to have ceased in two of the cases. However, assuming the deflections will continue in a semi-logarithmic fashion, the two pipes in Daviess County will not reach five percent strain in 50 years, and the two pipes in Warren County will deflect approximately six percent in 50 years. Again, it should be emphasized this is probably a slight overestimate. In general, it appears long-term deflections probably will not be a problem (assuming proper backfill material and construction procedures).

General Construction Considerations

It appears that significantly more problems, including deflections, have been occurring in the outfall pipes in comparison to the storm drains and cross drains. On US 68/KY 80, the only pipe that had over five percent deflection was in an outfall pipe. This was also the case on KY 17 in a 24-inch outfall pipe, and on KY 207 in a 36-inch outfall pipe (5 percent of the 30-inch pipe on KY 207 had deflected over 5 percent in the storm drains). In all three cases, the outfall pipes were over 100 feet long and a considerable amount of the pipe that was inspected was deflected over 5 percent. On two of the projects, deflections of 10.5 and 12.5 percent were

measured. Construction practices may not be as rigid outside the actual roadway section.

Longitudinal shortening of the inner liner (wrinkling) was apparent where pipes discharged into box culverts or storm boxes at steep angles. The pipes are probably compressing due to the angle of installation and compaction and settlement of the backfill. A good granular backfill should help eliminate this.

Polyethylene pipe requires less equipment and fewer personnel than metal or concrete pipe for installation. Extreme care should be taken during backfilling around the pipe. On US 62, KY 54, and US 68/KY 80, portions of the pipes were not completely covered with bedding material. Cuts or tears were observed inside the N-12 pipe (7 total). It appears that the tears are occurring where the sections of plastic are wrapped together to form the pipe. The rips are probably occurring due to improper backfilling and unequal loading of the pipe wall. On Forbes Road and Nicholasville Road, the pipes were completely covered with one foot crushed stone before the remainder of the trench was backfilled with excavated material. This one foot of cover helps to protect the pipe against backfill damage. On several of the installations, it was apparent the ends of the pipes at the couplings are rarely butted completely together. This permits material to be deposited in this area. Care should be taken not to damage the plastic pipe during transportation.

Because polyethylene pipe is lightweight, the pipe has a tendency to rise or drift during backfilling. To eliminate this, the contractors should bed each side equally to approximately 1/2 to 3/4 of the pipe height before compacting (depends greatly on the backfill material).

Because polyethylene pipe is lightweight and easier to handle, it appeared to research personnel observing construction procedures that some contractors did not take necessary precautions in installing the pipe. It should be emphasized that because of the flexibility of the pipe possibly more care should be exercised in the installation process. Installation specifications should be followed carefully. The contractor should pay particular attention to bedding and backfilling operations. Inspectors should note in particular the coupling operations and where the pipe enters headwalls.

CONCLUSIONS

Polyethylene pipe appears to perform satisfactorily as cross drains, storm drains, and entrance pipe when properly bedded and backfilled with a high shear strength material.

From observations obtained in this study, long-term deflections do not appear to be a problem when pipe are properly installed.

Flammability of polyethylene pipe was beyond the scope of this study and no conclusions can be made.

Most problems with pipe damage, such as rips, delamination, or punctures appear to be traceable to improper handling and/or construction procedures.

Sags in grade, misalignment, and poor coupling do not appear to be a material related problem but are largely due to poor construction techniques.

RECOMMENDATIONS

It is recommended that polyethylene pipe be approved for use as storm sewers, cross drains, and entrance pipe subject to the following limitations:

1. All polyethylene pipe should be installed according to Kentucky Standard Drawing No. RDI-20-04, with the addition of granular backfill. Granular backfill should be used to a minimum height of one foot above the crown of the pipe.

2. An ASTM Class I or Class II type backfill should be used for polyethylene pipe.

3. Entrance pipe should have a minimum of one foot of cover.
More aggressive inspection of all pipe installations should be implemented.

4. Continued long-term inspections of selected installations using various materials are suggested.

Further research is recommended to determine the minimum shear strength needed to provide adequate side support for flexible pipe.

REFERENCES

1. Sharff, P. A. and Chambers, P. E., "The New ASTM Standard for Installation of Plastic Sewer Pipe," Public Works Magazine, November, 1991, pp. 52-57, 82.

2. American Association of State Highway and Transportation Officials (AASHTO), Section 18, "Soil-Thermoplastic Pipe Interaction Systems," pp. 233-238.

3. Subcommittee on New Highway Materials, (AASHTO-AGC-ARTBA), Task Force 22, Development of Cross-Reference for Materials Specification for Waterways, Airports, Railroads, Transit and Highways, "Report on Drainage Pipe," September 1988.

4. North Carolina DOT, Materials and Tests Unit, "Performance Evaluation of ASSHTO M 294 Type "S" Polyethylene Pipe," August, 1991.

TABLE 1. FORBES ROAD, FAYETTE COUNTY

PIPEDIA. (IN.)	FEET OF STORM DRAIN INSTALLED	FEET INSPECTED	PERCENT INSPECTED	DEFLECTION > 5 % (%)
15	240	240	100	0

TABLE 2. KY 54, DAVIESS COUNTY

PIPE DIA. (IN.)	FEET OF STORM/CROSS DRAIN INSTALLED	FEET INSPECTED	PERCENT INSPECTED	DEFLECTION > 5 % (%)	DEFLECTION > 10 % (%)
15	500	500	100	0	0
18	600	600	100	3	3

TABLE 3. US 62, MCCRACKEN COUNTY

PIPE DIAMETER (INCHES)	NUMBER OF ENTRANCES	DEFLECTION > 5 % (%)	DEFLECTION > 10 % (%)
15	2	50.0	50.0
18	5	80.0	40.0
24	2	50.0	50.0

TABLE 4. US 68/KY 80, WARREN COUNTY

PIPE DIA. (IN.)	FEET OF STORM/CROSS DRAIN INSTALLED	FEET INSPECTED	PERCENT INSPECTED	DEFLECTION > 5 % (%)	DEFLECTION > 10 % (%)
15	4,068	4,068	100	0	0
18	1,128	1,128	100	0	0
24	756	756	100	10.6	10.6
30	560	0	100	0	0
36	436	436	100	0	0

TABLE 5. NICHOLASVILLE ROAD, FAYETTE COUNTY (SSP 34-27-24-46C)

PIPE DIA. (IN.)	FEET OF STORM/CROSS DRAIN INSTALLED	FEET INSPECTED	PERCENT INSPECTED	DEFLECTION > 5 % (%)
12	160	160	100	0
15	660	660	100	0
18	1,200	1,200	100	0
24	1,440	1,440	100	0
30	20	0	0	---
36	1,760	1,760	100	0

TABLE 6. KENTUCKY 207, GREENUP COUNTY (SSP 45-207-16-18-42)

PIPE DIA. (IN.)	FEET OF STORM/CROSS DRAIN INSTALLED	FEET INSPECTED	PERCENT INSPECTED	DEFLECTION > 5 % (%)	DEFLECTION > 10 % (%)
15	5,640	504.5	8.9	0	0
18	080	86.0	8.7	0	0
24	1,580	247.5	15.6	0	0
30	1,260	373.0	29.6	5.3	0
36	1,760	297.0	16.8	20.0	0

TABLE 7. US 62, HARDIN COUNTY (SSP 47-62-11-14-39C)

PIPE DIA. (IN.)	FEET OF CROSS DRAIN INSTALLED	FEET INSPECTED (APPROX.)	PERCENT INSPECTED	DEFLECTION > 5 % (%)	DEFLECTION > 10 % (%)
15	1,400	620	44	0	0
18	420	305	72	* 19	* 0
24	80	50	62	0	0

* A lot of 18-inch pipe failed Materials testing but was installed

TABLE 8. US 127, ANDERSON COUNTY

PIPE DIAMETER (INCHES)	NUMBER OF ENTRANCES	DEFLECTION > 5 % (%)	DEFLECTION > 10 % (%)
15	16	56.2	40.0
18	1	100.0	100.0
24	1	0.0	0.0

TABLE 9. ANDERSON ROAD, CRESENT SPRINGS, KENTON COUNTY (SSP 059 7250)

PIPE DIA. (IN)	FEET OF STORM/CROSS DRAIN INSTALLED	FEET OF STORM/CROSS DRAIN INSPECTED	PERCENT INSPECTED	DEFLECTION > 5 % (%)	DEFLECTION > 10 % (%)	VERTICAL OFFSET AT COUPLING	PIPES WITH NOTICEABLE DIP IN GRADE
12	10	0	0	---	---	---	---
15	281	0	0	---	---	---	---
18	2,088	245	11.7	16.3	8.1	SEVERAL	SEVERAL
24	988	320	28.3	12.5	12.5	SEVERAL	SEVERAL

TABLE 10. DONALDSON ROAD, BOONE-KENTON COUNTY (IR 75-8(70)183)

PIPE DIA. (IN)	FEET OF STORM/CROSS DRAIN AND ENTRANCE PIPE INSTALLED	FEET OF STORM AND CROSS DRAIN INSPECTED	PERCENT INSPECTED	DEFLECTION > 5 % (%)	DEFLECTION > 10 % (%)	PIPES WITH NOTICEABLE DIP IN GRADE (%)
12	80	0	0	---	---	---
15	3,400	1,000	29	28.0	20.0	67
18	2,000	40	2	0.0	0.0	0
24	1,500	325	21	15.0	15.0	81

TABLE 11. KY 236, BOONE-KENTON COUNTY (IR 75-8(70)183)

PIPE DIAMETER (INCHES)	NUMBER OF ENTRANCES	DEFLECTION > 5 % (%)	NUMBER WITH DIP IN GRADE
15	4	0.0	1

TABLE 12. KY 17, KENTON COUNTY (SSP 059 0017 018-021)

PIPE DIA. (IN.)	FEET OF STORM/CROSS DRAIN AND ENTRANCE PIPE INSTALLED	FEET OF STORM AND CROSS DRAIN INSPECTED	PERCENT INSPECTED	DEFLECTION > 5 % (%)	DEFLECTION > 10 % (%)	PIPES WITH NOTICEABLE DIP IN GRADE (%)
15	----	0	---	0.0	0.0	67
18	-----	130	---	0.0	0.0	0
24	----	305	---	40.0	40.0	81

TABLE 13. KY 17, KENTON COUNTY (SSP 059 0017 018-021)

PIPE DIAMETER (INCHES)	NUMBER OF ENTRANCES	DEFLECTION > 5 % (%)	DEFLECTION > 10 % (%)
15	2	50	0
18	2	* 0	* 0

* An 18-inch entrance pipe was damaged on the end. The pipe had been compressed horizontally approximately 9 inches. This was not included in the table.

TABLE 14. PIPES BACKFILLED WITH NO. 57 OR NO. 9 SIZE STONE

PIPE DIA. (IN.)	FEET OF STORM/CROSS DRAIN INSPECTED	DEFLECTION > 5 % (%)
12	160	0
15	900	0
18	1,200	0
24	1,440	0
30	20	0
36	1,760	0

TABLE 15. PIPES BACKFILLED WITH UNKNOWN BACKFILL

PIPE DIA. (IN.)	FEET OF STORM/CROSS DRAIN INSPECTED	DEFLECTION > 5 % (%)	DEFLECTION > 10 % (%)
12	0	---	---
15	6,192	4.5	3.2
18	1,934	5.0	0
24	1,963	14.7	13.7
30	373	5.3	0
36	733	8.0	0

TABLE 16. DIVISION OF MATERIALS TEST RESULTS

MANUFACTURER	DIAMETER (INCHES)	LENGTH (INCHES)	MATERIAL TYPE	GAGE	PSI 5%	PSI 10%	PSI 20%
				RIVETED ANNULAR			
ARMCO	30	31	STEEL	.057	55	33	19
	30	31	STEEL	.075	73	50	27
	36	36	STEEL	.076	47	32	17
	36	36	STEEL	.059	37	23	12
WHEELING STEEL	30	31	STEEL	.075	84	51	27
	36	36	STEEL	.113	78	51	27
CONTECH	30	31	ALUMINUM	.058	25	16	9
	36	36	ALUMINUM	.062	17	11	6
KAISER	30	31	ALUMINUM	.076	29	23	13
	36	36	ALUMINUM	.077	22	16	10
				HELICAL WELDED SEAM			
ARMCO	30	30	STEEL	.063	44	28	12
	30	56	STEEL	.062	55	36	19
	36	30	STEEL	.079	56	36	18
	30	56	STEEL	.079	43	43	23
	36	36	STEEL	.062	33	20	10
	36	36	STEEL	.076	50	32	16
	36	56	STEEL	.062	34	22	12
	36	56	STEEL	.077	55	36	18
				HELICAL LOCK SEAM			
CONTECH	30	36	ALUMINUM	.075	28	21	12
	30	56	ALUMINUM	.076	28	23	14
	36	36	ALUMINUM	.060	24	20	19
	36	56	ALUMINUM	.059	27	19	8
	36	56	ALUMINUM	.074	45	32	15
KAISER	36	36	ALUMINUM	.076	15	12	7
				ANNULAR END			
ADS	30	30	PLASTIC	N/A	32	N/A	N/A
(M-294)	36	36	PLASTIC	N/A	28	N/A	N/A

Figure 1. 18-Inch CPEP

KY 54, Daviess County, Station 137+88

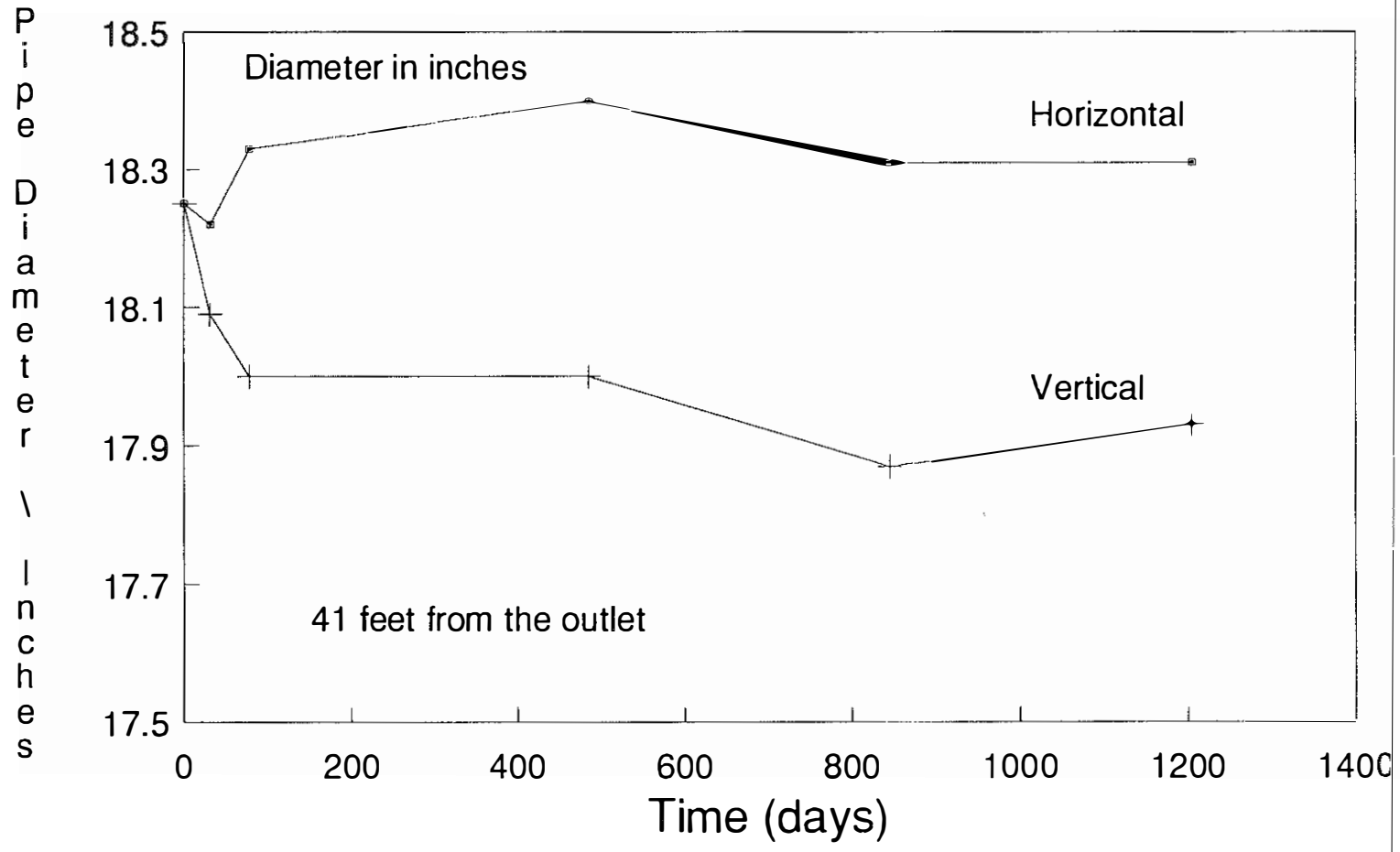


Figure 2. 18-Inch CPEP

KY 54, Daviess County, Station 137+88

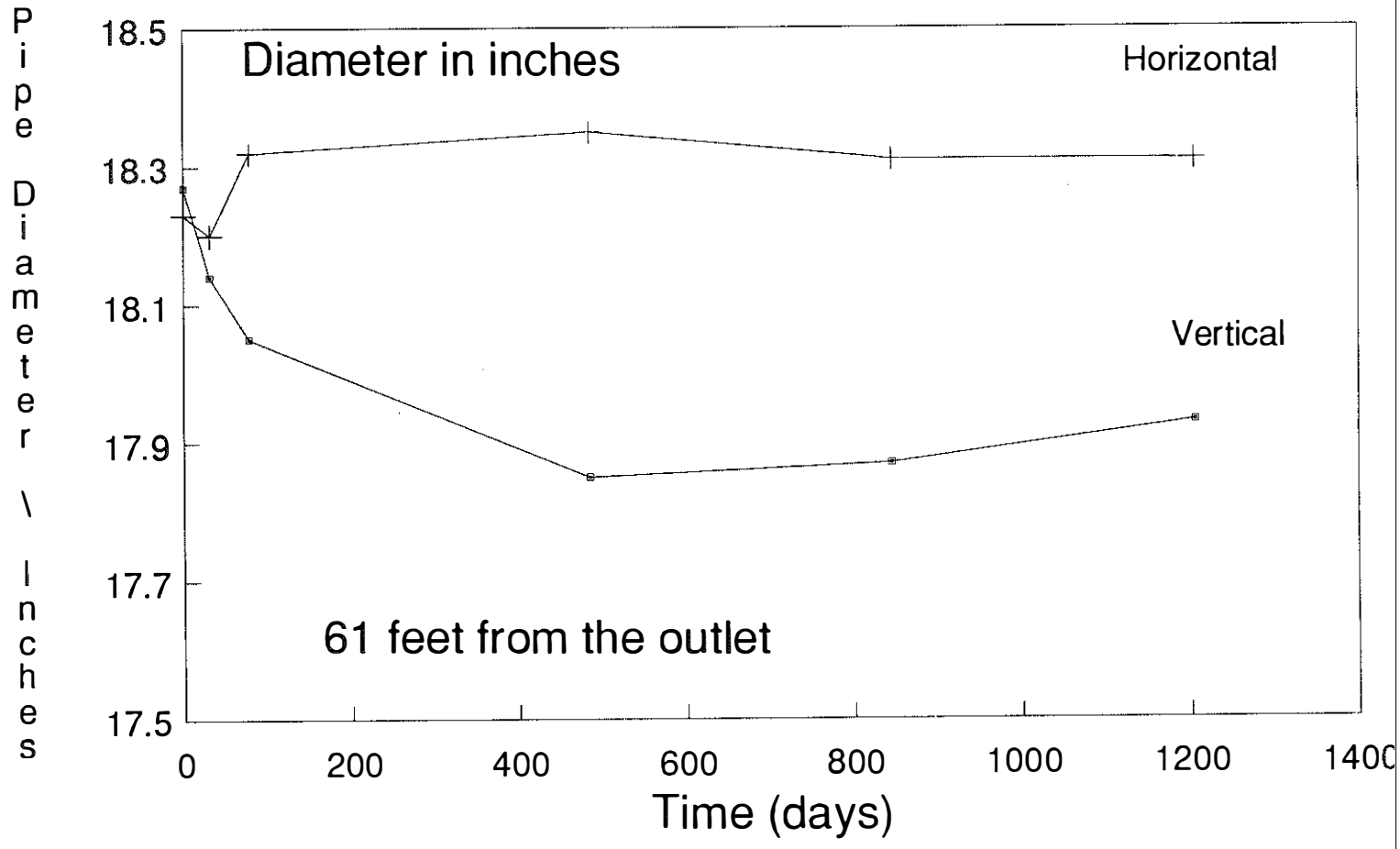


Figure 3. 36-Inch CPEP

US 68/KY 80, Bowling Green (Storm Drain)

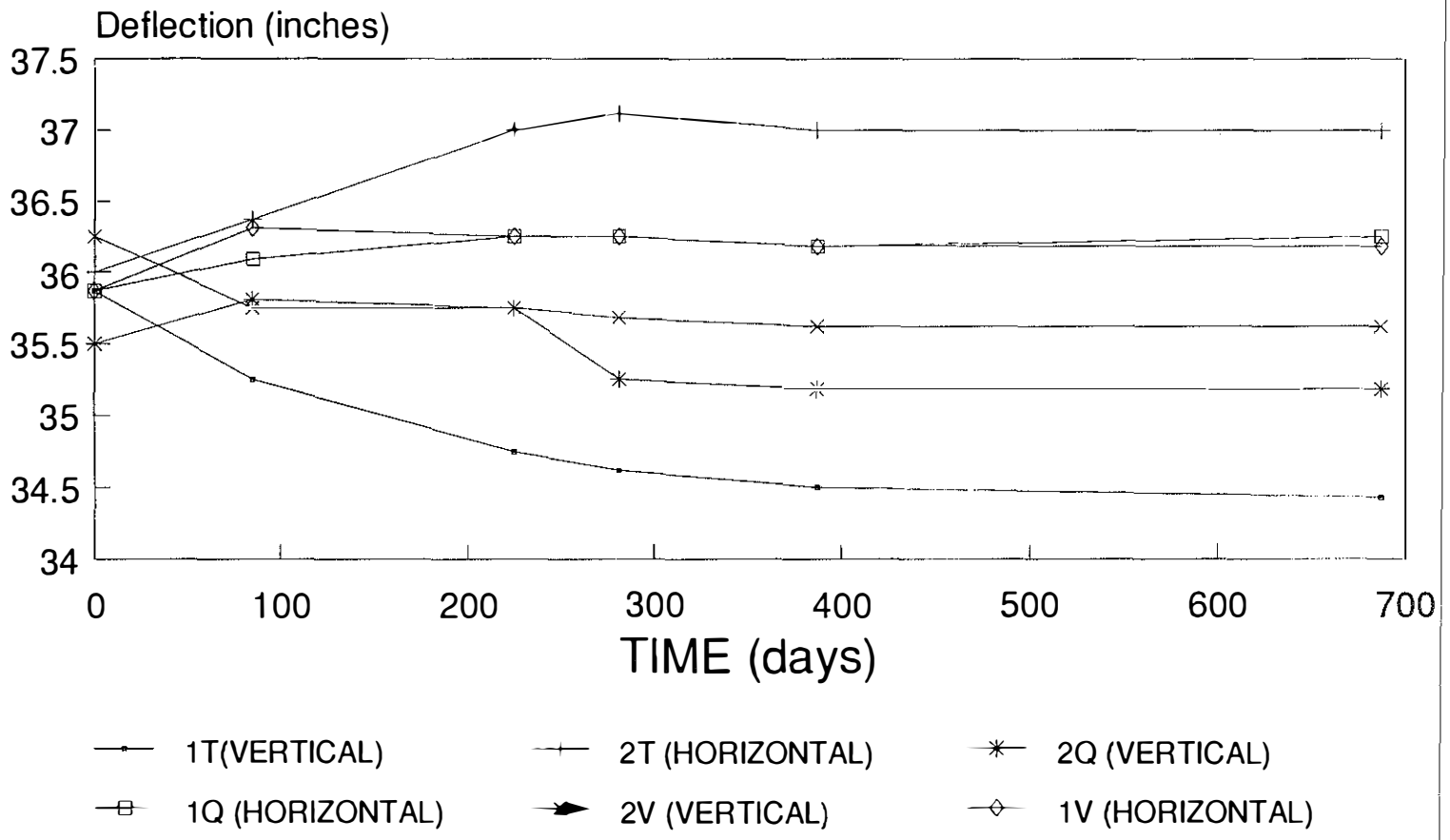


Figure 4. 36-Inch CPEP

US 68/KY 80, Bowling Green (Cross Drain)

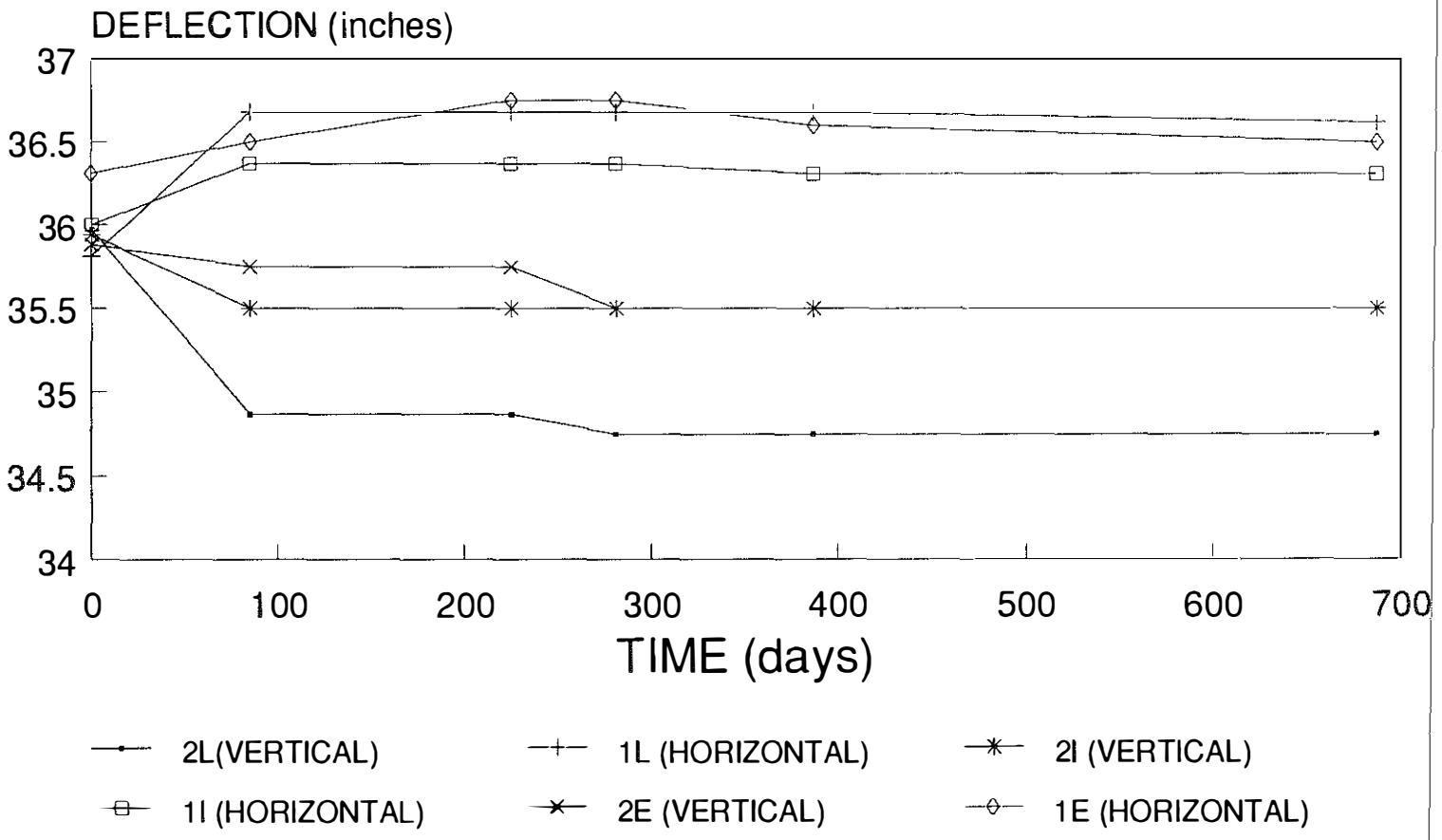


FIGURE 5. KY 54, DAVIESS COUNTY
STATION 137+88, 41 FEET FROM OUTLET

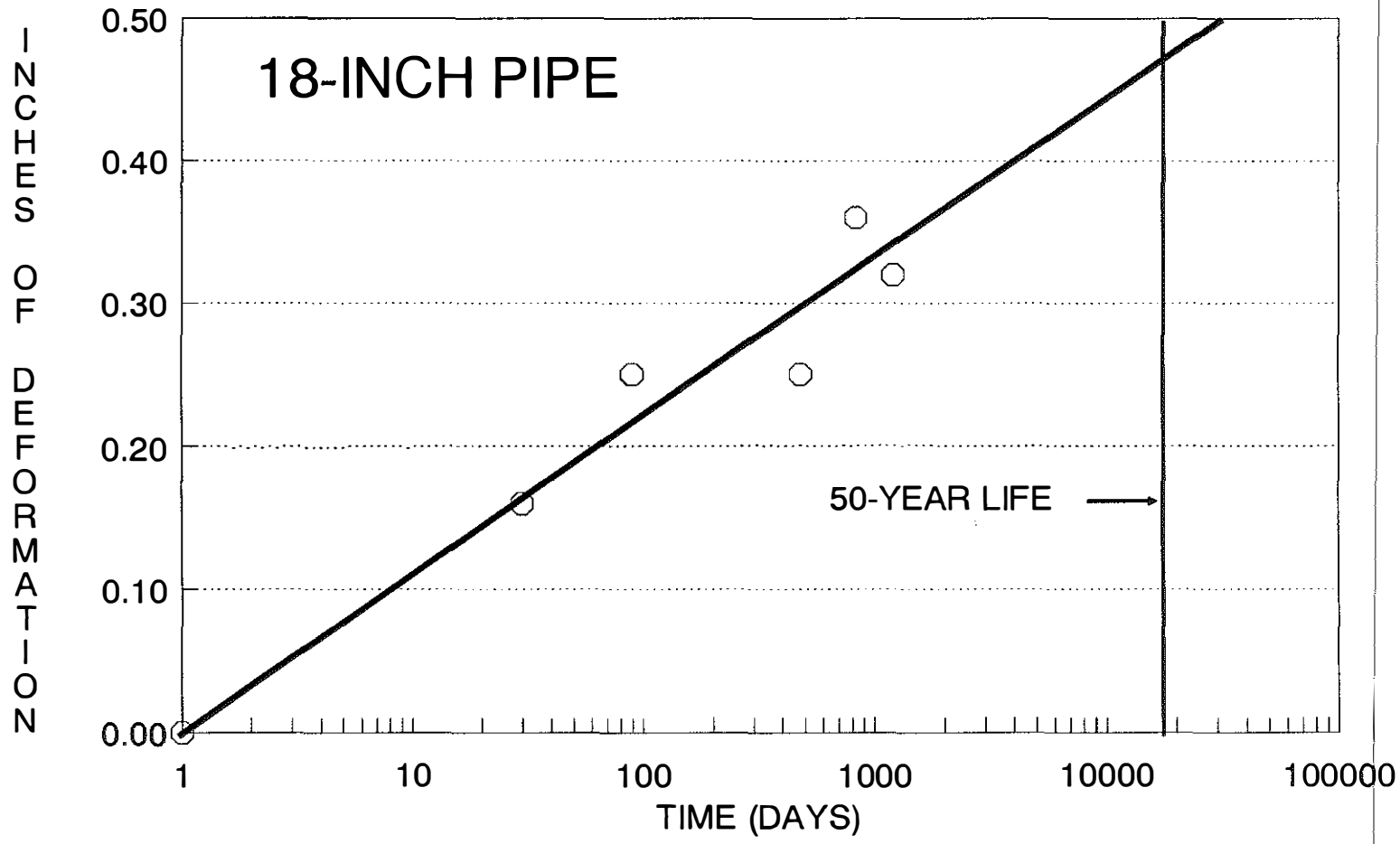


FIGURE 6. KY 54, DAVIESS COUNTY
STATION 137+88, 61 FEET FROM OUTLET

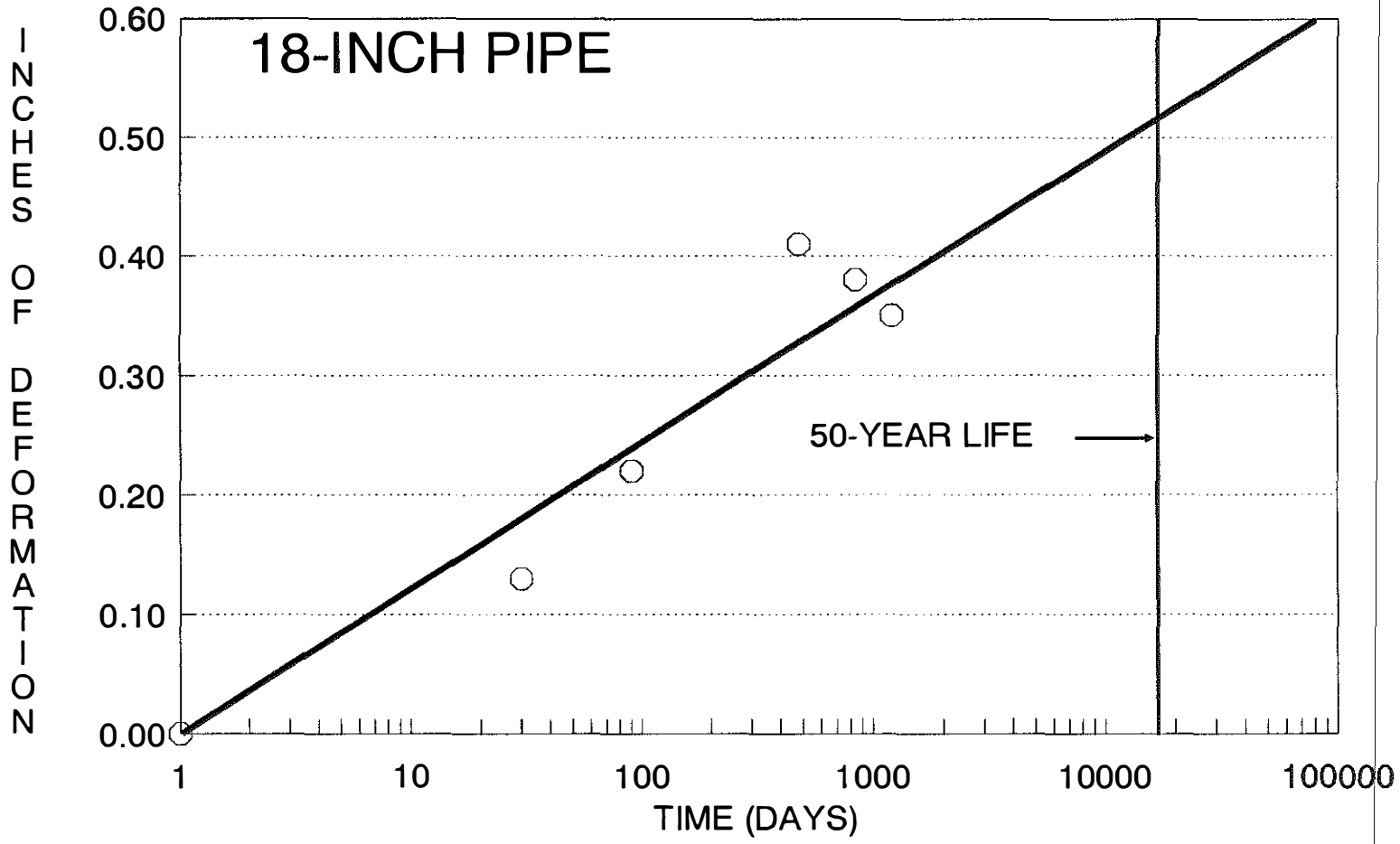


FIGURE 7. US 68/KY 80, WARREN COUNTY STORM DRAIN

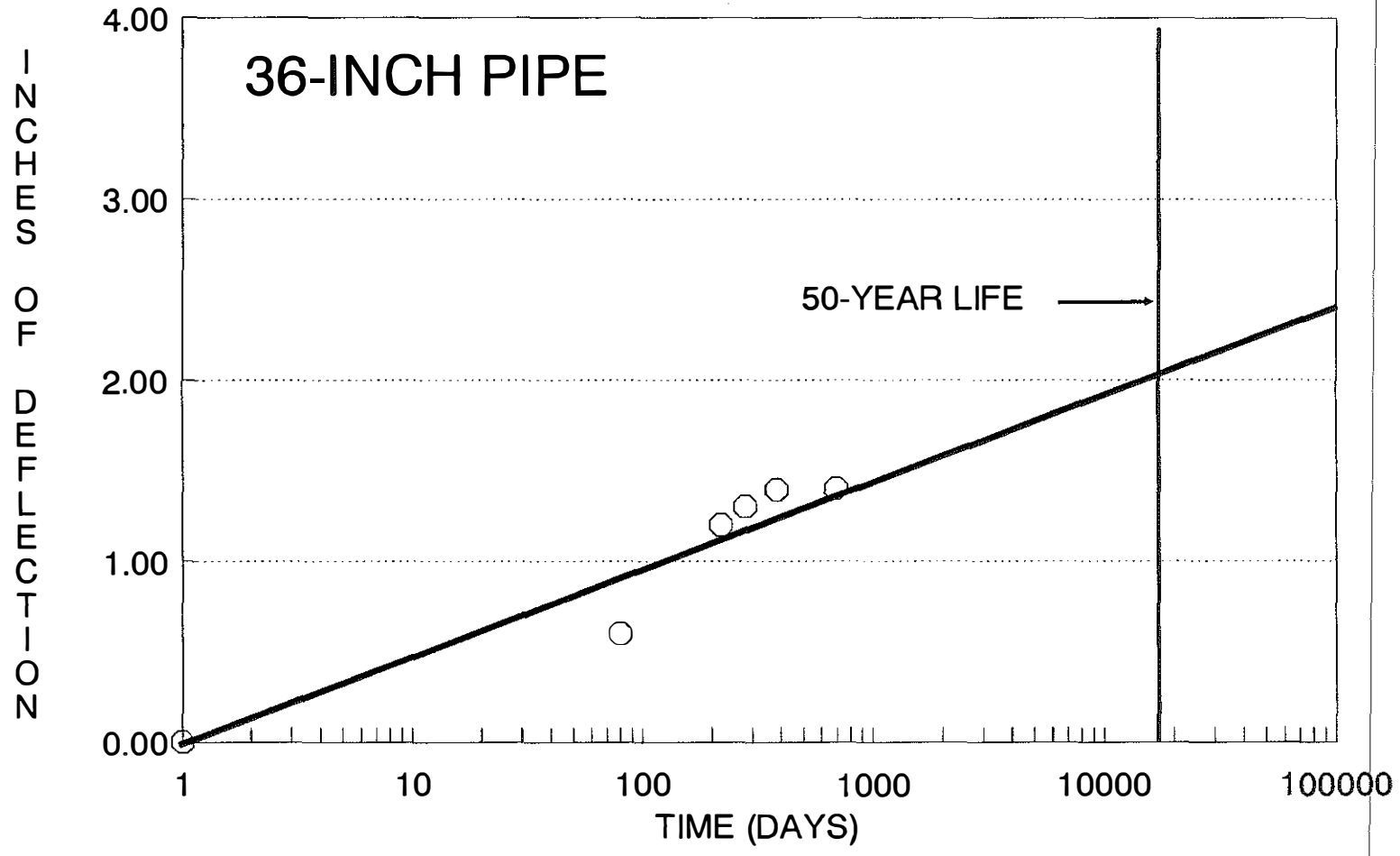
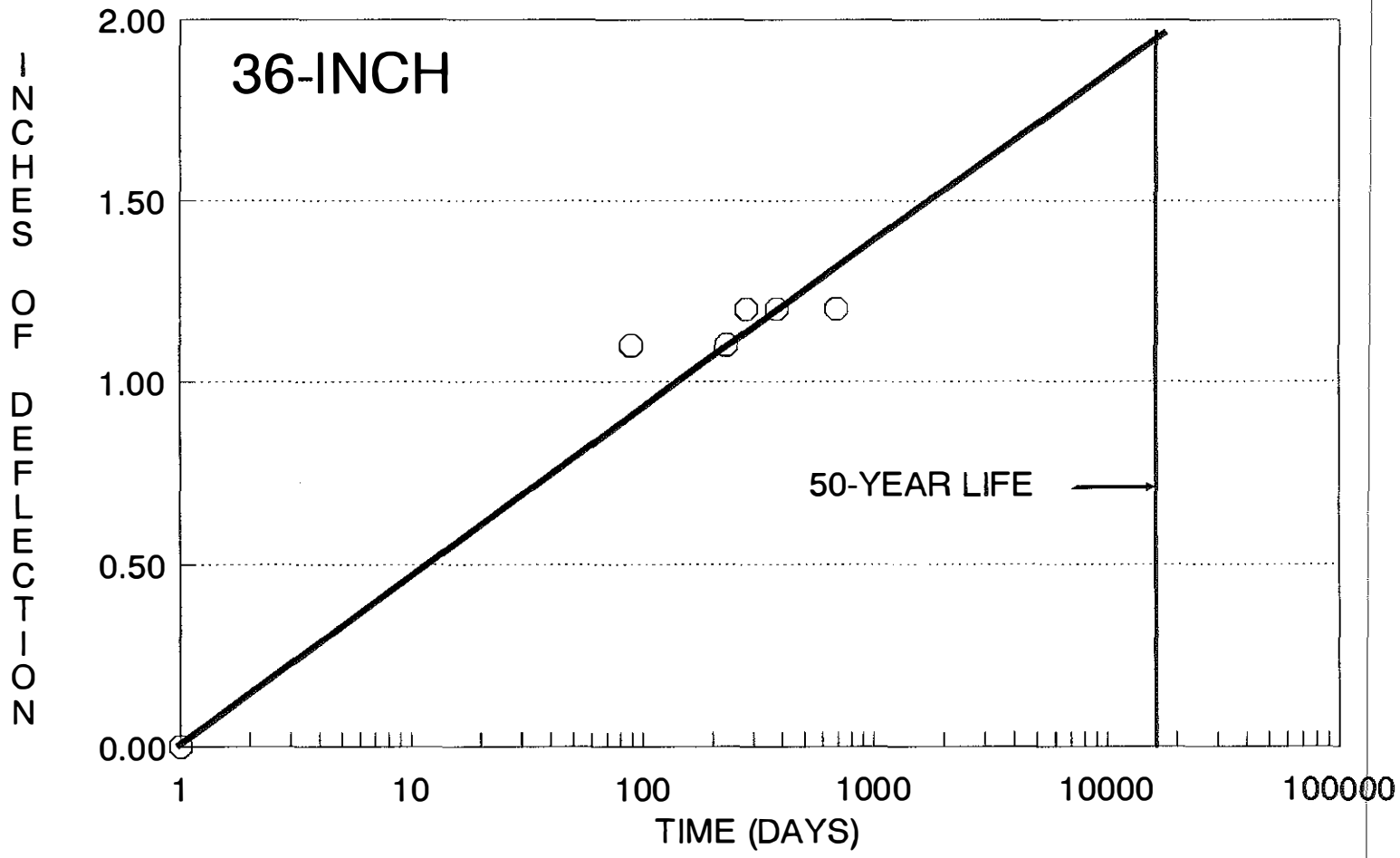


FIGURE 8. US 68/KY 80, WARREN COUNTY CROSS DRAIN



APPENDIX A
US 62 N-12 PIPE INSPECTION
SEPTEMBER 18, 1989

SITE	DESCRIPTION
No. 1	18-inch entrance pipe slightly irregular.
No. 2	24-inch entrance pipe (Station 174+00). Approximately 2.3 inches of deflection at the pipe connection. Some settlement observed in the gravel drive above the pipe. Approximately 1.5 feet of cover at the south end of the pipe, south side of the gravel drive. The pipe sections are not completely connected.
No. 3	18-inch entrance pipe (Station 167+50). The pipe has approximately 3 inches of cover at 6 feet north of the south end. Approximately 2 inches of compression noticeable at this point. Endloader tracks are also present on the surface at this point.
No. 4	18-inch entrance pipe (Station 161+50). Slight bow present at the joint in the pipe. Overall installation looks good. Asphalt surface has been placed within 1 to 2 inches of the top of the pipe.
No. 5	18-inch entrance pipe (Station 151+00-Highland Road). The installation is in good condition.
No. 6	24-inch entrance pipe (Station 138+50). Approximately 2 inches of compression on the south end. Approximately 4 to 4.5 feet of fill. Pipe does not appear to be bedded on sand or crushed stone.
No. 7	24-inch culvert pipe (Station 134+50). Good installation.
No. 8	30-inch culvert pipe (Station 124+50). Slight vertical deflection approximately 25 inches from the east end. Fairly good shape.
No. 9	15-inch entrance pipe (Station 121+00). Truck entrance for Turner Dairy. Half full of soil. Not much deflection.
No. 10	15-inch entrance pipe (Station 111+00). Half full of soil. Little to no deflection.

APPENDIX B
US 62 N-12 PIPE INSPECTION
MARCH 13, 1990

SITE	DESCRIPTION	DEFLECTION READING (Vertical)	(Horizontal)
No. 1	18-inch entrance pipe (Station 180+00).	15.12"	20.5"
No. 2	24-inch entrance pipe (Station 174+00). Approximately 3-4 inches of deflection. Not able to measure due to sediment. New concrete drive.		
No. 3	18-inch entrance pipe to field (Station 167+50). Backfill has been washed away.	16.87"	19.87"
No. 4	18-inch entrance pipe (Station 161+50).	17.0"	18.75"
No. 5	18-inch entrance pipe (Station 151+00-Highland Road). The installation is in good condition.		
No. 6	24-inch entrance pipe (Station 138+50).	22.83"	25.25"
No. 7	24-inch culvert pipe (Station 134+50).	22.25"	24.43"
No. 8	30-inch culvert pipe (Station 124+50).	29.5"	30.16"
No. 9	15-inch entrance pipe (Station 121+00). New concrete drive has been recently installed. Approximately 2 inches of defection in the pipe.		
No. 10	15-inch entrance pipe to field (Station 111+00). Fence blocking access. Pipe appears to be in good shape.		
No. 11	18-inch entrance pipe to residence with new concrete drive. Indentation in pipe approximately 1.5 feet in length.	9.25"	21.75"