

M.J. SCHIFF & ASSOCIATES, INC.

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March 17, 2005

WUTC
1300 S. Evergreen Park Drive, S.W.
P.O. Box 47250
Olympia, Washington 98504-7250

Attention: Ms. Kim West

Re: Soil Corrosivity Study
Bellevue Incident
Bellevue, Washington
MJS&A #04-1391HQ

INTRODUCTION

Laboratory tests have been completed on twenty-seven soil samples you provided for the referenced project. The locations and sample identifications for the samples you provided are attached to this report. The purpose of these tests was to assess the soil corrosivity toward ferrous piping.

The scope of this testing is limited to the determination of soil corrosivity.

TEST PROCEDURES

The electrical resistivity of each sample was measured in a soil box per ASTM G57 in its as-received condition and again after saturation with distilled water. Resistivities are at about their lowest value when the soil is saturated. The pH of the saturated samples was measured. A 5:1 water:soil extract from each sample was chemically analyzed for the major soluble salts commonly found in soils and for ammonium and nitrate. Sulfide and oxidation-reduction (redox) potential were determined on sample 040804B. Test results are shown in Table 1.

Tests were performed on sample 040804B to semi-quantitatively determine the presence of bacteria associated with microbiologically-influenced corrosion (MIC) using a MICKit[®] 5 from BTI Products, LP. Test results are shown on Table 2.

SOIL CORROSIVITY

A major factor in determining soil corrosivity is electrical resistivity. The electrical resistivity of a soil is a measure of its resistance to the flow of electrical current. Corrosion of buried metal is an electrochemical process in which the amount of metal loss due to corrosion is directly proportional to the flow of electrical current (DC) from the metal into the soil. Corrosion currents, following

Ohm's Law, are inversely proportional to soil resistivity. Lower electrical resistivities result from higher moisture and soluble salt contents and indicate corrosive soil.

A correlation between electrical resistivity and corrosivity toward ferrous metals is:

Soil Resistivity in ohm-centimeters			Corrosivity Category
over		10,000	mildly corrosive
2,000	to	10,000	moderately corrosive
1,000	to	2,000	corrosive
below		1,000	severely corrosive

Other soil characteristics that may influence corrosivity towards metals are pH, soluble salt content, soil types, aeration, anaerobic conditions, and site drainage.

Electrical resistivities were in mildly corrosive to corrosive categories with as-received moisture and at saturation.

The soluble salt content was very high in the sample 040804B, moderate in the sample 040803T, and low in the others. Sulfate salts were the predominant constituents.

The wide variations in soil resistivity and soluble salt concentrations can create concentration type corrosion cells that increase corrosion rates above what would be expected from the chemical characteristics alone.

Soil pH values varied from 5.1 to 7.0. This range is strongly acidic to neutral.

The ammonium concentration was high enough to be deleterious to copper.

Sulfide, which is aggressive to copper and ferrous metals, was found to be present in a qualitative test performed on the sample 040804B. The negative redox potential indicates reducing conditions in which anaerobic, sulfide-producing bacteria are active.

MIC tests found positive indications for the presence of low nutrient, acid-producing, iron-related, and low nutrient bacteria. Photo 1 (below) shows the inoculated test samples in comparison with uninoculated vials.



CLOSURE

Our services have been performed with the usual thoroughness and competence of the engineering profession. No other warranty or representation, either expressed or implied, is included or intended.

Please call if you have any questions.

Respectfully Submitted,
M.J. SCHIFF & ASSOCIATES, INC.

/s/

James T. Keegan

Enc: Soil Sample Inventory Docket PG041624

Tables 1 and 2

Reviewed by,

/s/

Graham E.C. Bell, Ph.D., P.E.

04-1391HQ 27 samples
 WUTC - Bellevue Incident
 Puget Sound Energy Spirit Ridge Soil Sample Inventory
 Docket PG041624

Inventory #	Date	Location	Description
04120801B	12/08/04	16645 SE 26 th PL - 050032	At the main, 4 feet away and East, near failure site
040802T	12/08/04	16645 SE 26 th PL - 050033	At the main, 4 feet away and East, near failure site
040803T	12/08/04	16645 SE 26 th PL - 050034	At the meter, south side of house
040804B	12/08/04	16645 SE 26 th PL - 050035	At the meter, south side of house
040805T	12/08/04	16645 SE 26 th PL - 050036	Lawn area, north side of house
040806B	12/08/04	16645 SE 26 th PL - 050037	Lawn area, north side of house
040807T	12/08/04	16641 SE 26 th PL - 050038	
040808B	12/08/04	16641 SE 26 th PL - 050039	
040809T	12/08/04	16648 SE 26 th PL - 050040	
040810B	12/08/04	16648 SE 26 th PL - 050041	
040811T	12/08/04	16636 SE 26 th PL - 050042	
040812B	12/08/04	16636 SE 26 th PL - 050043	
040813T	12/08/04	16642 SE 26 th PL - 050044	
040814B	12/08/04	16642 SE 26 th PL - 050045	
040815T	12/08/04	16639 SE 26 th PL - 050046	Between houses from twin service

All soil samples are temporarily housed in the Safeguard Self Storage unit #373 located at 1015 - 164th Avenue NE, Bellevue, Washington

Puget Sound Energy Spirit Ridge Soil Sample Inventory
Docket PG041624

<u>Inventory #</u>	<u>Date</u>	<u>Location</u>	<u>Description</u>
040816B ✓	12/08/04	16639 SE 26 th PL 0500 47	Between houses from twin service
041517 ✓	12/15/04	16621 21 th PL SE 0500 48	
041518 ✓	12/15/04	16644 SE 22 nd - 0500 49	Near main in the street 3 feet deep
041519 ✓	12/15/04	16421 SE 22 nd St. - 0500 50	½" steel service near house
04120820 ✓	12/08/04	165th PL SE & SE 21st PL 0500 51	At the main
04120821 ✓	12/08/04	16557 SE 19 th St. - 0500 52	Service at the riser
04120822 ✓	12/08/04	16557 SE 19 th St. - 0500 53	At the main 3 feet deep
04121623 ✓	12/16/04	16411 SE 23 rd St. - 0500 54	2" PE main approx. 30" deep near sidewalk
04121624 ✓	12/16/04	2018 166 th Ave SE - 0500 55	End of new service line, 2 feet deep, front yard.
04121625 ✓	12/16/04	2017 166 th Ave SE 0500 56	Backyard service line, approx. 18" deep
04122126 ✓	12/21/04	16444 SE 22 nd St. 0500 57	Backyard, serv. riser to meter new PE, service to replace existing one under the house.
04122227 ✓	12/22/04	2040 166 th Ave SE 0500 58	From service ¾" at top near sidewalk on L. side of house.

All soil samples are temporarily housed in the Safeguard Self Storage unit #373 located at 1015 - 164th Avenue NE, Bellevue, Washington

Table 1 - Laboratory Tests on Soil Samples

*WUTC
Bellevue Incident
MJS&A #04-1391HQ
11-Jan-05*

Sample ID

		04120801B	040802T	040803T	040804B	040805T	
Resistivity	Units						
as-received	ohm-cm	43,000	35,000	35,000	2,300	53,000	
saturated	ohm-cm	33,000	26,000	1,600	1,400	40,000	
pH		5.1	5.4	6.5	7.0	5.6	
Electrical							
Conductivity	mS/cm	0.06	0.08	0.30	3.86	0.06	
Chemical Analyses							
Cations							
calcium	Ca ²⁺	mg/kg	16	16	253	5,956	36
magnesium	Mg ²⁺	mg/kg	19	22	32	323	17
sodium	Na ¹⁺	mg/kg	ND	ND	ND	ND	ND
Anions							
carbonate	CO ₃ ²⁻	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO ₃ ¹⁻	mg/kg	ND	ND	15	67	ND
chloride	Cl ¹⁻	mg/kg	ND	ND	15	20	ND
sulfate	SO ₄ ²⁻	mg/kg	ND	41	507	14,024	48
Other Tests							
ammonium	NH ₄ ¹⁺	mg/kg	8.7	22.7	15.8	14.4	3.3
nitrate	NO ₃ ¹⁻	mg/kg	17.0	4.2	2.9	4.4	2.9
sulfide	S ²⁻	qual	na	na	na	Positive	na
Redox		mV	na	na	na	-270	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.

mg/kg = milligrams per kilogram (parts per million) of dry soil.

Redox = oxidation-reduction potential in millivolts

ND = not detected

na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

*WUTC
Bellevue Incident
MJS&A #04-1391HQ
11-Jan-05*

Sample ID

		040806B	040807T	040808T	040809T	040810B	
Resistivity	Units						
as-received	ohm-cm	72,000	7,800	19,000	11,000	14,000	
saturated	ohm-cm	54,000	7,800	18,000	10,000	11,000	
pH		6.0	6.9	6.7	7.0	6.8	
Electrical							
Conductivity	mS/cm	0.05	0.11	0.11	0.11	0.12	
Chemical Analyses							
Cations							
calcium	Ca ²⁺	mg/kg	32	72	84	108	104
magnesium	Mg ²⁺	mg/kg	ND	17	ND	ND	7
sodium	Na ¹⁺	mg/kg	ND	ND	ND	ND	ND
Anions							
carbonate	CO ₃ ²⁻	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO ₃ ¹⁻	mg/kg	ND	27	61	92	104
chloride	Cl ¹⁻	mg/kg	ND	15	ND	ND	ND
sulfate	SO ₄ ²⁻	mg/kg	35	ND	ND	38	ND
Other Tests							
ammonium	NH ₄ ¹⁺	mg/kg	4.4	12.0	19.5	9.1	23.4
nitrate	NO ₃ ¹⁻	mg/kg	2.7	ND	ND	2.9	4.0
sulfide	S ²⁻	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.

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Table 1 - Laboratory Tests on Soil Samples

*WUTC
Bellevue Incident
MJS&A #04-1391HQ
11-Jan-05*

Sample ID

			040811T	040812B	040813T	040814B	040815T
Resistivity		Units					
as-received		ohm-cm	14,000	24,000	33,000	40,000	62,000
saturated		ohm-cm	13,000	20,000	27,000	32,000	48,000
pH			6.8	6.5	6.3	6.1	5.9
Electrical							
Conductivity		mS/cm	0.19	0.18	0.15	0.18	0.14
Chemical Analyses							
Cations							
calcium	Ca ²⁺	mg/kg	208	156	108	128	120
magnesium	Mg ²⁺	mg/kg	17	24	15	24	15
sodium	Na ¹⁺	mg/kg	ND	ND	ND	ND	ND
Anions							
carbonate	CO ₃ ²⁻	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO ₃ ¹⁻	mg/kg	110	76	137	37	12
chloride	Cl ¹⁻	mg/kg	ND	ND	ND	ND	ND
sulfate	SO ₄ ²⁻	mg/kg	76	62	37	49	36
Other Tests							
ammonium	NH ₄ ¹⁺	mg/kg	46.5	287.7	30.6	44.0	33.2
nitrate	NO ₃ ¹⁻	mg/kg	4.4	8.2	5.5	11.7	3.5
sulfide	S ²⁻	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.

mg/kg = milligrams per kilogram (parts per million) of dry soil.

Redox = oxidation-reduction potential in millivolts

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Table 1 - Laboratory Tests on Soil Samples

*WUTC
Bellevue Incident
MJS&A #04-1391HQ
11-Jan-05*

Sample ID

			040816B	# 041517	# 041518	# 041519	# 04120820
Resistivity	Units						
as-received	ohm-cm		98,000	16,000	57,000	86,000	33,000
saturated	ohm-cm		44,000	14,000	35,000	48,000	14,000
pH			5.7	6.4	6.8	6.4	6.7
Electrical							
Conductivity	mS/cm		0.07	0.07	0.03	0.06	0.04
Chemical Analyses							
Cations							
calcium	Ca ²⁺	mg/kg	68	48	20	64	24
magnesium	Mg ²⁺	mg/kg	ND	15	ND	ND	7
sodium	Na ¹⁺	mg/kg	ND	ND	ND	ND	ND
Anions							
carbonate	CO ₃ ²⁻	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO ₃ ¹⁻	mg/kg	15	37	15	12	18
chloride	Cl ¹⁻	mg/kg	ND	ND	ND	ND	ND
sulfate	SO ₄ ²⁻	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH ₄ ¹⁺	mg/kg	10.4	5.9	3.1	6.7	1.7
nitrate	NO ₃ ¹⁻	mg/kg	2.9	ND	ND	ND	ND
sulfide	S ²⁻	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.

mg/kg = milligrams per kilogram (parts per million) of dry soil.

Redox = oxidation-reduction potential in millivolts

ND = not detected

na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

*WUTC
Bellevue Incident
MJS&A #04-1391HQ
11-Jan-05*

Sample ID

		# 04120821	# 04120822	# 04120823	# 04120824	# 04120825	
Resistivity	Units						
as-received	ohm-cm	9,600	39,000	270,000	56,000	13,000	
saturated	ohm-cm	9,600	21,000	99,000	24,000	13,000	
pH		6.8	6.8	7.0	6.1	5.5	
Electrical							
Conductivity	mS/cm	0.09	0.05	0.02	0.07	0.10	
Chemical Analyses							
Cations							
calcium	Ca ²⁺	mg/kg	84	32	12	48	72
magnesium	Mg ²⁺	mg/kg	ND	ND	ND	7	19
sodium	Na ¹⁺	mg/kg	ND	ND	ND	ND	ND
Anions							
carbonate	CO ₃ ²⁻	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO ₃ ¹⁻	mg/kg	113	40	21	82	37
chloride	Cl ¹⁻	mg/kg	20	ND	ND	ND	ND
sulfate	SO ₄ ²⁻	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH ₄ ¹⁺	mg/kg	9.8	2.9	1.1	11.1	12.7
nitrate	NO ₃ ¹⁻	mg/kg	2.2	ND	ND	ND	ND
sulfide	S ²⁻	qual	na	na	na	na	na
Redox	mV		na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.

mg/kg = milligrams per kilogram (parts per million) of dry soil.

Redox = oxidation-reduction potential in millivolts

ND = not detected

na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

WUTC
Bellevue Incident
MJS&A #04-1391HQ
11-Jan-05

Sample ID

04120826 # 04120827

Resistivity		Units		
as-received		ohm-cm	140,000	45,000
saturated		ohm-cm	13,000	27,000
pH			6.6	6.8
Electrical				
Conductivity		mS/cm	0.08	0.03
Chemical Analyses				
Cations				
calcium	Ca ²⁺	mg/kg	60	28
magnesium	Mg ²⁺	mg/kg	12	ND
sodium	Na ¹⁺	mg/kg	ND	ND
Anions				
carbonate	CO ₃ ²⁻	mg/kg	ND	ND
bicarbonate	HCO ₃ ¹⁻	mg/kg	88	40
chloride	Cl ¹⁻	mg/kg	ND	ND
sulfate	SO ₄ ²⁻	mg/kg	ND	ND
Other Tests				
ammonium	NH ₄ ¹⁺	mg/kg	6.1	1.7
nitrate	NO ₃ ¹⁻	mg/kg	3.1	ND
sulfide	S ²⁻	qual	na	na
Redox		mV	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1: soil-to-water extract.
 mg/kg = milligrams per kilogram (parts per million) of dry soil.
 Redox = oxidation-reduction potential in millivolts
 ND = not detected
 na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

*WUTC
Bellvue Incident
MJS&A #04-1391HQ
11-Jan-05*

Sample ID

			# 04120821	# 04120822	# 04120823	# 04120824	# 04120825
Resistivity	Units						
as-received	ohm-cm		9,600	39,000	270,000	56,000	13,000
saturated	ohm-cm		9,600	21,000	99,000	24,000	13,000
pH			6.8	6.8	7.0	6.1	5.5
Electrical							
Conductivity	mS/cm		0.09	0.05	0.02	0.07	0.10
Chemical Analyses							
Cations							
calcium	Ca ²⁺	mg/kg	84	32	12	48	72
magnesium	Mg ²⁺	mg/kg	ND	ND	ND	7	19
sodium	Na ¹⁺	mg/kg	ND	ND	ND	ND	ND
Anions							
carbonate	CO ₃ ²⁻	mg/kg	ND	ND	ND	ND	ND
bicarbonate	HCO ₃ ¹⁻	mg/kg	113	40	21	82	37
chloride	Cl ¹⁻	mg/kg	20	ND	ND	ND	ND
sulfate	SO ₄ ²⁻	mg/kg	ND	ND	ND	ND	ND
Other Tests							
ammonium	NH ₄ ¹⁺	mg/kg	9.8	2.9	1.1	11.1	12.7
nitrate	NO ₃ ¹⁻	mg/kg	2.2	ND	ND	ND	ND
sulfide	S ²⁻	qual	na	na	na	na	na
Redox		mV	na	na	na	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.

mg/kg = milligrams per kilogram (parts per million) of dry soil.

Redox = oxidation-reduction potential in millivolts

ND = not detected

na = not analyzed

Table 1 - Laboratory Tests on Soil Samples

*WUTC
Bellvue Incident
MJS&A #04-1391HQ
11-Jan-05*

Sample ID

04120826 # 04120827

Resistivity	Units			
as-received	ohm-cm		140,000	45,000
saturated	ohm-cm		13,000	27,000
pH			6.6	6.8
Electrical				
Conductivity	mS/cm		0.08	0.03
Chemical Analyses				
Cations				
calcium	Ca ²⁺	mg/kg	60	28
magnesium	Mg ²⁺	mg/kg	12	ND
sodium	Na ¹⁺	mg/kg	ND	ND
Anions				
carbonate	CO ₃ ²⁻	mg/kg	ND	ND
bicarbonate	HCO ₃ ¹⁻	mg/kg	88	40
chloride	Cl ¹⁻	mg/kg	ND	ND
sulfate	SO ₄ ²⁻	mg/kg	ND	ND
Other Tests				
ammonium	NH ₄ ¹⁺	mg/kg	6.1	1.7
nitrate	NO ₃ ¹⁻	mg/kg	3.1	ND
sulfide	S ²⁻	qual	na	na
Redox		mV	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.

mg/kg = milligrams per kilogram (parts per million) of dry soil.

Redox = oxidation-reduction potential in millivolts

ND = not detected

na = not analyzed

Table 2 - Laboratory Tests for Microbiologically Influenced Corrosion Bacteria

Bellevue Incident
MJS&A #04-1391HQ
21-Jan-05

Sample ID

040804B - Trial 1

Days Incubation	2-Days				5-Days				15-Days				
	Bottle Number	1	2	3	4	1	2	3	4	1	2	3	4
Classification													
Aerobic	P	P	P	N	P	P	P	N	P	P	P	P	P
Acid-Producing	P	P	P	N	P	P	P	P	P	P	P	P	P
Sulfate-Reducing	N	N	N	N	N	N	N	N	N	N	N	N	N
Iron Related	P	P	P	P	P	P	P	P	P	P	P	P	P
Low Nutrient	P	P	P	P	P	P	P	P	P	P	P	P	P

P = Positive indication of the presence of bacteria
 N = Negative indication of the presence of bacteria

Highest Bottle Number to Turn Positive

1
 2
 3
 4

Range of Viable Bacteria Per mL of Sample

1-10
 10-100
 100-1000
 1,000 to <= 10,000

Table 2 - Laboratory Tests for Microbiologically Influenced Corrosion Bacteria

Bellevue Incident
MJS&A #04-1391HQ
7-Feb-05

Sample ID

040804B - Trial 2

Days Incubation	2-Days				5-Days				15-Days				
	Bottle Number	1	2	3	4	1	2	3	4	1	2	3	4
Classification													
Aerobic	P	P	P	N	P	P	P	N	P	P	P	P	P
Acid-Producing	P	P	P	N	P	P	P	P	P	P	P	P	P
Sulfate-Reducing	N	N	N	N	N	N	N	N	N	N	N	N	N
Iron Related	P	P	P	P	P	P	P	P	P	P	P	P	P
Low Nutrient	P	P	P	P	P	P	P	P	P	P	P	P	P

P = Positive indication of the presence of bacteria
 N = Negative indication of the presence of bacteria

Highest Bottle Number to Turn Positive

- 1
- 2
- 3
- 4

Range of Viable Bacteria Per mL of Sample

- 1-10
- 10-100
- 100-1000
- 1,000 to <= 10,000