Electrokinetic Based Soil Desalinization System Achieves Closure at a Brine Contaminated Site

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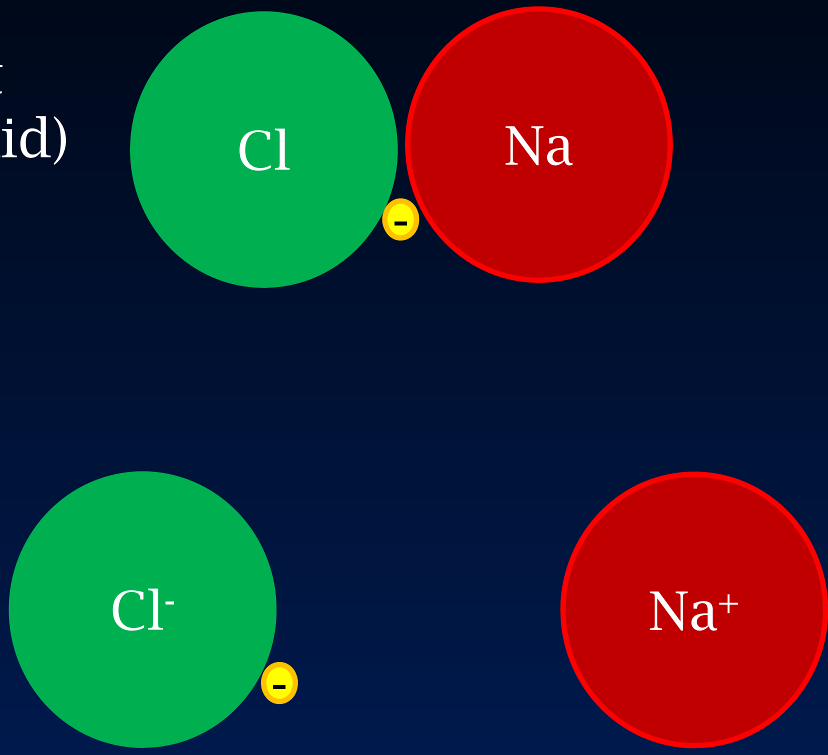
Salt Dissociation

Salt
(solid)

Salt in Water
(brackish, sea
water, brine)



Anion
(negative charge)

Cation
(positive charge)

Salt Impacts

- Short Term – Brine *(concentrated salt solution)* restricts plants ability to uptake water *(Salinity)*
- Long Term - Sodium exchanges with calcium in the soil, collapses the soil, leaving the land barren. Chloride percolates to the water table with precipitation, possibly contaminating well water

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Bad News

- Chloride and Sodium do not break down any further
- To treat soil, they must **be removed or diluted**

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Electrokinetic Remediation ?

- Application of direct current (DC) electricity to the soil
- Polarized electrodes invoke movement of pore water and *ions* contained in the pore water, even in low permeability soils
- Effective in saturated and unsaturated soils

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Electrokinetics

- Electroosmosis – Movement of pore water and contaminants toward the cathode

- Electromigration – Migration of ionic species toward respective electrodes *(anions toward anode, cations toward cathode)* by electrical attraction

- *Transport rates proportional to voltage gradient*

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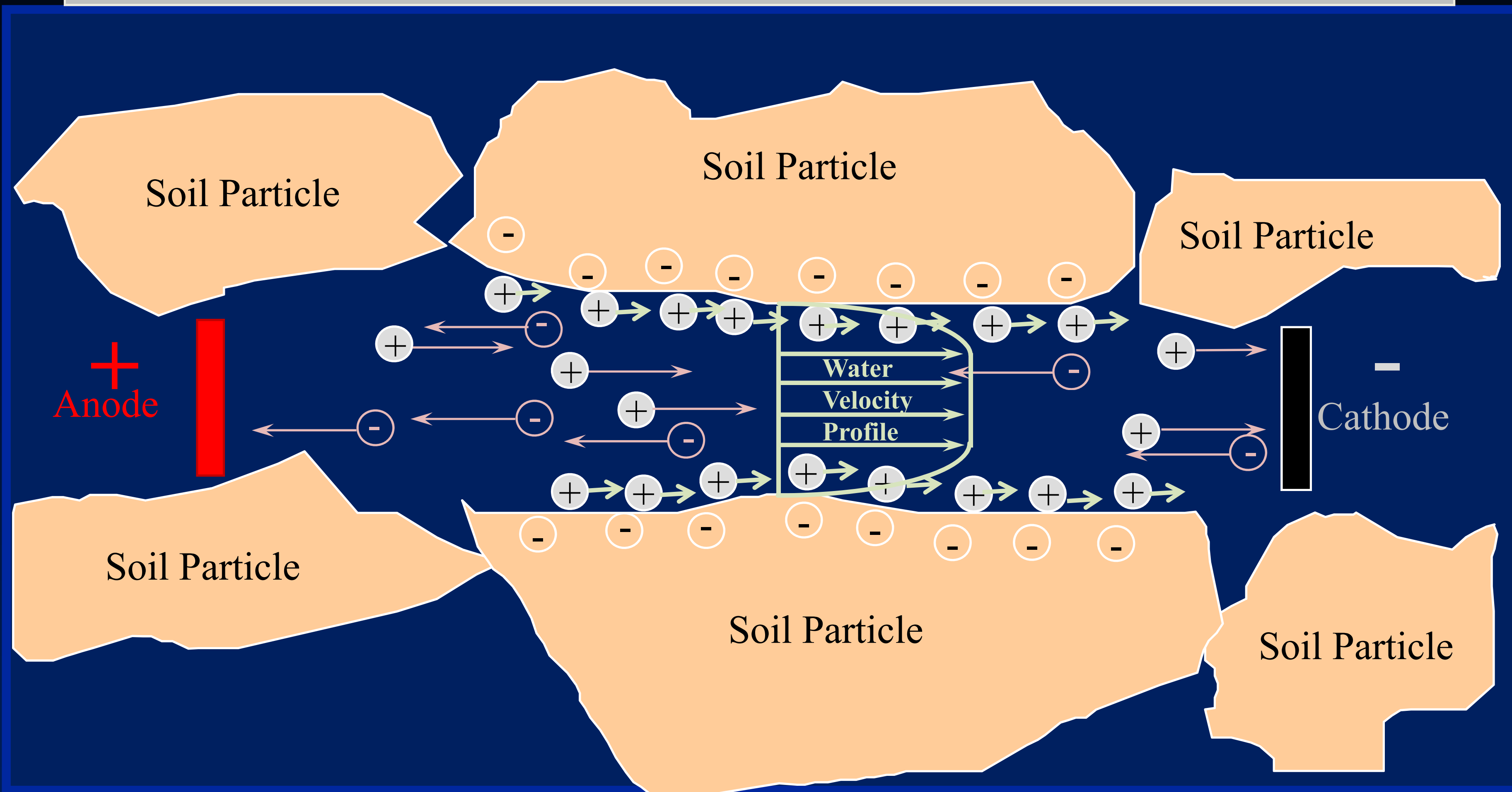
Principles of Electrokinetics

Electroosmosis = Water Transport from anode to cathode
Electromigration = Ion Transport to the opposite electrode



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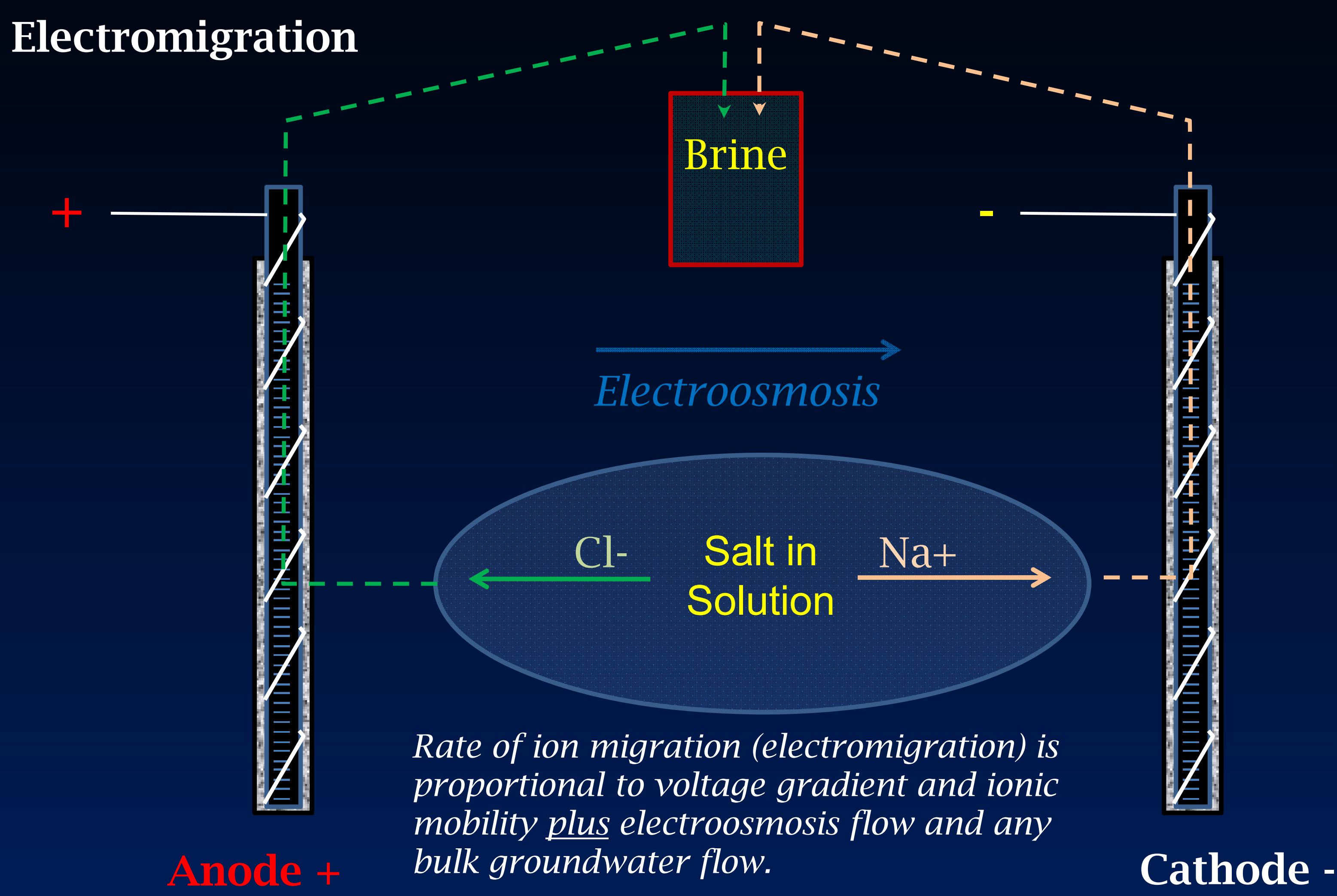
EK Desalinization Application



Rate of ion migration (electromigration) is proportional to voltage gradient and ionic mobility plus electroosmosis flow and any bulk groundwater flow.

Transport Rate = EM ± EO ± GF

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Cost Effective Design

- Readily available equipment and parts *(lowest costs)*
- Electrodes are installed like miniature wells
  - Slotted 1" PVC well screen for cathodes and anodes
  - DSA wire wrapping as primary electrode
  - Backfill annulus with cathodic backfill material *(example-Loresco SWS®)*
  - Installed with hydraulic push *(Geoprobe®)* or small drill rig
- Extraction *(siphon)* equipment is multi-head peristaltic pumps operated on timers – extremely low flow
- Passive as possible operation

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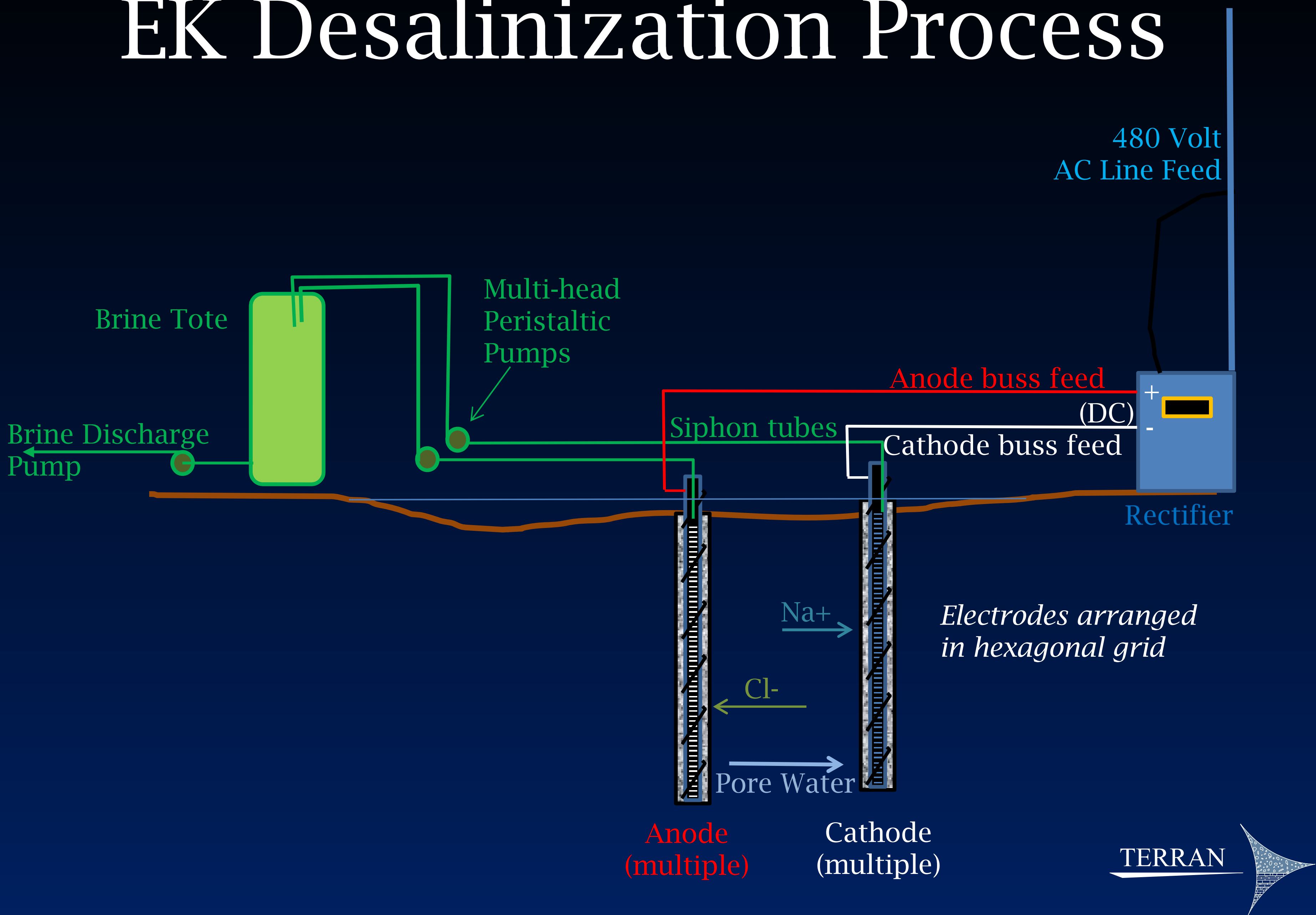
EK Desalinization Process



Demonstration Site Description:

Prairie pothole region in North Dakota

Saturated clay/silt (10^{-8}) high organic, Fe, Mn, Mg, SO_4

~500 bbl process water release from pipeline leak

Environmentally sensitive area

Elevated chloride to 10 feet deep

EK Desalinization utilized as mass removal option

First action was to isolate the small slough from larger, begin pumping affected water from the small slough, and excavate contaminated soil around release point and above the slough.

What a muck hole !

(effectively a swamp bottom)

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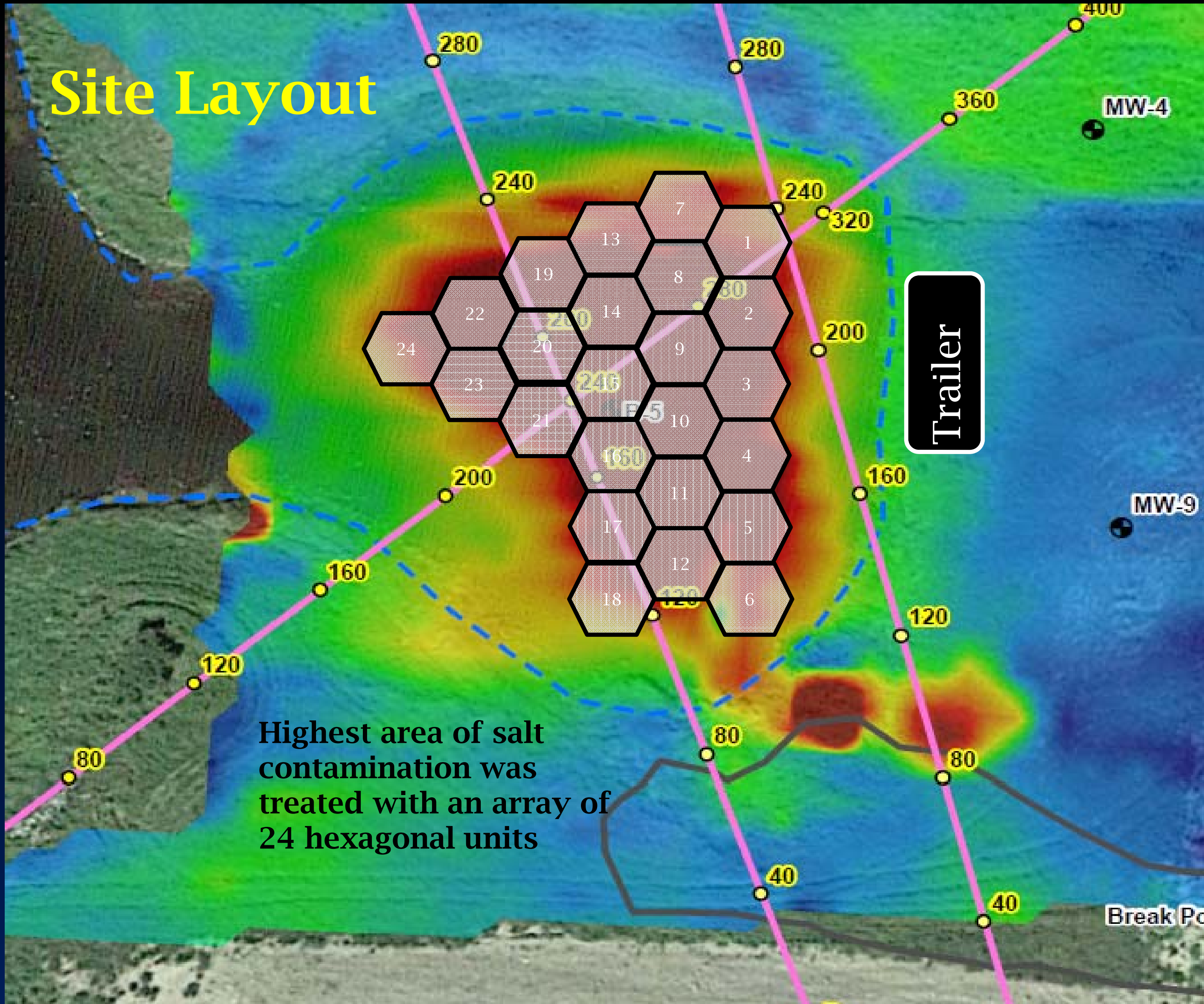
Site Layout



Highest area of salt contamination was treated with an array of 24 hexagonal units

Area was covered with geofabric, geogrid, and cover rock to confine the contaminated soil and create a firm working surface. Surface materials were removed at completion.

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Installation was accomplished using a Geoprobe rig

Installing the EK system

Site after completed installation

Operations

System began operations June 2, 2016
System shut down for winter October 13, 2016
Restarted May 11, 2017
Shut down for winter October 2, 2017
Restarted May 4, 2018
Shut down for winter September 29, 2018

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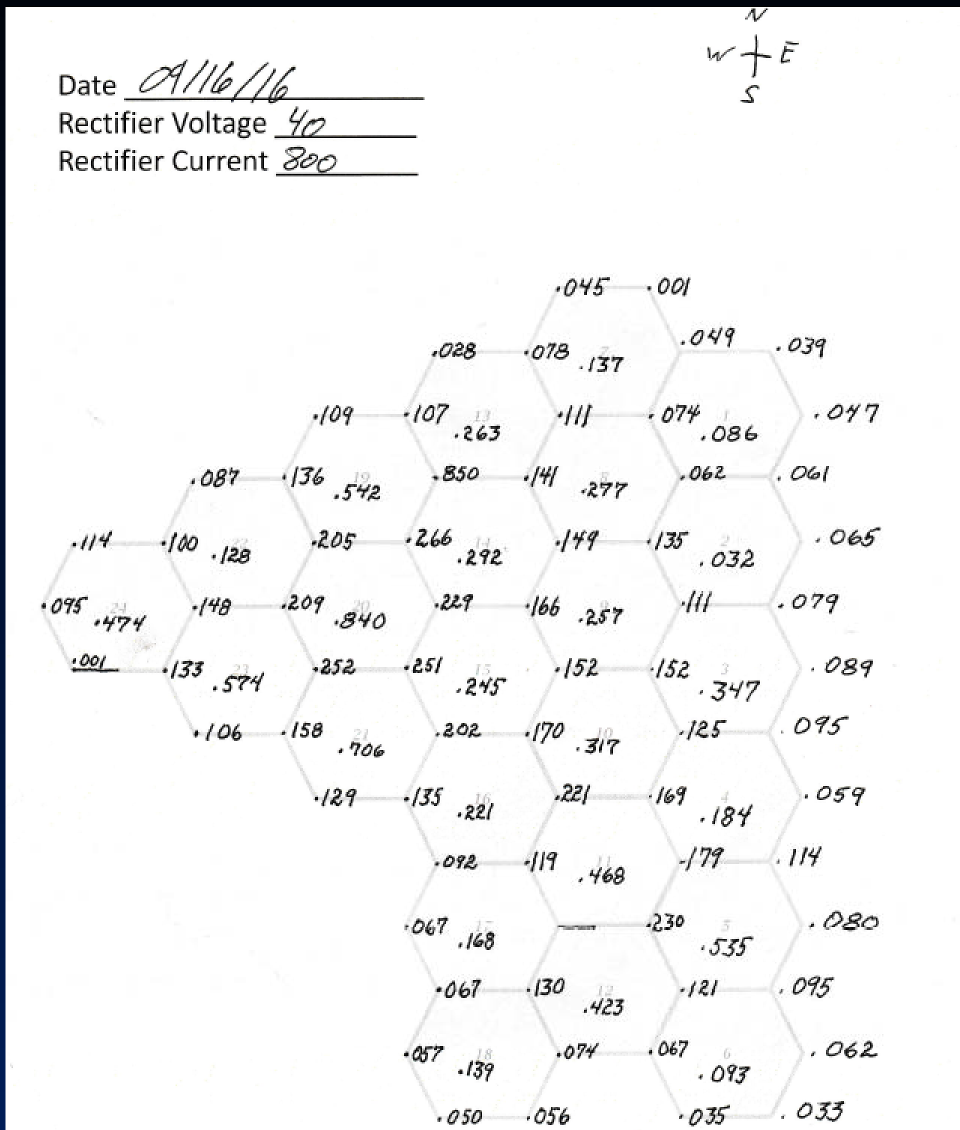
Site Current Mapping



Current measurements were made at each electrode during operations help identify bad electrodes and general operating uniformity *(Readout is amps/100)*

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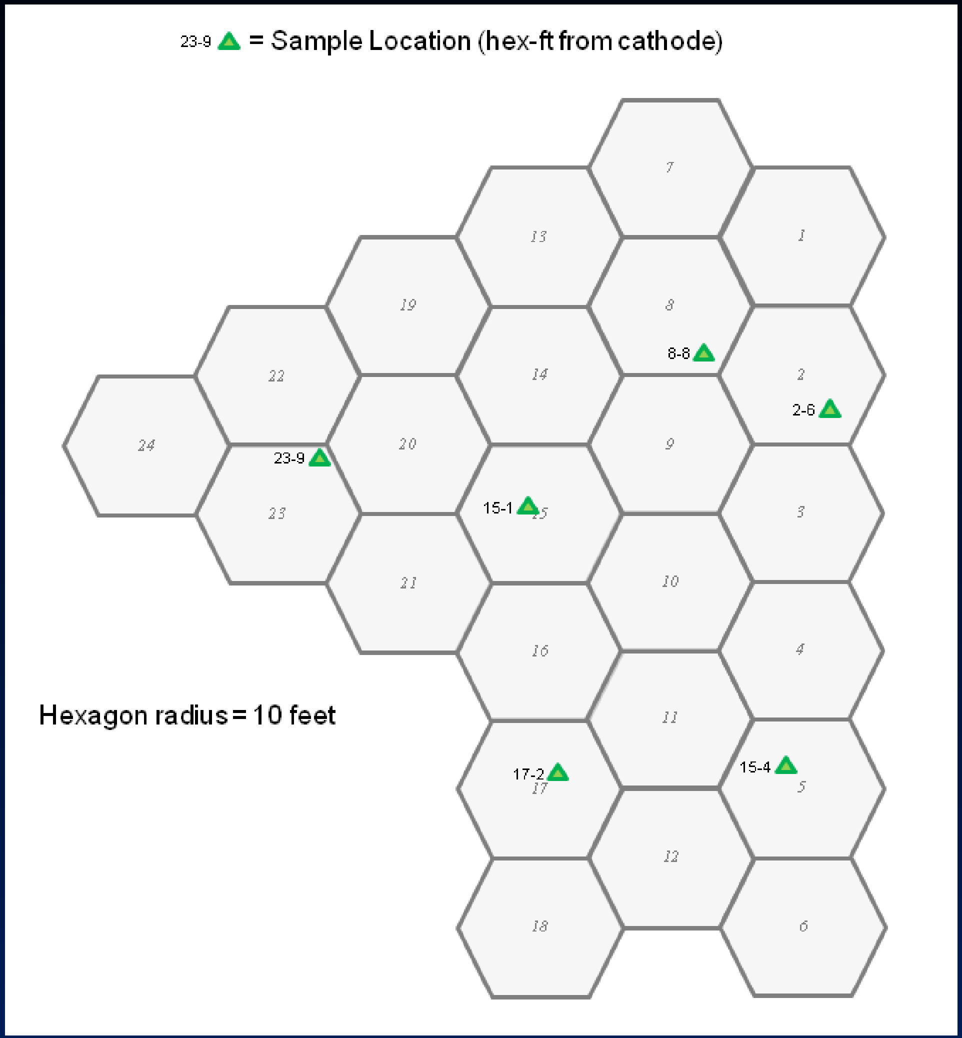
Soil Sampling Locations

Matched samples collected before and during operations (6 locations, 2 depths, n=12)



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Operations Summary

– First summer (2016) operations went well: Removal after 1st summer was 41%

– Poor electrode operations during second summer contributed to lower rates. July 2017 interim samples showed 47% removal.   Conductance and EM surveys confirmed reductions

– Results for November 2017 sampling indicated a regress to only 25% removal ????.
  - 2017 was a dry year and water was brought in to hydrate the electrodes and a reverse-pulse was attempted

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Operations Summary

- For the 3rd summer (2018), the electrode conductors were replaced and operations went much smoother.
  - November 2018 results show an overall 68% removal – very close to the target of 70-80%
  - Site Closure was granted by the North Dakota Department of Health

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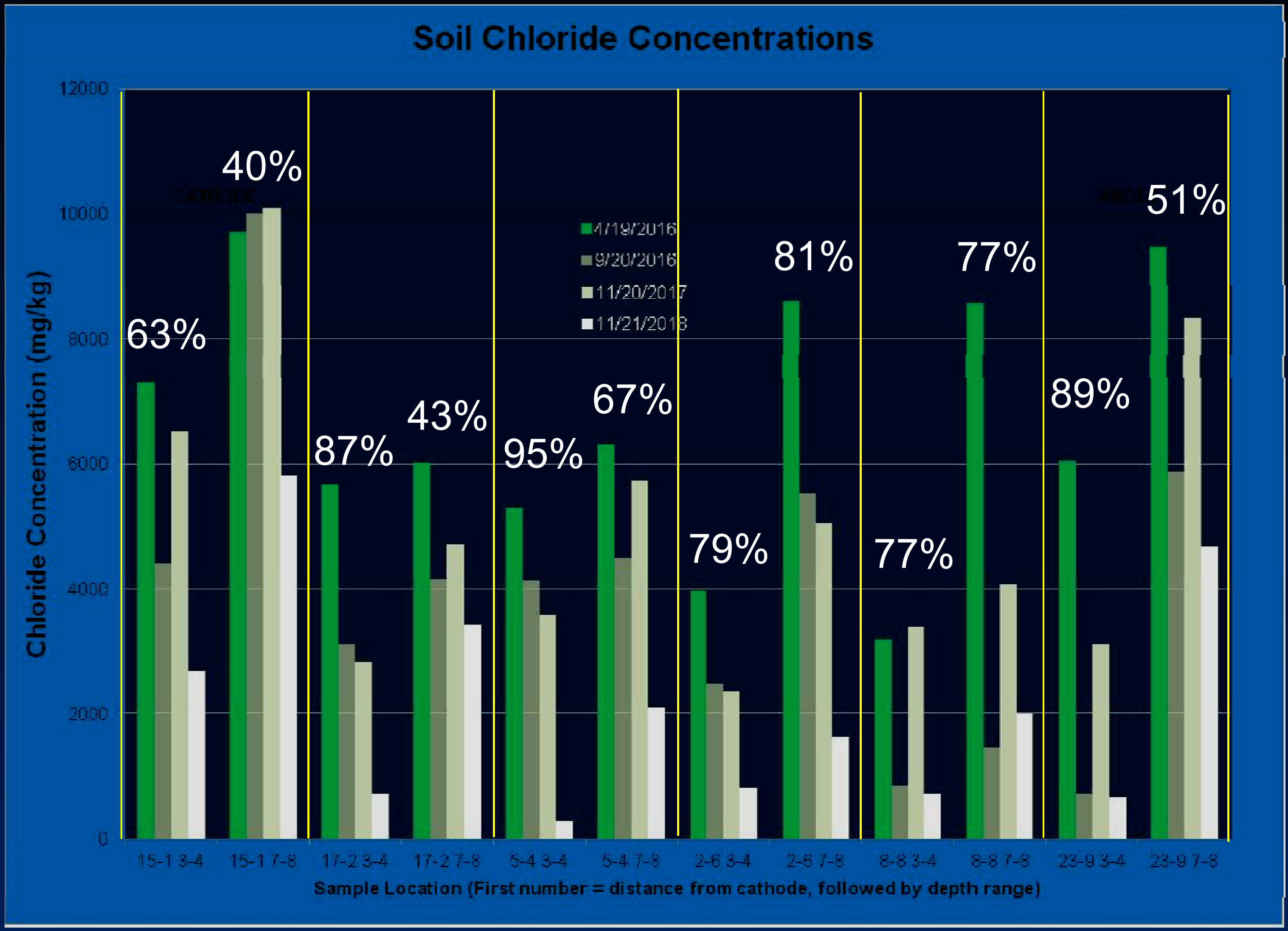
Chloride Soil Data



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Lessons Learned

- Improved electrode connections.
- Low levels of chlorine gas generated at anode *(expected)*
- Choose materials and pump equipment wisely *(better grade pump tubing)*
- Water addition at anodes may be necessary during dry periods
- Chloride moves much slower than sodium

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Conclusions

- EK desalinization worked at the demonstration site
- Site closure from ND Dept of Health!
- If it works at the Connie site, it can work at most any site

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Future Projects

- Addition of lime to anodes to increase calcium/sodium re-exchange to rejuvenate the soil
- Maximize removals using pulsed-DC
- Low voltage DC ideal for solar power *(NDIC grant for solar EK pilot)*

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