R-94-13

HAIGHTS CREEK RPM PIPE FAILURES

September 1994

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Technical Service Center
Research and Laboratory Services Division
Materials Engineering Branch

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1994	Final

4. TITLE AND SUBTITLE
Haights Creek
RPM Pipe Failures

5. FUNDING NUMBERS
PR

6. AUTHOR(S)
Amster K. Howard

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Bureau of Reclamation
Technical Service Center
Denver CO 80225

8. PERFORMING ORGANIZATION REPORT NUMBER
R-94-13

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Bureau of Reclamation
Denver Federal Center
PO Box 25007
Denver CO 80225-0007

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DIBR

11. SUPPLEMENTARY NOTES
Microfiche and hard copy available at the Denver Office, Denver, Colorado

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Available from the National Technical Information Service,
5285 Port Royal Road, Springfield, Virginia 22161

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
In 1989, Haights Creek Irrigation Company replaced 730 linear feet of 24- and 27-inch-diameter RPM (reinforced plastic mortar) pipe because of several failures. Bureau of Reclamation personnel examined the pipe before and after exhumation, the surrounding soil conditions, and measured diametral deflections. Major longitudinal cracks in the pipe invert appear to be the result of hard spots in the pipe foundation. Some of these hard spots were caused from mounding, or using a mound of soil under one end of the pipe to bring it to grade without providing an equivalent uniform support along the remainder of the pipe.

14. SUBJECT TERMS--pipe/ RPM pipe/ flexible pipe/ deflection/ field density/ soil mechanics/ soil tests/ time factors/ soil-structure interaction/ Haights Creek/ Bonneville Project Office/

15. NUMBER OF PAGES
41

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UL	UL	UL	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

R-94-13

HAIGHTS CREEK
RPM PIPE FAILURES

by

Amster K. Howard

Materials Engineering Branch
Research and Laboratory Services Division
Technical Service Center
Denver, Colorado

September 1994

UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

U.S. Department of the Interior
Mission Statement

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

CONTENTS

TABLES

FIGURES

APPENDIXES

INTRODUCTION

In the fall of 1989, the Haights Creek Irrigation Company in Kaysville, Utah, excavated and replaced 730 linear feet of 24- and 27-inch-diameter RPM (reinforced plastic mortar) pipe. This particular type of RPM pipe is no longer manufactured, but newer types of RPM pipe are commercially available. Several failures had occurred in this 730-foot section of the Haights Creek line, and because of its proximity to homes in a recent housing development (as shown on fig. 1), the irrigation company decided to replace the RPM pipe with 24-inch ductile iron pipe. Kaysville is about 20 miles north of Salt Lake City on Interstate 15.

Before the pipe was removed, Reclamation personnel participated in a crawl-through inspection to ascertain the condition of the pipe and possible causes of the failures (Swihart and Howard, 1989). This crawl-through inspection was followed by an examination of the pipe after it had been exhumed and cleaned (Swihart, 1989).

Information in this report is presented regarding the following items:

1. Observations of cracks.
2. Examination of bedding and backfill.
3. Soil test results.
4. Pipe deflection measurements.

A history of the RPM pipe used by the Haights Creek Irrigation Company is presented in appendix A. A detailed list of the observations made during the two examinations of the pipe interior is presented in appendix B. In appendix C are copies of handwritten notes about the soil foundation of the pipe.

RPM PIPE

RPM pipe is a type of fiberglass pipe consisting of a composite of polyester resin, silicate sand, and glass filament reinforcing. This RPM pipe was built up in layers on a mandrel by a filament winding process modified to incorporate the sand into the process. The result was a lightweight, flexible pipe that provided high tensile hoop strength and improved (higher) pipe stiffness compared to conventional fiberglass pipe without sand filler. The pipe was manufactured in standard 20-foot lengths with bell-and-spigot, rubber-gasketed (O-ring) joints. The joint was essentially Reclamation's (Bureau of Reclamation) R-4 joint design. The bell was fabricated as an integral part of the pipe on the mandrel during the winding process. The spigot was cast (molded) on the outside of the pipe wall at the other end of the pipe.

In the early 1970s, Reclamation began specifying RPM pipe as one of the pipe options for contractors to use on Reclamation Projects. RPM pipe was used on several Reclamation projects until the early 1980s, when the pipe was no longer manufactured. During this period, some irrigation districts, with funds from the SRPA (Small Reclamation Projects Act) Program also used RPM pipe. The Haights Creek Irrigation District installed about 3 miles of 18- to 27-inch-diameter RPM pipe under the SRPA Program in 1972.

Markings on the 27-inch pipe indicated the various pipe sections were designed for 200, 225, and 300 feet of head. Other interior and exterior markings gave the date of manufacture, identification data, and the hydrotest results. These markings are reported in table B-1 in appendix B.

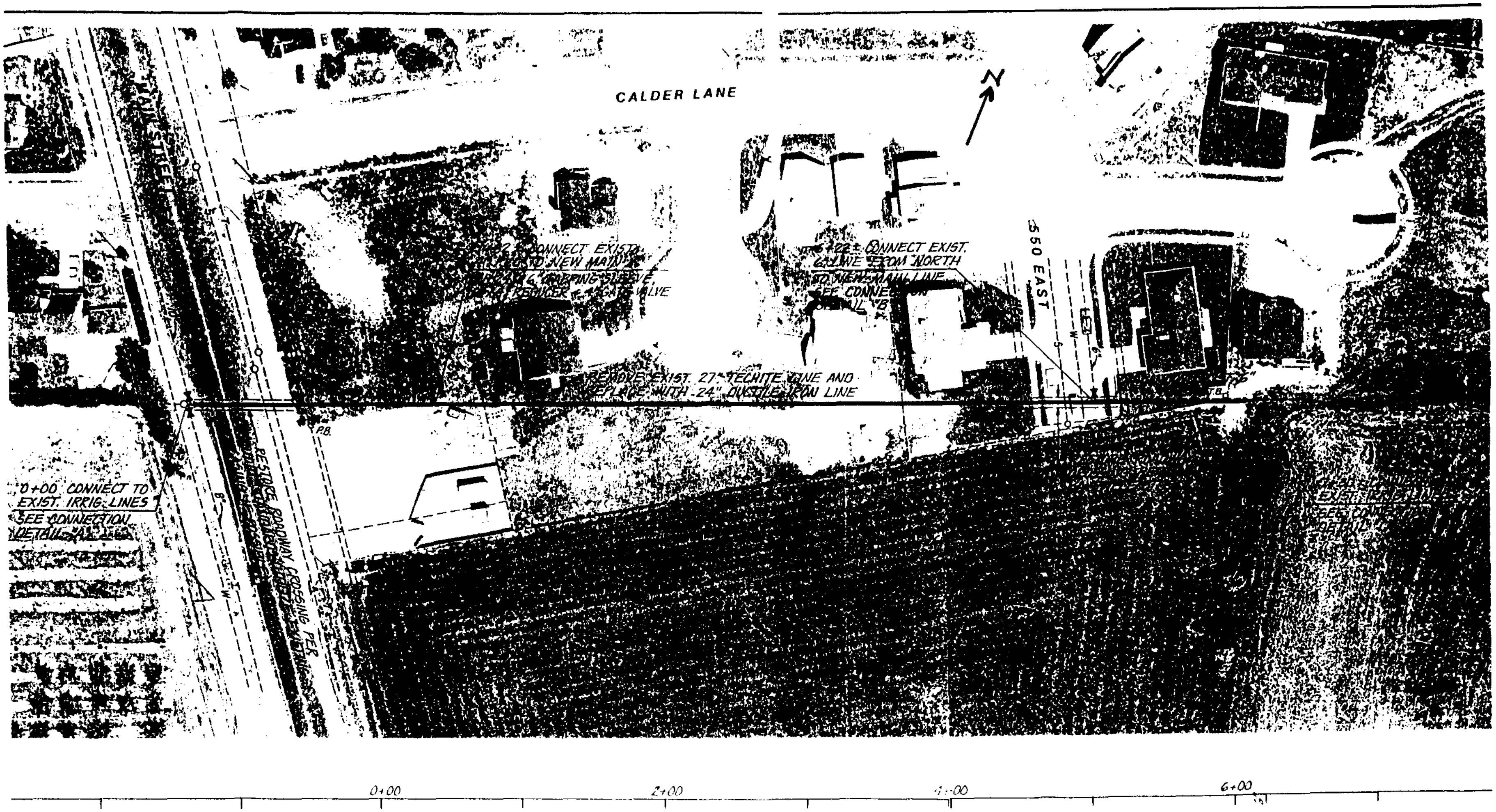


Figure 1. - Location map of RPM replacement - Haights Creek Irrigation District - Kaysville, Utah.

BEHAVIOR OF FLEXIBLE PIPE

External load on a buried pipe is created by the backfill soil placed over the top of the pipe and any surcharge and live load on the backfill surface over the pipe. Flexible pipe is designed to transmit the load on the pipe to the soil at the sides of the pipe. As the load on the pipe increases, the vertical diameter of the pipe decreases and the horizontal diameter increases. The increase in horizontal diameter is resisted by the stiffness of the soil at the sides of the pipe.

In the design of structural members, the strain (or deformation) of an element of the material can be determined from the ratio of the load (or stress) on the member to its modulus of elasticity (strain = stress/modulus of elasticity). The deflection of a buried pipe can be predicted in a similar fashion. The cross-sectional ring deflects (deforms) according to the ratio of the load on the ring to the modulus of elasticity of the "material." However, the material modulus is more complicated because a soil-structure interaction takes place. The material modulus becomes a combination of the structural modulus (stiffness) of the pipe and the modulus (stiffness) of the soil beside the pipe, so that:

$$\text{pipe deflection} = \frac{\text{load on the pipe}}{\text{pipe stiffness} + \text{soil stiffness}}$$

Several variations of this relationship are used to predict the deflection of a buried flexible pipe. The most common is the Iowa Formula (Spangler, 1941; Watkins and Spangler, 1958) developed by Professor M. G. Spangler of Iowa State University. A variation of the Iowa Formula commonly used is written as follows

$$\Delta Y\ (\%) = T_f \frac{0.07\gamma h}{EI/r^3 + 0.061\ E'}$$

where:

$\Delta Y\ (\%)$	=	percent vertical deflection
T_f	=	time-lag factor, dimensionless
0.07	=	combination of conversion factors and bedding constant, ft^2/in^2
γ	=	backfill density, lbm/ft^3
h	=	height of cover, ft
EI/r^3	=	pipe stiffness factor, lbf/in^2
E'	=	modulus of soil reaction, lbf/in^2

OBSERVATIONS OF CRACKS

Table 1 gives a summary of the observations of cracks in the pipe as a result of two separate examinations (a detailed presentation of observations is contained in appendix B). First, a crawl-through inspection was made of the pipe in place. Only very obvious cracks could be observed because the interior of the pipe was coated with soil. After the pipe was very carefully removed, the pipe interiors were washed to examine the cracks more closely.

In appendix B, the observations of cracks made after the cleaning are presented in a distinct manner to illustrate that most of the cracks were undetectable during the crawl-through inspection because of the dirty condition of the pipe interior. Damage to the pipe during excavation is also indicated.

Table 1. - Summary of RPM pipe inspection.

Pipe No.	Length (ft)	Comments
1	20	Longitudinal hairline cracks in invert.
2	20	Numerous 1-inch circumferential cracks.
3	20	Longitudinal 1/2-inch long cracks in invert.
4	20	Longitudinal hairline crack in invert.
5	20	Longitudinal hairline crack in invert.
6	20	
7	20	
8	20	
9	20	Flat area in invert with numerous longitudinal hairline cracks.
10	20	
11	20	Numerous hairline longitudinal cracks - 3 to 7 o'clock.
12	10	Long-bell repair kit.
13	10	Long-bell repair kit.
14	10	Long-bell repair kit.
15	10	Long-bell repair kit.
16	10	Long-bell repair kit.
17	10	Long-bell repair kit.
18	20	Numerous hairline longitudinal cracks in invert.
19	20	Flat area in invert near bell with numerous hairline longitudinal cracks. Flat area in invert near spigot with numerous hairline longitudinal cracks.
20	20	Flat area in invert with several hairline longitudinal cracks.
21	20	Longitudinal 1/2-inch long hairline crack in invert.
22	20	Flat area in invert with longitudinal cracks. Two areas with longitudinal hairline cracks in invert.
23	20	Two **major** cracks in invert area with numerous longitudinal hairline cracks in invert.
24	20	
25	20	Two **major** cracks in invert.
26	20	Numerous circumferential and some longitudinal cracks in invert.
27	20	

Table 1. - Summary of RPM pipe inspection (continued).

Pipe No.	Length (ft)	Comments
28	20	Circumferential crack in invert.
29	20	Three longitudinal cracks in invert.
30	20	Flat area in invert with longitudinal crack in center. Longitudinal hairline cracks in invert.
31	10	Long-bell (closure section?) kit.
32	10	Long-bell kit.
33	20	
34	20	**Major** longitudinal 3-inch crack in invert (found 4- by 4-inch timber under pipe at crack site). 1/2-inch-diameter star crack.
35	20	
36	Transition section 27 to 24 inches diameter.	

About 620 continuous linear feet of pipe was inspected. Included in this section of pipeline were three 20-foot long-bell repair kits and a 20-foot long-bell kit that was probably an original closure section. The remaining 540 feet consisted of 27 (quantity) 20-foot lengths of pipe. No cracks could be detected in 8 pipe sections (No. 6, 7, 8, 10, 24, 27, 33, and 35), 16 pipe sections had "minor" cracks, and 3 pipe sections (No. 23, 25, and 34) had "major" cracks. "Major" cracks are defined as those where some delamination apparently occurred between the liner and the remainder of the pipe wall. The area around these major cracks is raised (swollen), and water comes out of the crack when hand pressure is applied. Of the major cracks, no observable sign of a crack or of any distress was present on the exterior of the pipe.

Pipe No. 23 had two major longitudinal cracks in the invert as shown on figure 2. These cracks were about 2 feet from the bell end of the pipe and oozed water when pressed.

Pipe No. 25 had two major longitudinal cracks, one 6-1/2 inches long, in the invert as shown on figure 3. Water would come out of the crack when pushed in place. This crack was located about 2 feet from the bell end. The crack was raised as shown by the shadows in the close-up view on figure 4. The area around the cracks sounded hollow when tapped.

Pipe No. 34 had a major longitudinal invert crack about 3-1/2 feet from the spigot end of the pipe as shown on figure 5.

Although a few circumferential cracks were noticed, most of the minor cracks were longitudinal and in the invert of the pipe. Flat areas were noticed in the invert of six pipes with longitudinal cracks in the center of each flat area. All of the major cracks were in a flattened area. The flattening of the pipe creates tensile strains on the interior pipe wall that can lead to cracking.

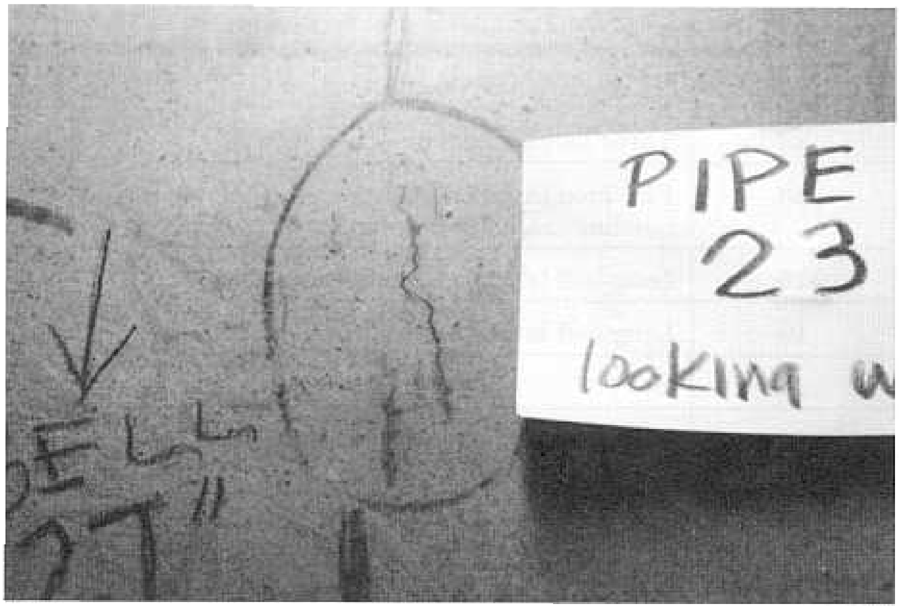


Figure 2. - Longitudinal invert crack in pipe No. 23.

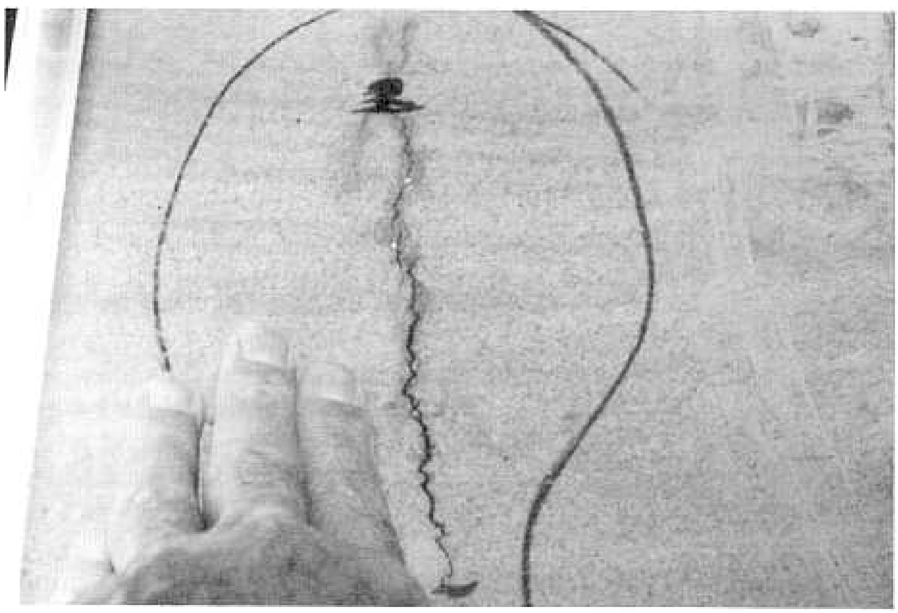
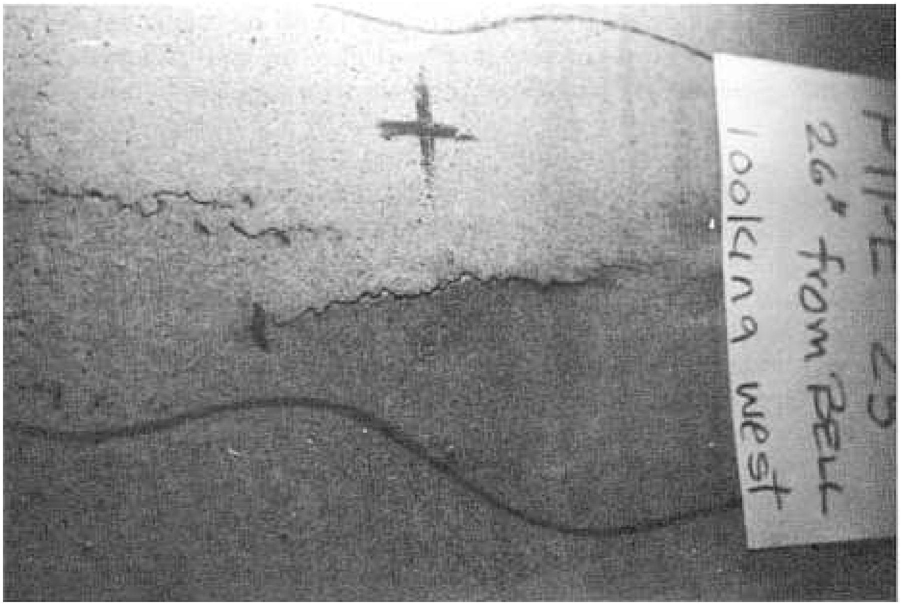
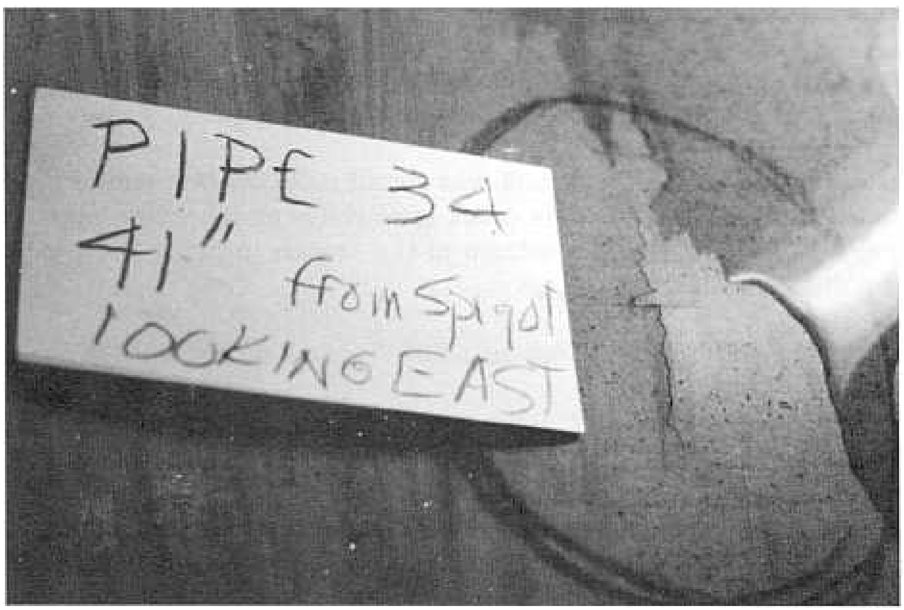


Figure 3. - Major longitudinal crack in pipe No. 25.



Close crack in pipe



Flattened with longitudinal invert of pipe No.

EXAMINATION OF BEDDING AND BACKFILL

Following the crawl-through inspection, several of the pipes were carefully excavated so that the bedding and backfill conditions around the pipe could be inspected. On September 27, 1989, pipes No. 21 through 26 were removed and the soil conditions were evaluated. On September 28, 1989, pipe No. 34 was carefully removed and the bedding and backfill were checked.

In pipe No. 34, a flat spot in the invert containing a severe crack had been detected during the crawl-through. Figure 5 shows the flat spot and crack as it appeared in place. The reason for the flat spot was readily apparent as shown on figure 6. During construction, a 4- by 4-inch timber had been placed under the pipe. The area around this pipe was all recent fill and the timber was obviously used to bring the pipe to grade while soil was placed under the pipe, and then the timber was left in place, probably erroneously. The piece of timber created a hard spot and a point loading on the bottom of the pipe, and as the pipe settled and deflected, the hard spot created a flattened area in the invert, causing excessive tensile strains on the inner surface of the pipe and resulting in longitudinal cracking of the pipe.

Several other flat spots in the pipe invert were observed during the crawl-through inspection. Although no other 4- by 4-inch timbers were found at the flat spot locations, evidence of "mounding" or a hard spot in the pipe foundation was found near the flat spots and associated interior longitudinal cracks. Details of the investigation of the pipe foundation are presented in appendix C.

For pipe No. 23, a soil mound was apparently placed under the bell end of the pipe during construction. This area of the mound is at the same location as the major interior longitudinal invert cracks.

For pipe No. 24, no cracks were detected in the pipe, and the foundation was uniform under the pipe with no signs of mounding.

Pipe No. 26 had numerous small circumferential cracks with one small longitudinal invert crack. The foundation appeared to be uniform under this pipe.

A major interior longitudinal invert crack was found near the bell end of pipe No. 25. This crack is shown on figures 3 and 4. The crack is at the area where an apparent soil mound was used to raise the pipe off of the bottom of the trench to bring the pipe to grade. The evidence for a soil mound is:

1. Area is a different soil color, as illustrated on figure 7 as the lighter shade.

2. As the soil dried, the "soil mound" soil separated from the surrounding soil, revealing an outline of a different soil as shown on figure 7.

3. The blade of a putty knife penetrated less at the site of the crack than anywhere else along the pipe, indicating a hard spot in the foundation at that point.

4. A cross section of the soil beneath the pipe shows this area of lighter color to be about 1 inch deep over the trench bottom, as shown on figure 8. The in situ material was easy to detect because it was a stratified material.

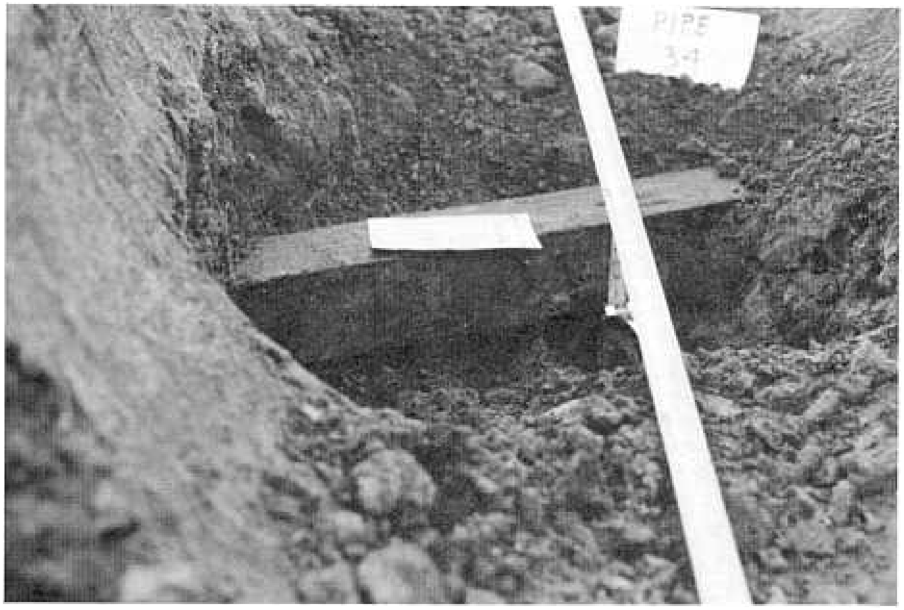


Figure 6. - 4- by 4-inch timber found directly under crack in pipe No. 34.

Figure 7. Soil foundation of pipe No. 25 showing mound.

Figure 8. - Cross section of soil foundation of pipe No. 25 showing 1-inch-thick soil mound.

Although mounding is not a recommended practice for any type of pipe, unfortunately, the practice is commonly used. Although the hard spot created by the mound can crack a rigid pipe in extreme cases, rigid pipe may bridge over the mound without causing serious distress to the pipe. Flexible pipe, such as steel, PVC (polyvinyl chloride), and fiberglass, tend to "mold" to the hard and soft areas in the surrounding soil. A very hard spot, such as a rock, may even cause a reverse curvature of the pipe wall as the pipe bends to fit around the rock.

DEFINITIONS

As illustrated on figure 9, "embedment" refers to soil beside the pipe up to a height of 2/3 of the outside diameter of the pipe. "Backfill" refers to soil over the pipe, and "cover" is the vertical distance from the top of the pipe to the top of the backfill.

IN-PLACE SOIL DENSITY

In-place soil density tests were performed in the vicinity of pipe No. 25 in the embedment next to the pipe, in the backfill placed over the pipe, and in the in situ soil in what would have been the trench walls during construction. The tests were performed by Reclamation personnel from the Bonneville Projects Office in Provo, Utah, in accordance with designation E-23 in the *Earth Manual* (Reclamation, 1974). In addition, gradation analysis and Atterberg limits tests were performed on the soil removed from the density test in order to classify the soil. The results of the tests showing the in-place densities are given in table 2. In table 3, the results of gradation tests, Atterberg limits tests, and the resulting soil classification are shown.

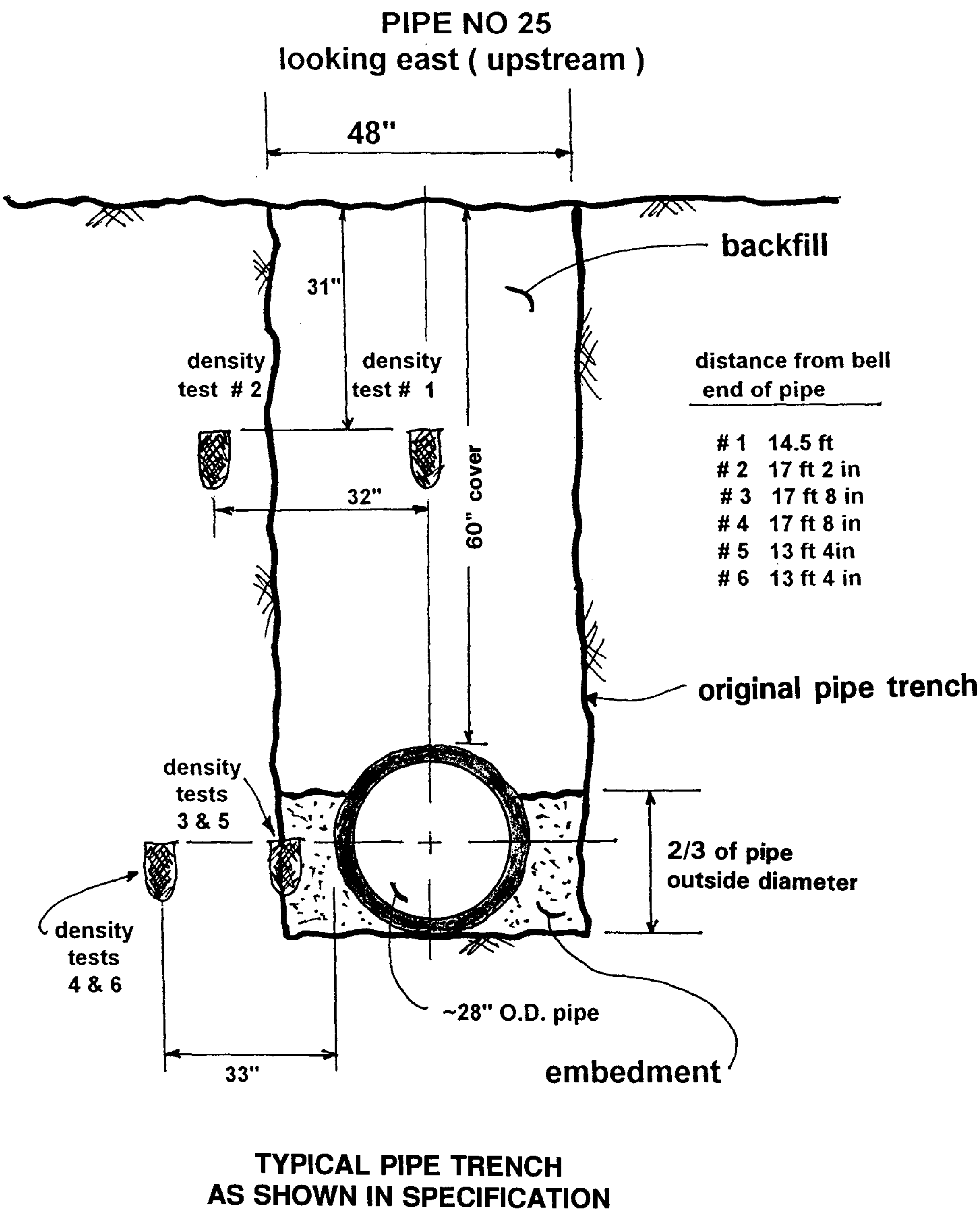


Figure 9. - Locations of six field density tests about pipe No. 25.

Table 2. - In-place soil density tests.

Test No.	In-place density			Laboratory density		Percent compaction (%)
	Wet density (lbm/ft^3)	Dry density (lbm/ft^3)	Moisture content (%)	Maximum dry density (lbm/ft^3)	Optimum moisture (%)	
	Backfill over pipe					
1	100.3	93.2	7.6	100.9	10.7	92.4
	Pipe embedment					
3	96.9	88.9	9.0	104.1	14.2	85.4
5	112.2	94.6	18.6	109.0	15.4	86.8
	In situ material (trench walls)					
2	96.9	88.9	9.0	104.1	14.2	85.4
4	109.3	92.7	17.9	104.8	17.8	88.5
6	116.8	97.9	19.3	103.9	18.6	94.2

Table 3. - Physical properties of soil from in-place soil density tests.

Test No.	Gradation - %			Atterberg limits*		Soil classification	Location
	Gravel	Sand	Fines	LL	PI		
1	0	28	72	25	5	CL-ML Silty clay with sand	Backfill
2	0	22	78	27	6	CL-ML Silty clay with sand	Trench wall
3	0	23	77	25	4	CL-ML Silty clay with sand	Embedment
4	0	14	86	-	NP	ML Silt	Trench wall
5	0	26	74	25	8	CL-ML Silty clay with sand	Embedment
6	0	13	87	-	NP	ML Silt	Trench wall

*Performed on oven-dried soil (test normally performed on air-dried soil).

Figure 9 illustrates the location of the six density tests. One test was in the backfill over the pipe, two in the embedment material placed between the pipe and the in situ trench walls during construction, and three in the in situ material representing the trench walls.

In density test No. 3 in the pipe embedment, a cylindrical density hole was excavated. The embedment soil had been placed in a semicircular excavation at the trench bottom, and as a result, the cylindrical hole was excavated into a portion of the in situ material. Therefore, the result of the test was influenced by the density of the in situ soil. However, the density of the in situ material was in the same range as the embedment soil, 85 to 90 percent compaction.

In density test No. 5, the hole for the density test was excavated only in the embedment material so that the density hole was not a cylindrical shape. Because the density sand is calibrated for a cylindrical hole, the volume determined using the density sand may not be entirely accurate. However, the variation is such that the density of the embedment can still be considered in the range of 85 to 90 percent compaction.

In general, the density of the trench walls was between 85 and 95 percent compaction (same as percent Standard Proctor); the density of the embedment was between 85 and 90 percent compaction; and the backfill density was between 90 and 95 percent compaction. Reclamation generically specifies 95 percent minimum compaction to assure adequate pipe support. Lower compaction is acceptable as long as the pipe does not deflect excessively (more than 5 percent).

For selecting E' values (soil stiffness) for use in the Iowa Formula, the embedment soil density is divided into four categories, dumped, slight (below 85 percent compaction), moderate (85 to 95 percent compaction), and high (over 95 percent compaction) (Howard, 1977a). The embedment soil for this project fell into the *moderate* category. When the embedment zone is not very wide, the influence of the trench walls should be considered as significant in resisting the deflection of the pipe. At this site, the embedment was only 10 inches wide on each side of the pipe at the springline of the 27-inch pipe. However, the density of the in situ soil was about the same as the embedment and would fall into the same *moderate* category for soil stiffness.

A soil classified as CL-ML and ML with less than 30 percent sand and gravel in the *moderate* degree of compaction category would have an E' value of 400 lbf/in^2 (Howard, 1977a).

PIPE DIAMETER MEASUREMENTS

Vertical and horizontal pipe diameter measurements were made to evaluate load-deflection behavior of the pipe. Because the bell and spigot pipe joint is stiffer than the barrel, the maximum deflection typically occurs at the midspan of the pipe. Diameter measurements were made at the midspan at random pipe sections to ascertain the deflection of the pipe. Additional diameter measurements were also made at other selected points of particular interest as indicated in table B-1.

Procedure for Obtaining Pipe Diameter Measurements

To find the midspan point in the pipe, the distance from the end of the pipe was measured with a tape measure. The bottom point for the vertical diameter measurement was located by placing a small pocket level perpendicular to the pipe axis on the bottom of the pipe, moving it until it was level, and marking the center of the pocket level. If standing water was present in the invert, the bottom (lowest) point of the pipe was selected as the middle of the water. A plumb bob was then used to find the pipe crown. The end of an inside micrometer was placed on the bottom point and the other end of the micrometer was maneuvered along the crown to find the smallest dimension, which would be the point perpendicular to the axis of the pipe. This measurement was recorded as the vertical diameter of the pipe.

The horizontal diameter was located using the inside micrometer in a horizontal position, moving it up and down vertically to find the widest horizontal diameter of the pipe, then swinging one end of the micrometer in a horizontal plane to find the point which was perpendicular to the axis of the pipe and checking with the pocket level to be sure the micrometer was horizontally level. This procedure usually required several trials to find the diameter that was measured and recorded. These points were not marked on the pipe. The measurements are probably not the true vertical and horizontal diameter, but are the largest dimensions, vertically and horizontally, perpendicular to the pipe axis.

The term "deflection" refers to a decrease in the vertical diameter and an increase in the horizontal diameter caused by the backfill load over the pipe and subsequent live loads. Because the exact diameter of the pipe in the trench after compacting the soil at the sides is not known, the true deflection cannot be measured. An estimate can be made by assuming the pipe was a perfect circle with the pipe diameter equal to the average of the 1989 diameter measurements. Calculation of the average diameter is shown in table 4. The deflection can be calculated as follows:

$$\%\ \text{deflection} = \frac{(\text{average diameter} - \text{vertical diameter}) \times 100}{27 \text{ inches (nominal diameter)}}$$

Midspan Pipe Deflection

The midspan pipe diameter measurements and calculated deflections are shown in table B.1 in appendix B and summarized in table 4. RPM pipe is tapered to facilitate removal from the mandrel so one end has a larger diameter than the other end. However, the diameters in the center (midspan) of each pipe section should be about equal. The mean of the average diameter at the midspan was 27.101 inches, and was about ±0.050 inch for all the readings. If the pipe diameter is assumed to be exactly the same for each pipe section, then the ±0.050-inch figure can be regarded as the accuracy of the deflection, or about ±0.2 percent. The mean pipe deflection was 3.5 percent and had a range of 2.6 to 4.1 percent.

Comparison with Theoretical Values

An installation of RPM pipe should be designed and constructed so that the vertical deflection of the pipe is 5 percent or less. With actual deflections computed to be about 3 to 4 percent, this installation met the criteria for deflection.

Using the Iowa Formula to calculate the predicted vertical deflection results in an average value of 3.2 percent and a range of ±1.0 percent, or 2.2 to 4.2 percent (Howard, 1977a). This result compares well with the actual values of 3.5 percent average and a range from 2.6 to 4.1 percent. To calculate the predicted deflection, the following values were used: E' of 400 lbf/in^2, T_f of 2.5 (Howard, 1977a), backfill density of 100 lbm/ft^3, h of 5 feet, and an EI/r^3 of 3 lbf/in^2 (Howard and Metzger, 1973).

Deflection of Pipe Joint

As shown in table 5, pipe diameter measurements were made at pipe joint 10/11. Midspan diameter measurements were made in pipe 10 and in pipe 11 and at the spigot end of pipe 10 and at the bell end of pipe 11.

Table 4. - Midspan diameter measurements - RPM pipe inspection - Haights Creek Irrigation Company, September 25-26, 1989.

Pipe No.	Vertical diameter (inches)	Horizontal diameter (inches)	Average diameter (inches)	Deflection	
				(inches)	(%)
2	25.974	28.131	27.053	1.079	4.0
4	25.970	28.198	27.084	1.114	4.1
7	26.269	27.880	27.075	0.806	3.0
10	26.044	28.216	27.130	1.086	4.0
11	26.167	28.072	27.120	0.953	3.5
18	26.475	27.855	27.165	0.690	2.6
26	26.187	28.003	27.095	0.980	3.4
29	26.124	28.090	27.107	0.983	3.6
30	26.307	27.854	27.081	0.774	2.9
		Minimum	27.053		2.6
		Maximum	27.165		4.1
		Mean	27.101		3.5

Table 5. - Pipe deflection at joint 10/11 - RPM pipe inspection - Haights Creek Irrigation Company, September 25-26, 1989.

Pipe No. and location	Vertical diameter (inches)	Horizontal diameter (inches)	Average diameter (inches)	Deflection	
				(inches)	(%)
10 - midspan	26.044	28.216	27.130	1.086	4.0
10 - spigot end	26.781	27.230	27.006	0.225	0.8
11 - bell end	26.911	27.588	27.250	0.339	1.3
11 - midspan	26.167	28.072	27.120	0.953	3.5

The bell end of the pipe deflected more than the spigot end. As shown in table 6, the magnitude of the joint deflections and the ratio between bell and spigot deflections were about the same as those measured on other RPM pipe projects (Howard, 1977b; Howard and Metzger, 1973).

Table 6. - Comparison of selected RPM pipe installations.

	Pipe diameter, inches	Internal pressure rating, lbf/in^2	Depth of cover, feet	Vertical deflection		Ratio of bell deflection to spigot deflection
				Bell (%)	Spigot (%)	
Haights Creek	27	90 to 130	5	1.3	0.8	1.6
Lower Yellowstone[1]	39	Not known	3 to 5	1.0	0.8	1.3
Apache Lateral[2] Yuma Project	30	100	4	1.2	0.7	1.7

[1] Howard, 1977b.

[2] Howard and Metzger, 1973.

The barrels of the adjacent pipe (measured at midspan) deflected three to four times more than the joint. Table 7 shows the relative joint and barrel deflection of Haights Creek pipe compared to other RPM pipe installations (Howard, 1977b; Howard and Metzger, 1973). These comparisons show that the deflections of the bell, spigot, and barrel of the Haights Creek pipe are similar to other installations.

Table 7. - Comparison of selected RPM pipe installation.

	Vertical deflection - %		
	Bell	Spigot	Barrel
Haights Creek	1.3	0.8	3.5
Lower Yellowstone[1]	1.0	0.8	1.3
Apache Lateral[2] Yuma Project	1.2	0.7	2.5

[1] Howard, 1977b.
[2] Howard and Metzger, 1973.

Because the pipe vertical deflection is within allowable limits and there is nothing unusual about the deflection of the joints, the local deformation caused by mounds and other hard spots beneath the pipe appears to be the reason for the longitudinal invert cracks.

SUMMARY

Following several failures, the Haights Creek Irrigation Company in Kaysville, Utah, replaced 730 linear feet of 24- and 27-inch-diameter RPM pipe. The pipe was installed in 1972 and transported irrigation water. Before the pipe was removed, Reclamation personnel did a crawl-through inspection. Then several pipe sections were carefully excavated to allow a thorough examination of the pipe embedment. The results of these investigations are summarized as follows:

1. Out of 27 (quantity) 20-foot pipe sections from the original installation, 16 sections had "minor" cracks and 3 sections had "major" cracks. A "major" crack is used to describe apparent delamination between the liner of the pipe and the remainder of the pipe wall.

2. The cracks were in the pipe interior and no observable signs of a companion crack or marks of distress were present on the exterior of the pipe.

3. Based on pipe diameter measurements, the vertical deflection of the barrel of the pipe ranged from 3 to 4 percent, within the design limits (5 percent) for the pipe.

4. The vertical deflection of the pipe joints was about 1 percent, which is comparable with other field data for RPM pipe with joints of similar stiffness.

5. In the three pipe sections with major cracks, the cracks were in the invert on the bell end of the pipe. The pipe was resting on a 4- by 4-inch timber at one crack site. At the other crack sites, evidence was found of a soil mound placed to bring the pipe to grade.

6. Timber or soil mounds under RPM pipe create hard spots and the pipe tends to flatten or even show reverse curvature at these locations. High tensile strains can produce cracks on the interior of the pipe.

7. Several other "flat" areas were observed in the invert of the pipe, all exhibiting longitudinal cracks.

8. The soil densities, vertical pipe deflections, and visual observations do not indicate any unusual installation circumstances.

9. Except for the mounding and the 4- by 4-inch timber, the pipe appears to have been installed using acceptable construction techniques.

BIBLIOGRAPHY

Bureau of Reclamation, *Earth Manual*, 2d Ed., U.S. Government Printing Office, Washington, D.C., 1974.

Howard, A. K. and Metzger, H. G., "RPM Pipe Deflections on Yuma Project Field Test," Report No. REC-ERC-73-7, Bureau of Reclamation, Denver, Colorado, April 1973.

Howard, A. K., "Modulus of Soil Reaction Values for Buried Flexible Pipe," *Journal of the Geotechnical Engineering Division*, ASCE, vol. 103, No. GT1, Proc. Paper 12700, January 1977a.

Howard, A. K., "Flexible Pipe Deflections at Santa Ana River Siphon, California; Sidney, Mont; and Carrington, N. Dak." Report No. GR-3-77, Bureau of Reclamation, Denver, Colorado, May 1977b.

Howard, A. K., "Diametral Elongation of Buried Flexible Pipe," Proceedings of the International Conference on Underground Plastic Pipe, ASCE, New Orleans, Louisiana, March 1981a.

Howard, A. K., "The USBR Equation for Predicting Flexible Pipe Deflection," Proceedings of the International Conference on Underground Plastic Pipe, ASCE, New Orleans, Louisiana, March 1981b.

Spangler, M. G., "The Structural Design of Flexible Pipe Culverts," Iowa Engineering Experiment Station Bulletin No. 153, Ames, Iowa, 1941.

Swihart, J. J., "Inspection of Reinforced Plastic Mortar RPM Pipe - Haights Creek Irrigation Company - Kaysville, Utah (Geosynthetics)," Travel Report, Bureau of Reclamation, November 20, 1989.

Swihart, J. J. and Howard, A. K., "Inspection of Reinforced Plastic Mortar (RPM) Pipe - Haights Creek Irrigation Company - Kaysville, Utah (SRPA)," Travel Report, Bureau of Reclamation, October 13, 1989.

Watkins, R. K. and M. G. Spangler, "Some Characteristics of the Modulus of Passive Resistance of Soil: A Study of Similitude," Highway Research Board Proceedings, vol. 37, Washington, D.C., pp. 576-583, 1958.

APPENDIX A

HISTORY OF RPM PIPE USAGE

The RPM pipe was installed by the Haights Creek Irrigation Company under the SRPA (Small Reclamation Projects Act) Program.

The specifications were based on Reclamation Standard Specifications for RPM pipe and were developed by the designer and consultant for the project, Mr. Trevor Hughes, a professor at Utah State University in Logan, Utah. The project was constructed in 1972 and began operating during the summer of 1973. The contractor was Hartwell Construction Company of Idaho Falls, Idaho. The RPM Techite pipe used on this project was manufactured by United Technology Corporation of Riverside, California. The pipe diameters ranged from 18 to 27 inches over a length of about 15,000 feet. The system is gravity fed from a reservoir and does not use any pumps. The reservoir elevation remains relatively constant. The system is drained in the winter.

Only a few pipe failures occurred prior to 1987. In 1987, three failures occurred, and in 1988, seven failures occurred. Repairs were made using Ershing long-bell pipe repair kits.

Reclamation representatives visited the project in November 1988 to discuss the pipe failures because the irrigation company had became concerned about the increasing number of failures (Kinney et al., 1988). In mid-1989, the irrigation company decided to replace a 730-linear-foot section of 24- and 27-inch RPM pipe with 24-inch ductile iron pipe. Several failures had occurred in this section of pipe, which is in close proximity to private homes. In some cases, the pipeline alignment went through the yards of some houses. At the time of the pipe replacement, new houses were being constructed in this area close to the pipeline.

Before the removal of the RPM pipe in this section, Reclamation representatives made a crawl-through inspection and participated in a very careful exhumation of some of the pipes (Swihart and Howard, 1989). Once all the pipe was removed and the interiors cleaned, a follow-up inspection by a Reclamation representative was made to more carefully map cracks found in the pipes (Swihart, 1989). Many cracks were not discovered until the interior had been carefully cleaned.

BIBLIOGRAPHY

Kinney, Leo; Walters, Phil; and Samuel, Will, "Field Review of Techite Pipe Problems on Haights Creek Irrigation Company Project, Utah (SRPA)," Travel Report, Bureau of Reclamation, November 4, 1988.

Swihart, J. J., "Inspection of Reinforced Plastic Mortar RPM Pipe - Haights Creek Irrigation Company - Kaysville, Utah (Geosynthetics)," Travel Report, Bureau of Reclamation, November 20, 1989.

Swihart, J. J. and Howard, A. K., "Inspection of Reinforced Plastic Mortar (RPM) Pipe - Haights Creek Irrigation Company - Kaysville, Utah (SRPA)," Travel Report, Bureau of Reclamation, October 13, 1989.

APPENDIX B

OBSERVATIONS OF RPM PIPE CONDITION FROM CRAWL-THROUGH INSPECTION SEPTEMBER 1989

Table B-1
Notes on RPM Pipe Inspection
Station 45+10 to 51+30
Haight's Creek Irrigation Company
September 25-26, 1989

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
1	20	45 + 10	None detected	Entry section, portion cut out of top * 2 ft from spigot are numerous 1" longitudinal hairline cracks from 4 to 6 o'clock	

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
2	20	45 + 30	Interior: 527091 - A11 4-13-2 Exterior: 27 in RPM 225 Hydrotested 200 lb/in^2	Flaking of cosmetic repair on spigot end * 1 circumferential cracks 2 @ 10 - 11 o'clock - 94" from bell 7 @ 9 - 3 o'clock - 120" from bell 3 @ 8 - 11 o'clock - 132" from bell 1 @ 10 - 11 o'clock - 160" from bell 6 @ 10 - 1 o'clock - 180" from bell 2 @ 11 o'clock - 208" from bell ** *Spigot cracked from exhumation*	Midspan diameter measurements: Vertical = 25.974 Horizontal = 28.131 @ 12-5/8 above invert 4.0% deflection
3	20	45 + 50	Interior: 527091 - A11 3-29-2 Exterior: 27 in RPM 225 Hydrotested 200 lb/in^2	2 ft from bell - five 1/2" longitudinal invert cracks *14 ft from bell - 1/2" star crack with 1" dia. blister at 1 o'clock*	

*Data in boxes from 10-16/17-89 inspection of pipe after cleaning.

**Data in italics in dashed boxes - damaged during exhumation of pipe.

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
4	20	45 + 70	Interior: 2-9-73-2 Exterior: 27 in RPM 300 IRR Hydrotested 293 lb/in^2	* 19-1/2 from bell - 2" hairline longitudinal invert crack - not raised, visible only when wet ** *Spigot broken at crown during excavation*	Midspan diameter measurements: Vertical = 25.970 Horizontal = 28.198 @ 12-5/8 above invert 4.1% deflection
5	20	45 + 90	Interior: 527091 - A11 3-31-3 Exterior: 27 in RPM 225 Hydrotested 200 lb/in^2	Joint 5/6 lower than invert of barrels of pipes 6 and 5. Standing water extends 12 inches into pipe 5 and extends 24 inches into pipe 6. 15 ft from bell - 1/2" hairline circumferential invert crack - tiny liner separation at spigot - cannot tell age *New chip on bell step*	

*Data in boxes from 10-16/17-89 inspection of pipe after cleaning.

**Data in italics in dashed boxes - damaged during exhumation of pipe.

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
6	20	46 + 10	Interior: 527091 - A11 6-24-1 Exterior: 27 in RPM 225 Hydrotested 200 lb/in^2	* Axial tape overlap (black lines) highly visible in interior	
7	20	46 + 30	Interior: 2-10-72-1 Design No. 227131-A11 Serial No. 13254 Exterior: 27 in RPM 300 IRR Hydrotested 293 lb/in^2		Midspan diameter measurements: Vertical = 26.269 Horizontal = 27.880 @ 12-7/8 above invert 3.0% deflection
8	20	46 + 50	Interior: 13422 227131 - A11 2-11-72-1 Exterior: 27 in RPM 300 IRR Hydrotested 293 lb/in^2	Joint 8/9 is lower than invert of barrels of pipes 8 and 9, standing water ** *Cracked spigot at crown 9 ft from bell - backhoe damage* *4" dia. bulge with 4" circumferential tear*	

*Data in boxes from 10-16/17-89 inspection of pipe after cleaning.

**Data in italics in dashed boxes - damaged during exhumation of pipe.

Table B-1
Sheet 5 of 15

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
9	20	46 + 70	Interior: 227131 - A11 013325 2-10-72-2 Exterior: 27 in RPM 300 IRR Hydrotested 293 lb/in^2	Flat spot on invert 13 ft from bell w/numerous very fine hairline longitudinal cracks in invert Joint 9/10 is lower than invert of barrels of pipes 9 and 10, 1" water standing @ joint extends 2 ft into pipe 9 and extends 4 ft into pipe 10 ** *Freshly chipped bell step - top 60°*	Diameter measurements at flat spot: Vertical = 26.034 Horizontal = 28.057
10	20	46 + 90	Interior: Design No. 227131 - A11 Serial No. 13 Exterior: 27 in RPM 300 IRR Hydrotested 293 lb/in^2	Joint 10/11 is lower than invert of barrels of pipes 10 and 11, standing water	Midspan diameter measurements: Vertical = 26.044 Horizontal = 28.216 @ 12-11/16 above invert 4.0% deflection Spigot diameter measurements: Vertical = 26.781 Horizontal = 27.230 @ 13-7/16 above invert 0.8% deflection

**Data in italics in dashed boxes - damaged during exhumation of pipe.

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
11	20	47 + 10	Interior: 2-11-72-1 227131 - A11 013410	* $\boxed{\text{19-1/2 ft from bell - 3 to 7 o'clock - numerous small (1/2" - 2") hairline longitudinal cracks}}$	Bell diameter measurements: Vertical = 26.911 Horizontal = 27.588 @ 13-3/8 above invert 1.3% deflection Midspan diameter measurements: Vertical = 26.167 Horizontal = 28.072 @ 12-13/16 above invert 3.5% deflection
12	10	47 + 30		Long bell section of "long-bell repair kit"	
13	10	47 + 40		Spigot section of "long-bell repair kit"	
14	10	47 + 50		Long-bell section of "long-bell repair kit"	
15	10	47 + 60		Spigot section of "long-bell repair kit"	
16	10	47 + 70		Long-bell section of "long-bell repair kit"	
17	10	47 + 80		Spigot section of "long-bell repair kit"	

*Data in boxes from 10-16/17-89 inspection of pipe after cleaning.

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
18	20	47 + 90	Interior: 227131 - A11 13419 2-11-72-1 Exterior: 27 in RPM 300 IRR Hydrotested 293 lb/in^2 * **	Low spots with standing water at about 22 and 25' from bell end (flat spot in between ?). Joint 18/19 is lower than invert of barrels of pipes 18 and 19. Standing water. 17 ft from bell - numerous tiny hairline longitudinal invert cracks *10 ft from bell - several 2 to 3" circumferential cracks in crown*	Midspan diameter measurements: Vertical = 26.475 Horizontal = 27.855 @ 13-1/4 above invert 2.6% deflection

*Data in boxes from 10-16/17-89 inspection of pipe after cleaning.

**Data in italics in dashed boxes - damaged during exhumation of pipe.

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
19	20	48+ 10	Interior: 227131 - A11 13251 2-10-72-1 Exterior: 27 in RPM 300 IRR Hydrotested 293 lb/in^2	Flat spot in pipe invert 26" from bell, numerous hairline longitudinal cracks covering an area about 2 by 6". Biggest crack in center of area and is 1-1/2" long. Flat spot in pipe invert 199 to 202" from bell numerous tiny hairline longitudinal cracks in flat spot. Joint 19/20 is lower than invert of barrels of pipes 19 and 20, standing water.	
20	20	48 + 30	Interior: 227131 - A11 013417 2-11-72-2 Exterior: 27 in RPM 300 IRR Hydrotested 293 lb/in^2	Entry section, portion cut out of of pipe Flat spot in pipe invert Several small hairline longitudinal cracks 58" from bell	
21	20	48 + 50	Interior: 227131 - A11 13479 2-11-72-2 Exterior: 27 in RPM 300 IRR Hydrotested 293 lb/in^2	Joint 21/22 is lower than invert of barrels of pipes 21 and 22, standing water * 19-1/2 ft from bell - 1/2" hairline longitudinal invert crack - not raised	

*Data in boxes from 10-16/17-89 inspection of pipe after cleaning.

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
22	20	48 + 70	Interior: 2-10-72-2 227131 - A11 013319 Exterior: 27 in RPM IRR Hydrotested 293 lb/in^2	Flat spot in pipe invert 69" from bell, two 1/2" long longitudinal hairline invert cracks 1/2" hairline longitudinal invert crack at 81" from bell 1/2" hairline longitudinal invert crack at 94" from bell Joint 22/23 is lower than invert of barrels of pipes 22 and 23, standing water 18" into pipe 22 and pipe 23 * Some glass disbonding on bell exterior	
23	20	48 + 90	Interior: Date/shift 2-11-72-1 Design No. 227131 - A11 Serial No. 013425 Exterior: 27 in RPM 300 IRR Hydrotested 293 lb/in^2	2" longitudinal crack in invert 22" from bell, oozes water, sounds hollow when tapped 2-1/2" longitudinal crack in invert 26" from bell, oozes water, sounds hollow when tapped Numerous small hairline longitudinal cracks at 88" from bell	

*Data in boxes 10-16/17-89 inspection of pipr after cleaning.

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
24	20	49 + 10	Interior: Design No: 227131 - A11 Serial No. 13329 2-10-72-2 Exterior: 27 in RPM 300 IRR Hydrotested 293 lb/in^2	Joint 24/25 is lower than invert of barrels of pipes 24 and 25, standing water	

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
25	20	49 + 30	Interior: 9-22-71-2 lot 1 (stencil) 227090 - A11 Exterior: 27" RPM 225 Hydrotested 200 lb/in^2	3" raised longitudinal invert crack beginning @ 20" from bell 6-1/2" raised longitudinal invert crack beginning @ 22-1/2" from bell, water comes out of crack when pushed on These two cracks range from 3/4 to 1-1/4" apart The 6-1/2" long crack is most severe crack found Distance from crown of pipe to crack which is 1-1/2" off invert = 25.890 * $\boxed{\text{12 ft from bell - three raised circumferential bumps - no cracks - @ 1 o'clock}}$ $\boxed{\text{16 ft from bell - two 1" hairline longitudinal invert cracks}}$	Diameter measurements at crack: Vertical = 26.127 Horizontal = 28.088 @ 12-1/2" above invert 3.6% deflection

*Data in boxes from 10-16/17-89 inspection of pipe after cleaning.

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
26	20	49 + 50	Interior: 527091 - A11 6-24-1 Exterior: 27 in RPM 225 Hydrotested 200 lb/in^2	Numerous circumferential cracks in invert and some longitudinal cracks	Midspan diameter measurements: Vertical = 26.187 Horizontal = 28.003 @ 12-5/8" above invert 3.4% deflection
27	20	49 + 70	Interior: 227090 - A11 9-23-71-2 Type 1 lot 1 27 RPM 225 UTC Exterior: 27 in RPM 225 Hydrotested 200 lb/in^2	Standing water at joint 27/28	
28	20	49 + 90	Interior: 227090 - A11 9-22-71-1 27 RPM 225 UTC **	Small raised circumferential crack in invert at 16 ft from bell end Standing water at joint 28/29 *4 ft from bell - external impact damage at crown*	

**Data in italics in dashed boxes - damaged during exhumation of pipe.

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
29	20	50 + 10	Interior: 227080 - B11 225297 9-18-72-2	2-1/2" raised longitudinal crack in invert 5'1" from bell end * [8' from bell - 2" raised longitudinal invert crack 9 1/2 from bell - 1" hairline longitudinal invert crack] ** *Fresh crack on bell step* Standing water at joint 29/30	Midspan diameter measurements: Vertical = 26.124 Horizontal = 28.090 @ 12-7/8" above invert 3.6% deflection
30	20	50 + 30	Interior: 9-23-71-2 227090 - A11 Exterior: 27 in RPM 225 Hydrotested 200 lb/in^2	Flat spot on invert about 16 ft from bell end with 1-1/2" long longitudinal crack in center [2-1/2 ft from bell - 1/2" hairline longitudinal crack in invert] *backhoe damage* *- 16-1/2 ft from bell 1 ft x 1 ft at crown* *- 11 ft from bell 1 ft x 6" @ crown*	Midspan diameter measurements: Vertical = 26.307 Horizontal = 27.854 @ 13-1/16" above invert 2.9% deflection

*Data in boxes from 10-16/17-89 inspection of pipe after cleaning.

**Data in italics in dashed boxes = damaged during exhumation of pipe.

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
31	10	50 + 50	Interior: 5/10/73 1st	Long bell section of "long-bell repair kit" UTC (closure section?) * 4' from bell - numerous parallel circumferential crown cracks - 2 to 3" long spigot - 3" dia. delamination of linear - appears old	
32	10	50 + 60	Interior: S.N. 293339 D.N. 327207-C31 Exterior: 27 in PRESS 200 Hydrotested 450 lb/in^2	Spigot section of "long-bell repair kit" UTC Numerous tiny hairline invert longitudinal cracks in a 2" diameter area 9 ft from bell end Standing water at joint 32/33 ** *2-1/2 ft from bell - fresh 2" dia. bulge at 4 to 5 o'clock with 1" circumferential crack*	
33	20	50 + 70	Interior: 227090 - A11 9-22-71-2 lot 1 Type I UTC 27 RPM 225	3-inch service outlet at springline north side of pipe at about midspan. Had steel band around exterior of pipe. Standing water at joint 33/34	

*Data in boxes from 10-16/17-89 inspection of pipe after cleaning.

**Data in italics in dashed boxes - damaged during exhumation of pipe.

Pipe No.	Length (feet)	Beginning station of pipe (moving downstream)	Pipe markings	Comments (bell is upstream end of pipe)	Diameter measurements (inches)
34	20	50 + 90	Interior: Design No. 227080-B11 Serial No. 25300 Date/Shift 8-18-72-2 Exterior: 27 in RPM 200 Type I * Hydrotested 185 lb/in^2	3" raised longitudinal crack in invert with 1" circumferential crack in center, 2" north of invert (between 5 and 6 o'clock looking downstream) and 198" from bell end. 6' from bell - 11 o'clock 1/2" dia. star crack No external damage Standing water at joint 34/35	
35	20	51 + 10	Interior: 227080 - B11 225295 9-18-72-2 **	Entry section, portion cut out of pipe crown *14 ft from spigot, backhoe damage at 2 to 3 o'clock*	
36		51 + 30		Transition section 27 to 24"	
37				24" RPM, not inspected	

Total length inspected = 620 feet

*Data in boxes from 10-16/17-89 inspection of pipe after cleaning.

**Data in italics in dashed boxes - damaged during exhumation of pipe.

APPENDIX C

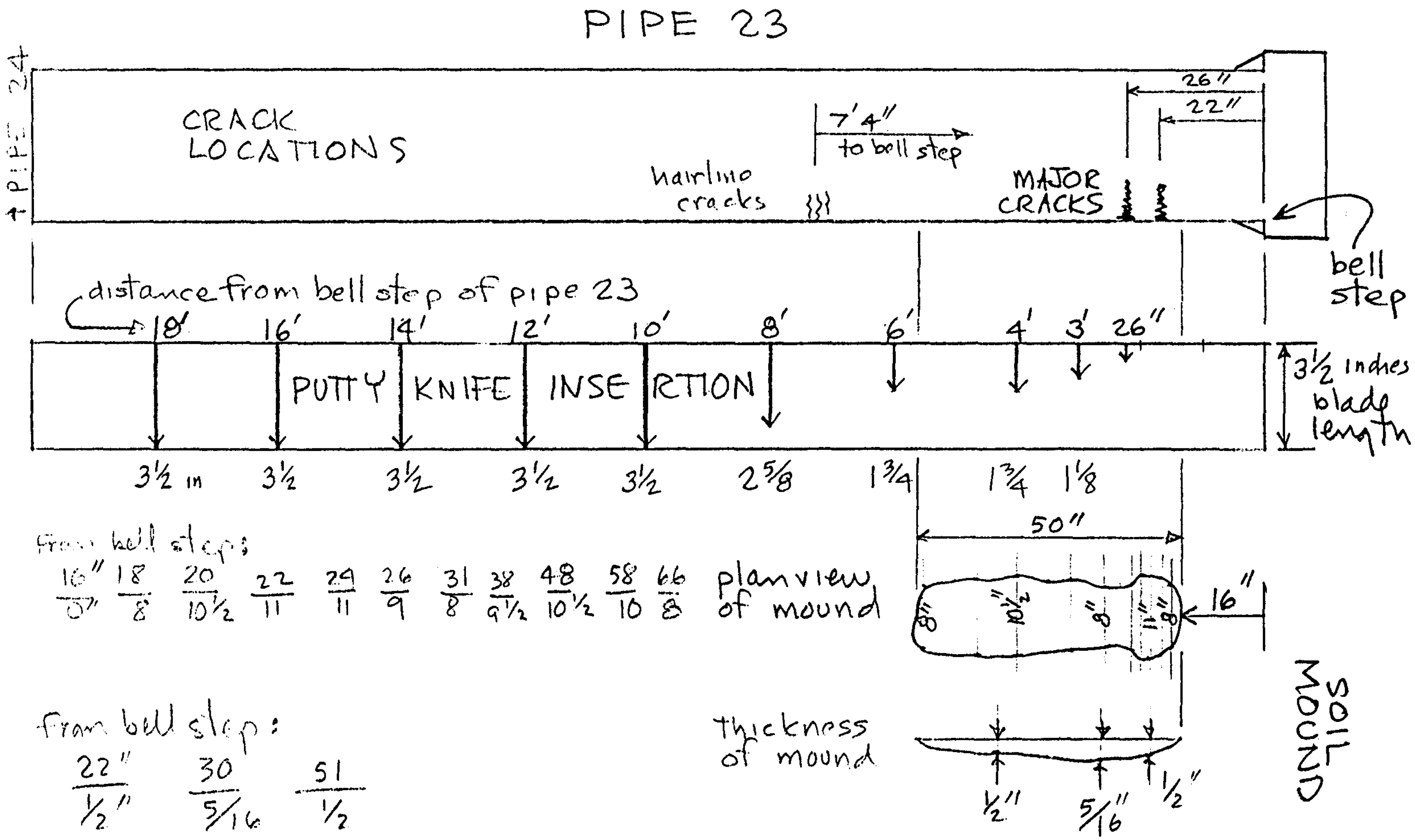
FIELD NOTES OF OBSERVATIONS ON SOIL FOUNDATION BENEATH RPM PIPE SEPTEMBER 1989

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT HAIGHTS CREEK	SHEET ___ OF ___
CHKD BY	DATE	FEATURE RPM PIPE INSPECTION	
DETAILS PIPE 23			

PIPE 23



from bell step:

16"	18	20	22	29	26	31	38	48	58	66
5"	8'	10½	11	11	9	8	9½	10½	10	8

from bell step:

22"	30	51
½"	5/16	½

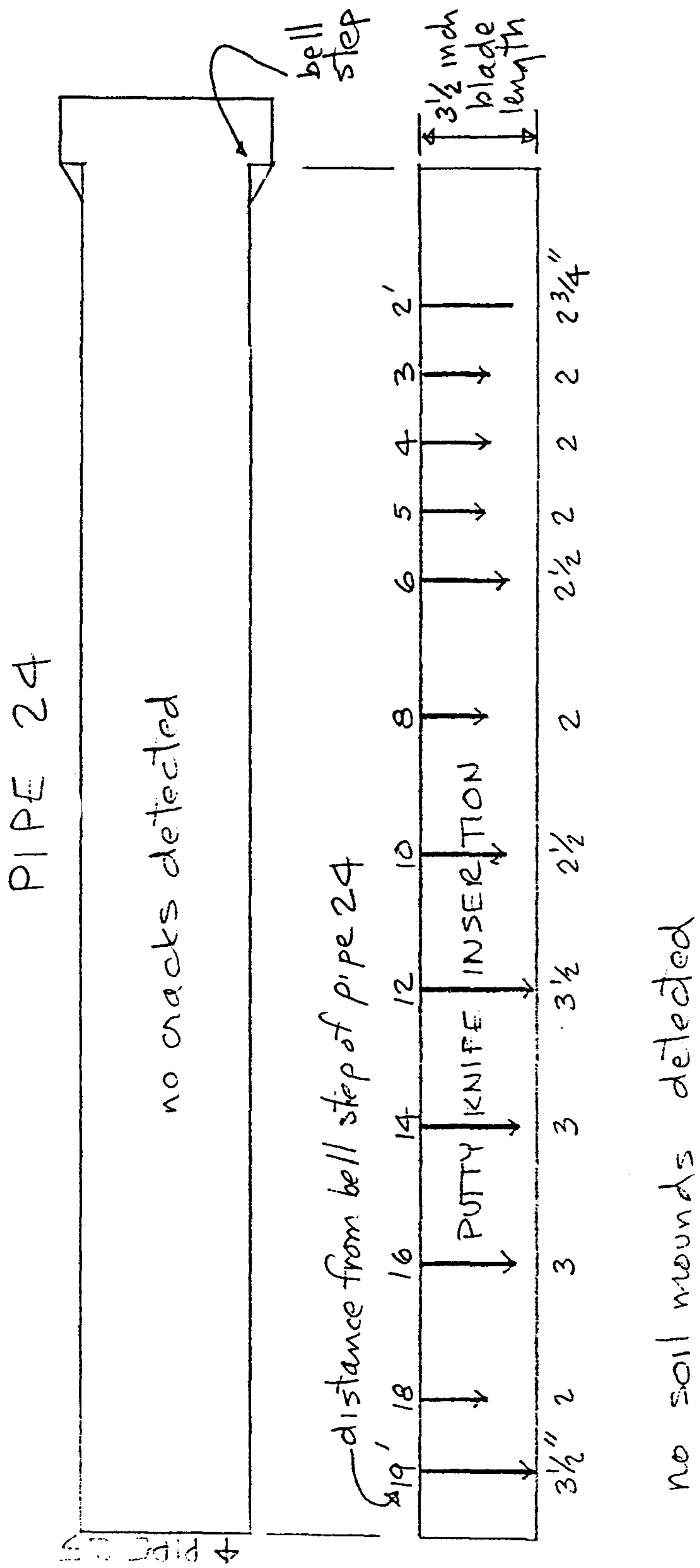
crack at 22" from bell step is 2" long, longitudinal in invert
oozes water when pushed, sounds soft

crack at 26" from bell step is 2½" long, longitudinal in invert
oozes water when pushed, sounds soft

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT HAIGHTS CREEK	SHEET ____ OF ____
CHKD BY	DATE	FEATURE RPM PIPE INSPECTION	
DETAILS	PIPE 24		

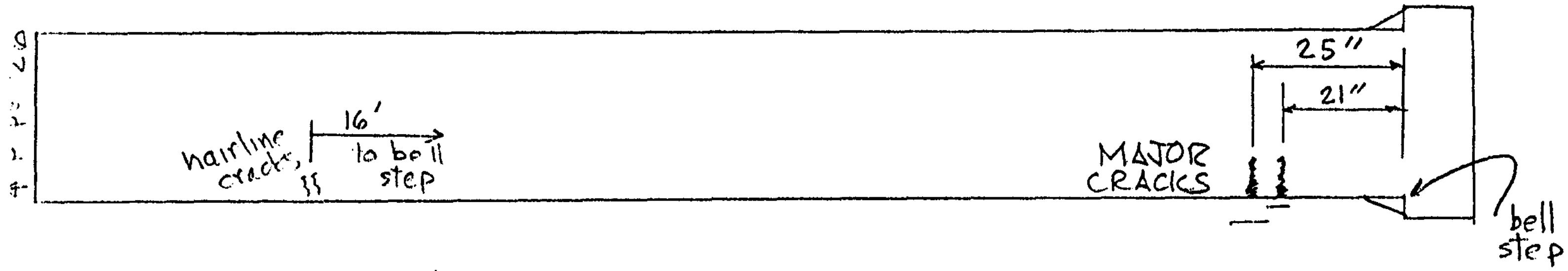


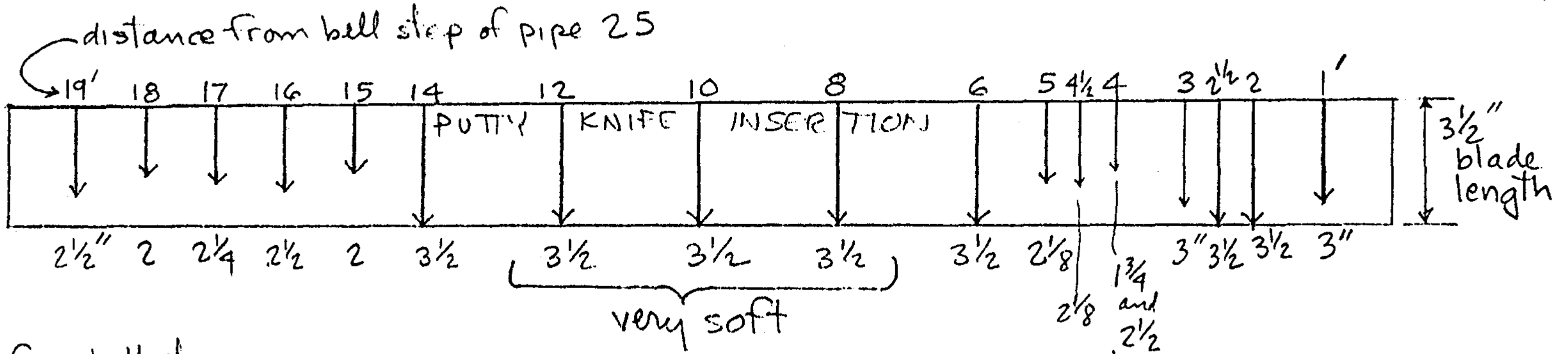
7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT HAIGHTS CREEK	SHEET ___ OF ___
CHKD BY	DATE	FEATURE EPM PIPE INSPECTION	
DETAILS	PIPE 25		

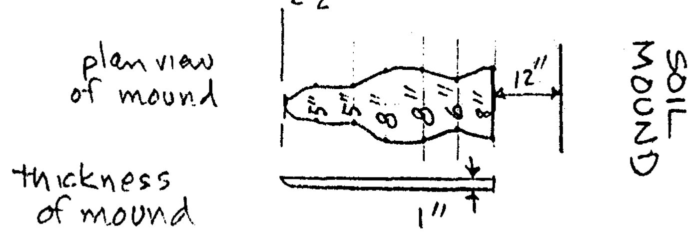
PIPE 25





from bell step:

$\frac{1'}{8''}$ $\frac{1\frac{1}{2}'}{6}$ $\frac{2'}{8}$ $\frac{2\frac{1}{2}}{8}$ $\frac{3}{5}$ $\frac{3\frac{1}{2}'}{5''}$ $\frac{16'}{0}$



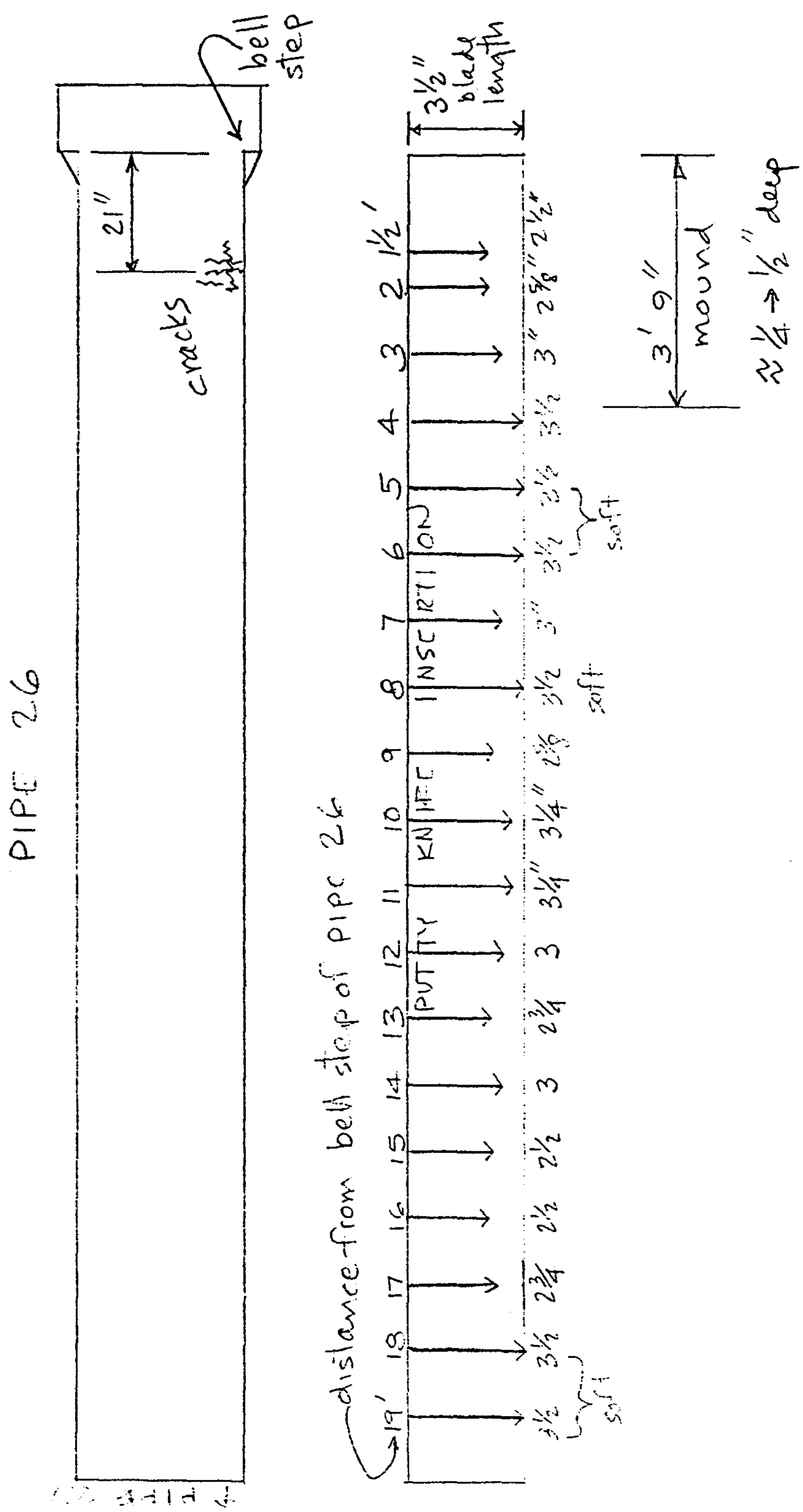
longitudinal invert crack is 3" long, from 20" to 23" from bell step

longitudinal invert crack is 6½" long, from 22½" to 29" from bell step
oozes water when pushed

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT HAIGHTS CREEK	SHEET ___ OF ___
CHKD BY	DATE	FEATURE RPM PIPE INSPECTION	
DETAILS		PIPE 26	



Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public.