# PIPE REHABILITATION WITH POLYETHYLENE PIPE LINERS

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Iowa Highway Research Board
Project HR-370

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# PIPE REHABILITATION WITH POLYETHYLENE PIPE LINERS

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**8. ABSTRACT**

Corroded, deteriorated, misaligned, and distorted drainage pipes can cause a serious threat to a roadway. Normal practice is to remove and replace the damaged drainage structure. An alternative method of rehabilitating these structures is to slip line them with a polyethylene liner.

Twelve drainage structures were slip lined with polyethylene liners during 1994 in Iowa. Two types of liners installed were "Culvert Renew" and "Snap-Tite". It was found that the liners could be easily installed by most highway, county, and city maintenance departments. The liners restore the flow and increase the service life of the original drainage structure. The liners were found to be cost competitive with the removal and replacement of the existing drainage structure. Slip lining has the largest economic benefit when the roadway is paved, the culvert is under a deep fill, or traffic volumes are high. The annular space between the original pipe and the liner was filled with flowable mortar. Care should be taken to properly brace and grout the annular space between the liner and the culvert.

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TABLE OF CONTENTS


Page

Introduction . . . . . 1

Objective . . . . . 1

Project Locations and Descriptions . . . . . 2

Research Funded Installations . . . . . 2
- Dallas County . . . . . 2
- Jefferson County . . . . . 4
- Jones County . . . . . 6
- Mahaska County . . . . . 9
- Taylor County . . . . . 11

Installations Without Research Funding . . . . . 12
- Audubon County . . . . . 12
- Crawford County . . . . . 13
- Henry County, Geode Park . . . . . 14
- Jones County . . . . . 14
- Mahaska County . . . . . 14
- Pottawattamie County . . . . . 15

General Installation Procedure . . . . . 15
- Clean the Existing Culvert . . . . . 15
- Prepare the Work Area . . . . . 15
- Prepare Access Points for Grouting . . . . . 16
- Inserting a Cable Through the Culvert . . . . . 16
- Pulling Head or Nose Cone . . . . . 17
- Assembling the Culvert . . . . . 17
- Grouting . . . . . 18
- Headwalls . . . . . 18

Considerations for Grouting . . . . . 18

Bracing . . . . . 20

Flow Capacity . . . . . 21

Evaluation . . . . . 22

TABLE OF CONTENTS (CONT'D)


Page

Criteria for Using Polyethyelene . . . . . 22
Acid Conditions . . . . . 22
Deep Fill Sections and High Traffic . . . . . 22
Cost of Slip Lining . . . . . 23
Public Relations . . . . . 23
Pipe Alignment . . . . . 23

Discussion . . . . . 24

Acknowledgements . . . . . 25

References . . . . . 25

Appendices
Appendix A - Maps . . . . . 26
Appendix B - Photos . . . . . 36
Appendix C - Cost Comparisons . . . . . 45
Appendix D - Manning's Equation . . . . . 49
Appendix E - Grout Design . . . . . 51
Appendix F - Specification Committee Letters . . . . . 53


DISCLAIMER

The contents of this report reflect the views of the author and do not necessarily reflect the official views of the Iowa Department of Transportation. This report does not constitute any standard, specification or regulation.

## INTRODUCTION

Corroded, deteriorated, misaligned, and distorted drainage pipes can cause a reduction in flow or a loss of roadbed material into the pipe. These problems have the potential to be a serious threat to a roadway. The normal practice is to remove the damaged drainage pipe and install a new drainage structure. This practice causes considerable disruption to traffic since removal of the damaged drainage pipe and installation of a new pipe requires an open trench across the roadway. Also, the procedure has the risk of possible settlement problems.

An alternative method of rehabilitating damaged drainage culverts is slip lining with a polyethylene liner. Slip lining is the insertion of a prefabricated pipe inside the existing culvert. The liner can restore the flow volume, and it provides an extended service life for the existing culvert. Additionally, the technique of slip lining allows the roadway to remain open to traffic, and it negates the risk of settlement that may occur with the removal and installation of a new drainage pipe. The slip lining technique may have economic savings when it is compared with the removal of the old drainage structure and installation of a new drainage structure.

## OBJECTIVES

The objective of the proposed research is to demonstrate and evaluate the applicability of the pipe lining technique. Specific topics to be researched include:

1. The cost savings of rehabilitating roadway pipe with polyethylene liners.
2. The performance of polyethylene liners in the field.
3. The construction technique used in rehabilitating pipe with polyethylene liners.

## PROJECT LOCATIONS AND DESCRIPTIONS

There were twelve drainage structures slip lined with polyethylene pipe across the state of Iowa in 1994. Six of these culvert lining projects were partially funded by this research project. The installation of these liners are presented in detail. The other six projects were installed without any research funds by the roadway's governing agency. These projects are presented with as much information as is known by the author. The projects will be split into the two categories of "Research Funded Installations" and "Installations Without Research Funding." The projects in each category will be presented in alphabetical order according to the county of installation.

The polyethylene pipe liners that were used are "Culvert Renew" and "Snap-Tite." "Culvert Renew" is a profile wall, smooth interior and exterior, high density polyethylene pipe with a threaded joint coupling system known as "Thread-Loc." "Snap-Tite" is a solid wall, smooth interior and exterior, high density polyethylene pipe with an interlocking mechanical joint.

## RESEARCH FUNDED INSTALLATIONS

### Dallas County

The project site is 3.5 km (2.2 mi.) west of county road P58 on county road F51 (see map, page 27). The existing pipe was a 900 mm (36 in.) diameter corrugated metal pipe (CMP) with a length of 32 m (105 ft.). The bottom quarter of the pipe was unsound due to corrosion.

The installation of the liner took place on June 22, 1994. The product used for the installation was "Culvert Renew." The liner had an inner diameter (ID) of 760 mm (30.0 in.), an outer diameter of 860 mm (33.8 in.), and a length of 32 m (105 ft.). It was delivered to the project site in five 6.1 m (20 ft.) sections and one 1.5 m (5 ft.) section.

Liner installation began by excavating an assembly area beyond the north end of the pipe. An area about 8 m long (26 ft.) long and 1.5 m (5 ft.) wide was cleared, so the pipe could be assembled in the ditch and inserted at the same alignment as the pipe inlet. Earth was removed to expose the CMP approximately 1.2 m (4 ft.) from the north end and 3.7 m (12 ft.) from the south end. At the points of exposure, grout holes approximately 100 mm (4 in.) in diameter were cut with a torch into the top of the CMP.

Installation of the liner began with the 1.5 m (5 ft.) section being inserted into the CMP. About 0.6 m (2 ft.) of liner was left out of the existing CMP. The next section was lowered into place. The section was suspended slightly off the ground by a chain attached to the bucket of a backhoe. A laborer used a chain and a steel bar to thread the new liner section on. An aluminum plate was placed against the end of the liner. The bucket of the backhoe pushed against the plate until 0.6 m (2 ft.) of liner was left out of the existing CMP. This process was repeated until the culvert was lined.

The annular space was pressure grouted with a flowable mortar from both ends and at the grout holes cut into the top of the pipe. The pressure from the grouting caused the liner to float to the top of the CMP. Approximately 2.5 $m^3$ (3.3 cu. yds.) of flowable mortar were used.

The installation took four hours. One backhoe operator (4 hours), two laborers (4 hours each), and one welder (1 hour), for torch work, were required. The equipment used for lifting and inserting the culvert liner was a Case 580K backhoe. Expenses for slip lining the culvert and estimated expenses for replacing the culvert are on page 46 in Appendix C.

**Jefferson County**

The project site is 0.3 km (0.2 mi.) east of Umber Avenue on 195th Street (see map, page 28). The existing drainage structure was a 1.1 m (3.5 ft.) square wood box culvert (see photo 1, page 37) with a length of approximately 11 m (35 ft.). The wood had deteriorated, and granular material from the roadway was falling through the top of the culvert.

Installation of the liner took place on August 24, 1994. The product used for the installation was "Snap-Tite." The liner has an ID of 760 mm (30.0 in.), an OD of 810 mm (32.0 in.), and a length of 18 m (60 ft.). The pipe was delivered to the project in two segments.

The box culvert was prepared for lining. The foreslopes were cleared of brush. Wingwalls were removed from the north end of the culvert. Five timber braces were placed along the top of the wooden box culvert to prevent the liner from floating when the annular space was filled with flowable mortar. Braces were placed at each end of the culvert and approximately at each quarter point. The braces were made of 150 mm by 150 mm (6 in. by 6 in.) pieces of lumber.

The "Snap-Tite" liner was assembled at the north end of the pipe. The two segments were connected using a pair of chains and winches (see photo 2, page 37). One chain was tightly wrapped around each pipe segment. The winches were connected to the chains, and the two segments were pulled until they locked together. The complete pipe liner was pulled through the wood box culvert. Earth was placed around the end of the liner to form earth dams for the placement of flowable mortar.

Flowable mortar was used to fill the void between the culvert and the liner. As the flowable mortar was placed, deformation of the liner occurred near the middle of the culvert. Hydraulic pressure was causing deformation at the center brace. The deformation occurred about 0.3 m (1 ft.) from the liner connection joint. This produced a heavy stress on the connection. The joint held up to the stress, but it did allow some water to pass through the joint. The grouting process was stopped. The pipe was approximately half submerged in grout. The next day, the grouting process was completed. No further deformation was noticed. Total liner deformation was about 75 mm (3 in.). The installation took about six hours for initial preparation, pipe assembly, filling of the void space with grout, and cleaning up. The crew required was one equipment operator (6 hours) and two laborers (6 hours each). The equipment used for moving and inserting the culvert liner was a John Deere 595D wheel backhoe. Expenses for slip lining the culvert and estimated expenses for replacing the culvert are on page 47 in Appendix C.

**Jones County**

The project site is 2.2 km (1.4 mi.) east of US 151 on county road E23 (see map, page 29). The existing pipes are twin 1400 mm (54 in.) diameter concrete pipes (see photo 3, page 38). The joints between the concrete pipes have separated, and the pipes are showing signs of concrete deterioration. The road above the pipe has been replaced once because of excessive settlement probably due to piping. It has settled again. The road exhibits cracking, and a 25 mm (1 in.) fault has occurred at the centerline.

Installation of the liner occurred on September 13, 1994. The products used for the installation were "Culvert Renew" and "Snap-Tite." The west drainage pipe was lined with "Culvert Renew," and the east drainage pipe was lined with "Snap-Tite." The "Culvert Renew" liner had an ID of 1070 mm (42.0 in.), an OD of 1210 mm (47.5 in.), and a length of 21.3 m (70 ft.). The "Snap-Tite" liner has an ID of 1130 mm (44.3 in.), an OD of 1220 mm (48.0 in.), and a length of 20.1 m (66 ft.).

Culvert lining preparation included cleaning sediment out of both culverts. An area beyond the south end of the culverts was excavated to allow enough workroom for the assembly of the culvert liners. The area had received rain the previous night, so the ground was saturated. Gravel was placed to help improve the condition of the assembly area. The gravel helped, but the work area was still soft and difficult to work on. Braces were placed in the west concrete culvert to control the flow line of the liner. Traffic control was established. One lane was closed during the pipe installation procedure. Flaggers were used to maintain through traffic in the other lane.

"Culvert Renew" was the first liner installed. The first 6 m (20 ft.) section of pipe was lowered into place and pulled into the concrete culvert until 2 m (7 ft.) of liner was left exposed (see photo 4, page 38). The second 6 m (20 ft.) segment was lowered into position to attach to the first segment. The segment was suspended by a chain while it was threaded to the first segment with a torque bar and chain (see photo 5, page 39). The threading process was difficult due to the saturated ground, wet liner from standing water, and the weight of the pipe. Placing a board under the liner at the connection joint helped align the two segments together. After a segment was connected, a board was placed against the end of the liner (see photo 6, page 39). The bucket from the wheel backhoe pushed against the board to insert the pipe until 2 m (7 ft.) of liner was left exposed. The board prevented the bucket from damaging the liner. The next two sections were attached in the same manner. The last section was a 3 m (10 ft.) piece. This section was much easier to thread than the 6 m (20 ft.) sections. The biggest difference was the reduced weight of the shorter liner section.

The "Snap-Tite" liner was then installed. The liner was comprised of three 6.7 m (22 ft.) segments. The first segment was lowered into place and pushed into the existing concrete pipe until 2 m (7 ft.) of liner was left exposed. The second segment was placed, so it could be attached to the first liner segment. Placing a board under the liner segments at the connection joint helped align the two liner segments. A small amount of lubricant was placed around the joint to reduce the force needed to snap the pipe segments together. A seal was placed on the joint. A chain was tightly wrapped around each pipe segment. A

pair of winches was used to pull the two pipes together (see photo 7 and 8, page 40). The process was difficult because the liner segments had slightly deformed into an oval shape. The crew had to use a pry bar and a screwdriver to help the liners snap together. The liner segments were inserted until 2 m (7 ft.) of the liner remained exposed. The third segment was attached in a similar process. This time attention was given to align the oval shape of the pipe segments. The joint went together without any problem from the ovalization of the pipe segments.

The annular space was filled with flowable mortar the following day. The "Culvert Renew" liner experienced deformation during the grouting procedure. The hydraulic pressure caused the liner to deform approximately 100 mm (4 in.) at the braces. The deformation tapered off for approximately 0.3 m (1 ft.) on each side of the brace. The location of one brace was directly on a liner joint. The joint was stressed and deformed, but it kept the segments connected. The joint also prevented any water or flowable mortar from leaking into the pipe. The effect of the deformation will be a reduction in peak flow.

The installation took about ten hours. This included site preparation, lining the culverts, grouting the pipes and cleaning the work area. The crew required was one equipment operator (10 hours) and four laborers (three for 6 hours and one for 10 hours). The equipment used for moving and inserting the culvert liner was a Case 1085 wheel backhoe.

**Mahaska County**

The project is located 1.4 km (0.9 mi.) west of county road T67 on county road G77 in Harrison Township (see map, page 30). The existing drainage structure was a 600 mm (24 in.) diameter CMP with a length of 29.6 m (97 ft.). The bottom quarter of the CMP had rusted away (photo 9, page 41). At approximately 6 m (20 ft.) from the south end, the pipe was bent at a 30 degree angle due to an earth slide on the foreslope.

Installation of the liner occurred on July 27, 1994. The product used for the installation was a "Culvert Renew" liner. The liner had an ID of 460 mm (18.0 in.), an OD of 510 mm (20.2 in.), and a length of 29 m (95 ft.). Only 29 m (95 ft.) of liner was ordered since records indicated the length of the pipe should have been 29.6 m (97 ft.) instead of 29.6 m (97 ft.).

Installation began by unearthing 6 m (20 ft.) of the existing pipe on the south end. An attempt was made to straighten the pipe, so it would be in alignment with the rest of the culvert. Earth was placed below the unearthed CMP segment and compacted. The pipe was still bent approximately 5 degrees. A small area on the south end of the pipe was cleared to allow the assembly of the liner. The area was deep enough for the liner to be aligned with the existing culvert. The first segment of liner was lowered into position and inserted into the pipe until 1.5 m (5 ft.) of liner was left exposed (see photo 10, page 41). The second segment was aligned with the first segment. The liner was raised slightly off the ground by a track backhoe with the use of a chain. A laborer threaded the two segments together using

a chain and a steel bar (see photo 11, page 42). The chain is wrapped around the pipe. The steel bar is placed in the chain and twisted to tighten the chain. The bar is then used as a leverage device to turn the pipe which threads the liner. The connected segment was pushed into the CMP by the backhoe until 1.5 m (5 ft.) of liner was left exposed. An old sign was placed between the liner and the bucket to prevent the bucket from damaging the pipe. The process was repeated for the rest of the liner.

The pipe was prepared for the filling of the annular space with flowable mortar. The area above the CMP on the north side of the drainage structure was cleared of earth. A welder cut a hole approximately 150 mm (6 in.) in diameter in the top of the pipe. The hole was 2 m (7 ft.) from the north end of the pipe. A flowable mortar funnel was made from an empty steel barrel. The funnel was placed above the hole for the flowable mortar. Earth was placed around the bucket to hold it in place. The ends of the pipe were sealed with a heavy cloth material. The cloth material was packed into the annular space at the ends. Flowable mortar was poured into the annular space. Even though there was a 40% overrun on the flowable mortar, it did not reach the south end. The standing head in the funnel was not enough to push any more flowable mortar into the annular space. The extra mortar is believed to have filled void spaces below the pipe. The pipe liner supplier at the project site stated that enough annular space had been adequately filled.

The crew required for the installation was one equipment operator (6 hours), two laborers (5 hours), and one welder (1 hour), for the torch work. The equipment used to move and insert the pipe was a Link-Belt LS-2800 C-Series II track backhoe.

**Taylor County**

The project site is 3.2 km (2.0 mi.) west of IA 148 on county road J20 (see map, page 31). The existing drainage structure is a 800 mm (30 in.) diameter CMP with a length of 31.4 m (103 ft.). The pipe is rusted and deteriorated in the bottom quarter (see photo 12, page 42). There is approximately 5 m (16 ft.) of fill above the CMP.

Preparation for the liner installation occurred on November 2, 1994. An area was cleared on the south end for the installation of the liner. Holes were cut into the ends of the pipe with a torch for the flowable mortar. The holes were about 100 mm (4 in.) in diameter and 1.5 m (5 ft.) from the ends of the CMP.

Installation of the liner took place on November 3, 1994. A "Culvert Renew" liner was selected for the site. The liner had a 610 mm (24.0 in.) ID, a 690 mm (27.0 in.) OD, and a length of 33.5 m (110 ft.). A pulling cone was made on the first segment to be inserted. Wedge shapes were cut out of the end of the liner. Holes were drilled in the remaining wedges. A cable was looped through the holes, so a cone would be formed when the liner was pulled through the CMP (see photo 13, page 43).

A crane moved the first segment into position. A cable from a dragline attached to a truck was run through the CMP. The cable was attached to the cone end of the first segment. The dragline pulled the liner into the pipe until 1.5 m (5 ft.) of liner was left exposed. During this time, the crane moved the next segment into position. When the dragline was

done pulling the liner, the second segment was ready to be attached to the first segment. While the pipe was suspended by the crane, two laborers threaded the pipe segments together. The pipe was threaded by hand without a chain and torque bar (see photo 14 and 15, pages 43 and 44). Then, the dragline pulled the liner into the CMP. The process was repeated until the culvert was lined. The nose cone was cut off the pipe.

The ends of the pipe were prepared for grouting. Inner tubes from a truck were placed around the culvert liner and filled with air. The annular space was filled by pressure grouting. About 0.8 $m^3$ (1 cu. yd.) of grout was pumped into each end. The grout does not fill the entire length of the pipe, but it will keep the pipe in place according to the pipe liner supplier.

The crew required for lining the pipe was one equipment operator (10 hours) and two laborers (10 hours each). The time included site preparation, lining, grouting, and cleaning up the area. The liner itself was installed in less than one hour. The equipment required was one winch-equipped truck for the dragline and a Link-Belt HC-48A crane. Expenses for slip lining the culvert and estimated expenses for replacing the culvert are on page 48 in Appendix C.

## INSTALLATIONS WITHOUT RESEARCH FUNDING

### Audubon County

The project is located 2.4 km (1.5 mi.) west of US 71 on county road F16 (see map,

page 32). The existing structures are two 600 mm (24 in.) diameter concrete pipes with lengths of 18.3 m (60 ft.). "Snap-Tite" liners with a 480 mm (18.8 in.) ID and 510 mm (20.0 in.) OD were used. The liners were 18.3 m (60 ft.) and 18.9 m (62 ft.) in length.

The liners were installed on May 23, 1994. The longer liner was installed in the east pipe. The extra 0.6 m (2 ft.) was used to make a bullet nose. The bullet nose was formed by cutting out wedges in the end of the pipe with a chain saw (see photo 16, page 44). The remaining wedges on the liner were wired together to form a bullet nose. The liners were installed with a Gradal. The annular space was filled with a flowable mortar. Small headwalls were formed and pored on the inlet ends.

**Crawford County**

The project is 3.1 km (1.9 mi.) east of county road M55 on county road E16 (see map, page 33). The existing drainage structure was a 1050 mm (42 in.) diameter spiral CMP with a length of approximately 37 m (120 ft.). The pipe extended approximately 18 m (60 ft.) under the road, then it turned down the slope at an angle of about 20 degrees for an additional 18 m (60 ft.). The 18 m (60 ft.) section under the road was the only section of the pipe to be lined. The culvert was lined on May 25, 1994. A "Snap-Tite" liner with a 860 mm (34.0 in.) OD and a length of 20 m (66 ft.) was used. The extra liner length was to move the culvert inlet away from the shoulder. A headwall was built at the culvert entrance.

**Henry County, Geode Park**

The project is in Geode Park on the west side of the lake between the boat docks and a small picnic area (see map, page 34). The existing pipe was a 450 mm (18 in.) diameter CMP with a length of 18 m (60 ft.). The bottom quarter of the pipe was rusted out.

Installation of the liner occurred on September 8, 1994. The product used for this installation was a 410 mm (16.0 in.) OD "Snap-Tite" liner with a length of 19.8 m (65 ft.). The liner was gravity grouted with flowable mortar from the inlet end. Installation required two laborers and an equipment operator for 5 hours each. A John Deere backhoe was used to install the pipe liner.

**Jones County**

The project is north of Anamosa on county road X31 (see map, page 29). The culvert was a 900 mm (36 in.) diameter CMP with a length of 18.3 m (60 ft.). The liner was a 810 mm (32.0 in.) OD "Snap-Tite" liner with a length of 19.2 m (63 ft.). The liner was installed on September 12, 1994.

**Mahaska County**

The project site is located 7.5 mi. west of IA 137 on county road G71 in Section 23 of Jefferson Township (see map, page 30). The existing drainage structure is a 600 mm (24 in.) diameter CMP with a length of 27 m (90 ft.). The bottom quarter of the pipe was corroded. The liner used for the project was a "Culvert Renew" liner with a 460 mm

(18.0 in.) ID, 510 mm (20.2 in.) OD, and a length of 29 m (95 ft.). Installation of the liner occurred on November 27, 1994. On November 28, 1994 the annular space was filled with flowable mortar. The mortar was placed through a hole in the top of the CMP at the inlet end. The mortar did not fill the entire length of the pipe.

**Pottawattamie County**

The project is on county road M47 0.1 km (0.06 mi.) north of IA 6 (see map, page 35). The existing culvert was a 1800 mm (72 in.) diameter CMP with a length of 18.3 m (60 ft.). The bottom of the culvert was corroded. A "Snap-Tite" liner with a 1290 mm (50.7 in.) ID, 1370 mm (54.0 in.) OD, and a length of 18.3 m (60 ft.) was used. The liner was installed on May 24, 1994.

## GENERAL INSTALLATION PROCEDURE

### Clean the Existing Culvert

The liner is easier to push or pull through a clean culvert. A clean culvert is important for grouting the pipe in place. The culvert most commonly has been flushed clean with water. The culvert is generally flushed clean several days before the lining operation. This will allow the work site time to dry from the flushing operation.

### Prepare the Work Area

The work area is preferably dry. The operation is generally easier and faster in a dry work area. If water is flowing through the work area and the existing drainage structure, a dam may be desirable to temporarily stop the flow of water.

The work area should be cleared to allow easy assembly of the pipe. This may include the removal of fence and the excavation of soil. The pipe is easier to slip line if the pipe liner can be inserted at the same angle as the drainage structure. The work area should be long enough to allow a pipe segment to be attached to the liner already in the pipe. Generally, this minimal distance is the length of the longest segment of the liner plus 1.5 m (5 ft.).

**Prepare Access Points for Grouting**

If the desire is to grout the pipe at locations other than at the ends of the pipe, access holes will need to be cut into the existing culvert. When deciding on the location of the access points, consideration should be given as to how the mortar or flowable grout will be transported to the points of grouting. It is usually preferable to create the access points before lining the drainage structure.

**Inserting a Cable Through the Culvert**

If the liner is to be pulled through a culvert, a cable will need to be placed through the culvert. Care should be taken to make sure that the safety of workers will not be compromised while placing a cable through the culvert. Remember, the liner can be pushed through the drainage structure if no safe method can be found to place a cable through the culvert.

## Pulling Head or Nose Cone

Decide if a nose cone or pulling head will be required. If the existing structure is misaligned or badly deteriorated, a nose cone or pulling head is very desirable. A liner without a nose cone or pulling head will easily catch a very small obstruction. If the existing culvert has misaligned joints or is bent, a nose cone or pulling head is recommended.

A nose cone or pulling head can be easily constructed from the liner itself. Wedges can be cut out of the front part of the first segment of the liner. Holes are drilled through the remaining wedges. The wedges are then tied together with wire or a cable to form a cone. After lining the culvert, the nose cone is cut off. If several culverts are to be lined with the same diameter of liner, a short segment of liner may be purchased to make a detachable nose cone or pulling head. The segment would be made as described above, but after lining the segment would be detached and used again.

## Assembling the Culvert

Check to see if any of the segments have plain ends. If some of the sections do have plain ends, these sections will be the first and last segments used. If a reusable nose cone is to be utilized, make sure that the first segment was machined for a joint assembly.

The pipe may be completely assembled prior to installation, however, the lack of space will often make this procedure impossible. The other alternative is to assemble and insert the liner segment by segment. If it is required to assemble the liner segment by segment, the following tips will be helpful.

1. Don't insert each segment completely into the existing drainage structure. Leave enough of the liner exposed to attach the next liner segment.

2. A board placed under the two segments of liner being joined may help as a guide in aligning the segments.

3. Pushing the culvert in may be accomplished by attaching a choker chain around the pipe and pulling the chain with a backhoe arm. Also, insertion of the liner may be accomplished by pushing the pipe in with the bucket of a backhoe or other similar piece of construction equipment. Because the bucket might damage the joint of the pipe, a plate or board will need to be placed between the pipe and the bucket.

## Grouting

The pipe should be grouted according to manufactures specifications. The pipe may be forced upward during grouting. If flow lines are critical at the location, the pipe may need to be braced, or the pipe may need to be grouted in several lifts. More detailed consideration about grouting is given later.

## Headwalls

Headwalls may be built at the culvert inlet and outlet. Headwalls can be very beneficial to the lined culvert. The headwalls can anchor the pipe liner, reduce erosion, provide fire protection, and improve water flow.

## CONSIDERATIONS FOR GROUTING

The method of grouting is very important to polyethylene liner installations. If the liner is to be estimated at having a long service life, it must be able to withstand the possibility of the original drainage structure loosing its capacity to support soil and traffic loads. The liner would then be required to support the overburden and traffic loads. The polyethylene liners

have shown that they are susceptible to deformation from large point loads during grouting procedures. A slip lined culvert that is grouted the full length would be able to distribute the overburden and traffic loads if the existing culvert experienced structural failure. A lined culvert that is only grouted at the ends would remain susceptible to dramatic failures when the original drainage structure fails. The culvert lined at the ends would also allow material to fall into the annular space between the culverts as the original drainage structure corroded. This process could lead to the settlement of the roadway or a collapse of the roadway as material is lost into the annular space. An alternative to grouting the annular space the full length is to use a flowable mortar or flowable fill (Controlled Low-Strength Material) to fill the annular space. This gives the polyethylene liner a good backfill to distribute loads, and it prevents the loss of material into the annular space.

The type of grouting practice to be used may depend on the purpose of the slip lining and the condition of the drainage structure. If the lining is to restore flow until reconstruction can occur in a few years or even twenty years, the grouting technique will not be as critical as long as the culvert is in good structural condition. However, if the slip lining procedure is for a long term (50 to 100 year design life), stronger consideration should be given to grouting the annular space full length.

Grouting for most of the installations to date has been with a flowable mortar. The mortar has usually been placed by gravity through a hole in the top of the old drainage structure near the ends of the culvert. This method does not always allow the annular space to be

completely filled. More of the annular space may be filled by using some of the following methods:

1. The use of grout stand pipes when pouring the grout into the annular space. The grout stand pipes would increase the head on the grout being placed in the annular space.
2. The addition of more grout access points. Holes could be made near the shoulder or possibly drilled at the centerline to ensure that more of the culvert is properly grouted.
3. Use pressurized grouting procedures. This will allow the grout to be placed further into the annular space.
4. Use a long grout pipe starting at the far end. Then slowly withdraw the pipe as the annular space fills up.
5. Use the liner as a grout tube. Drill holes in the top of the liner. Use the holes to fill the annular space with grout.
6. Provide air outlet points or pipes so that no large air voids are trapped in the annular space.

More work needs to be done on grouting practices and on appropriate grout and flowable mortar mix designs. Page 52 in Appendix E has a grout design used by the Indiana Department of Transportation.

## BRACING

Bracing procedures were very important on several of the installations. Problems developed when the existing culvert and the liner had a large enough difference in diameter that the liner needed to be braced to maintain the flow line. Also, the bracing became more important as the diameter of the liner increased. Neither pipe supplier provided a bracing guideline; therefore, the responsibility of proper bracing was left to the engineer. This is an area that needs to be addressed in the future.

The pressures exerted on a liner are especially large when the entire annular space is grouted. These pressures can cause the pipe to experience excessive deflection or failure if the bracing is not adequate. Currently, the engineer will be required to develop an effective bracing system. The engineer can also use some of the following suggestions to help reduce the hydraulic pressures.

1. The annular space can be grouted or filled with a flowable mortar in several lifts.
2. Build headwalls at the ends of the culvert to weigh down and secure the culvert liner before grouting.
3. Use low density grouts to reduce hydraulic stresses.
4. Monitor the pressure applied if pressure grouting is used to fill the annular space.

## FLOW CAPACITY

An advantage of smooth interior wall polyethylene liners is the low Manning roughness coefficient of about 0.010. This coefficient is lower than both concrete pipe and corrugated metal pipe. The lower Manning coefficient means that a smaller diameter liner may have a flow equal to or greater than the original pipe. If pipe flow is simplified to consider only Mannings equation, a simple derivation can be performed to calculate the needed diameter for a liner to have the same flow as the original drainage structure. The derivation is on page 50, in Appendix D.

The reduced cross section may not reduce the flow, but it will increase the velocity of the water in the pipe. This increase in velocity might create a need for a special end treatment to prevent erosion.

## EVALUATION

The Iowa Department of Transportation and Dallas, Jefferson, Jones, Mahaska, and Taylor Counties will jointly conduct evaluations each year through 1999 on the research funded installations. The other installations will be evaluated each year by Iowa Department of Transportation personnel. The following table shows the evaluation plan for the research funded installations.

| TEST | CONSTRUCTION YEAR ORIGINAL PIPE | CONSTRUCTION YEAR LINER | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | YEAR 5 |
|---|---|---|---|---|---|---|---|
| Visual Examination | X | X | X | X | X | X | X |
| Video Camera | X | | | X | | | X |

## CRITERIA FOR USING POLYETHYLENE

### Acid Conditions

Locations where extensive mining has occurred can cause acid runoff which can corrode metal pipes. Polyethylene pipe is highly resistant to acids, and it may be a good alternative in other acidic conditions.

### Deep Fill Sections and High Traffic

Liner for locations that have deep fills or have high traffic can usually be justified economically. Replacing a pipe under a deep fill can be cost prohibitive. The cost to users

of a roadway can be high when large volumes of traffic need to be detoured for the replacement of a drainage structure. Slip lining a drainage structure with these conditions becomes econmically attractive.

## Cost of Slip Lining

Even when deep fills or high traffic volumes are not encountered, the cost of lining a drainage structure can be comparable to removing and replacing a drainage structure when all the costs associated with the project are calculated. These costs will include the cost of the pipe, excavation, backfill, repaving the road, labor, equipment, grouting, and detouring the traffic. Plus, there still exists the risk involved in having the road cut open, and the possibility of the roadway settling because of inadequate backfilling. Polyethylene liners are easily installed with the equipment that most county, highway or city maintenance departments have. The work crew and time required for the installation are minimal.

## Public Relations

The traveling public is quick to complain about any restrictions or repairs on a roadway. Slip lining with a polyethylene liner allows a crew to repair a deteriorated drainage structure without disrupting traffic or intruding on the public.

## Pipe Alignment

The pipe must be relatively straight to be lined with a polyethylene liner. The liner can go around small deflections, but large angle elbows will be difficult to pass with a liner. The

pipe liner supplier should be consulted before an attempt at lining a misaligned, curved, or bent culvert is made.

## DISCUSSION

Culvert slip lining with polyethylene liners can be a viable alternative to the removal and replacement of deteriorated drainage structures. The polyethylene liners can be easily installed with little time and equipment commitments by most highway, county, and city maintenance departments. The liners appear to be capable of being both a short term and a long term maintenance procedure. If the liner requires bracing, careful consideration should be given to the bracing design. The grouting procedure should be appropriate for the desired life of the lined culvert. The cost comparisons show that the slip lining technique can be competitive with the removal and replacement of an existing drainage structure. Culvert slip lining is most competitive economically when the roadway is paved, the culvert is under a deep fill, or traffic volumes are high.

The Iowa Department of Transportation does not have a specification for lining culverts with a polyethylene liner. At this time, the only approved uses for polyethylene pipe are for unclassified roadway pipe culverts and unclassified entrance pipe culverts. The Specifications Committee has approved both "Snap-Tite" and "Culvert Renew" for lining culverts when specified (see letters in Appendix F, pages 54 and 55).

## ACKNOWLEDGEMENTS

Research project HR-370 was sponsored by the Iowa Highway Research Board and the Iowa Department of Transportation. Partial funding for this project was from the Secondary Road Research Fund in the amount of $10,000.

The authors would like to thank the employees of Audubon, Crawford, Dallas, Jefferson, Jones, Mahaska, Pottawattamie, and Taylor Counties for their effort in installing the polyethylene liners. Thanks to the employees of the Iowa Department of Transportation who installed the liner in Geode Park. Thanks is extended to Vernon Marks and Kathy Davis for their help in the production of this report. Thanks is also given to Bob Steffes for assisting with the video camera work in evaluating the project sites.

## REFERENCES

1. California State University; Culvert Restoration Techniques; California Department of Transportation and Federal Highway Administration; FHWA/CA/TL #93-14; Caltran Study # F90TL15; 1993.

2. Minnesota Department of Transportation; Culvert Renewal; Minnesota Department of Transportation MN/RD-92-02; April 1992.

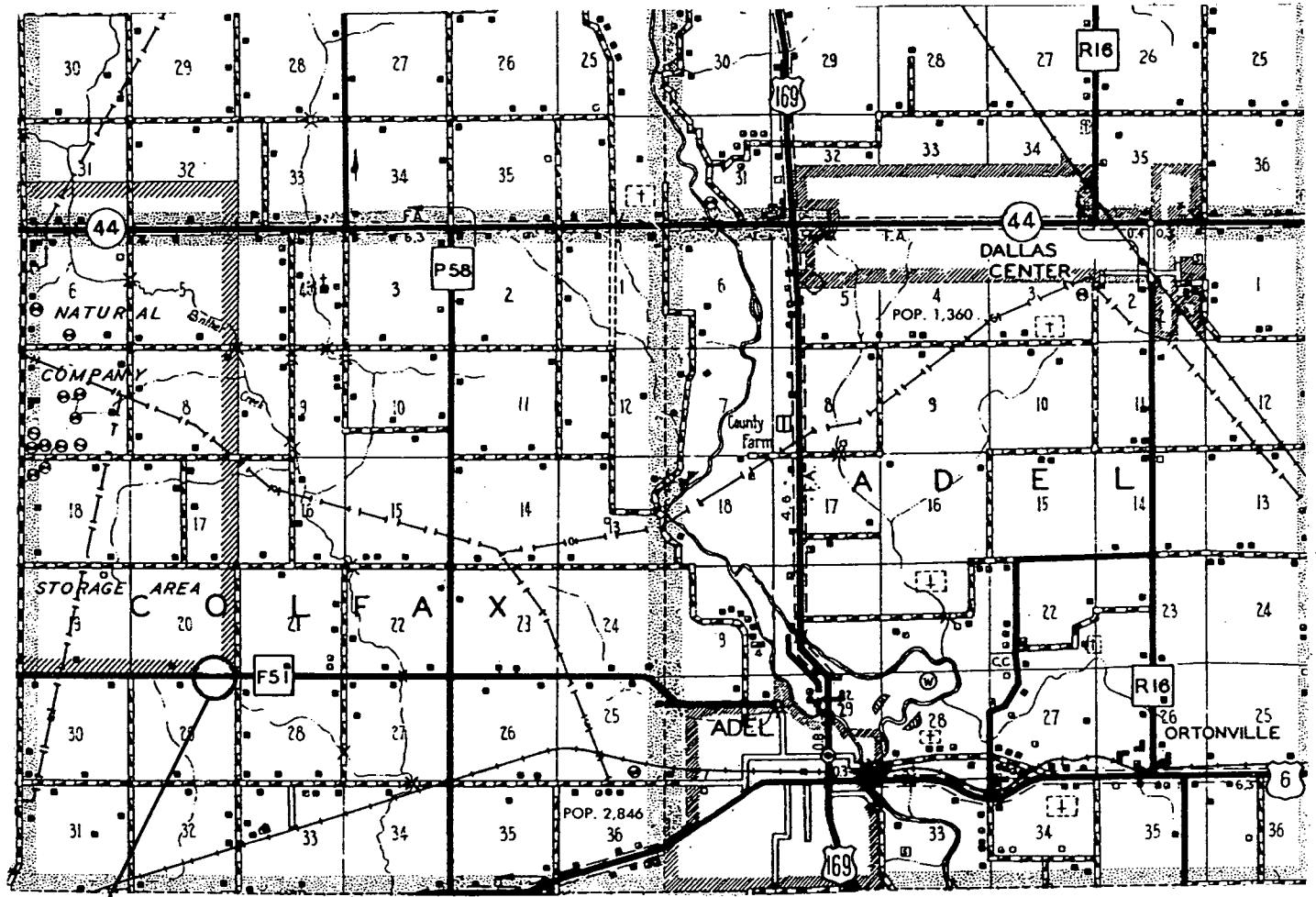
3. McCullouch, B.G.; Repair and Rehabilitation of Deteriorated Drainage Pipe; Indiana Department of Transportation and Federal Highway Administration; FHWA/IN/JHRP 91/14; October 1991.

4. Thomas, Richard; Indiana Department of Transportation; Presentation at Indiana Department of Transportation Annual Engineers Meeting 1990 titled "Polyethylene Liner Pipe."

5. Boles, Richard and Campbell, Steve; Liners Give Rusted Culverts New Life, Higher Capacity; Roads and Bridges; February 1994.

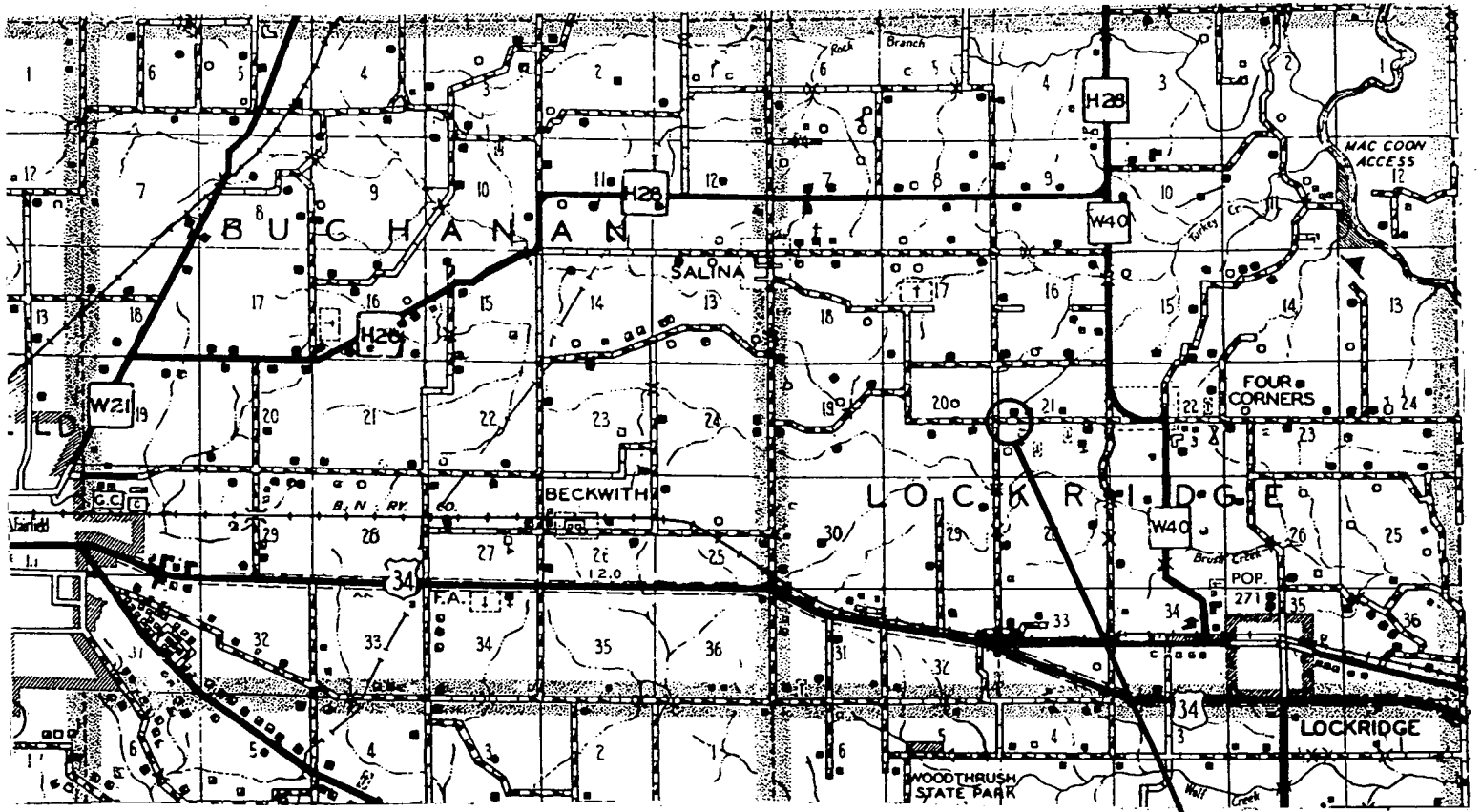
6. Adaska, Wayne; Controlled Low-Strength Material Turns Old Bridges to Roadways; Roads and Bridges; February 1995.

# DALLAS COUNTY




760 mm (30 in.) ID "CULVERT RENEW" LINER IN A 900 mm (36 in.) CMP

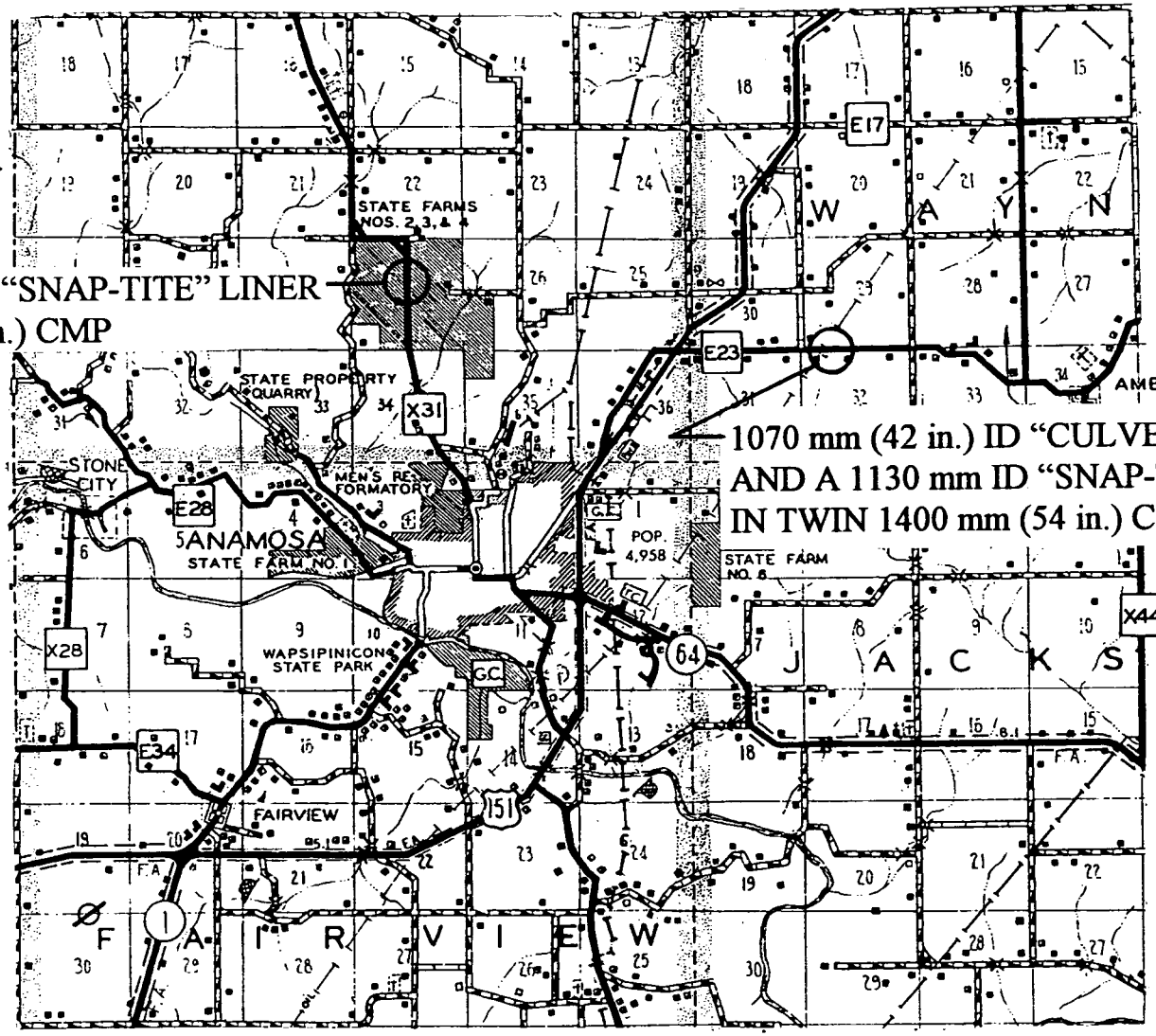
# JEFFERSON COUNTY




760 mm (30 in.) ID "SNAP-TITE" LINER IN A WOOD BOX CULVERT

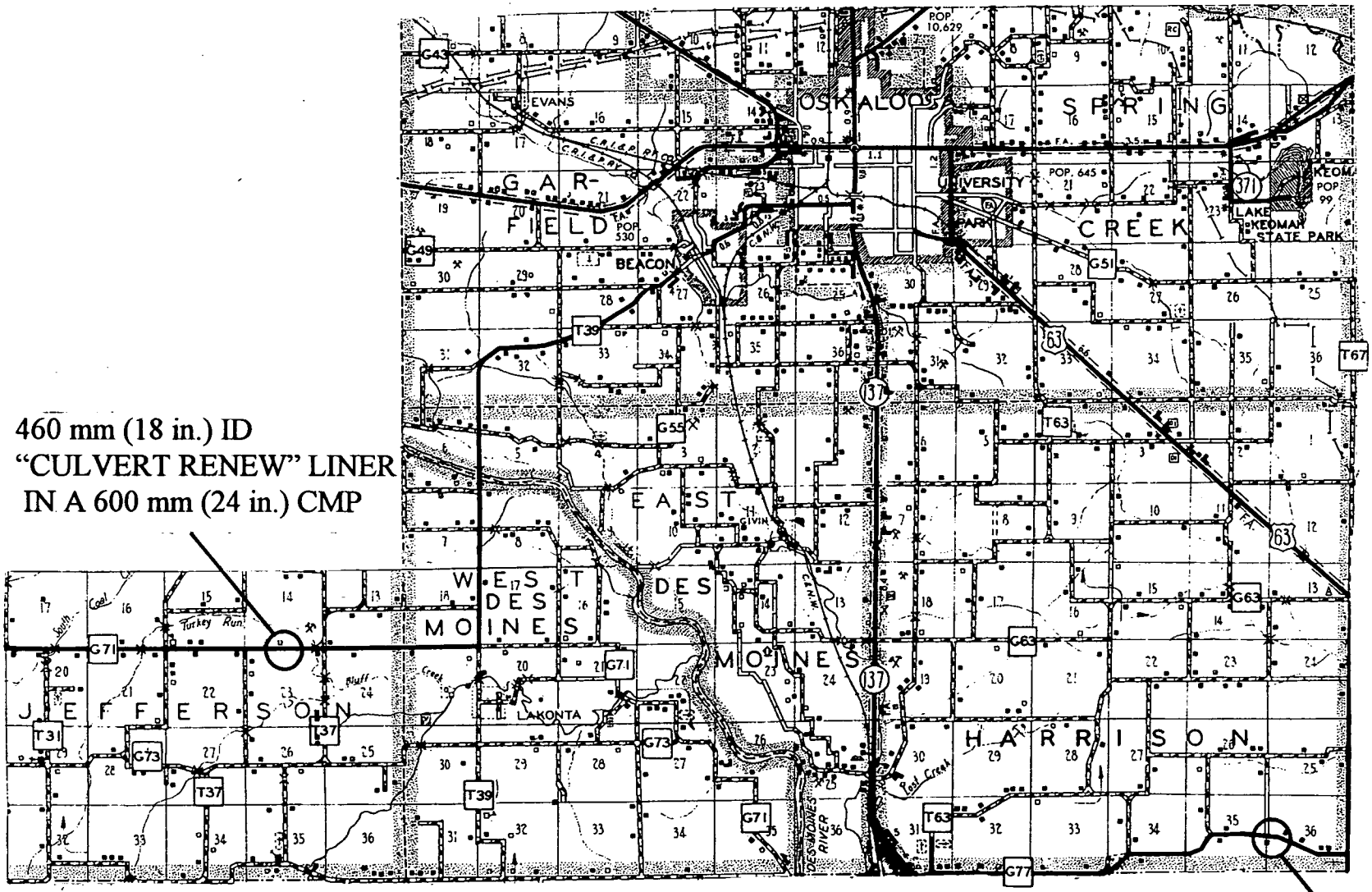
# JONES COUNTY

760 mm (30 in.) ID "SNAP-TITE" LINER
IN A 900 mm (36 in.) CMP

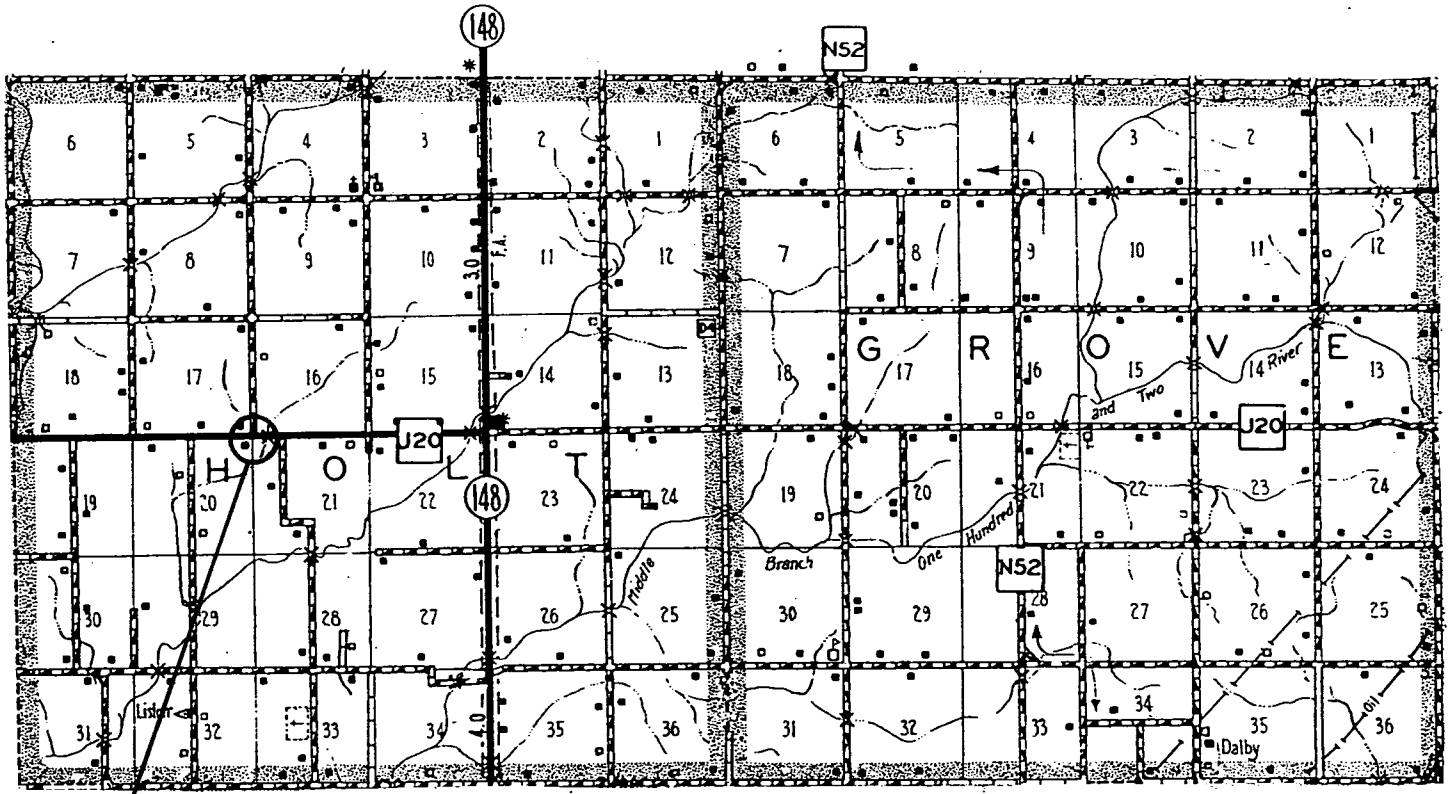



1070 mm (42 in.) ID "CULVERT RENEW" LINER
AND A 1130 mm ID "SNAP-TITE" LINER
IN TWIN 1400 mm (54 in.) CONCRETE PIPES

# MAHASKA COUNTY

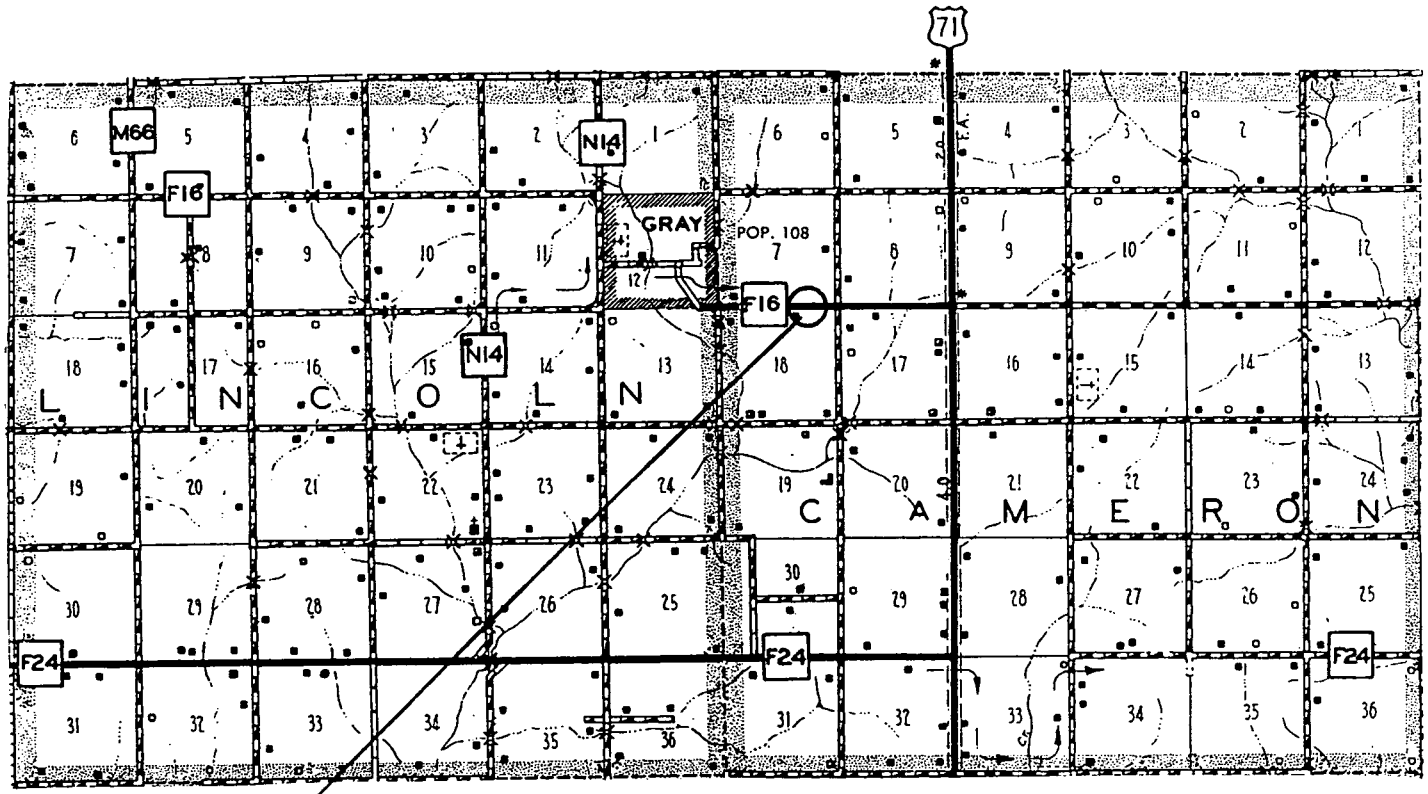


# TAYLOR COUNTY



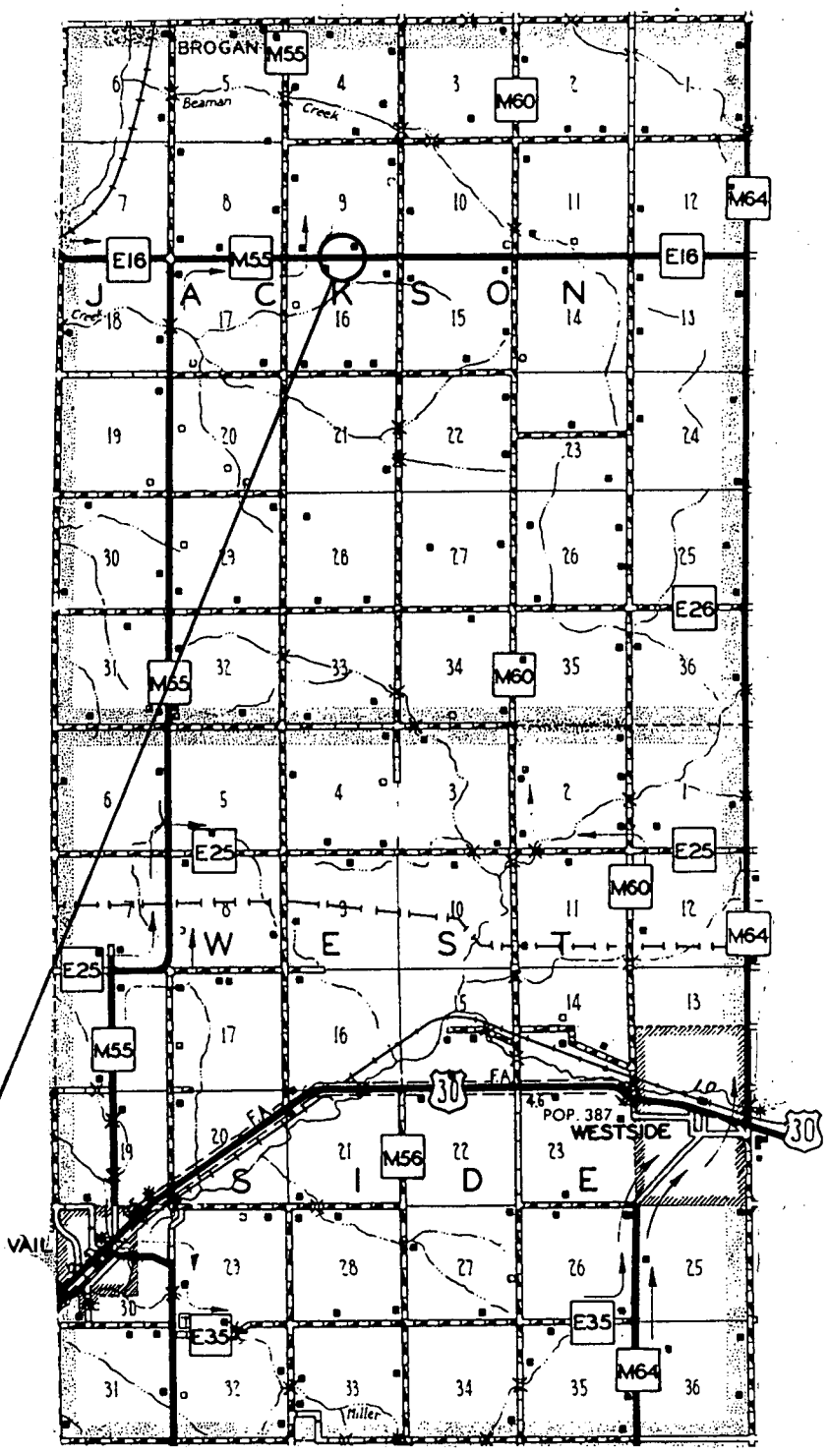

610 mm (24 in.) ID "CULVERT RENEW" LINER IN A 800 mm (30 in.) CMP

# AUDUBON COUNTY



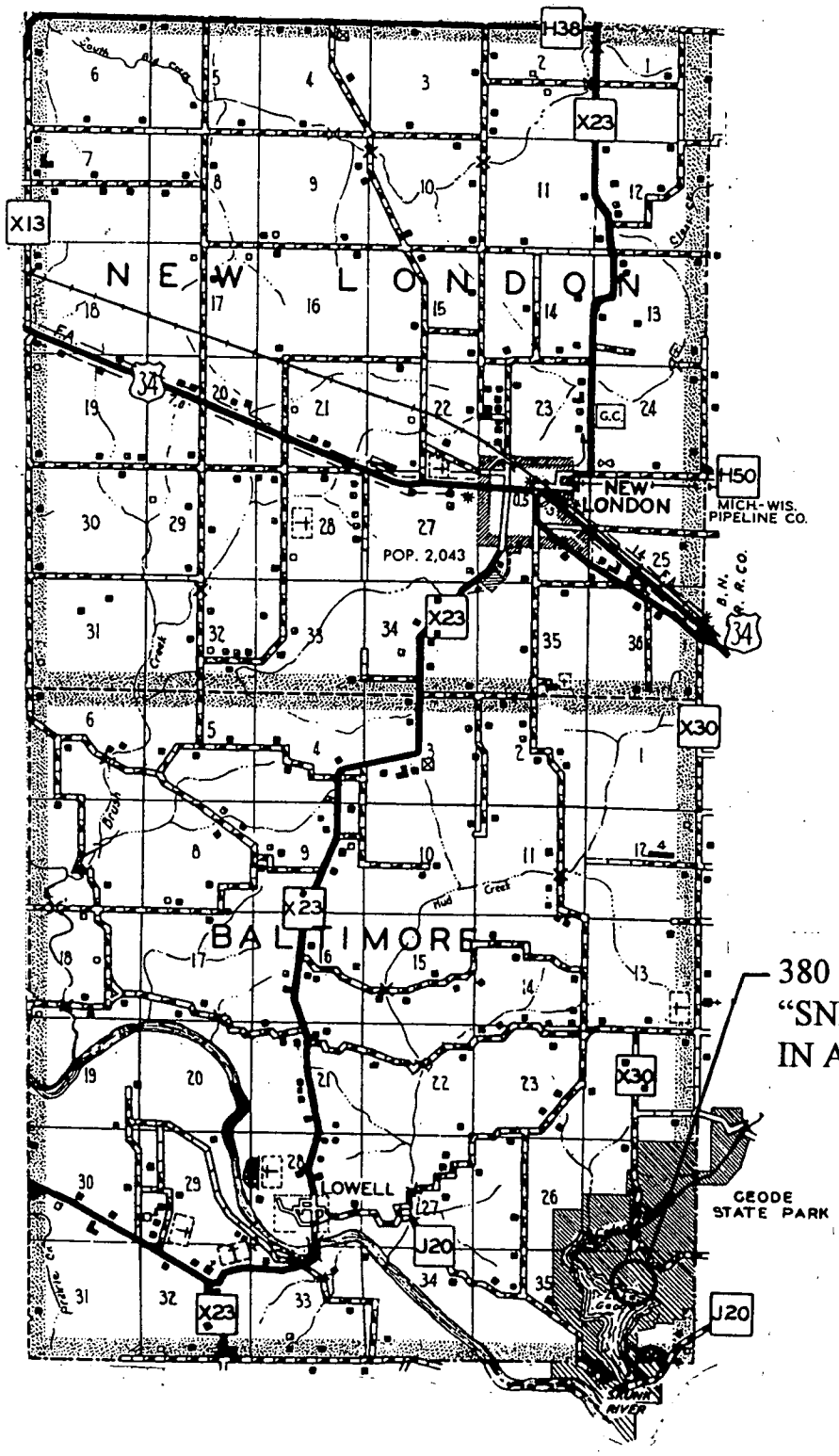

480 mm (18.8 in.) ID "SNAP-TITE" LINER IN A 600 mm (24 in.) CMP

# CRAWFORD COUNTY

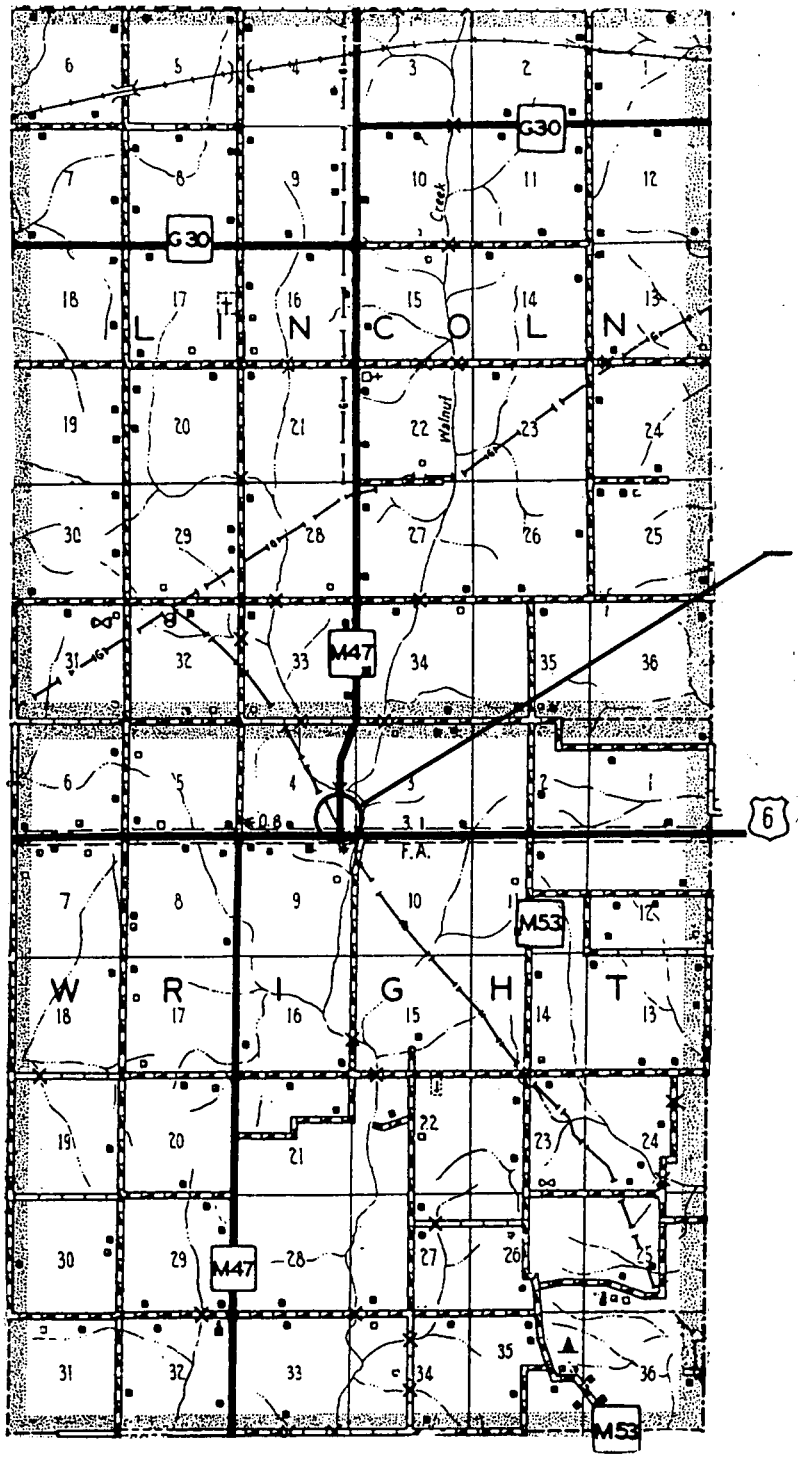



810 mm (31.9 in.) ID "SNAP-TITE" LINER IN A 1050 mm (42 in.) CMP

# HENRY COUNTY
# GEODE PARK



# POTTAWATTAMIE COUNTY




1290 mm (50.7 in.) ID
"SNAP-TITE" LINER
IN A 1800 mm (72 in.) CMP

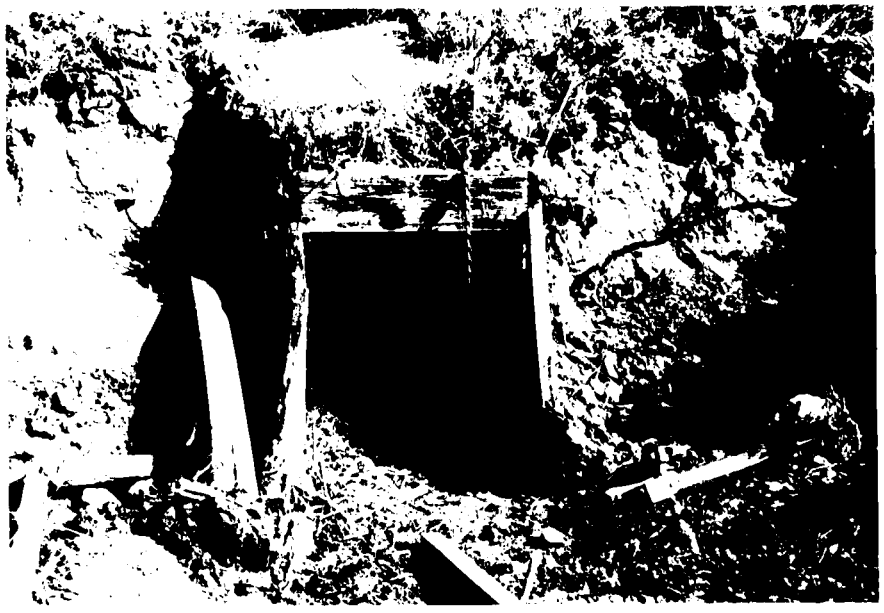


Photo 1
Wood Box Culvert in Jefferson County

Photo 2
Connecting "Snap-Tite" Liner Segments
Jefferson County

Photo 3
Twin Concrete Culverts in Jones County

Photo 4
First Segment of "Culvert Renew" Being
Pulled Into the Concrete Culvert (Jones County)

Photo 5
Threading "Culvert Renew" Liner Segments in Jones County

Photo 6
Use of a Board to Protect the Culvert Liner While it is Pushed into the Concrete Culvert (Jones County)

Photo 7
Connecting "Snap-Tite" Liner Segments (Jones County)

Photo 8
Connecting "Snap-Tite" Liner Segments (Jones County)

Photo 9
Bottom of CMP Has Rusted Away
(Mahaska County)

Photo 10
Approximately 1.5 m (5 ft.) of liner
is Left Exposed to Attach the Next
Segment (Mahaska County)

Photo 11
Threading "Culvert Renew" Liner
Segments (Mahaska County)

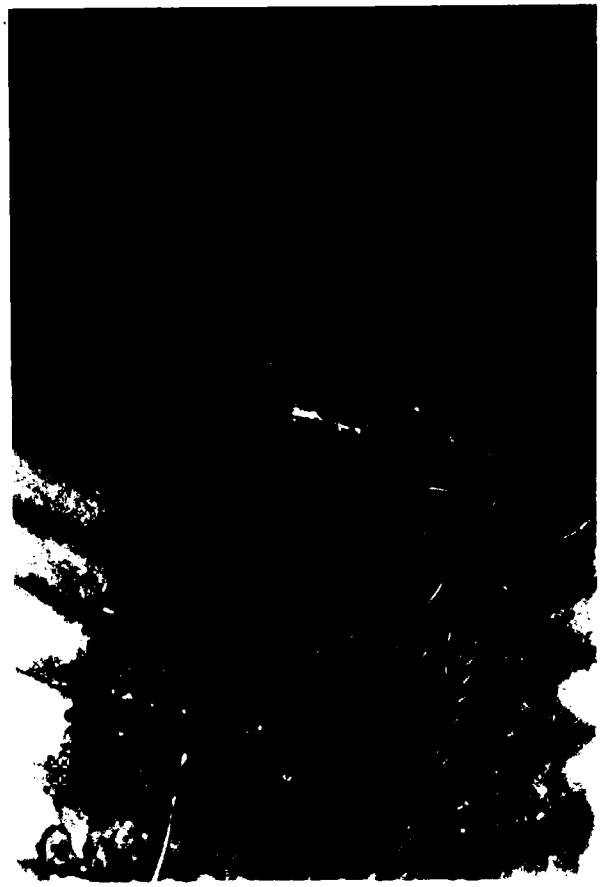


Photo 12
Bottom of CMP Exhibiting Corrosion
and Deterioration (Taylor County)

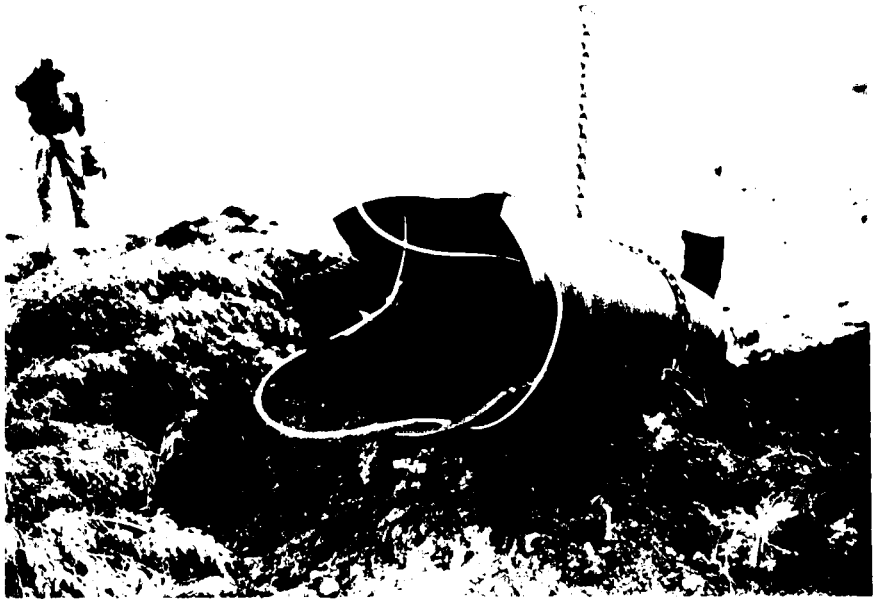


Photo 13
Nose Cone (Taylor County)

Photo 14
Threading "Culvert Renew" Liner Segment by Hand
(Taylor County)

Photo 15
Work Area for Assembling Liner
(Taylor County)

Photo 16
Cutting of Nose Cone With Chain Saw
(Audubon County)

DALLAS COUNTY
COST COMPARISONS

SLIP LINING ACTUAL EXPENSES

| | |
|---|---|
| 30 " ID POLYETHYLENE LINER | $4,058.28 |
| PRESSURE GROUTING AND MORTAR | $1,214.72 |
| LABOR | $ 532.19 |
| EQUIPMENT | $ 225.00 |
| TOTAL | $6,030.19 |

Note: The culvert liner was purchased at a reduced price for this research. The actual culvert price for the product was approximately 35% greater than the price listed in this summary of expenses.

ESTIMATED COST OF REPLACEMENT

| | |
|---|---|
| 30" CONCRETE ROADWAY PIPE ($39.22/LF* FOR 105 LF) | $4,118.10 |
| EXCAVATION, CLASS 20 ($5.30/CY* FOR 200 CY) | $1,060.00 |
| BACKFILL AND COMPACTION ($6.39/CY* FOR 200 CY) | $1,278.00 |
| PAVING OF PCC SURFACE, STANDARD P.C. CONCRETE CLASS C, 7 IN. ($44.70/SY* FOR 73 SY) | $3,263.10 |
| DETOURING TRAFFIC AND CLOSING ROADWAY# | $1,000.00 |
| TOTAL | $10,719.20 |

* Costs for the replacement of the culvert are estimated from the average unit costs listed in the Summary of Awarded Contract Prices 1994 for the Iowa DOT.

# Engineers Estimate

JEFFERSON COUNTY
COST COMPARISONS

## SLIP LINING ACTUAL EXPENSES

| | |
|---|---|
| 30" ID POLYETHYLENE LINER | $3,500.00 |
| FLOWABLE MORTAR (11.5 CUBIC YARDS) | $ 431.25 |
| LABOR | $ 253.70 |
| EQUIPMENT | $ 110.80 |
| TOTAL | $4,295.75 |

Note: The polyethylene liner was purchased at a reduced price for this research. The actual retail price for the product would have been greater than the price listed in this summary of expenses.

## ESTIMATED COST OF REPLACEMENT

| | |
|---|---|
| 36" CONCRETE ROADWAY PIPE ($45.58/LF* FOR 60 LF) | $2,734.80 |
| EXCAVATION, CLASS 20 ($5.30/CY* FOR 75 CY) | $ 318.00 |
| BACKFILL AND COMPACT ($6.39/CY* FOR 75 CY) | $ 479.25 |
| REPLACING GRANULAR SURFACING ON ROADWAY, CLASS B GRAVEL ($7.63/TON* FOR 16 TONS) | $ 122.08 |
| DETOURING TRAFFIC AND CLOSING ROADWAY# | $ 500.00 |
| TOTAL | $4,154.13 |

*Cost for the replacement of the culvert are estimated from the average unit costs listed in the Summary of Awarded Contract Prices 1994 for the Iowa DOT.

TAYLOR COUNTY
COST COMPARISONS

## SLIP LINING ACTUAL EXPENSES

| | |
|---|---|
| 24" ID POLYETHYLENE LINER | $3,768.10 |
| PRESSURE GROUTING | $1,444.17 |
| MORTAR (3 CUBIC YARDS) | $ 210.00 |
| LABOR | $ 622.53 |
| EQUIPMENT | $ 319.20 |
| TOTAL | $6,364.00 |

Note: The polyethylene liner was purchased at a reduced price for this research. The actual retail price for the product was approximately 35% greater than the price listed in the summary of expenses.

## ESTIMATED COST OF REPLACEMENT

| | |
|---|---|
| 30" CONCRETE ROADWAY PIPE ($39.22/LF* FOR 105 LF) | $4,118.10 |
| EXCAVATION, CLASS 20 ($5.30/CY* FOR 1050 CY) | $5,565.00 |
| BACKFILL AND COMPACT ($6.39/CY* FOR 1050 CY) | $6,709.50 |
| PAVING OF PCC SURFACE, STANDARD P.C. CONCRETE CLASS C, 7 IN. ($44.70/SY* FOR 147 SY) | $6,570.90 |
| DETOURING TRAFFIC AND CLOSING ROADWAY# | $1,000.00 |
| TOTAL | $23,963.50 |

* Costs for the replacement of the culvert are estimated from the average unit costs listed in the Summary of Awarded Contract Prices 1994 for the Iowa DOT.

# Engineers Estimate

# MANNING EQUATION

*Formula*: $V = \frac{0.284}{\eta} R_h^{\frac{2}{3}} S^{\frac{1}{2}}$

*Definitions:*

$Q$ = *Flow Rate (GPM)*

$A$ = *Area of pipe* = $\frac{\pi D^2}{4}$ *(square inches)*

$R_h$ = *Hydraulic Radius* = $\frac{D}{4}$ *for full flow (inches)*

$\eta$ = *Dimensionless Manning Roughness Coefficient*

$D_l$ = *Inner Diameter of Liner*

$D_c$ = *Inner Diameter of Drainage Culvert*

*For Equal Flows:*

*Set Flow of Culvert equal to Liner*

$$Q_c = Q_l$$

$$A_c V_c = A_l V_l$$

$$A_c \times \frac{0.284}{\eta_c} \times R_h^{\frac{2}{3}} S^{\frac{1}{2}} = A_l \times \frac{0.284}{\eta_l} \times R_h^{\frac{2}{3}} S^{\frac{1}{2}}$$

*Since the slope is the same the equation reduces to:*

$$\frac{A_c}{\eta_c} \times R_h^{\frac{2}{3}} = \frac{A_l}{\eta_l} \times R_h^{\frac{2}{3}}$$

$$\frac{\pi D_c^2}{4\eta_c} \times \left(\frac{D_c}{4}\right)^{\frac{2}{3}} = \frac{\pi D_l^2}{4\eta_l} \times \left(\frac{D_l}{4}\right)^{\frac{2}{3}}$$

$$\frac{D_c^2 \times D_c^{\frac{2}{3}}}{\eta_c} = \frac{D_l^2 \times D_l^{\frac{2}{3}}}{\eta_l}$$

Solve for the needed diameter of the liner using the following equation:

$$D_l = \left(\frac{\eta_l}{\eta_c}\right)^{\frac{3}{8}} D_c$$

GROUT DESIGN PRESENTED AT
1990 INDIANA ANNUAL ENGINEERS MEETING
by Richard Thomas
District, Maintenance Field Engineer

300 lb. cement (type 1)
1500 lb. fly ash (type C or F)
156 oz super plasticizer (Rheobuild 1000)
As needed air entraining admixture to obtain 10% air content
45 gal. water
1200 lb. fine aggregate (SSD)

The Indiana Vincennes District Maintenance used this mix to gravity grout liner with the use of PVC stand pipes. The mix was vibrated with a portable vibrator to help the mix flow.

800 Lincoln Way, Ames, Iowa 50010 515/239-1447

October 22, 1992 Ref. No.: 435.34D

Mr. Bruce Larson
STS Systems, Inc.
P.O. Box 328
Chesterfield, Missouri 63006

Dear Mr. Larson:

Thank you for your interest in supplying products for Iowa DOT use. Your Snap-Tite polyethylene pipe has been reviewed by the New Products Subcommittee and tested by the Materials Laboratory. The Specifications Committee has approved your Snap-Tite pipe for use when specified in the plans.

Sincerely,

Vernon J. Marks
Research Engineer
Materials - Research

VJM:kmd
cc: J. Hocker

800 Lincoln Way, Ames, Iowa 50010 515/239-1447

January 28, 1994 Ref. No.: 435.34D

Steve Campbell
Poly Systems Incorporated
P.O. Box 1157
Steelville, Missouri 65565

Dear Mr. Campbell:

Thank you for your interest in supplying Culvert Renew for Iowa DOT use. Culvert Renew has been reviewed by our New Products Evaluation Subcommittee. Upon their recommendation, the Specifications Committee has approved the culvert liner and coupler for Iowa DOT use. The Specifications Committee also suggested that the Office of Local Systems arrange for a demonstration project for