

# RECLAMATION

*Managing Water in the West*

*Corrosion Webinar Series*

## Cathodic Protection 101

**Presented by:**



**Jessica Torrey, PhD**

**Materials Engineer**

**TSC, Materials Engineering and Research Laboratory**



**U.S. Department of the Interior  
Bureau of Reclamation**

# Your TSC Corrosion and Coatings Staff:



## Cathy Chan

M.S. Materials Engineering  
cchan@usbr.gov  
303-445-2390



## Bobbi Jo Merten

Ph.D. Coatings and Polymeric Materials  
bmerten@usbr.gov  
303-445-2380



## Rick Pepin, PCS

Materials Engineer  
rpepin@usbr.gov  
303-445-2391



## Allen Skaja, PCS

Ph.D. Coatings and Polymeric Materials  
askaja@usbr.gov  
303-445-2396



## David Tordonato, P.E.

Ph.D. Materials Engineering  
dtordonato@usbr.gov  
303-445-2394

## Chrissy Daniels

Materials Engineer  
cdaniels@usbr.gov  
303-445-2348



## Daryl Little

Ph.D. Materials Engineering  
dlittle@usbr.gov  
303-445-2384



## Lee Sears, P.E.

Ph.D. Materials Engineering  
lsears@usbr.gov  
303-445-2392



## Roger Turcotte, P.E., CPS

Materials Engineer  
rturcotte@usbr.gov  
303-445-2383



## Jessica Torrey

Ph.D. Materials Science and Engineering  
jtorrey@usbr.gov  
303-445-2376



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# *What is Corrosion?*

*the deterioration of a material  
and/or its properties  
caused by a reaction with its environment*

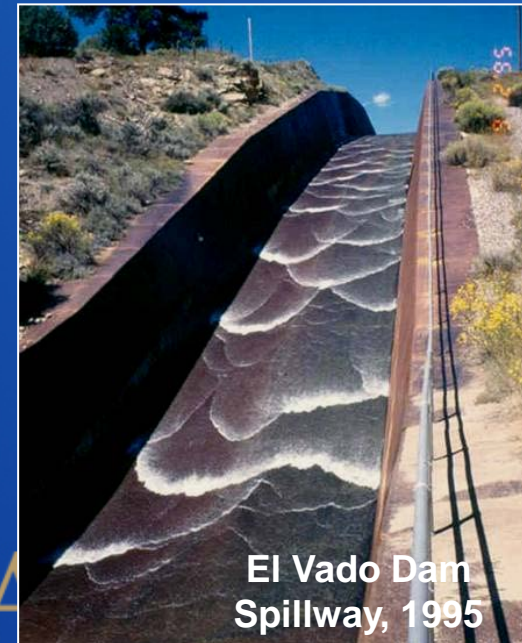
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# *The Corrosion Reaction*

Reaction between  
a Metal and an Electrolyte

***oxidation (rusting) of steel in water or soil***



# *Corrosion Mitigation Methods*

**Materials Selection**

**Protective Coatings**

**Cathodic Protection**

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# *What is Cathodic Protection?*

**Cathodic Protection (CP)** *is a technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell*

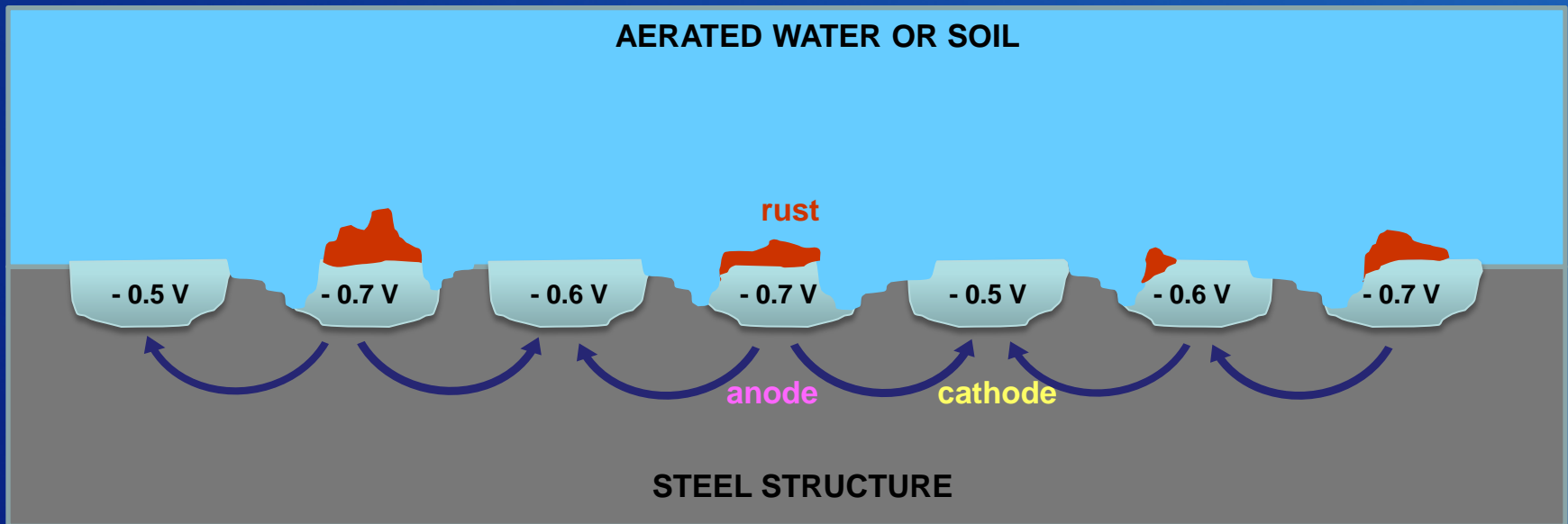
# How Cathodic Protection Works

## Corrosion

- Anodic and cathodic regions exposed to an electrolyte react with each other resulting in corrosion

### Four things needed for corrosion:

- **A**node – the corroding metal
- **C**athode – the metal that doesn't corrode
- **M**etallic Return Path – ex. the steel pipe
- **E**lectrolyte – the soil or water



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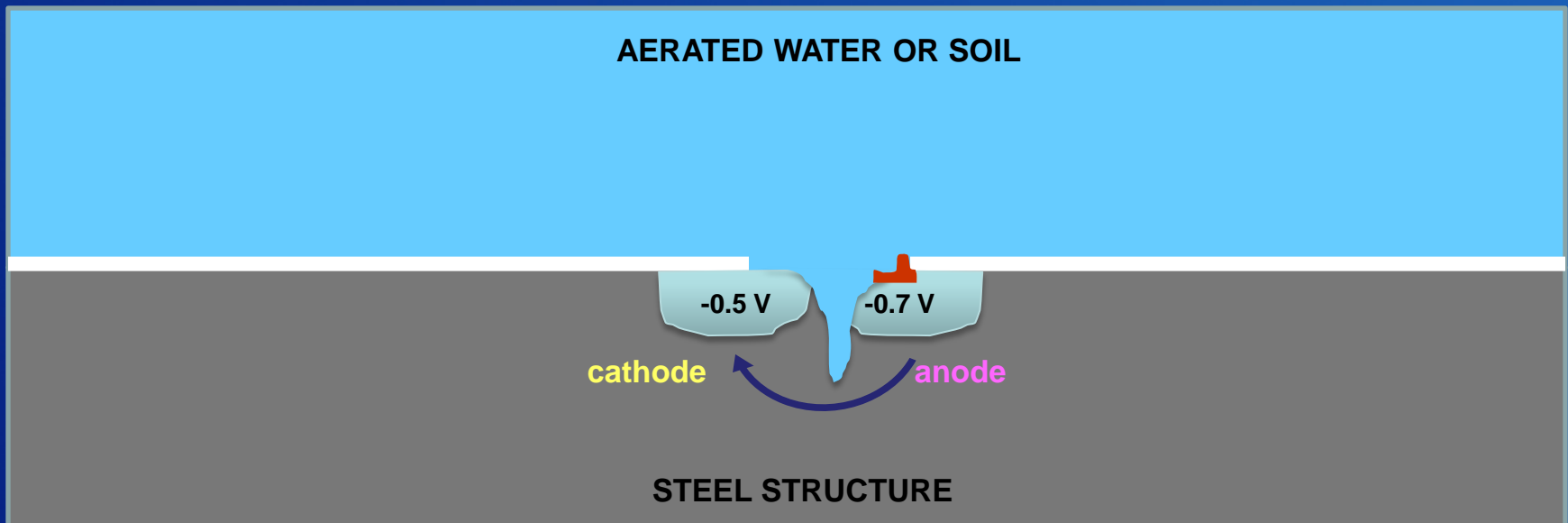
# How Cathodic Protection Works

## Mitigation- Coating

- Primary defense against corrosion acting as a barrier between metal and electrolyte
- May contain defects where corrosion can occur

## Four things needed for corrosion:

- *Anode* – the corroding metal
- *Cathode* – the metal that doesn't corrode
- *Metallic Return Path* – ex. the steel pipe
- *Electrolyte* – the soil or water



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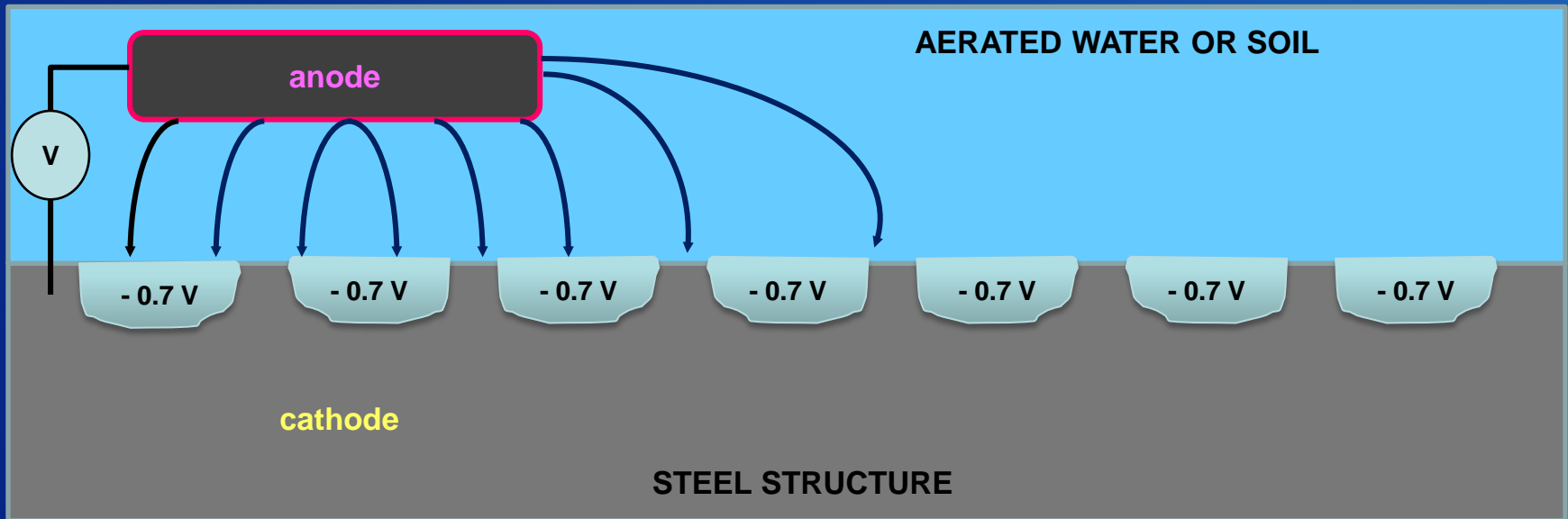
# How Cathodic Protection Works

## Mitigation- Cathodic Protection

- Control the corrosion by making the structure the cathode
- This takes a huge amount of current for a bare structure- not economical.

## Four things needed for corrosion:

- *Anode* – the corroding metal
- *Cathode* – the metal that doesn't corrode
- *Metallic Return Path* – ex. the steel pipe
- *Electrolyte* – the soil or water



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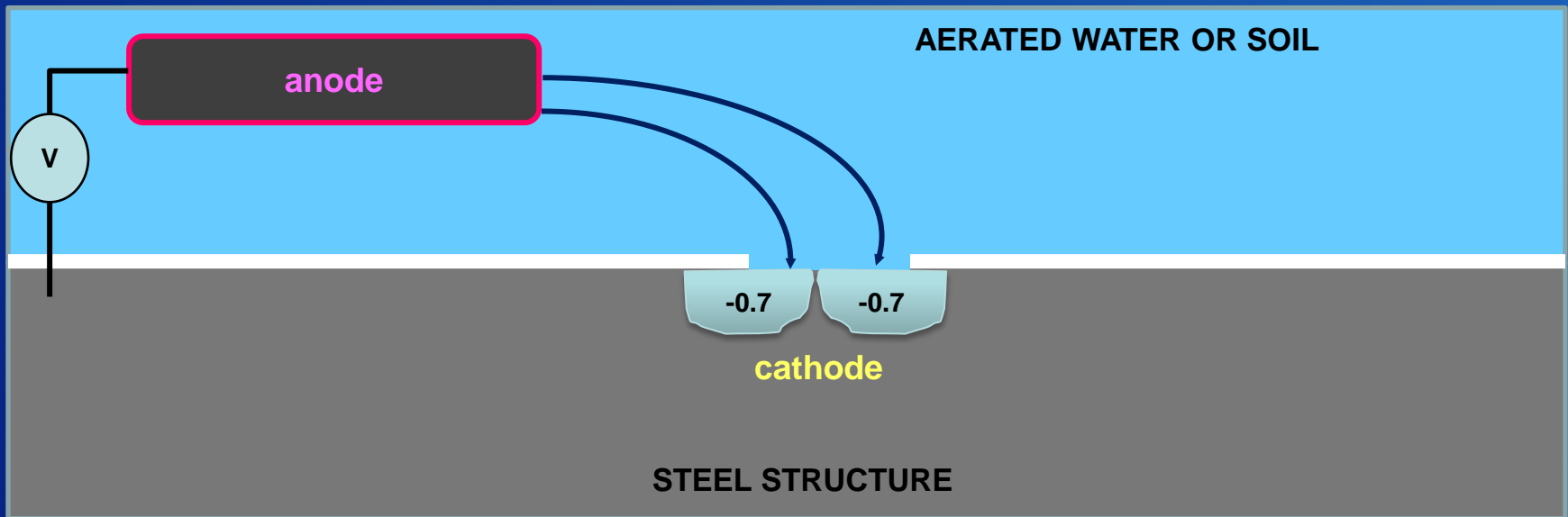
# How Cathodic Protection Works

## Mitigation- Coating with CP

- Coating- provides barrier and limits amount of bare steel
- CP- protects exposed steel only at defects in the coating

## Four things needed for corrosion:

- *Anode* – the corroding metal
- *Cathode* – the metal that doesn't corrode
- *Metallic Return Path* – ex. the steel pipe
- *Electrolyte* – the soil or water



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# Corrosion Protection

A **coating** is the primary defense against corrosion.

**Cathodic protection** works with the coating to protect the structure at defects in the coating.

***The most effective corrosion protection system for buried and submerged structures involves a good coating and cathodic protection.***

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# *Two Forms of Cathodic Protection*

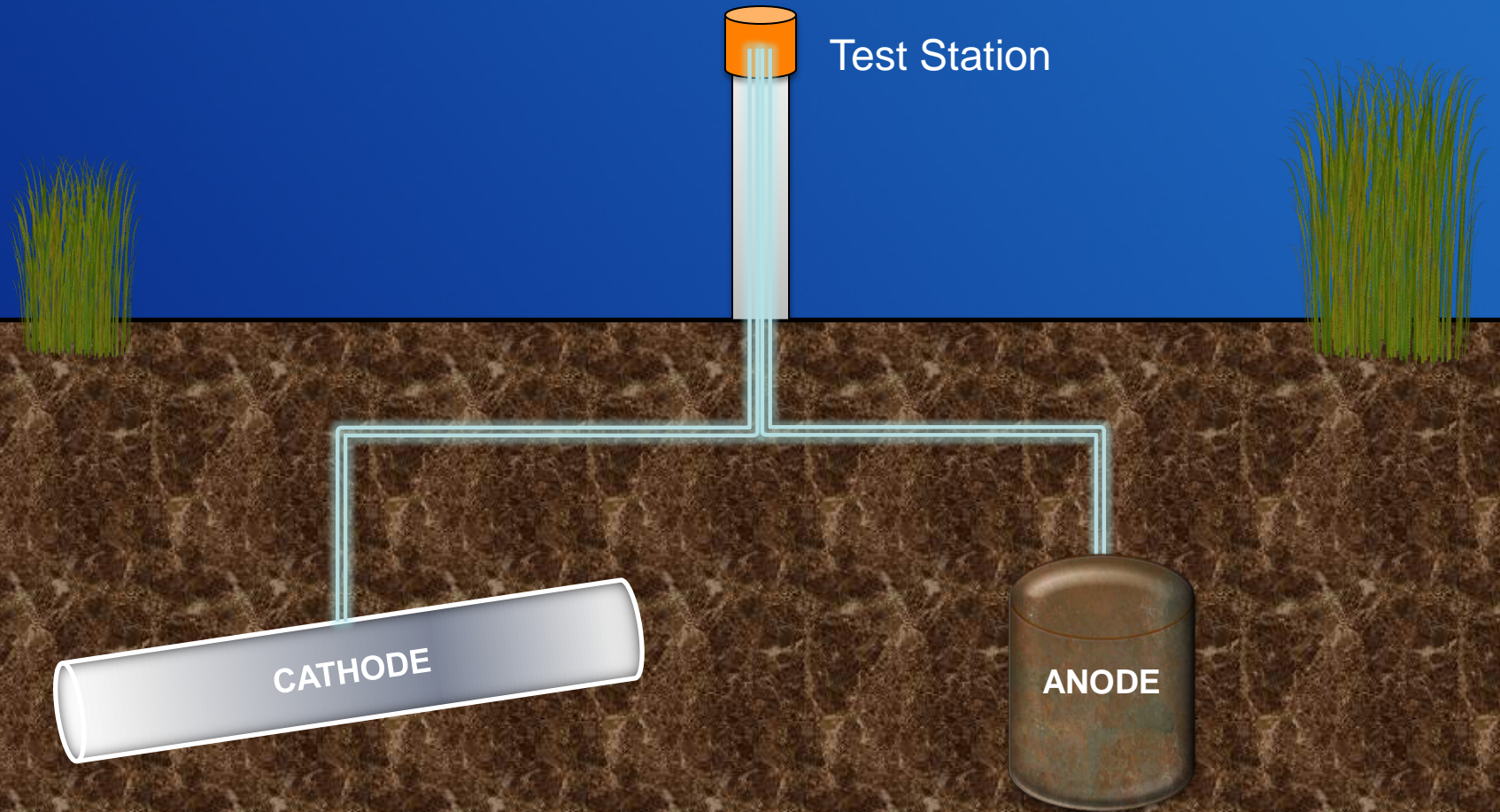
- **Galvanic Anode**
  - Structure directly connected to a sacrificial anode
  - Current provided by natural voltage difference between metals (galvanic corrosion)
- **Impressed Current**
  - Structure connected to anodes through rectifier
  - Current supplied by rectifier



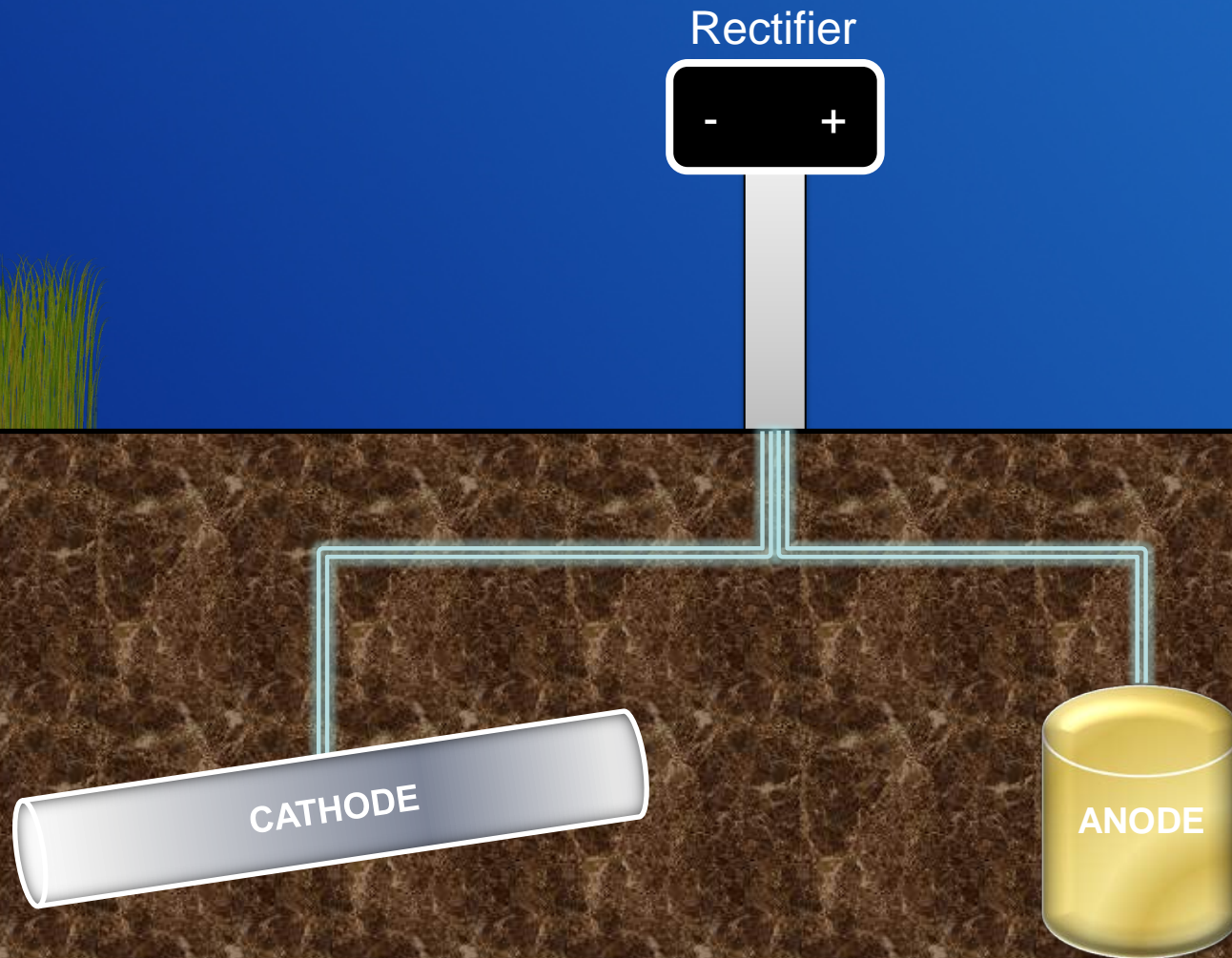
# *Galvanic Anode CP System*



# *Galvanic Anode CP System*



# *Impressed Current CP System*



# *CP System Components*

- **Anodes**
- **Metallurgical Bonds**
- **Test Stations**
- **Junction Boxes**
- **Rectifiers**
- **Cable**



# Buried/Submerged Components

## Sacrificial Anodes: Mg, Zn, Al



## Impressed Current Anodes: Graphite



**IC: Pt/Nb  
wire anode  
in slotted  
PVC tube for  
submersion**



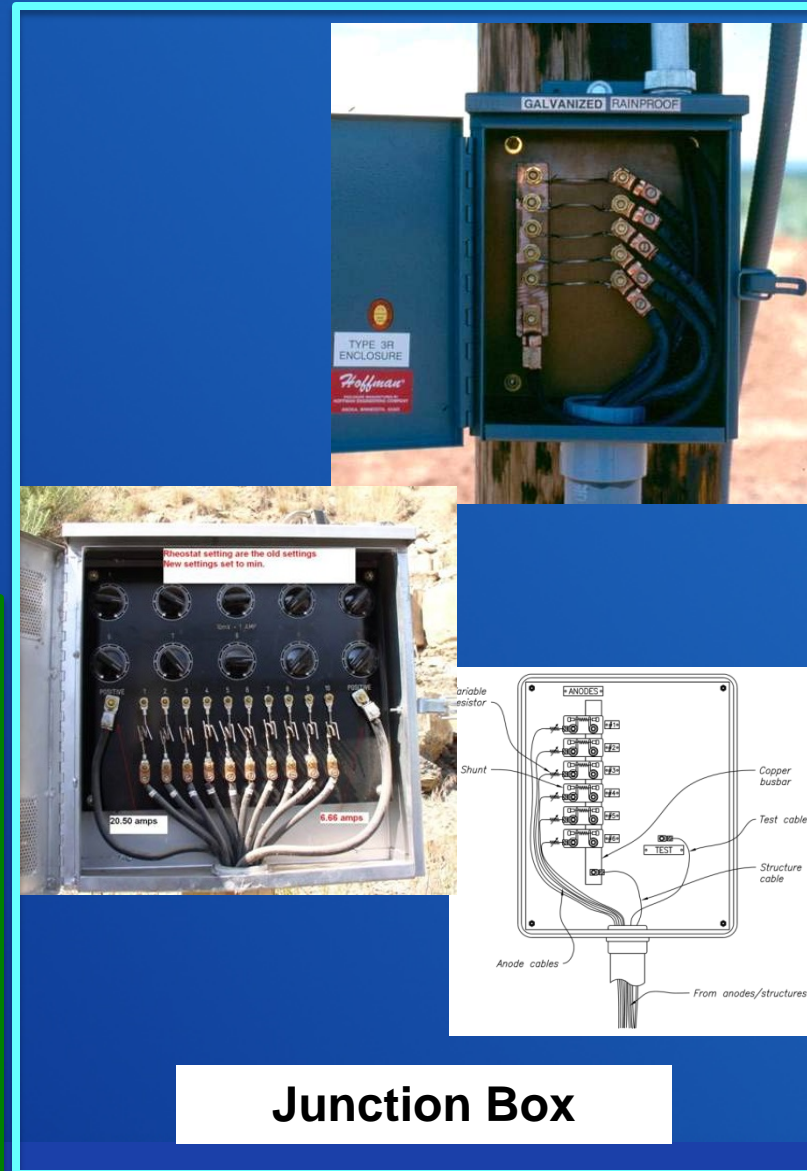
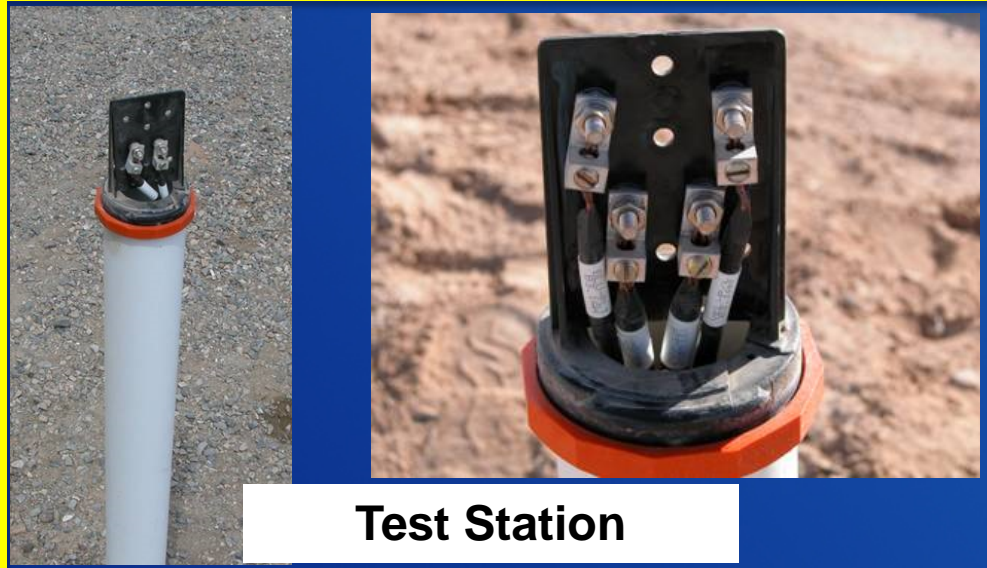
**Metallurgical Bond**



**IC: High-Silicon Cast  
Iron anodes**



# Above-Ground Components



# Test Station/Junction Box Components



**Hardware**



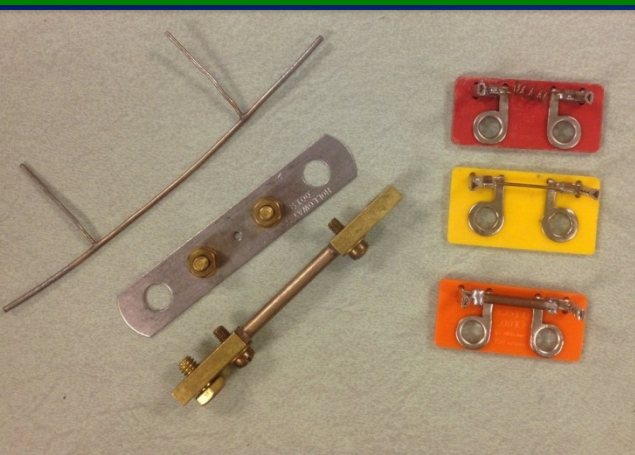
**Busbar**



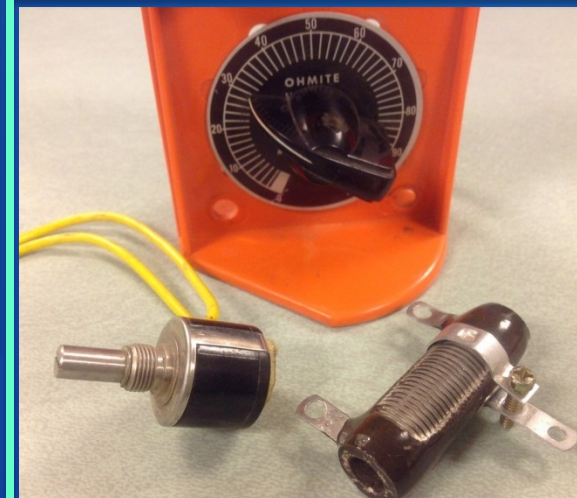
**Bond Bar**



**HMWPE Cu Cable**



**Shunt**



**Variable Resistor**



# Rectifier Components

Coarse Tap

Fine Tap

AC Primary  
Breaker

AC Secondary  
Breaker

Shunt

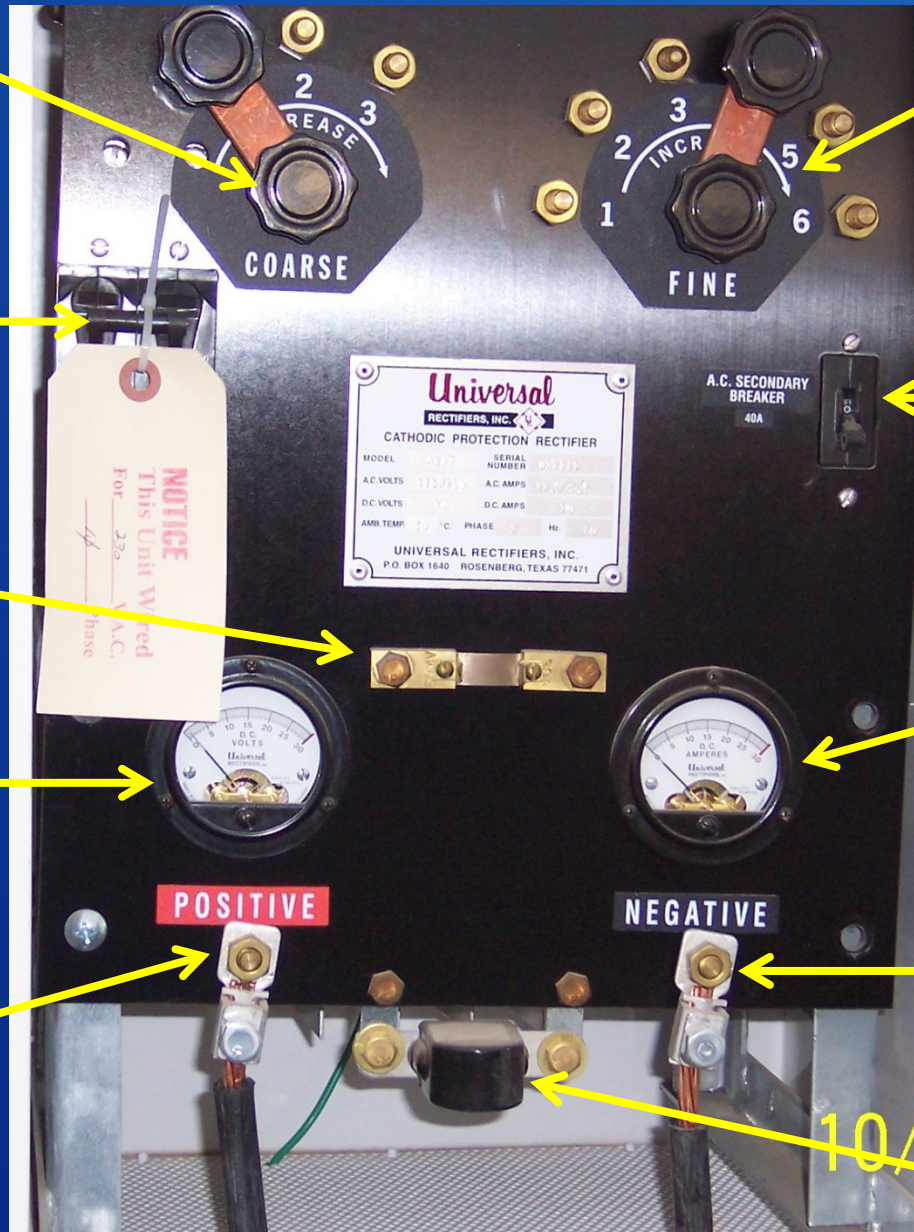
Ammeter

Voltmeter

Positive DC  
Output - to  
anode

Negative DC  
Output - to  
structure

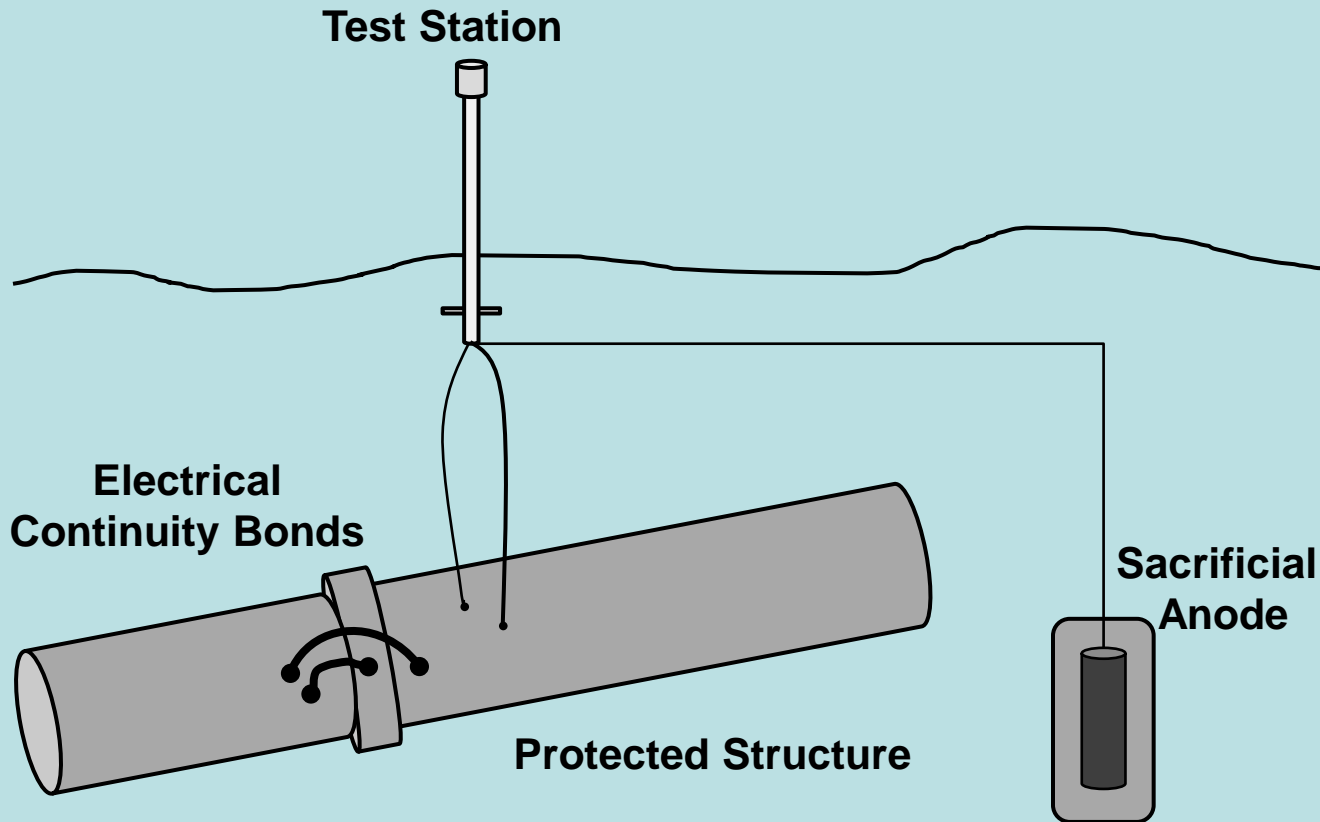
Lightning  
Arrestor





# Galvanic CP System

San Xavier Farm Rehabilitation,  
July 2007



Mg Anode for Burial

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# Galvanic Anode CP System

Palo Verde Diversion Dam Radial Gate, January 2013



- Also known as **Sacrificial Anode Cathodic Protection**
- This system provides a cathodic protection current by **galvanic corrosion** or by sacrificing one material to prevent corrosion of the other material

## Features:

- Low current requirements
- Typically protect smaller surface areas
- No external power needed
- Low maintenance

New Mg Anode



Old Mg Anodes



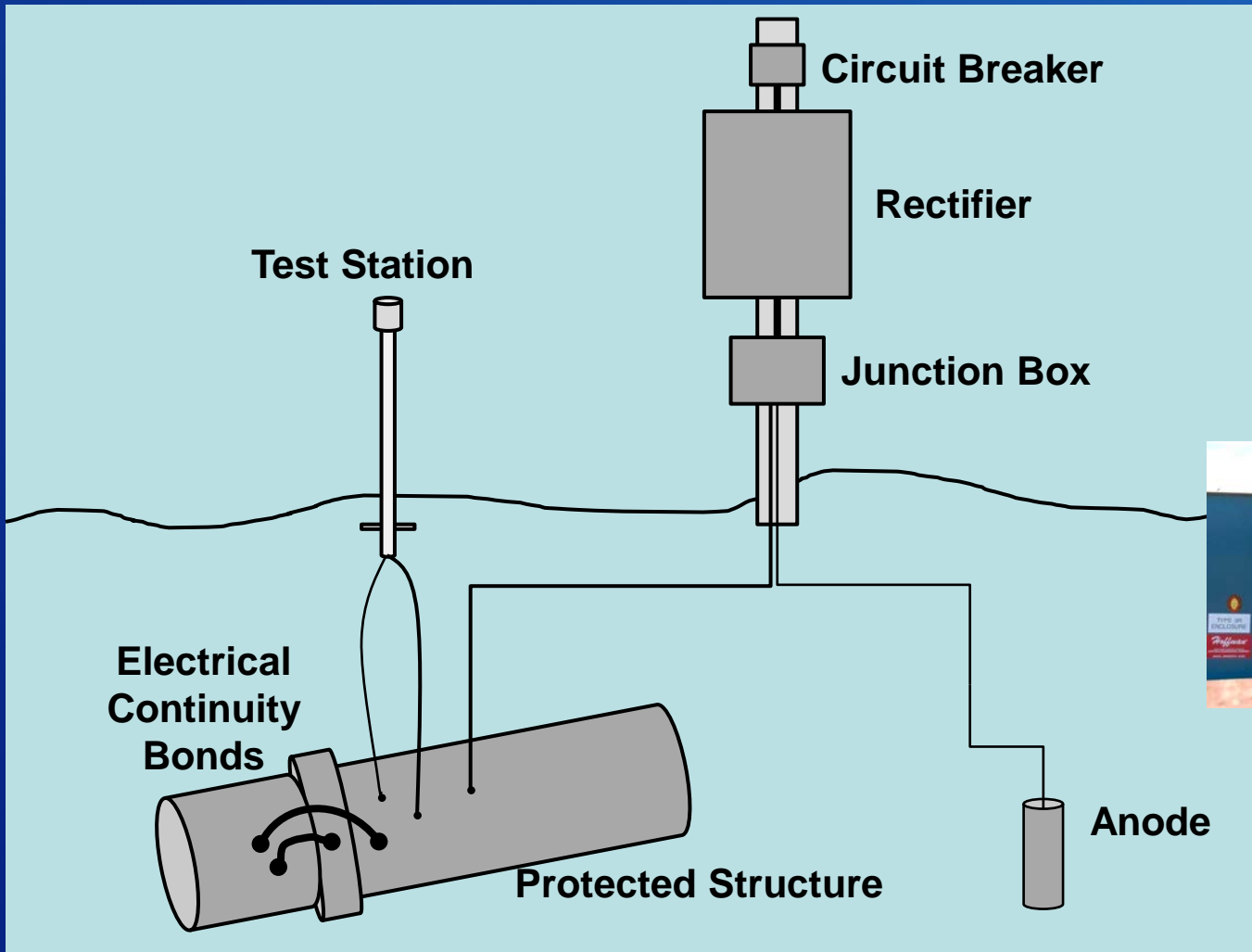
- Both the structure and the anode must be in contact with the electrolyte (water or soil)

## Anodes:

- Soil and Fresh Water- Magnesium (and Zinc)
- Brackish Water- Aluminum and Zinc

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# Impressed Current CP System



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# Impressed Current CP System



- This system provides a cathodic protection current from an **external power source**
- A direct current power source forces current to discharge from anodes, through the electrolyte, and onto the structure to be protected
- Both the structure and the anode must be in contact with the electrolyte

## Features:

- High flow of water
- High current requirements
- Can handle large or poorly coated structures

Mixed Metal Oxide Disk Anode



Graphite Anodes



## Anodes:

- Graphite, High-Si Cast Iron, Mixed Metal Oxide, Platinum

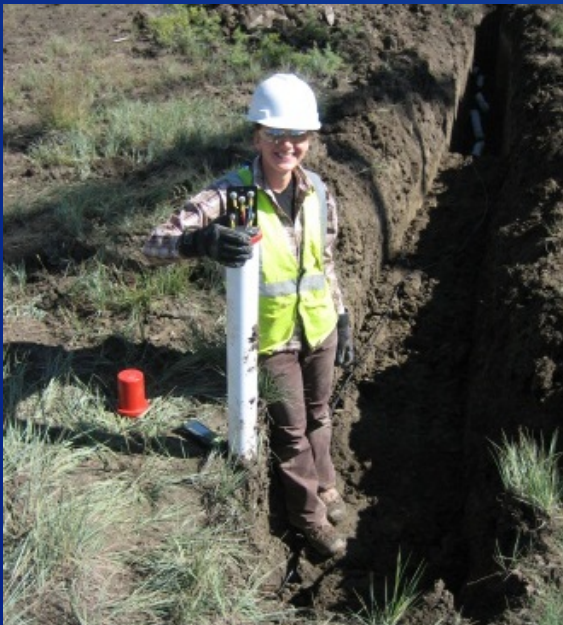
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# *Where will you find CP?*

## Burial:

- Pipelines
- Tanks/ Tank Bottoms
- Metallic Fittings



GACP, Mesa Verde National Park, 2013

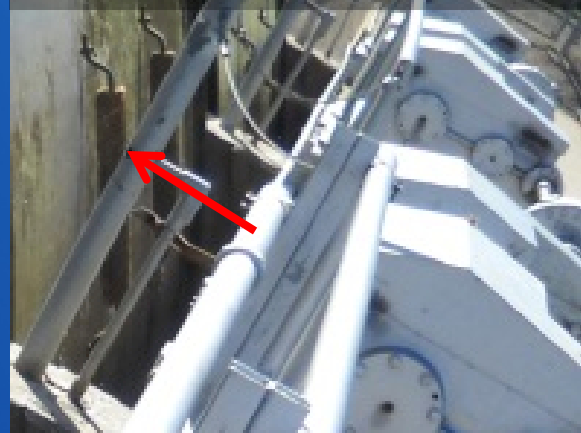


# Where will you find CP?

## Immersion:

- Gates
- Tank Interiors
- Air Chambers
- Pipe Interiors
- Trash Racks
- Fish Screens
- Pumps

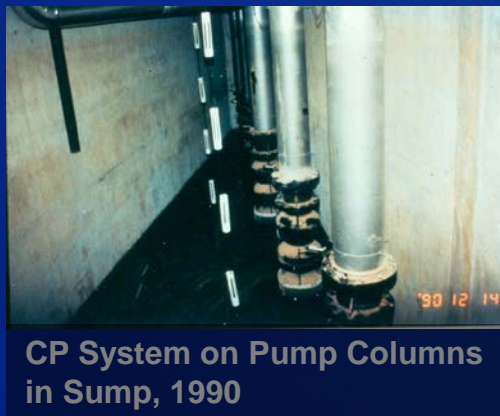
Delta-Mendota Canal, February 2013



Nimbus Radial Gate Hoist Ropes, 2010



Angostura Dam Radial Gates, May 2011



CP System on Pump Columns  
in Sump, 1990



# Operation & Maintenance

**TSC typically designs cathodic protection systems for a minimum 20-year lifetime.**

- Coating and corrosion visual inspection: preferably annually or when structure is available due to dewatering, etc.
- Check rectifiers: every 1-2 months; adjust when advised
- Pipeline survey at test stations: annually
- Repair/replace test stations and other components as needed
- Replace anodes: when there is insufficient current

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# NACE CP Protection Criteria

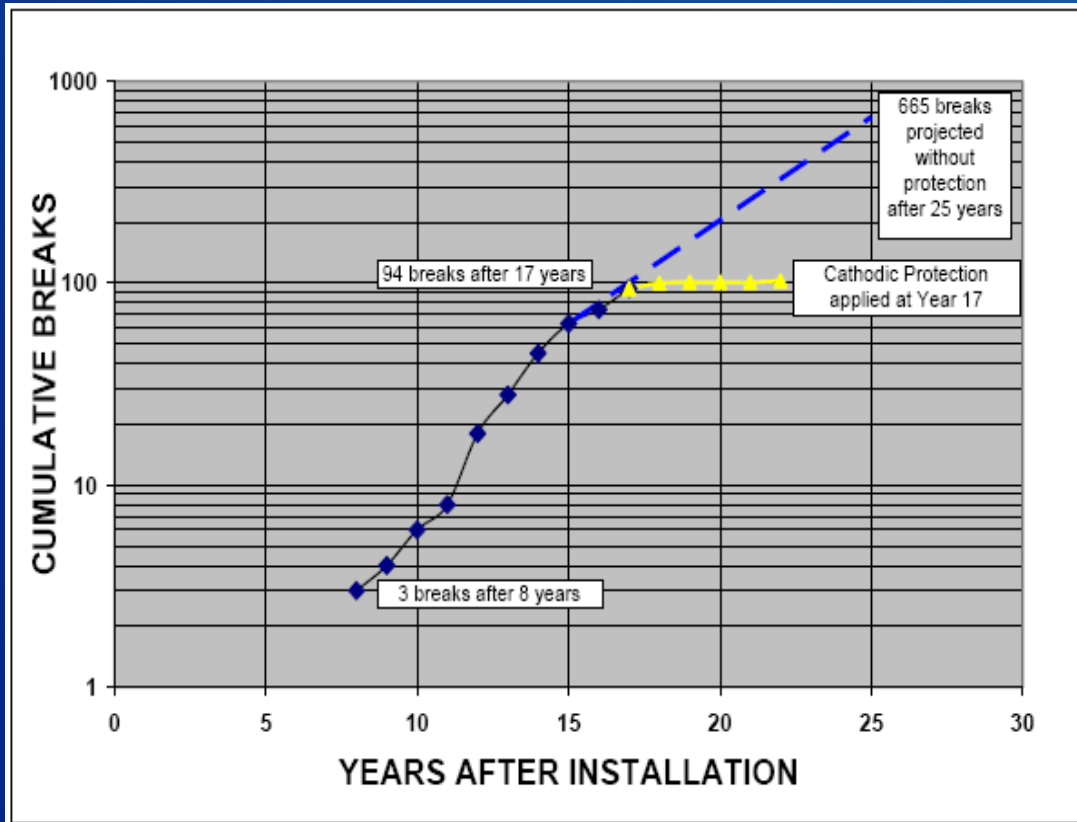
- A polarized potential of **-850 mV<sub>CSE</sub>** or more negative (a.k.a. Instant OFF structure-to-electrolyte potential)
- A minimum of **100 mV<sub>CSE</sub> shift** cathodic polarization, i.e. 100 mV more negative than the native potential of the structure
- In addition to the above criteria, Reclamation recommends that the polarized potential of the structure shall not be more negative than **-1100 mV<sub>CSE</sub>**

\*\* mV<sub>CSE</sub> means millivolts as measured with a copper-copper sulfate reference electrode



# Corrosion Management Programs

## Effectiveness of Well Designed Program



Durham Region, Ontario, Canada, Implemented in 1983

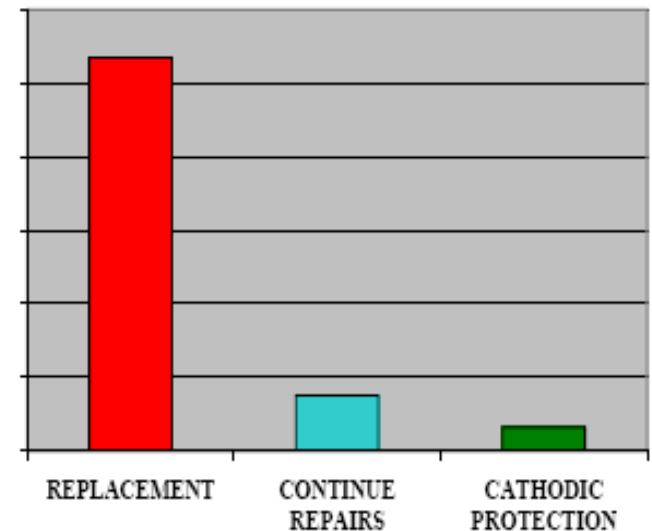
- 193 kilometers of ductile and cast iron water main cathodically protected,
- 17,032 anodes and 1,330 test stations
- ~100 known breaks/yr before CP down to 28 corrosive breaks in 2005
- \$5m to install CP, less than 4% of estimated cost to replace of \$135.4m

Ontario Centre for Municipal Best Practices, "Best Practices Summary Report, Water Loss Management- Cathodic Protection," February 2008.

## Economic Benefits

Annualized Costs – 20 Yr. Cycle

**Life Extension Cathodic Protection 58% less expensive than continuing with repairs**



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# *Corrosion Protection*

**The most cost effective corrosion protection system for buried and submerged structures involves a**  
**good coating and cathodic protection.**

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# Coatings and Corrosion Manuals



[http://www.usbr.gov/pmts/materials\\_lab/publications/](http://www.usbr.gov/pmts/materials_lab/publications/)

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# Questions/ Comments?



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