# Evaluation of Metal Drainage Pipe Durability After Ten Years

WILLIAM H. TEMPLE AND STEVEN L. CUMBAA

**This study represents an investigation of the comparative performance of coated and uncoated, corrugated, galvanized steel and aluminum drainage pipe in Louisiana. The highly corrosive environments in some areas of the state make durability requirements of metal pipe as critical as strength requirements. Department personnel installed 10 types of metal drainage pipes at each of 10 locations in 1973. The test sites were selected on the basis of the pH and the electrical resistivity of the soil and the effluent. One pair of each type of culvert was installed at each site. Every 2 years one designated culvert of each of the pairs was removed and subjectively rated by a panel. The final (10-year) panel ratings reflect the condition of the undisturbed culverts in each pair. It was found that, in general, the 16-gauge asphalt-coated aluminum; the 14-gauge asbestos-bonded, asphalt-coated galvanized steel; and the 16-gauge galvanized steel with a 12-mil interior and a 5-mil exterior polyethylene coating were the test pipes with the most resistance to corrosion at the majority of the test sites. It was also found that, although all of the coatings provided added resistance to corrosion to some degree, the thicker coatings tested provided increased protection to the base metal. Comparisons of actual versus predicted years to perforation are made for galvanized steel in the harsher environments where test culverts actually experienced perforation.**

The state of Louisiana annually receives approximately 60 in. of rainfall. The Louisiana Department of Transportation and Development (DOTD) road design engineer assigns a cross-slope and texture to the highways to rid them of this deluge of water. Drainage pipe is often used to remove the ensuing runoff from the highway right-of-way.

The hydraulics engineer can generally choose either reinforced concrete pipe or corrugated metal pipe in his designs. Concrete pipe is durable and with stable bedding conditions can normally serve effectively for the life of a highway.

The department also recognizes that metal pipe has its place in the field of hydraulics and maintains an interest in innovations in metal pipe. Metal pipe is relatively lightweight, an advantage that gains significance as the size of pipe increases. Metal pipe is relatively flexible, an advantage that could preclude failure under certain heavy loads. The major drawback with metal pipe is its tendency to corrode in the presence of moisture, oxygen, and salt. Additional information is needed on the rates at which galvanized steel and aluminum (with the various types of coatings recently introduced) will corrode.

In 1972 Louisiana found itself with a continuing need for drainage, a diverse set of environments, and a wide array of remedies offered by the metal culvert industry. The state responded with a major 10-year field study to determine the ability of available aluminum and galvanized steel culverts to resist corrosion while serving in moderate, acidic, and low-resistivity environments. A limited laboratory study parallels the field evaluations.

Research and Development Section, Louisiana Department of Transportation and Development, P.O. Box 94245, Capitol Station, Baton Rouge, La. 70804.

## PROCEDURE

### Site Selection

Research engineers selected 10 locations across the state as test sites to be representative of the seven general soil classifications found within Louisiana. The sites were expected to represent soil conditions normally encountered across the state as follows:

| | *Minimum Soil Resistivity (ohm-cm)* | |
|---|---|---|
| *Soil pH* | *Less than 2000* | *Greater than 2000* |
| 5.0–6.0 | Site 1 | Sites 4 and 8 |
| 7.0–8.0 | Sites 2 and 3 | Site 5 |
| 8.0–9.0 | Sites 6, 7, 9, and 10 | |

Table 1 gives the actual characteristics of the soil and effluent at the test sites. Figure 1 is a map showing the locations of the test sites. Sites 6 and 7 are ditch and canal installations, respectively, located on opposite sides of the highway at that location. The pipes at Site 6 were accidentally destroyed during a utility relocation and were not available for the final evaluation. An 11th site representing a pH of less than 5.0 was added later, in 1977.

### Materials Tested

Originally there were 10 varieties of coated and uncoated galvanized steel and aluminum culverts to be evaluated. During the course of the study several other types of pipes were installed at different times and locations. The types of pipes according to total field exposure time are as follows:

*Ten Years of Field Exposure, Sites 1 Through 10*

1. Uncoated, 16-gauge galvanized steel
2. Asphalt-coated, 16-gauge galvanized steel
3. Asbestos-bonded, asphalt-coated, 14-gauge galvanized steel
4. Uncoated, 16-gauge aluminum pipe, Alclad 3004
5. Asphalt-coated, 16-gauge aluminum pipe, Alclad 3004
6. 5052 structural aluminum plate arch
7. Sixteen-gauge galvanized steel with a 12-mil, coal-tar-based laminate applied to the interior and 0.3-mil modified epoxy coating on the reverse side
8. Sixteen-gauge galvanized steel with a 20-mil, coal-tar-based laminate applied to interior or exterior with a 0.3-mil, modified epoxy coating on the reverse side
9. Sixteen-gauge galvanized steel with a 10-mil interior and 3-mil exterior polyethylene coating
10. Sixteen-gauge galvanized steel with a 12-mil interior and a 5-mil exterior polyethylene coating

TABLE 1 pH AND ELECTRICAL RESISTIVITY

| Site No. | Location | Soil Type | Soil Resistivity (ohm-cm) | Soil pH | Effluent Resistivity (ohm-cm) | Effluent pH |
|---|---|---|---|---|---|---|
| 1 | New Roads | Clay | 1 023 | 6.5 | 9 500 | 6.7 |
| 2 | Breaux Bridge | Silty clay | 881 | 7.6 | 5 175 | 7.3 |
| 3 | Kaplan | Silty clay | 1 593 | 6.7 | 5 200 | 5.8 |
| 4 | Simpson | Silty clay | 11 169 | 5.5 | 18 333 | 6.2 |
| 5 | Winnfield | Sand | 3 720 | 6.7 | 3 375 | 6.9 |
| 6 | Hackberry | Sandy clay | 292 | 8.2 | 107 | 7.0 |
| 7 | Hackberry | Sandy silt | 281 | 8.0 | 123 | 7.0 |
| 8 | Starks | Silty clay | 3 786 | 5.7 | 15 833 | 6.7 |
| 9 | Grand Isle | Sand | 365 | 8.4 | 300 | 7.7 |
| 10 | Leeville | Silty clay | 219 | 7.9 | 121 | 7.2 |
| 11 | Kisatchie | Sandy loam | 2 083 | 4.9 | 4 400 | 7.4 |

*Eight Years of Field Exposure, Sites 1 Through 10*

11. Sixteen-gauge galvanized steel pipe with 10-mil interior and 3-mil exterior polymeric coating

*Six Years of Field Exposure, Site 11*

Pipes 1, 2, 3, 4, 6, and 11 were installed along with two additional types of pipes selected for evaluation. They are as follows:

12. Sixteen-gauge galvanized steel with a 10-mil, coal-tar-based laminate applied to interior and exterior

13. Sixteen-gauge galvanized steel with an 8-mil interior and 4-mil exterior polyethylene coating

*Four Years of Field Exposure, Sites 4, 9, and 10*

14. Sixteen-gauge steel with a 1.5-mil aluminum coating applied to the interior and exterior

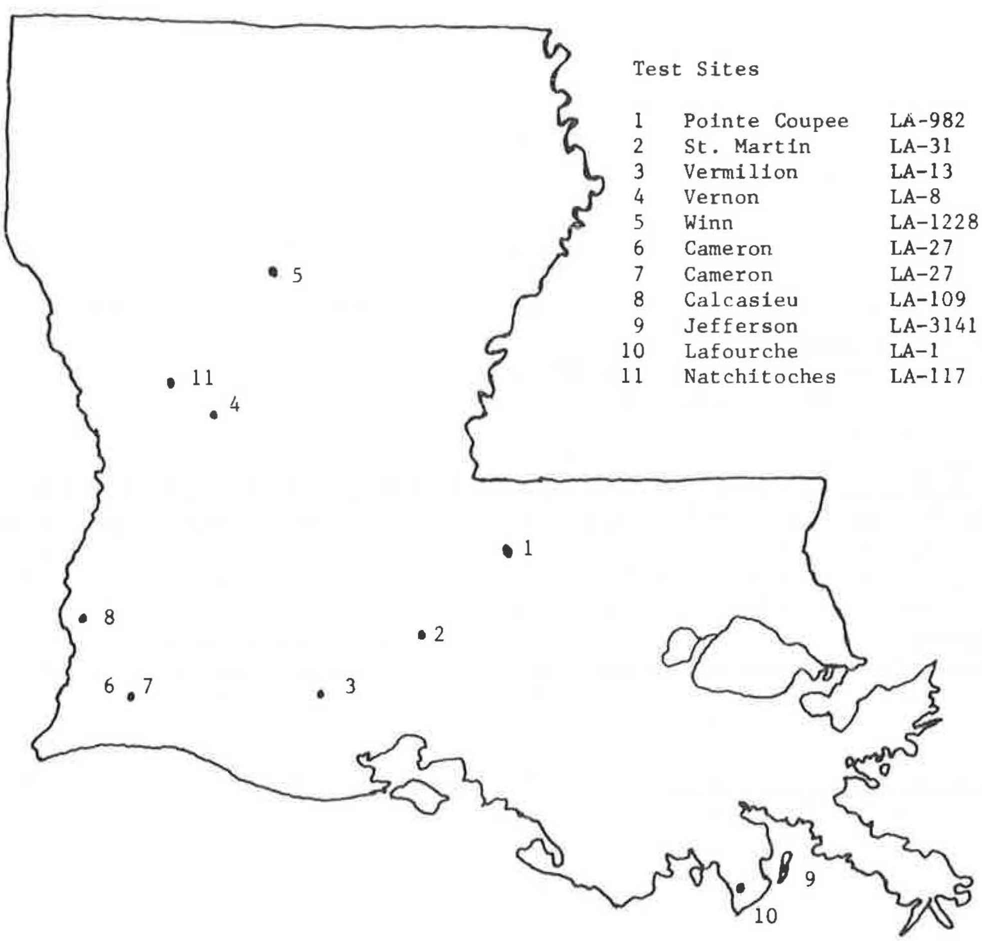


**FIGURE 1 Location of test sites.**

*Four Years of Field Exposure, Sites 4 and 10*

15. Sixteen-gauge galvanized steel with a 10-mil interior and a 7-mil exterior epoxy coating

*Four Years of Field Exposure, Sites 7, 9, and 10*

16. Fourteen-gauge aluminum pipe, Alclad 3004, with 10-mil interior and 5-mil exterior polymeric coating

## Field Inspection

During the months of October and November 1983, the fourth and final field inspection of pipes with a maximum of 10 years of exposure was conducted. All of the pipes at each site were removed for inspection using a chain hooked to both ends of the pipe and to a "Gradall" bucket. The 4-ft sections were then washed clean, removing as much of the soil as possible without contributing to the removal of the coatings.

After the pipes were cleaned, photographs were taken from several angles to document the condition of each. Next, a panel consisting of highway engineers and highway engineering technicians visually rated the interior and exterior of the pipes and defined the total condition of a pipe using the following criteria:

1. Excellent condition—if, under visual observation, there were no signs of deterioration;
2. Good condition—if, under visual observation, there were slight signs of deterioration and pitting;
3. Fair condition—if, under visual observation, there were moderate signs of deterioration and pitting;
4. Poor condition—if, under visual observation, there were extreme signs of deterioration and pitting; and
5. Very poor condition—if, under visual observation, there were signs of complete deterioration and the pipe was no longer useful as a drainage tool.

The rating method was selected to provide a fair indication of the culverts' usefulness as drainage tools in addition to providing a relative indication of corrosion. This procedure was thought to be more relatable to actual field service life than time to first perforation. Time to first perforation was recorded, however, because many available design methods predict pipe life using this parameter.

## Laboratory Analysis of Soil, Water, and Unexposed Culverts

Soil and water samples were initially collected from each installation site semiannually. Sampling frequency was later reduced to once a year because the results from the semiannual samples showed little change in pH and resistivity. These samples were tested for pH in accordance with Louisiana DOTD:TR 430–67 and for resistivity in accordance with Louisiana DOTD:TR 429–77. The two laboratory procedures require the use of a pH meter and a

**TABLE 2 PANEL RATINGS (fourth evaluation) FOR EACH PIPE AND EACH TEST SITE GROUPED BY CORROSIVE CONDITIONS**

| | | Sites by Corrosiveness | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mildly | | | | | Moderately | | | Very | |
| Type of Pipe | Age (yr) | 1 | 2 | 4 | 5 | 11 | 3 | 8 | 9 | 7 | 10 |
| Uncoated galvanized steel | 6 | | | | | 1.5 | | | | | |
| | 10 | 2.6 | 1.8 | 3.0 | 1.8 | | 4.4 | 3.8 | 4.1 | 5.0 | 5.0 |
| Asphalt-coated galvanized steel | 6 | | | | | 1.0 | | | | | |
| | 10 | 1.5 | 1.0 | 1.8 | 1.4 | | 3.0 | 2.9 | 3.0 | 5.0 | 5.0 |
| Asbestos-bonded asphalt- | 6 | | | | | 1.0 | | | | | |
| coated galvanized steel | 10 | 1.4 | 1.0 | 1.0 | 1.0 | | 1.9 | 1.1 | 2.9 | 3.1 | 3.2 |
| Uncoated aluminum | 6 | | | | | 1.6 | | | | | |
| | 10 | 1.4 | 1.5 | 1.9 | 1.8 | | 2.5 | 1.8 | 2.1 | 4.4 | 4.1 |
| Asphalt-coated aluminum | 6 | | | | | | | | | | |
| | 10 | 1.1 | 1.2 | 1.2 | 1.1 | | 2.0 | 1.5 | 2.6 | 2.2 | 2.6 |
| Structural aluminum plate | 6 | | | | | 2.5 | | | | | |
| arch | 10 | 2.1 | 1.5 | 1.5 | 3.2 | | 1.4 | 1.9 | 4.2 | 5.0 | 4.9 |
| 10-mil coal-tar-based polymer- | 6 | | | | | | | | | | |
| coated galvanized steel | 10 | 1.6 | 1.4 | 2.1 | 2.2 | | 2.6 | 2.6 | 3.5 | 5.0 | 5.0 |
| 20-mil coal-tar-based polymer- | 6 | | | | | | | | | | |
| coated galvanized steel | 10 | 1.2 | 1.2 | 1.9 | 1.4 | | 2.2 | 2.1 | 3.2 | 5.0 | 5.0 |
| 10-mil polyethylene-coated | 6 | | | | | | | | | | |
| galvanized steel | 10 | 1.1 | 1.2 | 1.8 | 1.8 | | 1.8 | 1.8 | 2.9 | 4.2 | 4.4 |
| 12-mil polyethylene-coated | 6 | | | | | | | | | | |
| galvanized steel | 10 | 1.2 | 1.2 | 1.6 | 1.6 | | 1.5 | 1.6 | 2.6 | 3.2 | 3.6 |
| 10-mil polymeric-coated | 6 | | | | | 1.0 | | | | | |
| galvanized steel | 8 | 1.0 | 1.0 | 1.0 | | | 1.5 | 1.5 | 2.5 | 2.8 | 3.2 |
| 12-mil coal-tar-based polymer-coated galvanized steel | 6 | | | | | 1.1 | | | | | |
| 8-mil polyethylene-coated galvanized steel | 6 | | | | | 1.6 | | | | | |
| Aluminized steel | 4 | | | 2.2 | | | | | 2.8 | | 3.6 |
| Epoxy-coated galvanized steel | 4 | | | 1.0 | | | | | | | 2.6 |
| 10-mil plastic-coated aluminum | 4 | | | | | | | | 1.1 | 1.1 | 2.1 |

resistivity meter. The soil samples were classified by laboratory technicians in accordance with Louisiana DOTD:TR 423–71.

Initially, the culvert-testing program dealt with determination of the physical characteristics of the various metals and their protective coatings as manufactured. The amount of zinc coating, expressed in ounces per square foot, was determined by measured weight loss as the zinc coating was dissolved in an acid solution. Thicknesses of the bituminous, asbestos, and various organic coatings were measured with a micrometer. The composition of steel and aluminum used in the culverts was determined by X-ray fluorescence, a process that provides a quantitative analysis of each element present in the metal alloys. Composition and thickness data are presented elsewhere *(1)*.

The durability of the culvert materials as manufactured has been evaluated in the laboratory by two primary methods, the salt fog exposure and the Weather-Ometer exposure tests. The salt fog exposure (Louisiana DOTD:TR 1011–74) consists of a closed salt spray cabinet equipped with a cyclic temperature control. This test was originally designed to test zinc-rich paint systems. The Weather-Ometer exposure (Louisiana DOTD:TR 611–75) consists of a carbon arc Weather-Ometer with automatic humidity controls. The evaluation of salt fog and Weather-Ometer exposure results is subjective and normally reported as satisfactory or unsatisfactory for the specified number of hours exposed. Initial durability test results are presented elsewhere *(1)*.

## DISCUSSION OF RESULTS

The average panel ratings given to each pipe at each site for this fourth and final evaluation are given in Table 2. The ratings reflect the collective opinions of a panel of Louisiana DOTD employees who examined the culverts and assigned a numerical rating ranging from one (excellent) to five (very poor). The panel thought that, because of improper handling and lack of protection, the ends of many of the pipes indicated excessive corrosion and distress. The panel members were therefore asked to provide their ratings without considering the condition of the pipe ends. This is a departure from previous evaluations in which the entire pipe was rated but is believed to be a better representation of actual in-service conditions and performance.

To help in analyzing the data obtained during this study, the locations at which the pipes were installed were grouped in three categories, mildly corrosive, moderately corrosive, and very corrosive. These groupings were based on the environmental conditions at the sites represented by the minimum resistivity of the soil and the effluent. The limits of each group were selected in an effort to categorize the corrosive effect of the minimum resistivity on the galvanized steel base metal. This categorization placed Sites 4, 5, and 8 in mildly corrosive environments, Sites 1, 2, and 3 in moderately corrosive environments, and Sites 6, 7, 9, and 10 in very corrosive environments. Site 11 was considered very corrosive because of the low pH of the soil in conjunction with moderate resistivity.

Figure 2 indicates that the ratings assigned to the uncoated galvanized steel pipe (Pipe 1) are not consistent with the expected performance when based on minimum resistivities only [i.e., some galvanized steel pipes located at an assumed moderately corrosive site have a rating lower (better) than the same pipe at what was thought to be a mildy corrosive site]. Because of these inconsistencies, a different criterion for categorization or grouping of the 11 separate sites was established. This different grouping is based on the combined effect of all environmental influences on corrosion of uncoated galvanized steel as indicated by the assigned rating. In other words, the relative condition of 10-year-old uncoated galvanized steel pipe was used to place the sites in categories of increasing corrosion potential. Figure 3 shows the ratings of the uncoated galvanized steel when the sites are placed in the new categories. The limits of each category were established as follows:

| *Corrosive Condition* | *Uncoated Galvanized Steel Rating (10 years)* |
|---|---|
| Mild | 1.0–3.4 |
| Moderate | 3.5–4.5 |
| Very | 4.6–5.0 |

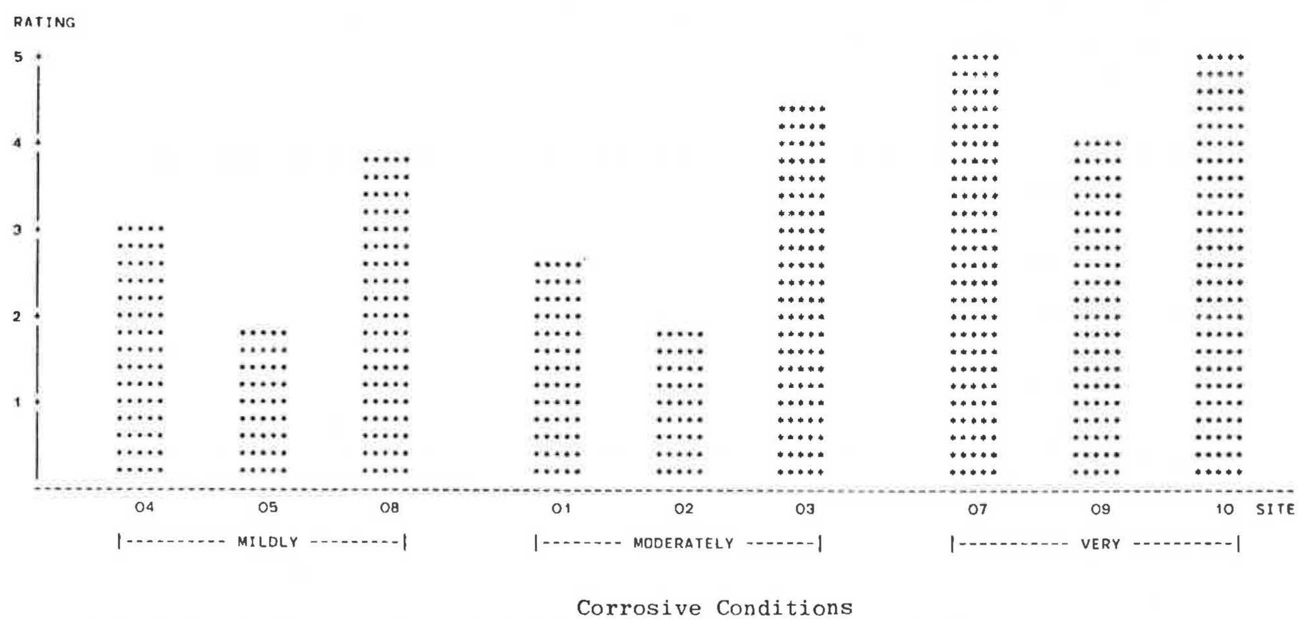


**FIGURE 2 Ratings for 16-gauge galvanized steel pipe, original grouping (based on resistivity only).**

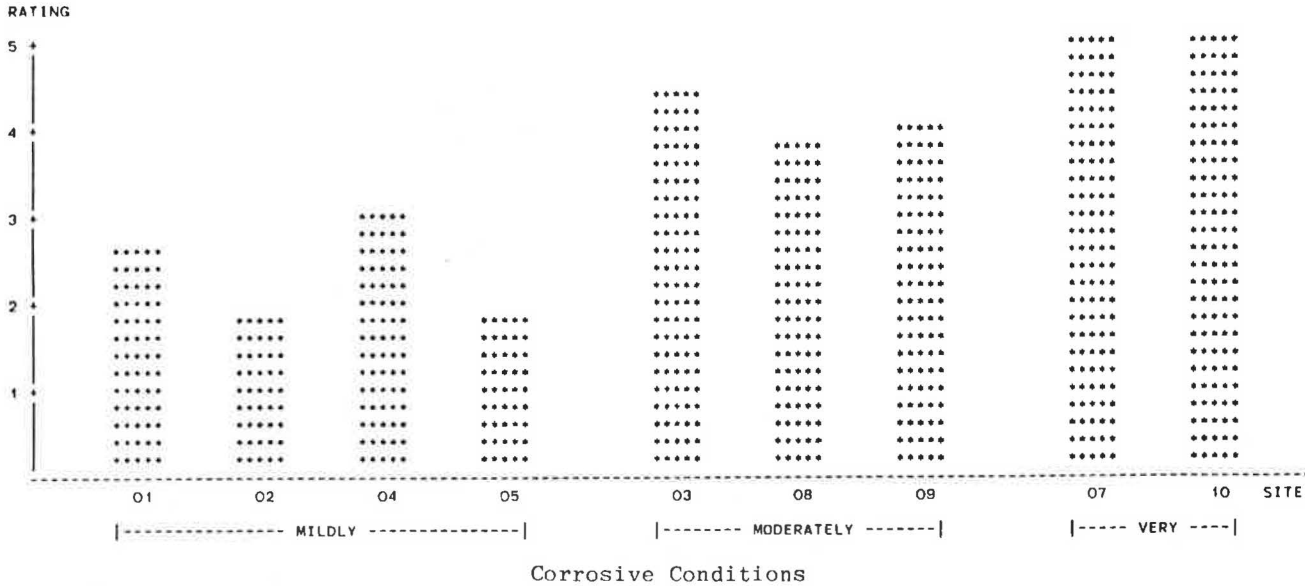


**FIGURE 3 Ratings for 16-gauge galvanized steel pipe, new grouping (based on 10-year performance).**

**TABLE 3 AVERAGE 10-YEAR RATING BY ENVIRONMENTAL CONDITION**

| Pipe No. | Description | Avg Rating |
|---|---|---|
| Mildly Corrosive | | |
| 03 | Asbestos-bonded, asphalt-coated galvanized steel | 1.1 |
| 05 | Asphalt-coated aluminum | 1.1 |
| 10 | 12-mil polyethylene-coated galvanized steel | 1.4 |
| 02 | Asphalt-coated galvanized steel | 1.4 |
| 08 | 20-mil coal-tar-based polymer-coated galvanized steel | 1.4 |
| 09 | 10-mil polyethylene-coated galvanized steel | 1.5 |
| 04 | Uncoated aluminum | 1.6 |
| 07 | 12-mil coal-tar-based polymer-coated galvanized steel | 1.8 |
| 06 | Structural aluminum plate arch | 2.1 |
| 01 | Uncoated galvanized steel | 2.3 |
| Moderately Corrosive | | |
| 10 | 12-mil polyethylene-coated galvanized steel | 1.9 |
| 03 | Asbestos-bonded, asphalt-coated galvanized steel | 2.0 |
| 05 | Asphalt-coated aluminum | 2.0 |
| 04 | Uncoated aluminum | 2.1 |
| 09 | 10-mil polyethylene-coated galvanized steel | 2.2 |
| 06 | Structural aluminum plate arch | 2.5 |
| 08 | 20-mil coal-tar-based polymer-coated galvanized steel | 2.5 |
| 07 | 12-mil coal-tar-based polymer-coated galvanized steel | 2.9 |
| 02 | Asphalt-coated galvanized steel | 3.0 |
| 01 | Uncoated galvanized steel | 4.1 |
| Very Corrosive | | |
| 05 | Asphalt-coated aluminum | 2.4 |
| 03 | Asbestos-bonded, asphalt-coated galvanized steel | 3.1 |
| 10 | 12-mil polyethylene-coated galvanized steel | 3.4 |
| 04 | Uncoated aluminum | 4.2 |
| 09 | 10-mil polyethylene-coated galvanized steel | 4.3 |
| 01 | Uncoated galvanized steel | 5.0 |
| 02 | Asphalt-coated galvanized steel | 5.0 |
| 06 | Structural aluminum plate arch | 5.0 |
| 07 | 12-mil coal-tar-based polymer-coated galvanized steel | 5.0 |
| 08 | 20-mil coal-tar-based polymer-coated galvanized steel | 5.0 |

TABLE 4 ACTUAL VERSUS PREDICTED LIFE FOR 16-GAUGE GALVANIZED STEEL

| Site Locations Where 16-Gauge Galvanized Steel Perforated | Actual Age to Perforation (yr) | Predicted Years to Perforation by California Chart by | | |
|---|---|---|---|---|
| | | Soil | Effluent | Combined |
| 3 | 6-10 | 21 | 23 | 22 |
| 7 | 2-4 | 19 | 6 | 12.5 |
| 8 | 6-10 | 20 | 38 | 29 |
| 9 | 6-10 | 29 | 19 | 24 |
| 10 | 2-4 | 17 | 12 | 14.5 |

These limits are based on the previously outlined criteria established and used for the 1 to 5 rating scale.

The panel ratings of Table 2 represent each pipe and each site grouped according to these limits. Site 11 was placed under mildly corrosive conditions because of the relatively good rating of the uncoated galvanized steel pipe after 6 years of exposure. The average rating of each pipe (10 year) within the three corrosive conditions is given in Table 3.

Indications based on the average (10-year) ratings within the three corrosive environments are discussed in the following subsections.

### Mildly Corrosive Environments

The asbestos-bonded asphalt-coated galvanized steel and the asphalt-coated aluminum pipes are the best-performing pipes tested, with an average rating of 1.1. The 10-year average rating for all pipes ranges from a best of 1.1 to a worst of 2.3. This indicates that all pipes tested performed well under mild environmental conditions.

### Moderately Corrosive Environments

The asphalt-coated aluminum, the 12-mil polyethylene-coated galvanized steel, and the asbestos-bonded asphalt-coated galvanized steel are among the best-performing pipes evaluated with 10-year average ratings of 1.9 and 2.0. All pipes with the exception of the uncoated galvanized steel performed reasonably well in moderately corrosive environments.

### Very Corrosive Environments

The asphalt-coated aluminum (rating of 2.4), the asbestos-bonded asphalt-coated galvanized steel (rating of 3.1) and the 12-mil polyethylene-coated galvanized steel (rating of 3.4) are the best-performing pipes in the very corrosive environments; these pipes stand out in their ability to resist corrosion under very harsh conditions and have some additional life remaining. The other pipes tested are at, or near, their end of life.

The only pipe with a maximum of 8 years of field exposure as of this final evaluation is the 10-mil polymeric-coated galvanized steel. This pipe performed well in the mildly and moderately corrosive environments and had an average rating of 3.0 in the highly corrosive environments.

Eight pipe types that were installed at Site 11 (mild environment) had a maximum of 6 years field exposure as of this final evaluation. The pipes that performed the best at this site, with a rating of 1.0 after 6 years, are the asphalt-coated galvanized steel, the asbestos-bonded asphalt-coated galvanized steel, and the 10-mil polymeric-coated galvanized steel.

Three pipe types had a maximum of 4 years of field exposure as of this final evaluation. The 10-mil plastic-coated aluminum was the pipe with the best performance in all three environments.

Table 4 is a list of sites at which 16-gauge uncoated galvanized steel pipes have perforated or reached a rating of 5.0 and the corresponding number of years elapsed to reach this end condition. Also included in this table is the pipes' expected life (years to perforation) as predicted by the California Chart *(2)* for the existing site conditions. The California Chart relates expected years to perforation versus minimum resistivity and pH of the site environment. As the data in Table 4 indicate and as is shown in Figure 4,

**FIGURE 4 16-gauge galvanized steel after 10 years of exposure at Site 7.**

**TABLE 5 PREDICTED YEARS TO PERFORATION, ALL SITES**

| Site No. | Years to Perforation |
|---|---|
| Mildy Corrosive | |
| 1 | 15.0 |
| 2 | 30.0 |
| 4 | 27.0 |
| 5 | 27.0 |
| | 25.0 avg |
| Moderately Corrosive | |
| 3 | 21.0 |
| 8 | 20.0 |
| 9 | 19.0 |
| | 20.0 avg |
| Very Corrosive | |
| 7 | 6.0 |
| 10 | 12.0 |
| | 9.0 avg |

Note: Predicted years to perforation for uncoated, 16-gauge galvanized steel pipe utilizing the California Chart and worst-case environmental condition.

**FIGURE 5 Asphalt coating cracked and removed.**

the California Chart overestimates the anticipated life of 16-gauge uncoated galvanized steel at those sites where perforation or failure has occurred during this study. The chart does, however, appear to provide predicted life relative to the available range of pH and resistivities when sites are grouped by performance of galvanized steel as indicated by the data in Table 5. It is impossible to accurately estimate or predict pipe life in all of the various environments on the basis of the ratings obtained during this study because of the nonlinearity of the 1 to 5 rating scale. For example, a rating of 3.0 (midpoint of the rating scale) does not necessarily indicate that one-half of the life or usefulness of the pipe is gone. All pipes tested would require field exposure times of such length that the pipes reach a rating of 5.0 before any accurate determination of pipe life or additional life due to the various pipe coatings could be made.

Three general types of coatings were used to protect the base metal of some of the (10-year) test pipes. The results of the ratings of coated and uncoated pipes indicate that all coatings provided some degree of additional life by reducing corrosion of the base metal. The three coatings fall into the following categories:

1. Asphalt,
2. Asbestos-bonded with asphalt coating, and
3. Polymeric.

The asphalt coatings tended to be removed during handling and tended to be removed or cracked from exposure to the environment (Figure 5). In harsh environments, rust stains, which indicate corrosion of the base metal, appeared in the asbestos (Figure 6). The polymers tended to blister in harsh environments and tended to peel (separate from the base) in moderate and harsh environments (Figure 7). The thicker polymeric coatings appeared to protect the base metal better than the thin coatings.

Maximum pit depths were measured on the aluminum test culverts because pitting was the principal mode of distress for the

**FIGURE 6 Corrosion between asbestos and base metal—Site 10.**

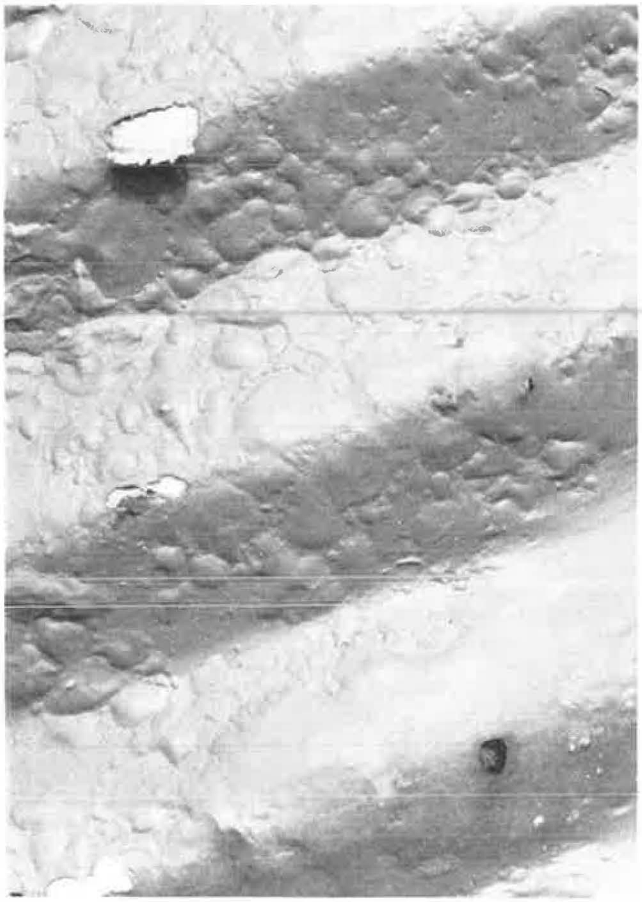

**FIGURE 7 Polymeric coatings—blisters and peeling in harsh environments.**

aluminum products. Pit depth values measured after 10 years of service are given in Table 6. It is evident that the observed rate of corrosion is significantly different for the aluminum 3004 and 5052 alloys.

TABLE 6 PIT DEPTH VALUES

| | Alloy 3004[a] | | Alloy 5052[b] | |
|---|---|---|---|---|
| Site No. | Depth (mils) | Rate (mils/yr) | Depth (mils) | Rate (mils/yr) |
| Mildly Corrosive | | | | |
| 1 | 2 | 0.2 | 40 | 4 |
| 2 | 3 | 0.3 | 16 | 1.6 |
| 4 | 2 | 0.2 | 16 | 1.6 |
| 5 | 3 | 0.3 | 100 | 10 |
| Moderately Corrosive | | | | |
| 3 | 3 | 0.3 | 16 | 1.6 |
| 8 | 2 | 0.2 | 20 | 2 |
| 9 | 3 | 0.3 | 100 | 10 |
| Very Corrosive | | | | |
| 7 | 60 | 6 | 100 | 10 |
| 10 | 60 | 6 | 100 | 10 |

[a] Nominal thickness = 60 mils.
[b] Nominal thickness = 100 mils.

## CONCLUSIONS

Ten years of field exposure have provided much information on the in-service comparative performance of the various types of test culverts. The following conclusions have been reached at this time:

1. The pipe types that provide the best overall performance after 10 years of exposure to the various environments are the 16-gauge asphalt-coated aluminum, the 14-gauge asbestos-bonded asphalt-coated galvanized steel, and the 16-gauge 12-mil polyethylene-coated galvanized steel.

2. Under the environmental conditions (moderately and very corrosive) encountered during this study, the California Chart overestimates predicted pipe life (years to perforation). The chart does, however, combine pH and resistivities to correctly predict life in a relative sense for the mildly, moderately, and very corrosive environments.

3. All coatings provided some degree of protection to the pipe base metal. The thicker polymeric coatings provided more protection against corrosion than the thinner polymeric coatings.

4. Pitting rates for aluminum culverts with the 3004 alloy were found to be significantly less than pitting rates for aluminum plate with the 5052 alloy.

## REFERENCES

1. W. H. Temple and S. L. Cumbaa. *Evaluation of Drainage Pipe by Field Experimentation and Supplemental Laboratory Experimentation.* Final Report. Louisiana Department of Transportation and Development, Baton Rouge, March 1985.
2. *Engineering Directives and Standards Manual.* Louisiana Department of Transportation and Development, Office of Highways, Baton Rouge, Nov. 1983, No. II.2.1.6, Figure 1.

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