# PRESENTATION

# Metallic Density Modeling to Support Cathodic Protection System Design and Optimization

## RADIATION SAFETY & CONTROL SERVICES

RSCS provides expert solutions from routine to complex nuclear and radiological projects including, specialty engineering, inspections and investigations, project management, professional consulting, technical staffing, radiation safety training, radiation training simulators, and instrument and analytical lab services.

Our Environmental and Engineering Services Division delivers a wide range of specialty solutions to clients dealing with civil, geotechnical, hydrogeological, asset management and inspection license renewal commitment support. The RSCS site investigation and geotechnical consulting staff include ABHP Certified Health Physicists and many professional and technical experts in various fields including Project Management, Regulatory Affairs, Engineering, Operational Health Physics, Geology, Hydrogeology, Soil Science, Chemistry, and Final Status Survey. We are recognized industry expert in the area of nuclear power and industrial site characterization and decommissioning.

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## Get in Touch

Have questions or need a quote? Contact Matt Darois, RSCS Director of Environmental & Engineering


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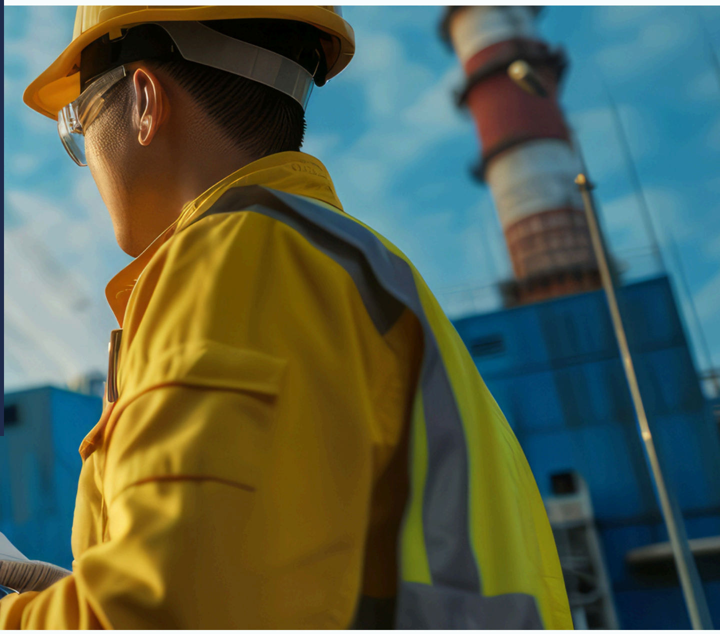
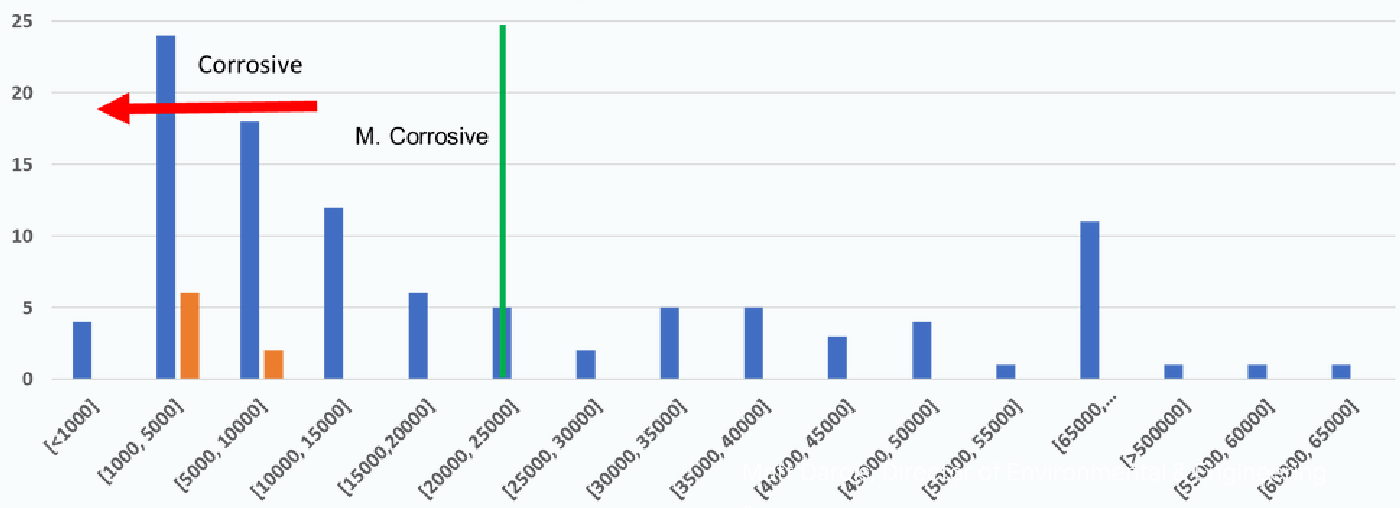


## How Bad Is It?

RSCS is the nuclear power industry leader in planning and performing soil corrosivity assessments in accordance with applicable industry standards and EPRI guidance. We have performed these assessments at more than half of the US nuclear sites and maintain a database for comparative assessment and reporting.  Results of these assessments demonstrate that the majority of nuclear power sites have corrosive soils.

Nuclear Power Plant Soil Corrosivity Assessment Example (NUREG-1801 Rev 2): Soil Resistivity (ohm.cm) Distribution (Orange) Compared to the US Nuclear Fleet Data (Blue)



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## Significance

**NUREG-1801 Rev. 2 (Guidance on Aging Management: SLR and EPO):**

- Enhancements to Aging Management Programs to subsequent renewal period.
- Includes modifications to cathodic protection (CP) systems or enhanced maintenance and monitoring strategies based on OE from pre-EPO periods.
- Greater emphasis on performance monitoring of CP systems
- Validation that CP systems meet protective criteria
- Performance/effectiveness through enhanced inspections, testing, and operating history:
  - i.e long-term trending that might indicate a reduction in system performance.
- Buried piping integrity must be maintained for the duration of the subsequent license renewal period
- Effective Cathodic Protection provides reasonable assurance that the buried piping will not corrode over time

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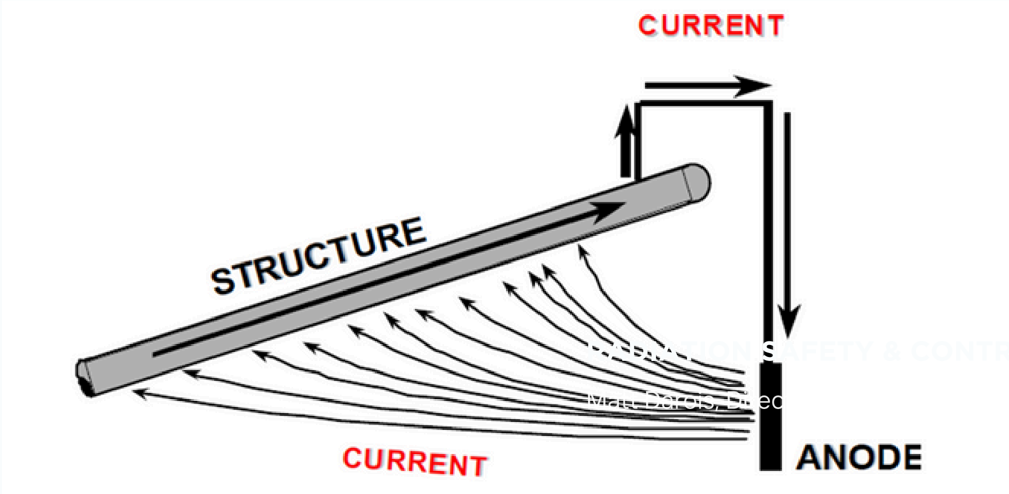
## Cathodic Protection Basic Overview

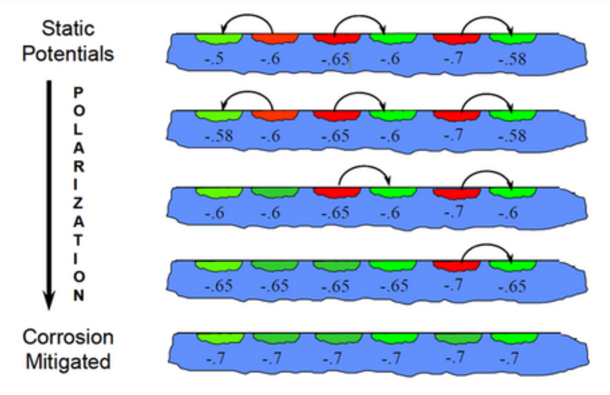
- Cathodic Protection (CP) provides corrosion control to external surfaces of buried or submerged metallic structures
- This is done by impressing a DC voltage and current, through the soil, onto the exposed metal surfaces
- CP systems use anodes either deep / remote or shallow / adjacent to structures intended for protection

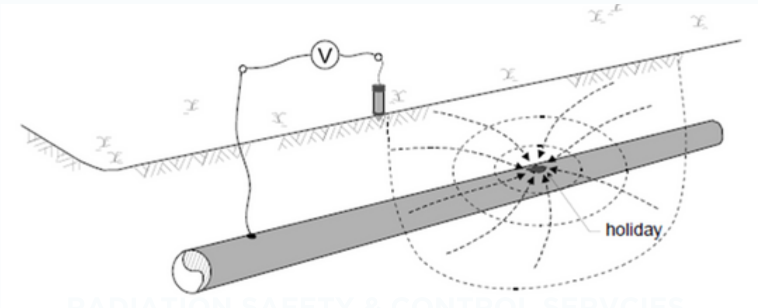


# Metallic Density Modeling to Support Cathodic Protection System Design and Optimization

## Cathodic Protection Basic Overview

- CP will polarize the pipes and arrest the corrosion process (electrochemical reactions)
- CP effectiveness is directly proportional to the current density delivered to the structure, per unit surface area
- (mA / sqft)





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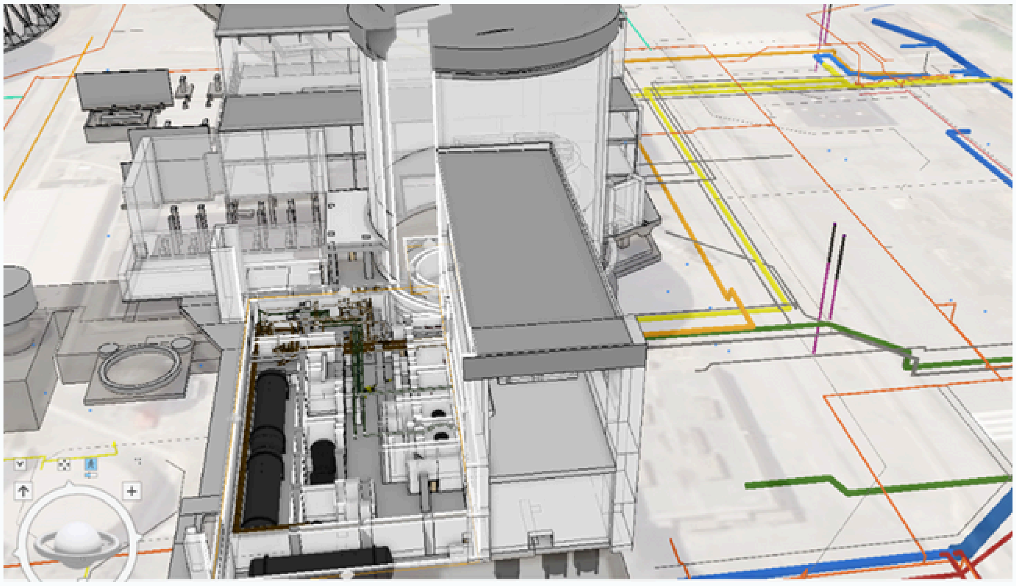
## Complex Subsurface Environments

- Nuclear power sites contain complex underground electrically bonded networks of:
    - Buried piping, electrical grounding systems, metallic structures, bare metal grounding, coated piping and tanks, and reinforcing steel.



*3D digital twin cross of a nuclear power facility showing mechanical equipment, below-grade reinforced concrete structures and buried pipe arrangement (color)*

# Metallic Density Modeling to Support Cathodic Protection System Design and Optimization

## Goal

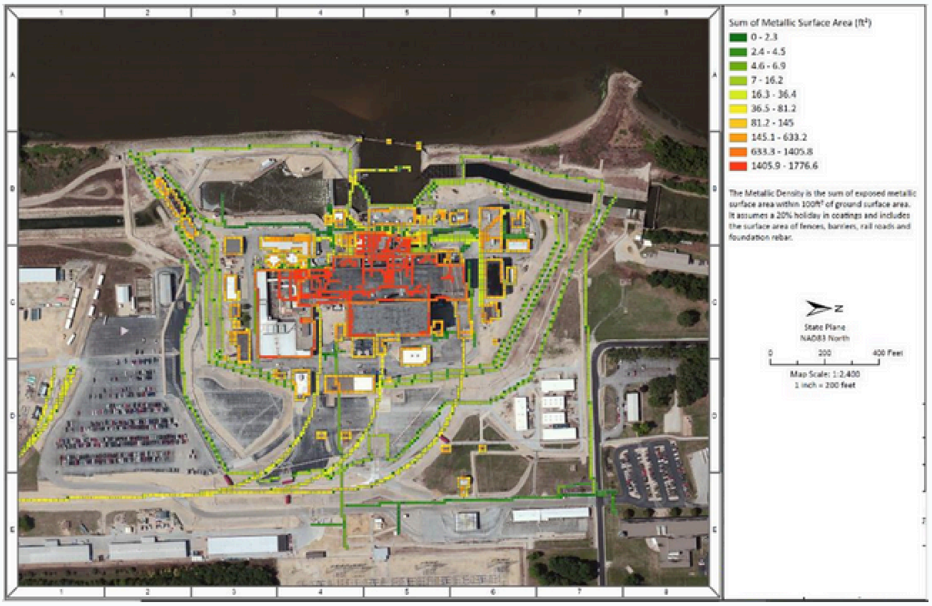
- Develop a methodology for quantifying and mapping buried metallic structures/Surface area. (FEM – Finite Element Modeling)
- Use FEM to perform FEA to estimate cathodic protection (CP) requirements.
- Identify areas where buried metals may interfere with conventional CP design.
- Optimize CP design to **reduce cost and increase effectiveness** for SLR


*GIS depiction of a nuclear facility buried piping digital twin (pipe centerlines and systems shown)*

# Metallic Density Modeling to Support Cathodic Protection System Design and Optimization

## Digital Twin – Finite Element Modeling

- **Finite Element Model:**
    - Discretize the digital twin into defined grids.
    - Calculate the metallic surface area in each grid, based on buried structures
    - Map distribution metallic surface area density of the site.
- Allows designers to visualize the subsurface environment and refine CP system design parameters based on detailed site-specific arrangement.




*FEM Example of 100 sqft grids containing in-scope buried pipe at a nuclear power plant. Grid colors indicate varying ranges of bare metallic surface areas within each grid.Example includes structures and 20% coating holidays on piping*

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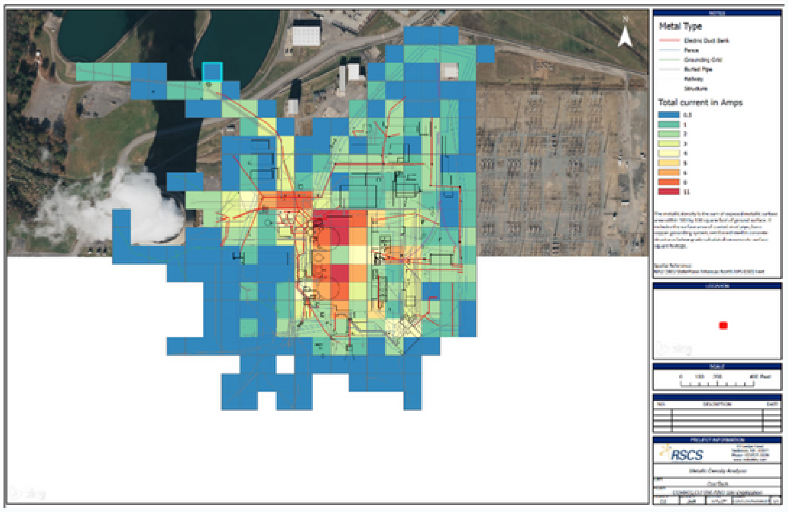
## CP System Current Demand - Finite Element Analysis

**Finite Element Analysis (FEA):**

- Enables adjustments to the CP design such as like accounting for coating failures, and areas of high metallic density to determine CP current demands.
- Aids in optimization of CP design, such as:
  - Selecting anode arrangements
  - Rectifier design
  - Anode coverage areas
  - Anode capacity within each grid




*Finite Element Analysis of the subsurface of environment of a nuclear power plant showing the distribution of CP current demand from all bare metallic surfaces.*

# Metallic Density Modeling to Support Cathodic Protection System Design and Optimization

## Practical Application

- A case study at a nuclear facility assessed coating degradation and current requirements for various structures.
- The facility's interconnected nature demanded an evaluation of all metal surfaces for CP.
- A distributed anode system was recommended due to geological factors, allowing localized influence on piping.
- Estimates of CP current needs were provided for different materials (e.g., coated steel pipe, copper grounding, steel conduits), noting variations based on coating conditions and soil properties.

| Buried Structure | Percent Uncoated | Current Required (mA / $ft^2$) |
|---|---|---|
| Coated steel pipe | 20% | 2.0 |
| Bare copper grounding | 100% | 2.0 |
| Electrical conduits | 100% | 2.0 |
| Reinforcing steel in concrete structures | 100% | 1.0 |
| Railroad Spur(s) | 100% | |
| Sheet Piling | 100% | |
| Security tower bases | 100% | 2.0 |

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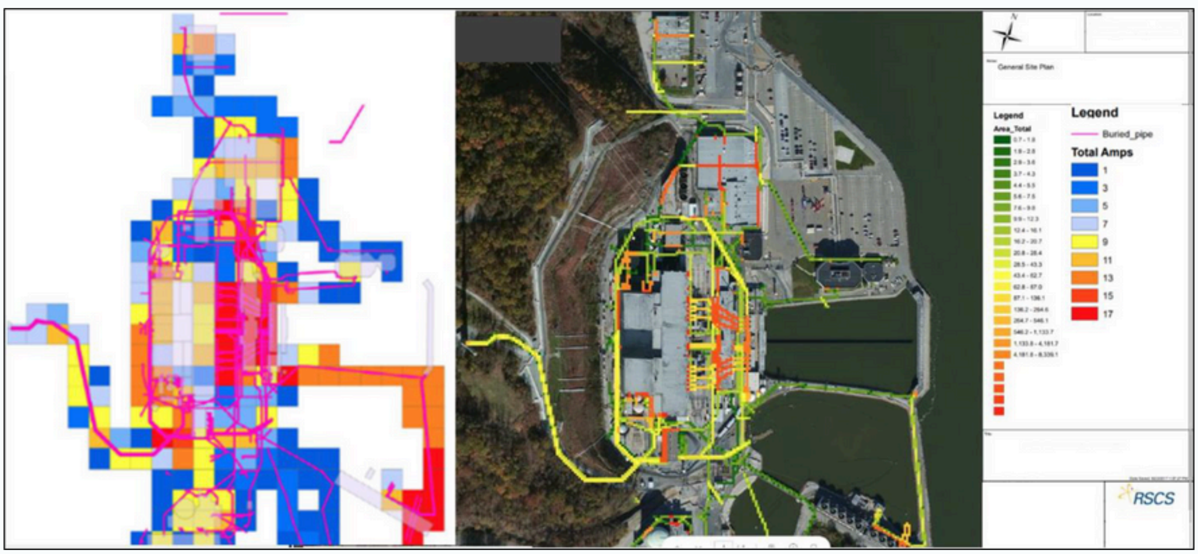
## Practical Application




- Design calculations provided for a total of 920A of current
- CP System installed over 5 years in targeted areas
- Cathodic protection was achieved at over 90% of the piping in the plant
- Design factor allows future adjustment of CP current levels should the demand increase.

# Metallic Density Modeling to Support Cathodic Protection System Design and Optimization

## Conclusion

- Metallic Surface Area Density Mapping using Finite Element Analysis proven effective for CP Design
- Digital Twin Generation improves site modeling and design
- SLR and AMP efforts are satisfied with effective prediction of scope associated with buried piping reasonable assurance for continued operation
- Reduced installation cost by optimizing design and increased CP effectiveness exceeding INPO expectations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RSCS is a division of the Allied Power Platform. The Allied Power Platform was formed with Allied Power's acquisition of Dominion Engineering and RSCS, combining industry-leading engineering, component integrity, asset management, and radiological protection services to deliver maintenance, modifications, and project services. To learn more about RSCS, visit www.radsafety.com.

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