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Cathodic Protection Case Study: Parker Dam Spillway Gates

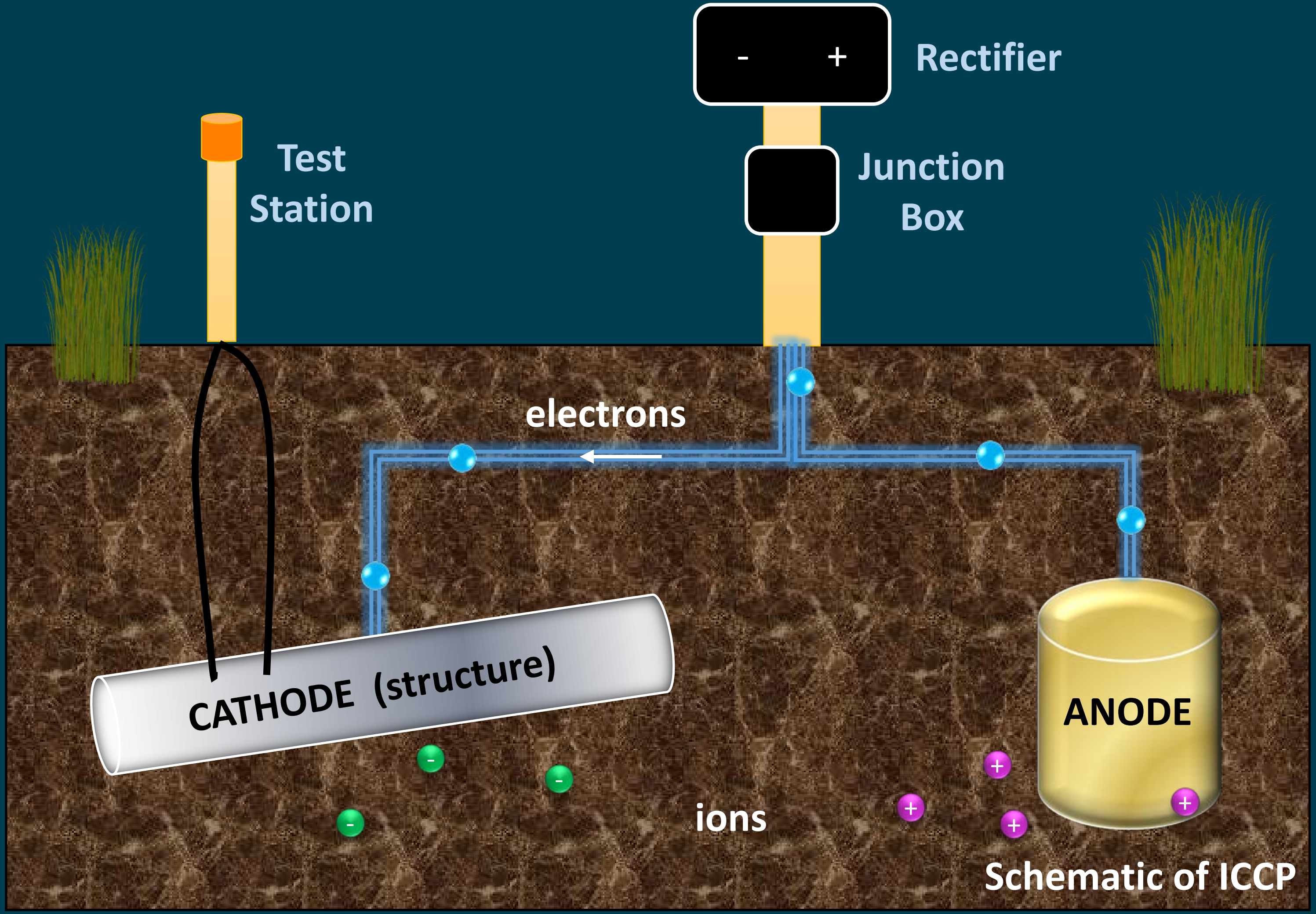
Grace Weber, M.S.
Materials Engineer, Materials & Corrosion Lab

Webinar Objectives

- General Cathodic Protection (CP) Design Process
  - What are the steps?
- Parker Dam Spillway Gate CP – Case Study

What is CP?

- Problem: corrosion
- One mitigation method is cathodic protection
  - Galvanic (GACP)
  - Impressed current (ICCP)
- Past Webinars go more in depth on types corrosion and CP



Parker Dam Spillway Gate CP

- Parker Dam, CA (1938)
  - Colorado River, Lake Havasu
  - "Deepest dam in the world"
  - Powerplant- four units: 30,000 kW each

Coated structures and equipment – receiving the most severe exposures
  - Spillway Gates (5), Penstock Roller Gates (4), Penstock (4)
  - Scroll Case, Turbine Runner, Draft Tube, Etc. (4)
  - Trash Rack panels

- Cathodic protection
  - Penstock Gates – GACP (Complete)
  - Spillway Gates – ICCP (In Progress)

Parker Dam Spillway Gate CP

- ICCP for spillway gates
  - Extend service life of coating
  - Provide extra protection for underlying steel
  - ICCP beneficial for large surface area of 50′ x 50′ gates


Spillway Gates

- Parker Dam staff will install
- Reclamation Materials and Corrosion Lab – CP design & installation support

CP System Design Process

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1. Contact us
2. What are your needs?
3. Project Management Plan
4. Design Data
5. CP Design

Project Management Plan

Project Management Plan

- Contacts
- Objectives
- Scope/tasks
- Schedule
- Budget
- Roles & responsibilities
- Risk management

Project Management Plan (PMP)	
Job Title: **Parker Dam Spillway Gate CP**	Date Submitted:
Accounting String (Fund and WBS):	WOID (if known):
Project Manager (Team Leader) (name/code/telephone/email): Jessica Torrey, 86-68540, 303-445-2376, jtorrey@usbr.gov	Client Group (or Region): Lower Colorado Region

Design Data

Design Data

- Structure dimensions
- Operation
- Drawings/photos
- Water quality data
- Soil samples
- Dissimilar metals
- Electrical isolation
- Coating condition
- Availability of power

Parker Dam Spillway Gates

Design Data:

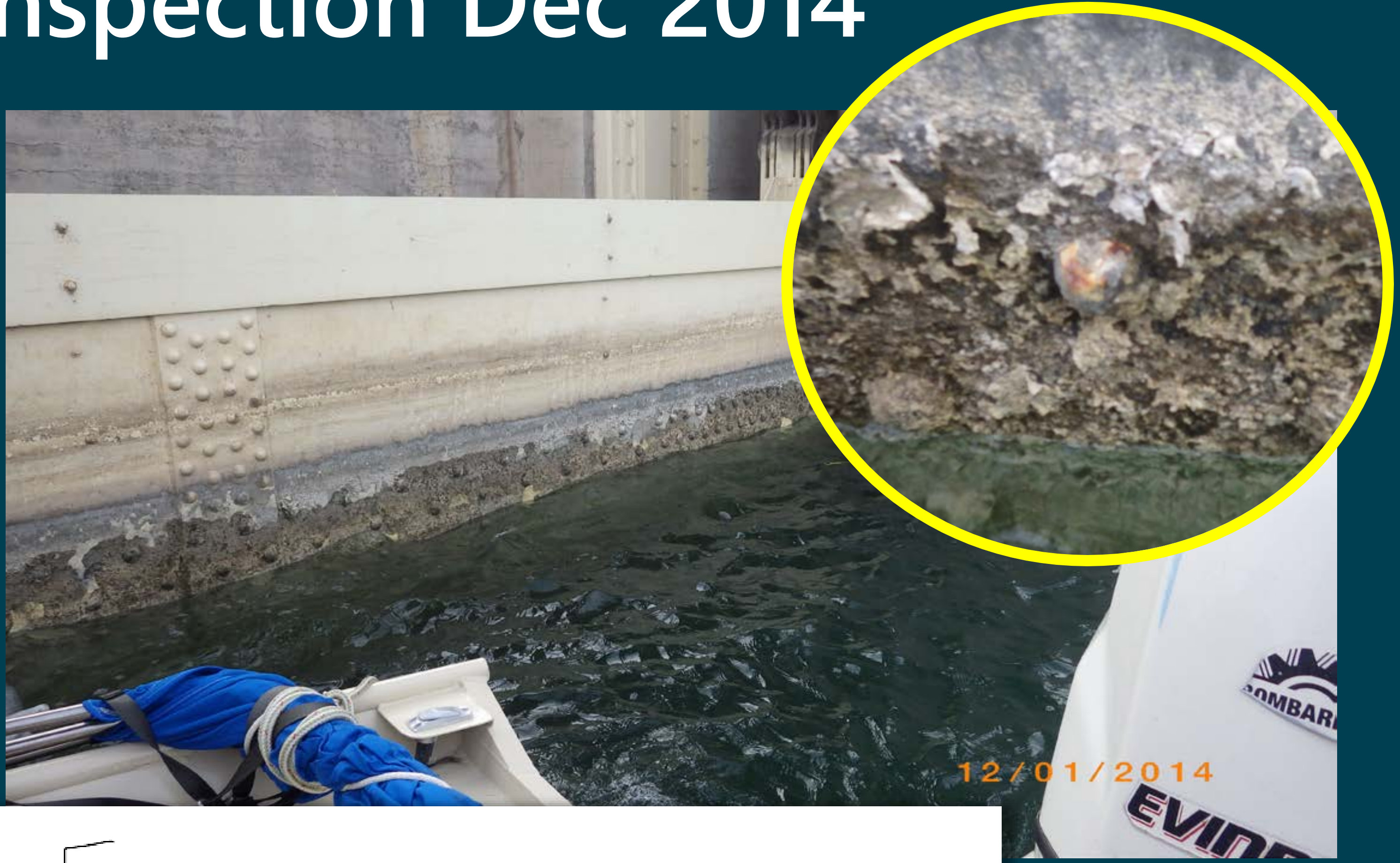
- Gate Size: 50 ft x 50 ft
- Riveted Construction
- Slide Gate Style (Stoney)
- Water line ~3-5 ft from top of gate
- Mudline ~ 2 ft from bottom of gate
- Water Specific Conductance (2008-2010)= 1000 µS/cm

Design Data – Gate Inspection Dec 2014

Dec 1 2014

surface	0.418V	vs C
5ft	0.410V	
10ft	0.403V	
20ft	0.398V	
30ft	0.397V	

Flow E→W (#1–5 E to W)
towards trashracks

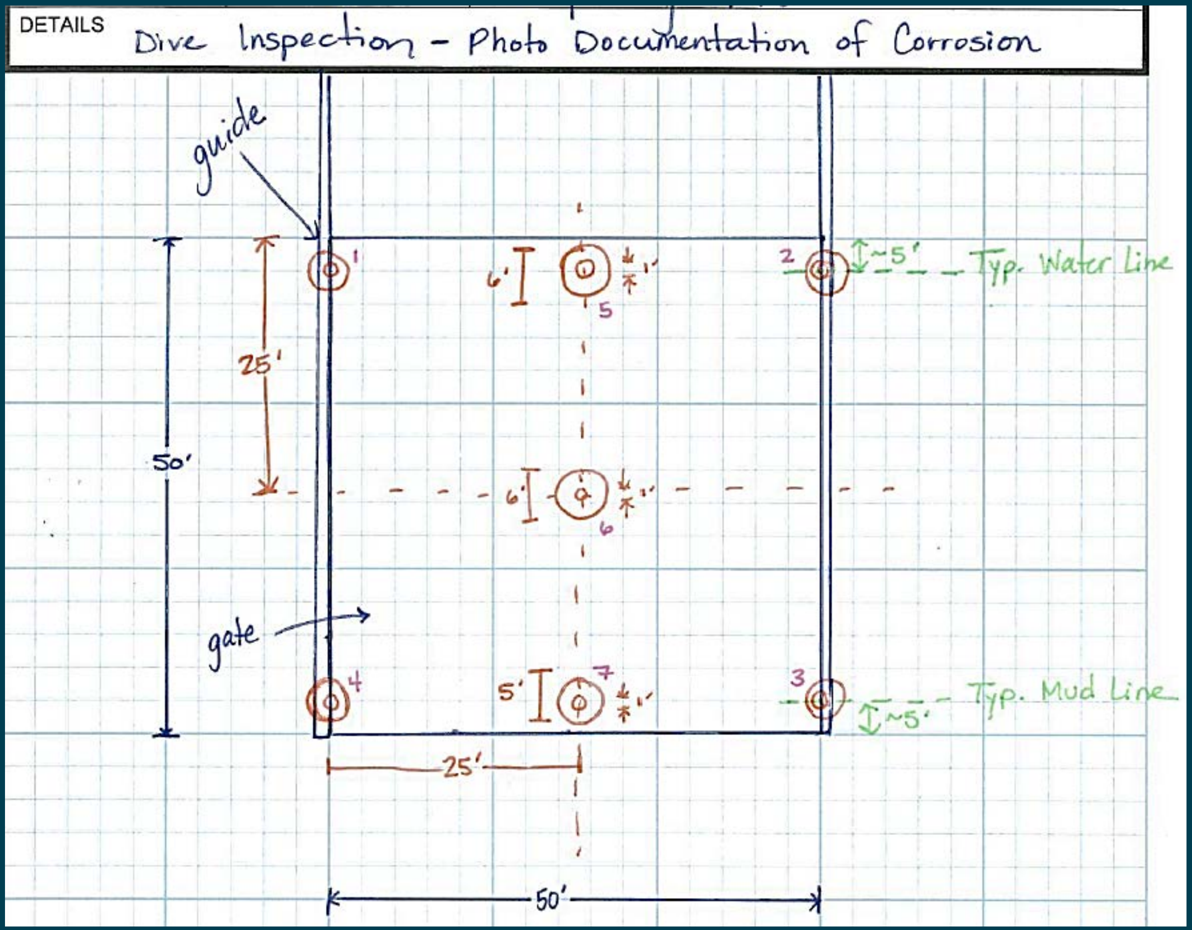


Gate 5

more rusting
of rivets – maybe due to higher flow at this gate

Design Data – Dive Inspection Feb 2015

Rust nodules by rivets on bottom section of Gate #5



CP System Design

CP System Design

- Determine metal surface area
  - Each gate ~6600 rivets; add ~120 sq. ft. (~5%)

Component Name	SA (ft^2)	SA (m^2)
upstream skinplate	2500	232
rivets flat SA	175	16
rivets dome SA	298	28
skinplate minus rivet flat	2325	216
skinplate w/ dome rivets	2622.5	243.6

CP System Design (cont.)

- Rectifier current requirement
- Current distribution calculations

  For steel:
  - Achieve -0.850 V_{CSE}
  - No more negative than -1.100 V_{CSE}
- Anode selection and cable sizes

Calculations									
System		Anode							
Safety Factor	I_{cp} (max design current for all structures)	Anode Style	L_{lineal} (Length of exposed area)		w (width of exposed area) or diameter		SA_{anode} (exposed surface area of anode)		
	A		in	m	in	m	in^2	m^2	
2.0	1.162	2.5/50	20	0.500	1.000	0.025	60.5	0.039	
		2.5/100	39	1.001	1.000	0.025	121.0	0.078	
		2.5C/FW20YR	20	0.508	0.750	0.019	47.1	0.030	
		4C/FW20YR	24	0.610	0.750	0.019	56.5	0.036	

CP System Design (cont.)

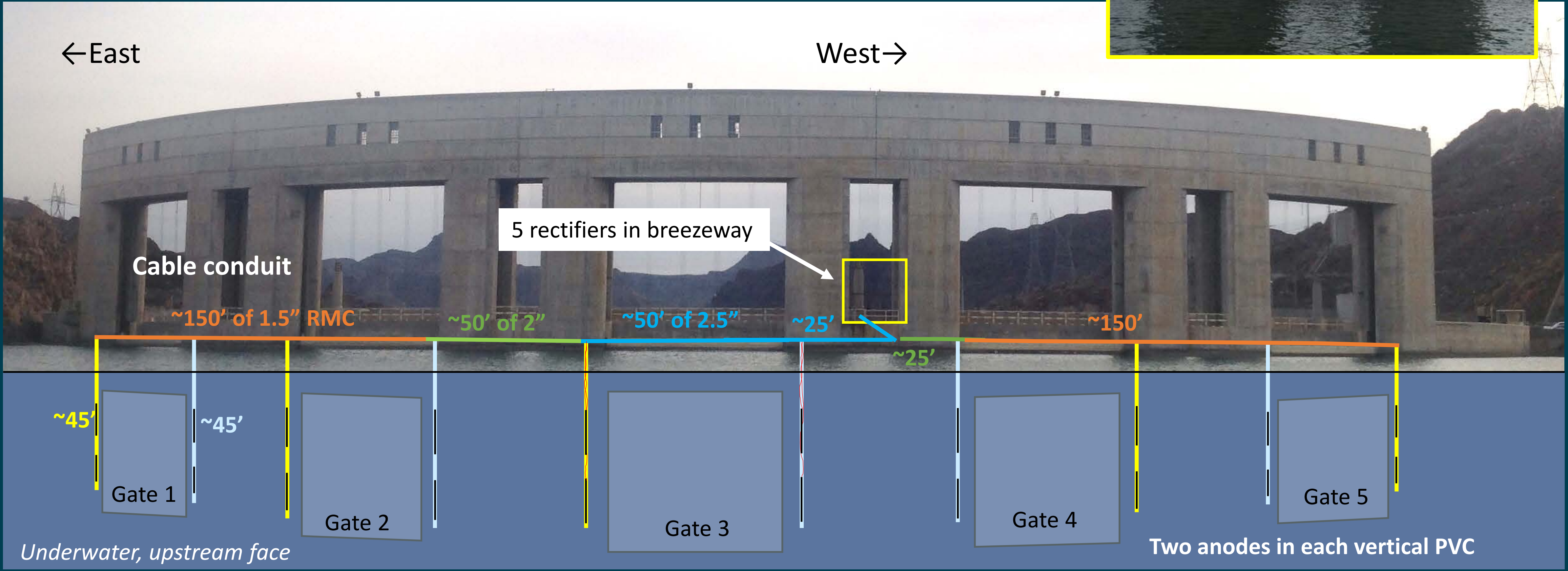
Anode mounting design

- Feasibility:
  Anodes hanging from suspended wire system

- Final:
  Slotted PVC mounted to concrete piers

CP System Design (cont.)

- Conduit size & path – diam. based on # of cables



CP Installation Upcoming

- Dates TBD
  - Delays during Summer 2020 due to COVID circumstances
- Trip #1: installation and initialization
- Trip #2: monitoring and training

Conclusions

- CP design process – case by case

- Work with client
  - Challenges and design changes

Acknowledgements

- John Steffen and Parker Dam staff
- TSC Materials and Corrosion Laboratory (8540), Plant Structures (8120), and Concrete & Structural Laboratory (8530)

Thank you!

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Cathodic Protection Case Study: Mni Wiconi Core Pipeline

Daryl Little, Ph.D.
Materials Engineer, Materials & Corrosion Lab

Cathodic Protection of Pipelines

Webinar Objectives:

- Review of Field Data Collection Procedures
- Data Analysis

CP System Evaluation Process

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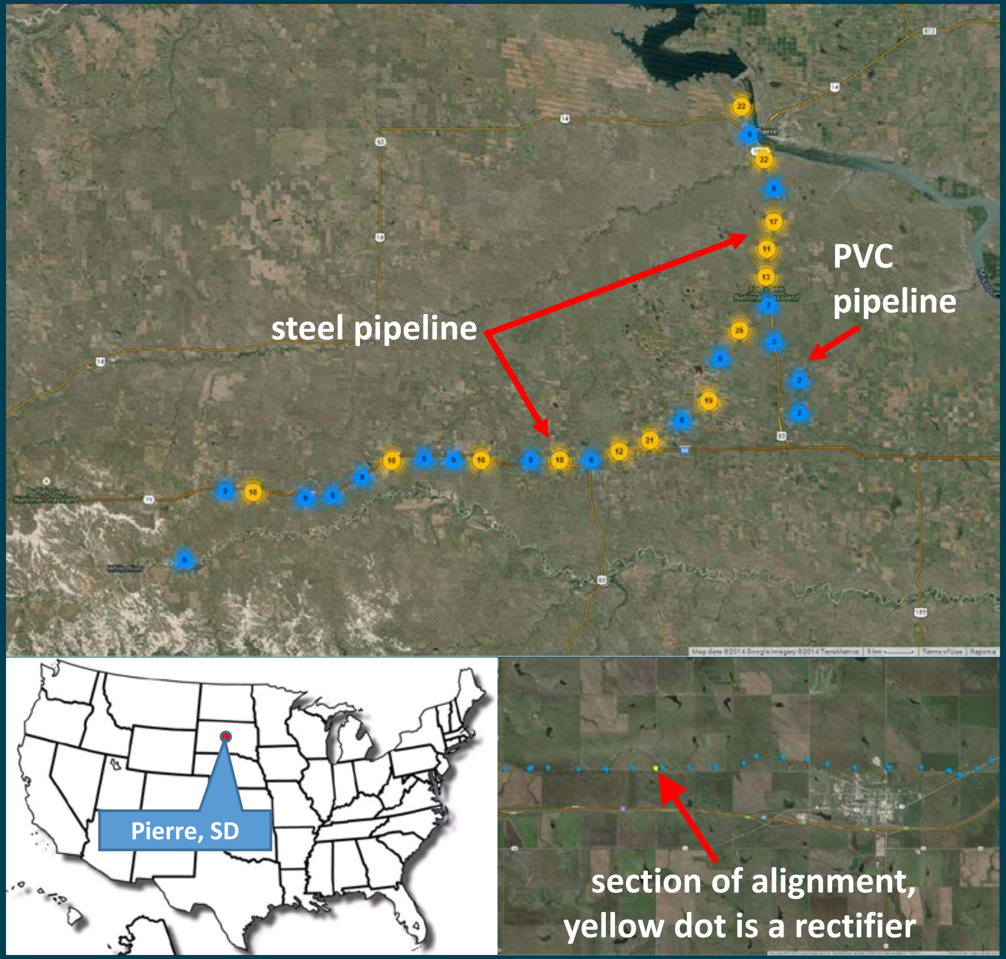
1. Contact us
2. What are your needs?
   a) Testing
   b) Inspection
   c) Repair services
   d) Training
3. What we need from client
   a) Scope of work or problem
   b) Photos
   c) Historical data
   d) Drawings
4. Final products
   a) Report including data, photos, observation, and recommendations/conclusions
      i. Some system repairs may be performed during the survey
   b) SOP for testing CP system

Mni Wiconi Core Pipeline - CP



- Mni Wiconi Core Pipeline
  - Delivers water from the Missouri River west to Kadoka, SD
  - Provides water to over 39,000 people
  - ~123 miles of mostly 26-in diameter welded steel pipe
  - ~94 miles of PVC pipeline
- Cathodic protection
  - Welded Steel Pipeline – ICCP
    - 10 Rectifiers approximately evenly spaced
    - Over 300 test stations
  - PVC pipeline – GACP
    - Zinc anodes on metallic fittings
- System testing
  - MCL was approached to evaluate the CP system in 2014.
  - The system had not been tested in several years.

Mni Wiconi CP System Testing

- MCL was approached to evaluate the CP system in 2014.
  - The system had not been tested in several years and data should be reviewed by MCL personnel approximately every 5 years.
- Annual testing is crucial to ensure the system is both operational and provides adequate protection.
- Utilizing Reclamation resources was desirable in this situation to avoid additional costs by contracting the work out.

Rectifier

Test Stations

CP System Testing

Rectifier Data Collected

- Data collected during the survey is crucial to determine the efficiency of a system.
- Rectifier Data needs include:
    - Condition (broken wires, vegetation overgrowth, insect infestation)
    - Rectifier information (rating, model, style, etc.)
    - Tap settings
    - Voltage output using meters and portable voltmeter
    - Current output using meters and portable voltmeter
    - Current output of anodes using portable voltmeter if possible

Taps

Voltage meter

Amperes meter

Shunt for current measurements

Test Station Data Collected

- Data collected during the survey is utilized to determine the efficiency of a system.
- Test stations are a crucial component for performing these types of surveys.
- Test Station Data needs include:
  - Condition (broken wires, vegetation overgrowth, insect infestation)
  - Uncorrected potential (“on” potential with system energized)
  - Polarized potential (“instant-off” potential with system interrupted)
  - Anode current output for galvanic anode systems
  - GPS coordinates and other identifying features

Test Station and Voltmeter

Reference Electrode

Data Collection Requirements

- To perform the survey the system must be interrupted briefly. This can be performed in the following manner:
  - Disconnecting the anode cable from the structure cable at the shunt for GACP systems.
  - Installing an interrupter in the output circuit of a rectifier for ICCP systems.

- Typical interruption cycle is 7 seconds on and 3 seconds off.
  - Newer data loggers can measure a faster interruption cycle.
  - It is critical to interrupt rectifiers at the same time for systems with multiple rectifiers.

- A previous webinar was given on how to test a cathodic protection system and is available.

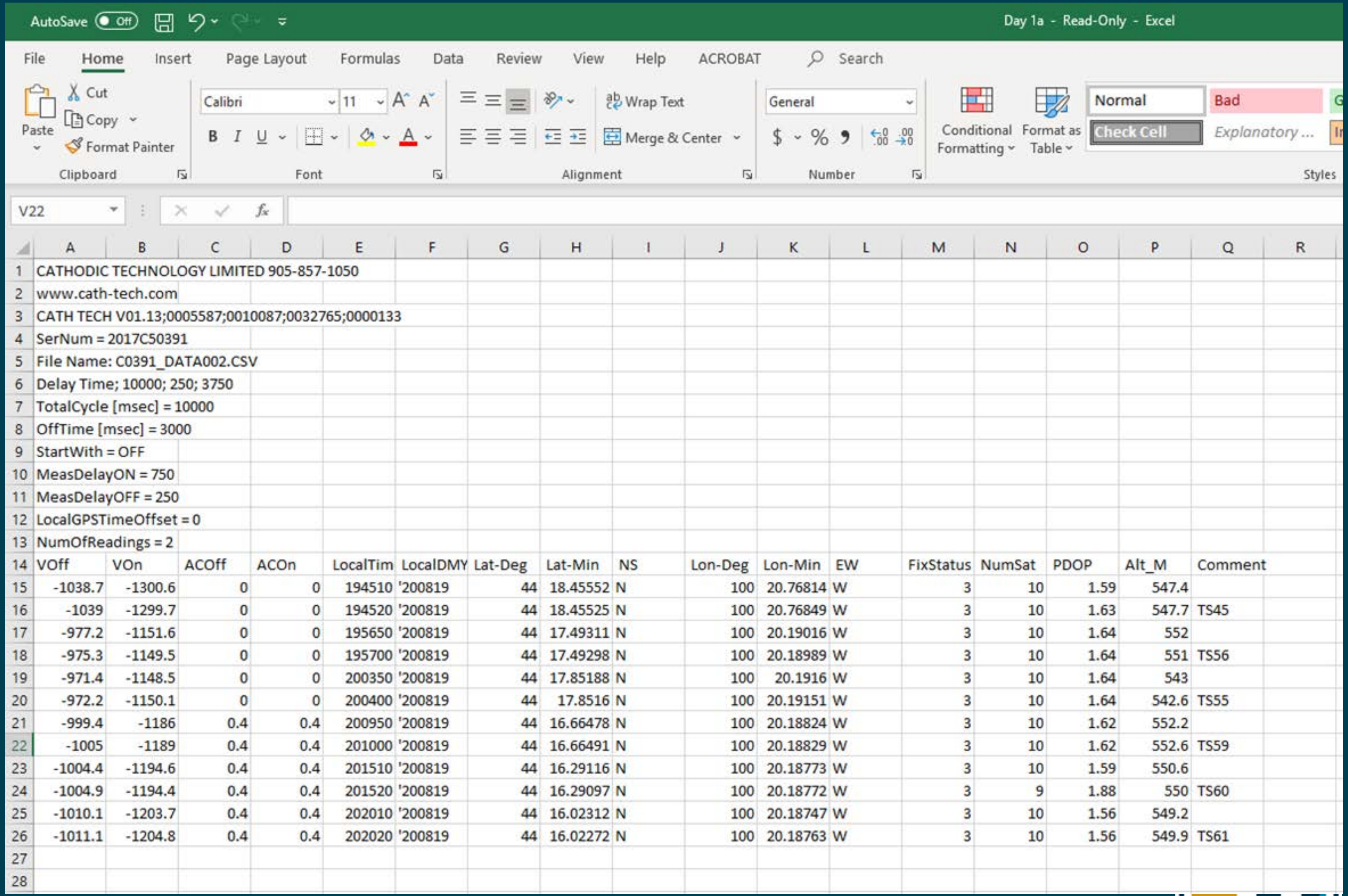
Current Interrupter Installation

Data Logger

Review and Analysis of Collected Data

Data Analysis - ICCP

- Utilizing programs such as Excel, Origin, or equivalent program.
- Upload or input the collected data.
- Data may look like the figure below depending on the method or collection.



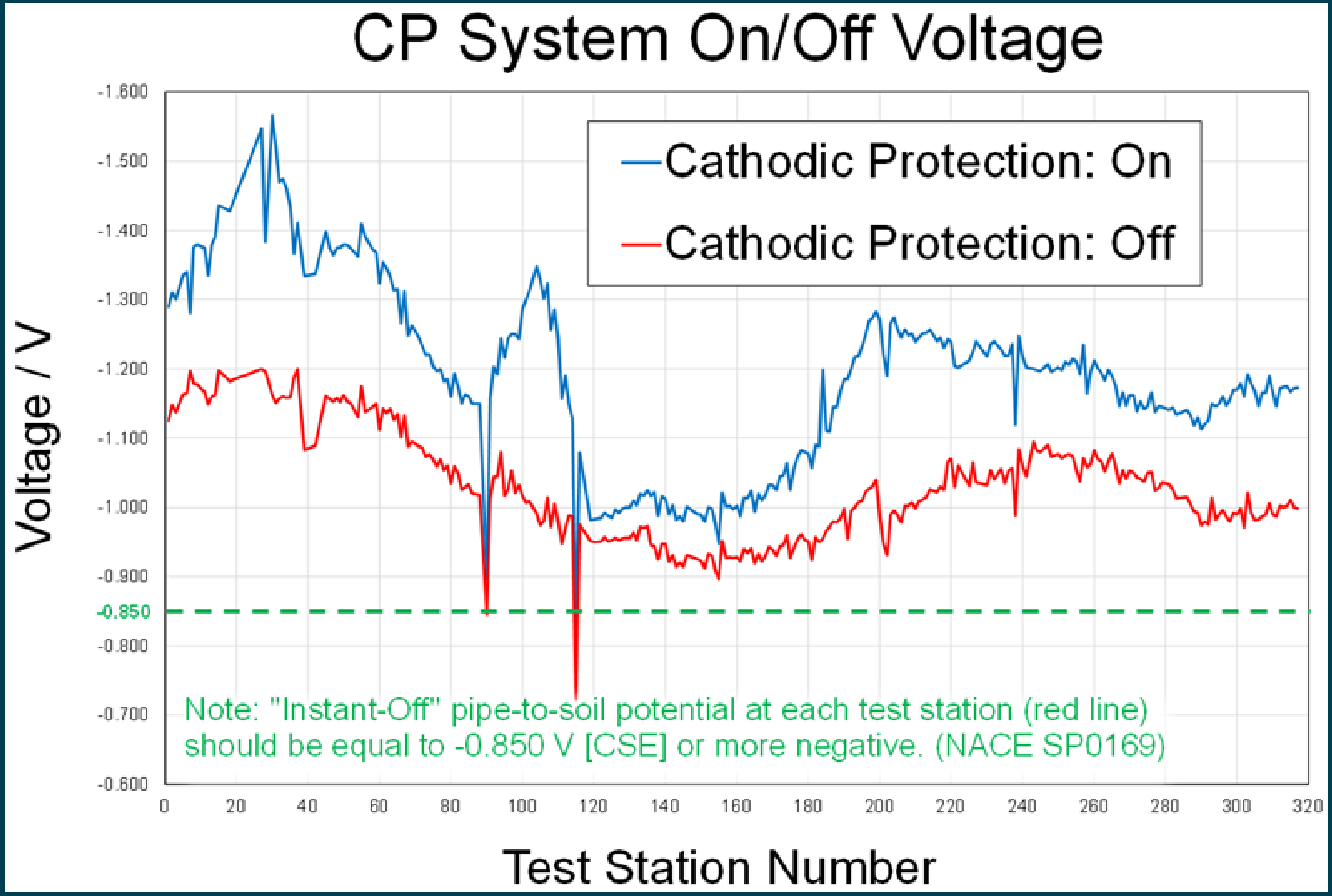
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	CATHODIC TECHNOLOGY LIMITED 905-857-1050																
2	www.cath-tech.com																
3	CATH TECH V01.13;0005587;0010087;0032765;0000133																
4	SerNum = 2017C50391																
5	File Name: C0391_DATA002.CSV																
6	Delay Time; 10000; 250; 3750																
7	TotalCycle [msec] = 10000																
8	OffTime [msec] = 3000																
9	StartWith = OFF																
10	MeasDelayON = 750																
11	MeasDelayOFF = 250																
12	LocalGPSTimeOffset = 0																
13	NumOfReadings = 2																
14	VOff	VOn	ACOff	ACOn	LocalTim	LocalDMY	Lat-Deg	Lat-Min	NS	Lon-Deg	Lon-Min	EW	FixStatus	NumSat	PDOP	Alt_M	Comment
15	-1038.7	-1300.6	0	0	194510	'200819	44	18.45552	N	100	20.76814	W	3	10	1.59	547.4	
16	-1039	-1299.7	0	0	194520	'200819	44	18.45525	N	100	20.76849	W	3	10	1.63	547.7	TS45
17	-977.2	-1151.6	0	0	195650	'200819	44	17.49311	N	100	20.19016	W	3	10	1.64	552	
18	-975.3	-1149.5	0	0	195700	'200819	44	17.49298	N	100	20.18989	W	3	10	1.64	551	TS56
19	-971.4	-1148.5	0	0	200350	'200819	44	17.85188	N	100	20.1916	W	3	10	1.64	543	
20	-972.2	-1150.1	0	0	200400	'200819	44	17.8516	N	100	20.19151	W	3	10	1.64	542.6	TS55
21	-999.4	-1186	0.4	0.4	200950	'200819	44	16.66478	N	100	20.18824	W	3	10	1.62	552.2	
22	-1005	-1189	0.4	0.4	201000	'200819	44	16.66491	N	100	20.18829	W	3	10	1.62	552.6	TS59
23	-1004.4	-1194.6	0.4	0.4	201510	'200819	44	16.29116	N	100	20.18773	W	3	10	1.59	550.6	
24	-1004.9	-1194.4	0.4	0.4	201520	'200819	44	16.29097	N	100	20.18772	W	3	9	1.88	550	TS60
25	-1010.1	-1203.7	0.4	0.4	202010	'200819	44	16.02312	N	100	20.18747	W	3	10	1.56	549.2	
26	-1011.1	-1204.8	0.4	0.4	202020	'200819	44	16.02272	N	100	20.18763	W	3	10	1.56	549.9	TS61

Data Analysis - ICCP

- On/Instant-Off potential data is then plotted versus location as shown and problem areas such as off or polarized potentials below the -850 mV_{CSE} criteria can be identified.

- The -100 mV of polarization can be used in this case due to historical data.

- Data indicates the following:
  - A difference between an on potential and an instant-off or polarized potential.
  - On potentials or uncorrected potentials are not indicators of adequate protection.



Data Analysis - ICCP

- Data can be separated by test station or location and the critical information such as the polarized potentials as shown.
- Not all test stations may be tested every year due to the condition of the test station, broken wires, access, etc.
- This is not an issue when looking at the overall system.
- It is ideal to locate them and test them each year if possible.

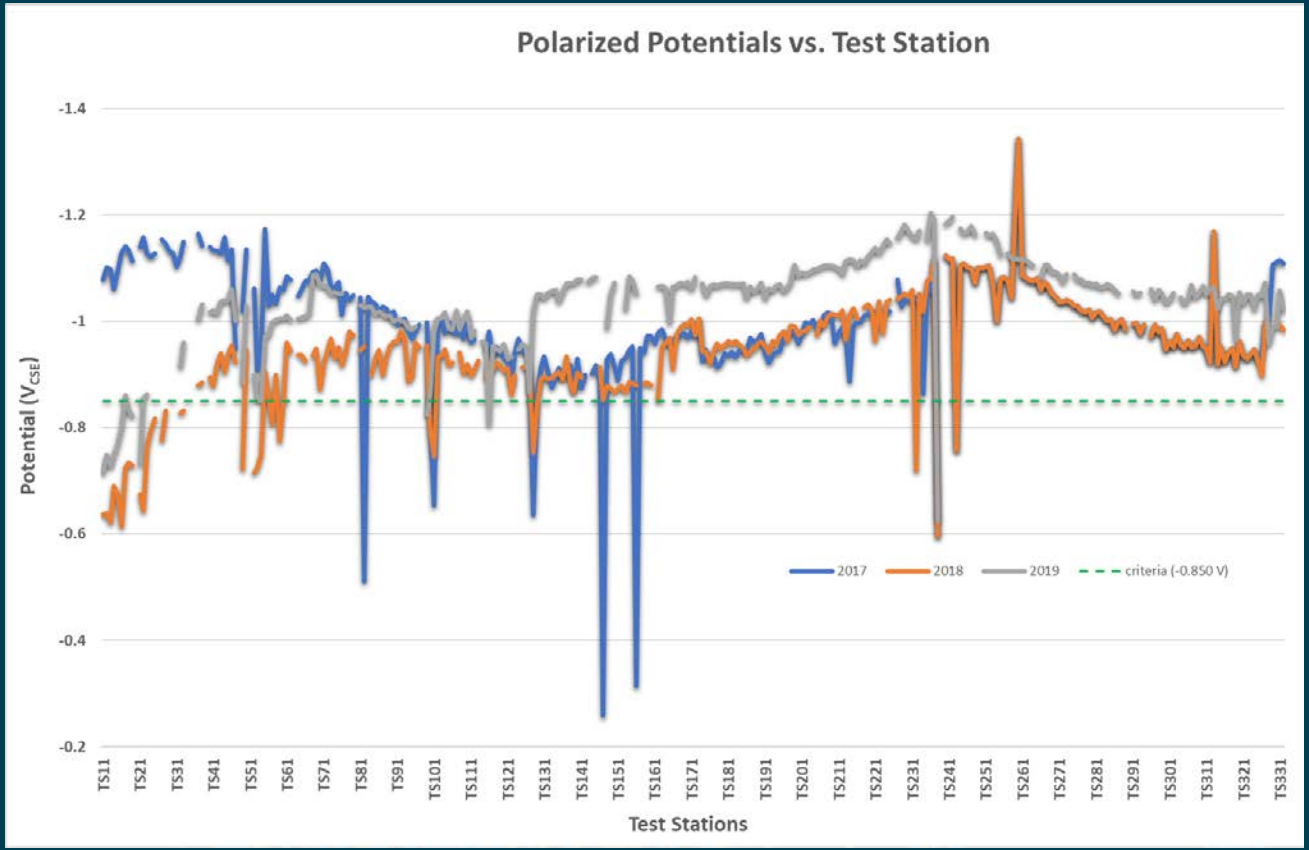
	2017	2018	2019		2017	2018	2019
TS11	-1078.4	-636.4	-715.1		-1.0784	-0.6364	-0.7151
TS12	-1101.7	-639.6	-748.6		-1.1017	-0.6396	-0.7486
TS13	-1097.1	-621.3	-726.7		-1.0971	-0.6213	-0.7267
TS14	-1060.5	-689.7	-747		-1.0605	-0.6897	-0.747
TS15	-1093.6	-674	-769.2		-1.0936	-0.674	-0.7692
TS16	-1129.1	-614	-798.2		-1.1291	-0.614	-0.7982
TS17	-1140.5	-724.7	-861.3		-1.1405	-0.7247	-0.8613
TS18	-1133.7	-734.6	-833.1		-1.1337	-0.7346	-0.8331
TS19	-1113.1	-728.8	-822.2		-1.1131	-0.7288	-0.8222
TS20							
TS21	-1140.1	-673.7	-730.8		-1.1401	-0.6737	-0.7308
TS22	-1159	-644.4	-855.5		-1.159	-0.6444	-0.8555
TS23	-1126.7	-765.4	-862.5		-1.1267	-0.7654	-0.8625
TS24	-1119.9	-795.3			-1.1199	-0.7953	
TS25	-1127.7	-817.9	-896.3		-1.1277	-0.8179	-0.8963
TS26							
TS27	-1154	-776.2			-1.154	-0.7762	
TS28	-1145.4	-832.4			-1.1454	-0.8324	
TS29	-1131.1				-1.1311		
TS30	-1128.8	-674.4	-876.3		-1.1288	-0.6744	-0.8763
TS31	-1103.1				-1.1031		
TS32	-1121.6	-827.1	-915.1		-1.1216	-0.8271	-0.9151
TS33	-1149.1	-831.7	-960.4		-1.1491	-0.8317	-0.9604
TS34							
TS35							
TS36							
TS37	-1164.3	-879.8	-1004.5		-1.1643	-0.8798	-1.0045
TS38	-1142.3	-884	-1031.7		-1.1423	-0.884	-1.0317
TS39							

Inaccessible due to flooding

Data Analysis - ICCP

- Data plotted for multiple years aids in determining any trends in the readings.
  - Effect of rectifier output changes.
  - Effect of a wet or dry season.
  - Which test stations were not tested and how often.
    - Gaps indicate missing, broken, or untested test stations.
    - Significant spikes could indicate a bad measurement, poor cable connection at the pipe.

- Data indicates the following:
  - Locations with polarized potentials between -850 mV_{CSE} and -1100 mV_{CSE} are adequately protected.
  - The polarized potential at TS238 is close to the native potential and a change in values was not observed during the interruption cycle.



Conclusions - ICCP

- The low polarized potentials observed at the beginning of the pipeline were low due to broken bond cables discovered in a vault.
  - Cables were reattached and the next annual survey should indicate higher polarized potential readings.

- The rectifier output should be increased, and the location monitored or investigated at locations with polarized potentials more positive than -800 mV_{CSE}.

- The rectifier output should be reduced where polarized potentials are more negative than -1100 mV_{CSE}.

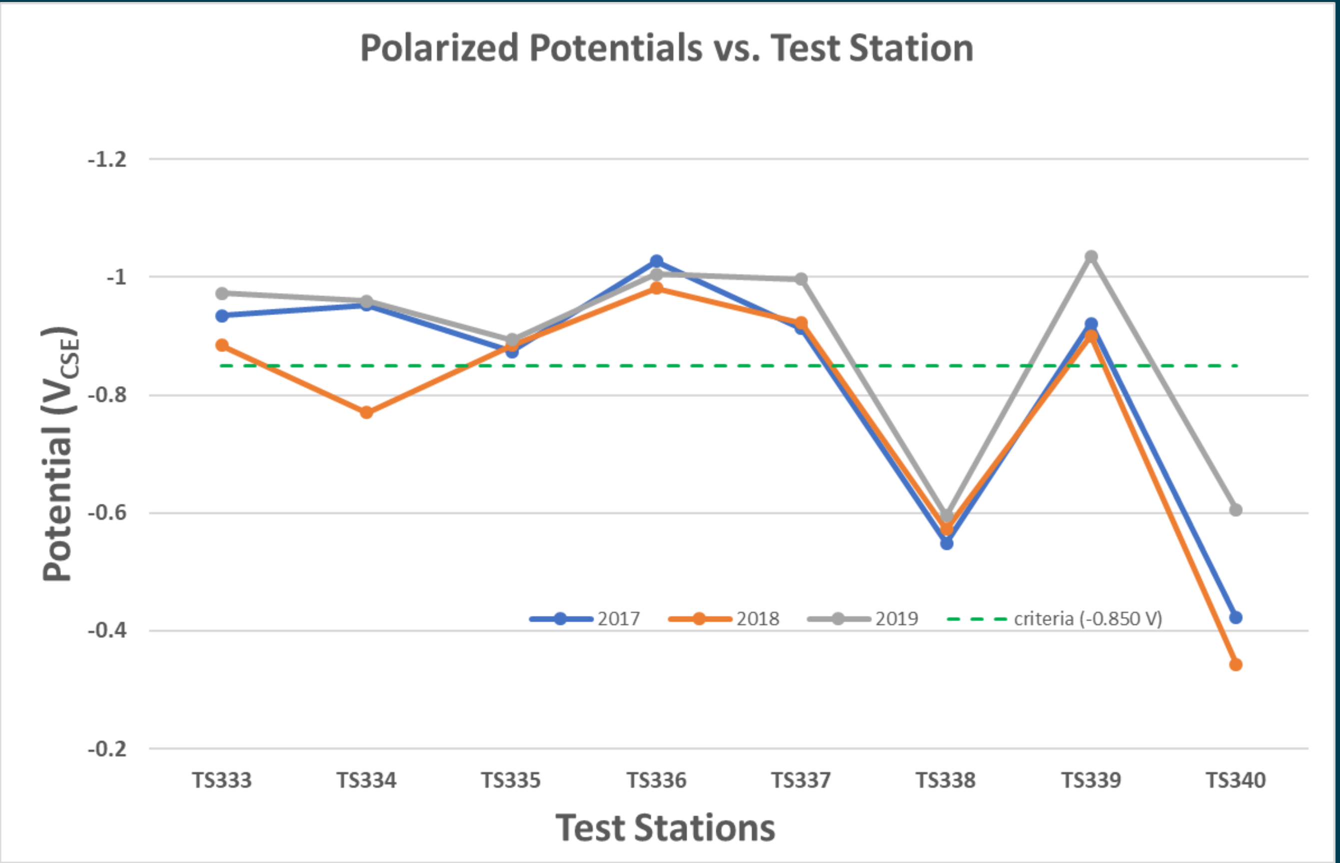
- TS238 should be investigated for a possible short to steel in concrete or other issue.

Data Analysis - GACP

- Galvanic anode cathodic protection data collected on non-metallic pipe is shown in the graph.

- Data plotted for multiple years aids in determining if an anode is nearing its life and when to replace.

- Data indicated the following:
  - Most locations were adequately protected in accordance with the -0.850 V_{CSE} criteria.
  - TS338 and TS340 indicate inadequate protection.



Conclusions - GACP

- It is recommended that the anodes at TS338 and TS340 be replaced as soon as possible.
- All locations should be closely monitored yearly due to the anode replacement required at the test stations.

Thank you!

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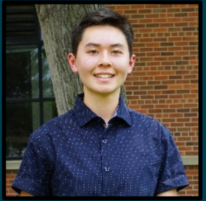

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