APPENDIX G

PIPELINE INSPECTION REPORT

March 26, 2001
<01-023soil_rpt>

Mr. Bruce Corwin
Black & Veatch
8950 Cal Center Drive, Suite 300
Sacramento, CA 95826

SUBJECT: Lopez Water Treatment Plant Water Pipeline Evaluation

Dear Mr. Corwin,

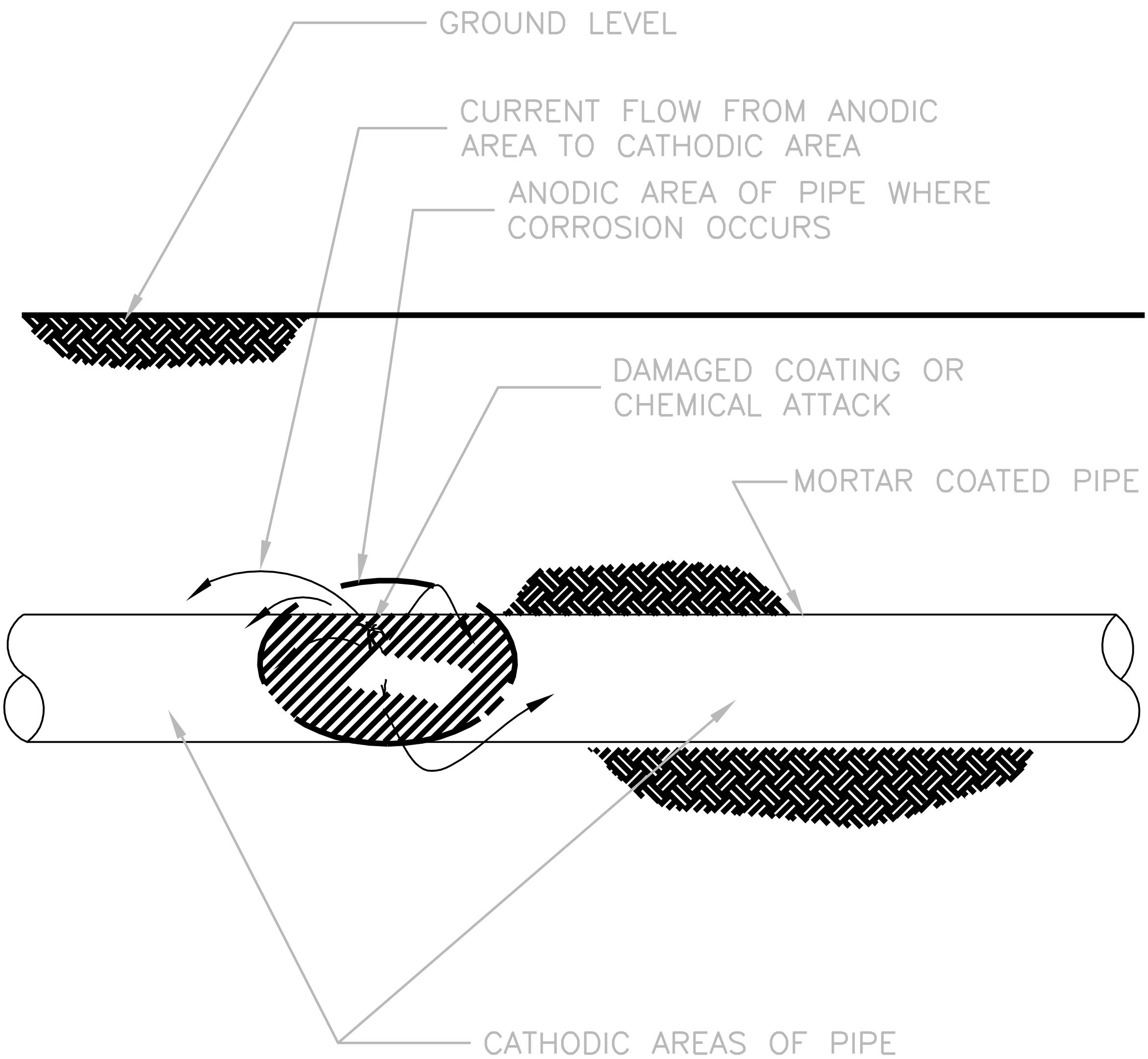
The purpose of this report is to provide the results of the pipeline inspection and evaluation for the subject 20-inch water pipeline. V & A performed a visual inspection of the piping, measured piping wall thickness, pipe-to-soil potential and measured soil resistivities at two locations along the pipeline alignment. An assessment of the pipeline and its cathodic protection system is provided, and recommendations are discussed. The cathodic protection system consists of a Goodall rectifier near the middle of the pipeline and an anode groundbed installed near the rectifier station. The cathodic protection system was energized in May 1985.

INTRODUCTION

Corrosion of Buried Piping

Corrosion is a natural chemical and electrical process that is, by definition, accompanied by the flow of electrical current. Corrosion is caused by chemical reactions that occur on the steel surface in the presence of moisture. The chemical reactions and their associated flow of electric current are the result of the formation of natural or manmade corrosion cells. There are four components of a corrosion cell. These include an anode (at which corrosion occurs), a cathode (which is protected from corrosion), an electrolyte (a conductive path that is a common environment for the anode and cathode), and a metallic path that connects the anode and cathode. Corrosion occurs in the anodic areas of the pipeline and is associated with the flow of current from the pipe to the soil. A schematic view of the corrosion of buried piping is shown in Figure 1.

The soil resistivity data indicates that the soils along the alignment are mildly corrosive to buried metallic pipe and appurtenances. Soil samples were selected from the excavation sites for further chemical analysis. The additional testing included determination of pH, minimum soil resistivity when saturated, and concentrations of water soluble chloride, water soluble sulfate, and bicarbonate ions, present in the soils along the proposed alignment. The soil samples were sent to Sequoia Analytical Laboratories Inc. for chemical analysis.



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CORROSION OF BURIED PIPING

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FIGURE 1

Cathodic Protection

Cathodic protection mitigates corrosion of piping that is electrically continuous and in contact with the soil. Cathodic protection requires the installation of anodes that are designed to corrode over a specified period of time and protect the piping. Current flows from the rectifier to the anodes, through the soil, to the pipe and returns to the rectifier via a wire to complete the electrical circuit. The anodic areas of the pipe are made cathodic due to the flow of current to the pipe. Aboveground piping is not protected by cathodic protection.

To mitigate the effects of corrosion on the piping, an impressed current cathodic protection system is employed. It is important that pipeline integrity is preserved and the pipeline is protected from corrosion and resulting corrosion caused leaks. A schematic view of a typical impressed current cathodic protection system is shown in Figure 2.

TESTING SUMMARY

Field Soil Resistivity

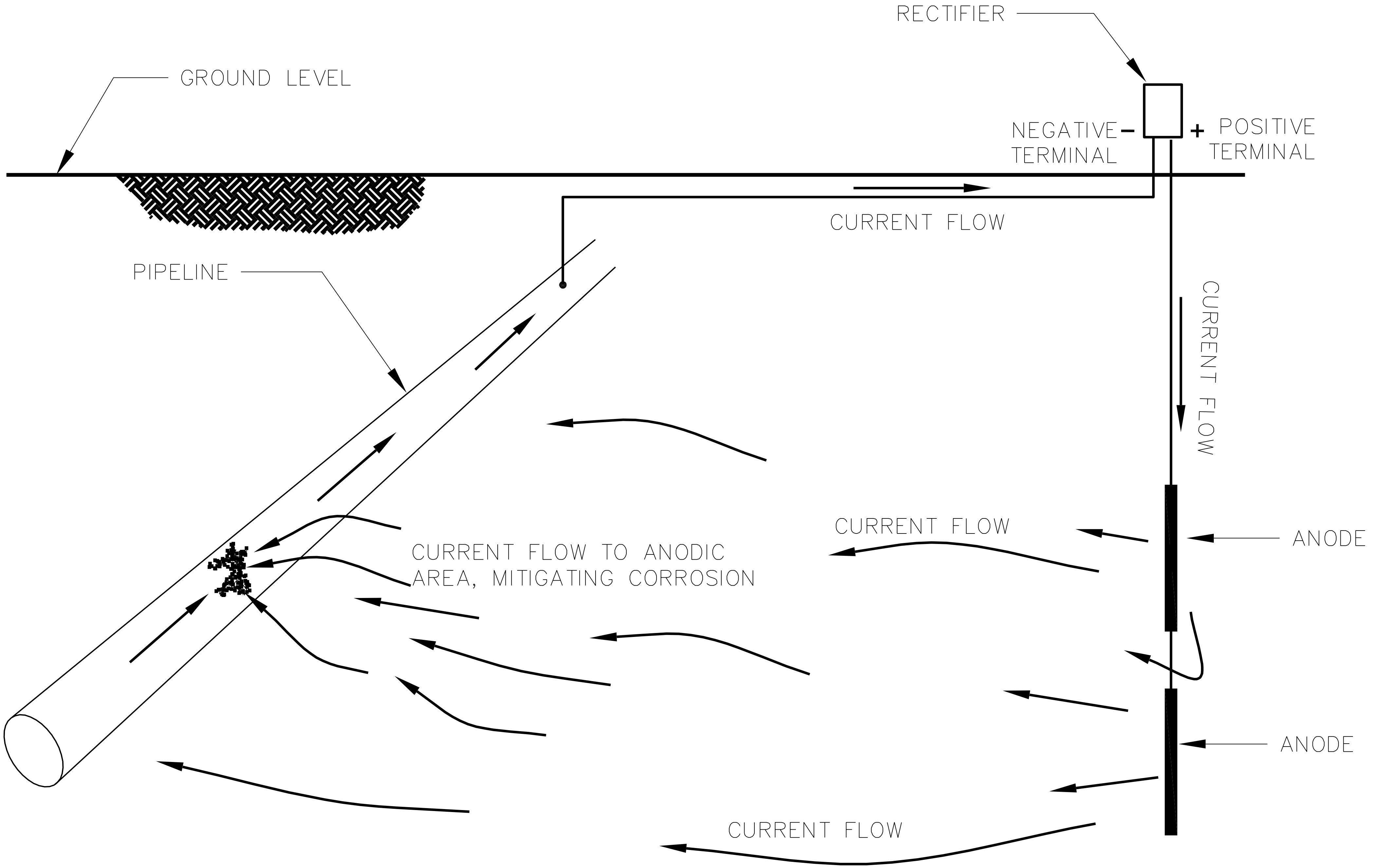
In attempting to predict corrosion problems associated with a particular type of pipe prior to installation, it is necessary to investigate the soil conditions the pipeline will traverse. Since corrosion of metal is fundamentally an electrochemical process which, by definition, is accompanied by current flow, the electrochemical characteristics of a soil are of primary importance when evaluating corrosivity. Test methods utilized during this investigation reflect the most practical methods of evaluating corrosivity.

Resistivity of the soil was measured at 2 locations along the pipeline alignment. Soil resistivity measurements were conducted by the Wenner 4-pin method, utilizing a Soil Resistance Meter, Model 400, manufactured by Nilsson Electrical Laboratory, Inc. The Wenner method involves the use of four metal probes or electrodes, driven into the ground along a straight line, equidistant from each other. An alternating current from the Soil Resistance Meter causes a current to flow through the soil between the outside probes, C1 and C2. Due to the resistance of the soil, the current creates a voltage gradient, which is proportional to the average resistance of the soil mass to a depth equal to the distance between probes. The voltage drop is then measured across pins, P1 and P2. Resistivity of the soil is then computed from the instrument reading according to the following formula:

$$\mathbf{p = 2pAR}$$

where:

p = soil resistivity (ohm-cm)
A = distance between probes (cm)
R = soil resistance, instrument reading (ohms)
p = 3.14159



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CATHODIC PROTECTION

IMPRESSED CURRENT SYSTEM

Job 01-023

FIGURE 2

Soil resistivity measurements were conducted at probe spacings of 5, 10, and 15 feet. The resistivity values obtained and listed in Table 1 represent the average resistivity of the soil to a depth equal to the pin spacing and the resistivity values for the designated layer of soil.

Laboratory Analysis of Soil

Two soil samples were selected for chemical testing. The samples were measured for 'minimum' and 'as-received' resistivity using the NACE soil box method in accordance with Caltrans guidelines. The samples were then forwarded to Sequoia Analytical Laboratory, to measure pH and determine the concentrations of chloride, sulfate and bicarbonate ions. Standard analytical methods were utilized for determination of these chemical constituents.

Visual Inspection

The piping was excavated at approximate Stations No. 28+70 and 140+75. The depth of the pipeline at each excavation is estimated at 4 feet. Photographs of the excavations are shown in Photos 1 to 4.

The condition of the pipe coating and the presence of corrosion by-products were evaluated.

Pipe-to-Soil Potential Testing

Pipe-to-soil testing was performed on the buried piping at each of the excavation sites, to determine if the piping is being adequately protected. Measurements were taken using a portable copper-copper sulfate reference electrode and a voltmeter with an input impedance greater than 10 megaohms. The reference cell was placed in contact with the soil. The terminals of the voltmeter were then connected to the pipe and the reference electrode. A schematic view of the test setup is shown in Figure 3.

Wall Thickness Testing

The piping wall thickness was measured using a Panametrics 36DL Plus ultrasonic thickness gauge. Measurements were taken on the piping at both excavation sites.

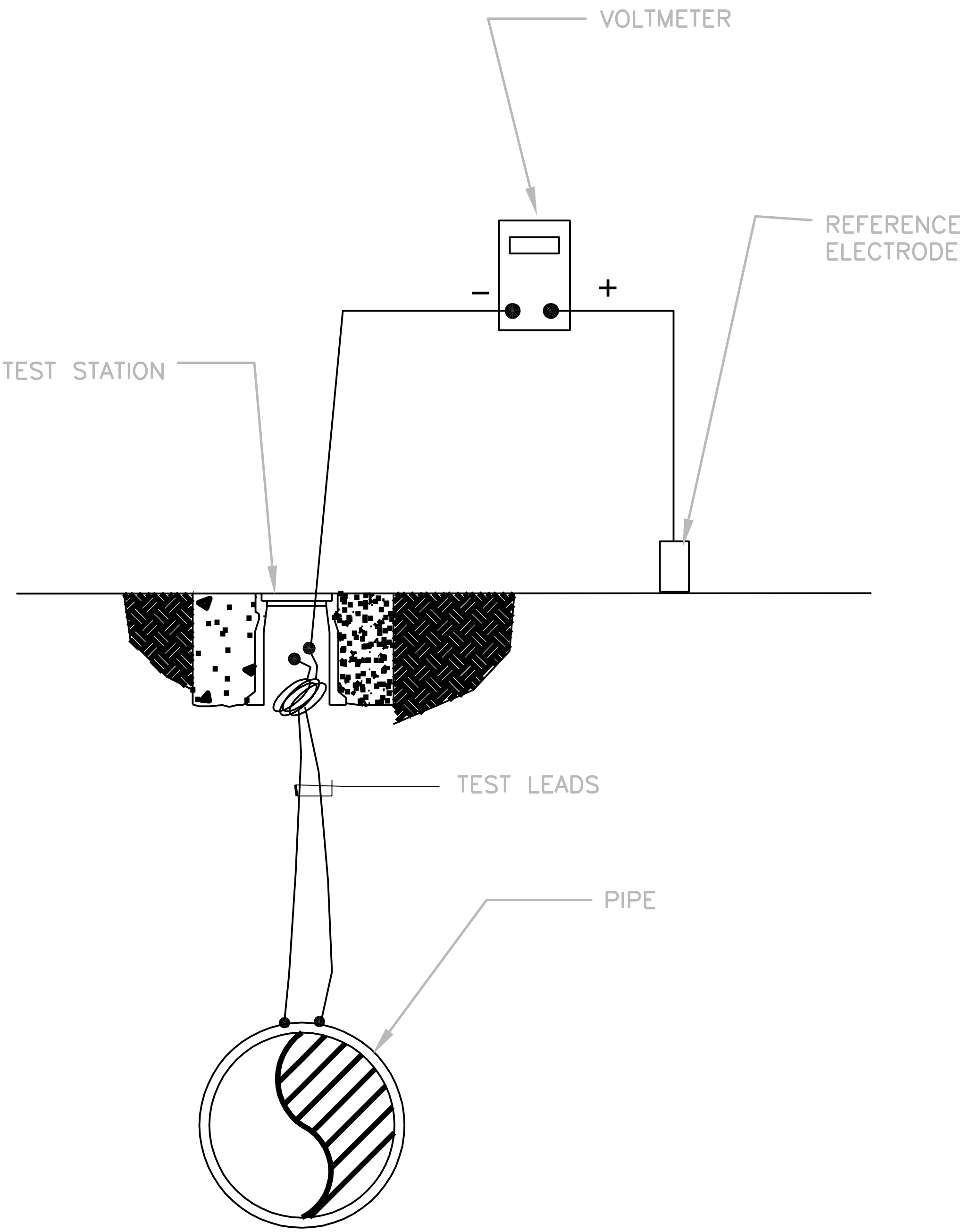
RESULTS

Visual Inspection

The somastic coating is in good condition at both excavation sites. No corrosion by-products were found on or around the steel pipe.

Pipe-to-Soil Potential Testing

The test data is shown in Table 2.



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HALF CELL POTENTIAL MEASUREMENT

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FIGURE 3

The National Association of Corrosion Engineer (NACE) Recommended Practice RP0169-96 "Control of External Corrosion on Underground or Submerged Metallic Piping Systems" provides criteria for adequate protection of buried or submerged piping. These include a polarized potential of -850 millivolts (mV) versus a copper-copper sulfate reference electrode (vs. Cu-$CuSO_4$), or a negative polarization of at least 100 mV, by comparison of the native potential versus the instant off potential (or as measured with the rectifier interrupted). Instant off potentials were not taken during this investigation. Therefore, no conclusions can be drawn in reference to the adequate cathodic protection of this pipeline.

Wall Thickness Testing

The test data is shown in Table 3.

Ultrasonic thickness tests were conducted at both excavation sites. The wall thickness averaged 0.107 inches at the Lopez/Rodriguez site and 0.106 inches at the Lopez/Orcutt site. The measured wall thicknesses were within 7 percent of the specified nominal wall thickness of 0.100 inches for AWWA Class 150 pipe. The standard deviations at both sites were less than 6 percent of the thickness, which indicates a uniform wall thickness.

Field Soil Resistivity

Data obtained during the field resistivity testing has been summarized in tabular form for analysis and presentation. Table 1 lists the results of the field soil resistivity measurements conducted at the sites.

Laboratory Analysis of Soil

Corrosion is a natural electrochemical process which is, by definition, accompanied by the flow of electrical current. Therefore, it is important to understand how easily current will travel through a medium surrounding a metal object. Resistivity is a measure of the ability of a soil to conduct an electric current. The higher the resistivity the more difficult it is for the soil to conduct a current. Soil resistivity is primarily dependent on the chemical and moisture content of the soil. The higher the level of chemical constituents the lower the soil resistivity. Additional moisture generally decreases the soil resistivity up to the point where the maximum solubility for the dissolved ionic chemicals is achieved. Beyond this point, an increase in moisture generally increases the resistivity as the chemicals become more and more diluted. Since corrosion rate depends on current flow to and from a metal and the adjacent medium, the corrosion activity of steel in soil normally increases as soil resistivity decreases. The following table correlates resistivity values with degree of corrosivity. The interpretation of corrosivity varies among corrosion engineers. However, this table is a generally accepted guide.

SOIL RESISTIVITY (ohm-cm)	DEGREE OF CORROSIVITY
0 – 500	Very Corrosive
500 - 1,000	Corrosive
1,000 - 2,000	Moderately Corrosive
2,000 - 10,000	Mildly Corrosive
Above 10,000	Negligible

Reference: NACE Corrosion Basics, page 191

Results of the soil laboratory analysis are shown in Table 4. A wide variety of soluble salts is typically found in soils. Two soils having the same resistivity may have significantly different corrosion characteristics, depending on the specific ions available. The major constituents which accelerate corrosion are chlorides, sulfates and the acidity (pH) of the soil. Calcium and magnesium tend to form insoluble oxide and bicarbonate precipitates, in basic environments, which can create a protective layer over the metal surface and reduce corrosion activity. Chloride ions tend to break down otherwise protective surface deposits, and can result in corrosion of buried metallic structures and reinforcing steel in concrete structures. Sulfates in soil can be highly aggressive to portland cement concrete by combining chemically with certain constituents of the concrete, principally tricalcium aluminate. This reaction is accompanied by expansion and eventual disruption of the concrete matrix. High concentrations of bicarbonates tend to decrease soil resistivities. However, bicarbonates are not aggressive to buried steel and concrete. Although bicarbonates are not aggressive, lower resistivity environments can promote corrosion activity.

The following tables correlate the effect of chlorides on the corrosion of steel, ductile iron or reinforcing steel in concrete, and the effect of sulfates on concrete:

WATER SOLUBLE CHLORIDE CONCENTRATION (ppm)	DEGREE OF CORROSIVITY
Over 5,000	Severe
1,500 - 5,000	Considerable
500 - 1,500	Corrosive
Below 500	Threshold

Reference: Extrapolation from California Test Method 532, Method for Estimating The Time To

Corrosion of Reinforced Concrete Substructures and V & A Consulting Engineers' experience.

WATER SOLUBLE SULFATE CONCENTRATION (ppm)	DEGREE OF CORROSIVITY
Over 10,000	Very Severe
1,500 - 10,000	Severe
150 - 1,500	Moderate
0 - 150	Negligible

Reference: ACI-318, Building Code Requirements for Reinforced Concrete

Acidity, as indicated by the pH value, is another important factor of soil. The lower the pH (the more acidic the environment), the higher will be the corrosivity with respect to buried metallic and concrete structures. As pH increases above 7 (the neutral value), conditions become increasingly more alkaline and passive to buried steel structures. V & A has developed a table correlating the effect of pH on corrosion of buried steel or concrete structures. The data is derived from V & A's extensive experience and review of the literature, e.g., Romanoff M., Underground Corrosion, and Uhlig H., Corrosion and Corrosion Control.

pH	DEGREE OF CORROSIVITY
< 5.5	Severe
5.5-6.5	Moderate
6.5-7.5	Neutral
> 7.5	Negligible

The laboratory minimum soil resistivities measured ranged from 1,700 ohm-cm to 2,400 ohm-cm, which is considered *moderately* corrosive to *mildly* corrosive. The pH ranged from 7.4 to 7.6, which is considered *negligibly* corrosive. The chloride levels ranged from 4 ppm to 30 ppm, which is considered *negligibly* corrosive. The results also show that the level of sulfates ranged from 10 ppm to 170 ppm, which is considered *negligibly* corrosive. The level of bicarbonates ranged from 910 ppm to 2,900 ppm. High concentrations of bicarbonates tend to decrease soil resistivities. However, bicarbonates are not aggressive to buried steel and concrete. Although bicarbonates are not aggressive, lower resistivity environments can promote corrosion activity.

CONCLUSIONS

- The pipeline and coating at the excavation sites are in excellent condition. No corrosion by-products were found.
- In general, the soils and resistivity data indicate that the environment in negligibly corrosive.

RECOMMENDATIONS

- The field investigation identified the presence of existing utilities that may be cathodically protected. The large diameter of the proposed pipeline and being located in the vicinity of existing cathodically protected pipelines makes it susceptible to the pickup of stray currents. An investigation of the impact of foreign utilities under cathodic protection on the subject line should occur.

- The pipe-to-soil potential should be recorded annually at the test stations to verify compliance with NACE RP0169 requirements. The rectifier outputs should be monitored and recorded annually. The anode current outputs should be measured annually to identify depleted anodes and plan for replacement when necessary.

- Any addition or improvement to the pipeline should be electrically isolated from the existing piping to prevent corrosion between dissimilar metals and materials in dissimilar environments.

Please call if you have any questions or comments.

Sincerely,

V & A CONSULTING ENGINEERS

Paul A. Sciuto, P.E.
Project Manager

Exposed 20" Pipeline

Photo 1

Photo 2

Photo 3

Photo 4

TABLE 1
LOPEZ WATER TREATMENT PLANT
WATER PIPELINE EVALUATION
FIELD RESISTIVITY TEST DATA

<3/22/00> <job01-023/Tab1fieldsoil>

Site No.	**Depth** (feet)	**R1 (ohm)** **Meter** Reading	Mult	**"K" Factor**	**Resistivity** (ohm-cm)	**1/R1 (mhos)**	**Del (1/R1)** Del mhos	**R2** (ohm)	**"K" FACTOR** (cm)	**Layer Resistivity** (ohm-cm)	**Depth** (feet)
1	5	3.5	1.0	958	**3,351**	0.3	-	-	0	**3,351**	0 - 5
	10	8.3	0.1	1,915	**1,590**	1.2	0.9	1.1	958	**1,042**	5 - 10
	15	3.9	0.1	2,873	**1,120**	2.6	1.4	0.7	958	**704**	10 - 15
2	5	7.4	1.0	958	**7,086**	0.1	-	-	0	**7,086**	0 - 5
	10	5.2	1.0	1,915	**9,959**	0.2	0.1	17.5	958	**16,749**	5 - 10
	15	3.8	1.0	2,873	**10,916**	0.3	0.1	14.1	958	**13,515**	10 - 15

	At Depth				Layer	
Depth	Total	5'	10'	15'	5-10'	10-15'
Average	5,670	5,219	5,775	6,018	8,896	7,110
Maximum	10,916	7,086	9,959	10,916	16,749	13,515
Minimum	1,120	3,351	1,590	1,120	1,042	704

TABLE 2
LOPEZ WATER TREATMENT PLANT
WATER PIPELINE EVALUATION
PIPE-TO-SOIL POTENTIALS

<3/26/01> <01-023/Tab4>

Pipe Station	Location	Test Point	(-mV vs. Cu-$CuSO_4$)	
			On	**Off**
28+70	Lopez / Orcutt	At pipe	731	661
140+75	Lopez / Rodriguez	At pipe	825	693

TABLE 3
LOPEZ WATER TREATMENT PLANT
WATER PIPELINE EVALUATION
ULTRASONIC THICKNESS MEASUREMENTS

<3/26/01> <01-023/Tab3>

Test Station	Test Location	Ultrasonic Thickness Measurement (inches)
28+70	Lopez / Orcutt	0.104
		0.107
		0.110
140+75	Lopez / Rodriguez	0.103
		0.107
		0.106
		0.106
		0.107
		0.108

TABLE 4
LOPEZ WATER TREATMENT PLANT
WATER PIPELINE EVALUATION
SOIL RESITIVITY AND CHEMICAL DATA

<3/26/01> <01-023\Tab2>

Item No.	Sample Station	Sample Location	Depth (ft)	Soil Resistivity		Chemical Data			
				As Received (ohm-cm)	Minimum (ohm-cm)	pH	Sulfate (ppm)	Chloride (ppm)	Bicarbonate (ppm)
1	28+70	Lopez / Orcutt	4	1,700	1,700	7.6	10	4	2,900
2	140+75	Lopez / Rodriguez	4	10,000	2,400	7.4	170	30	910