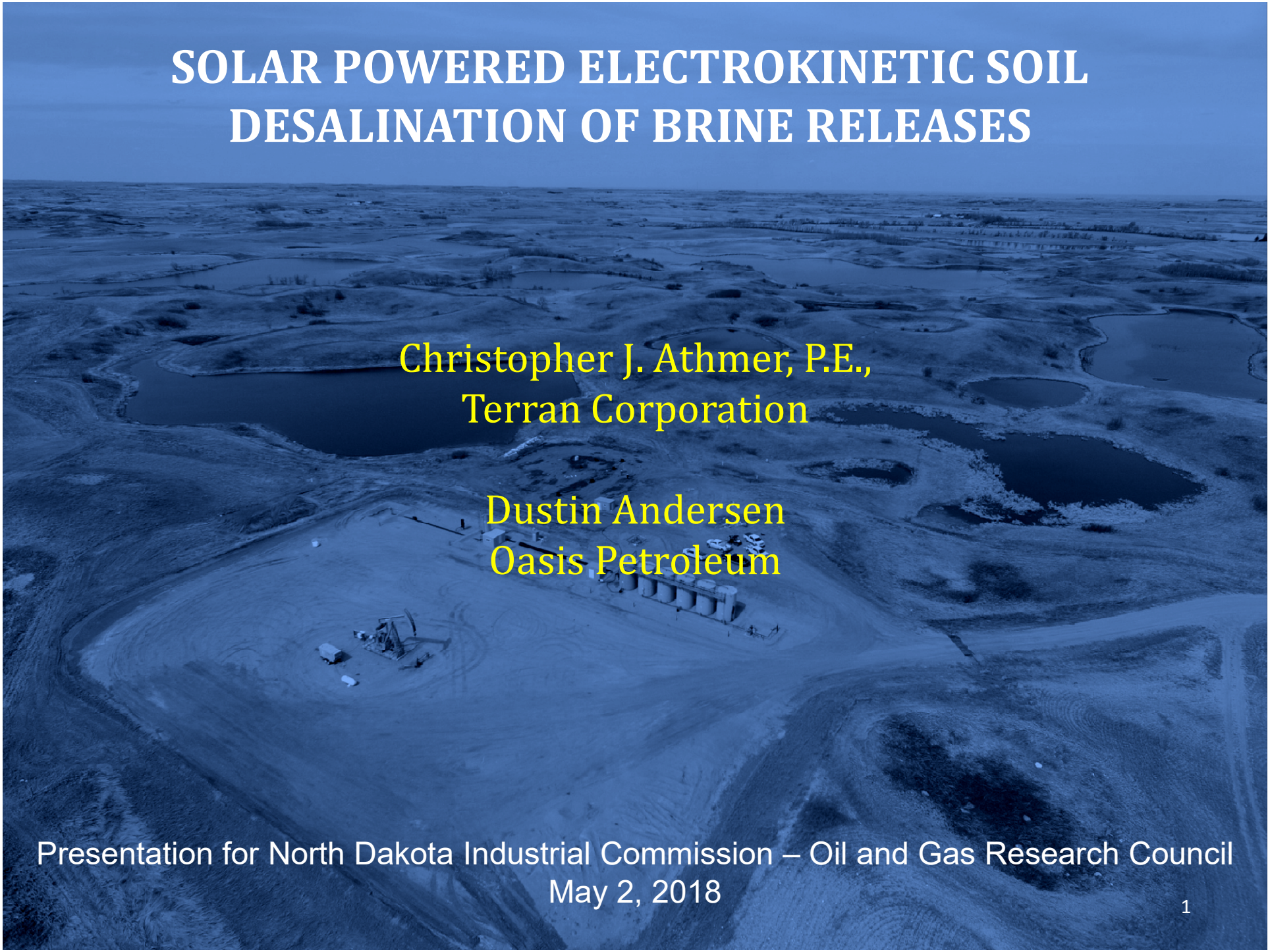
SOLAR POWERED ELECTROKINETIC SOIL DESALINATION OF BRINE RELEASES



Christopher J. Athmer, P.E.,
Terran Corporation

Dustin Andersen
Oasis Petroleum

Presentation for North Dakota Industrial Commission – Oil and Gas Research Council
May 2, 2018

Current Remediation Technologies for Brine Spills

- Dig and Haul
- Amend and/or Flush

  Protective of an aquifer ? Chloride?
- Cap

  Generally not acceptable to land owner
- Others??

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

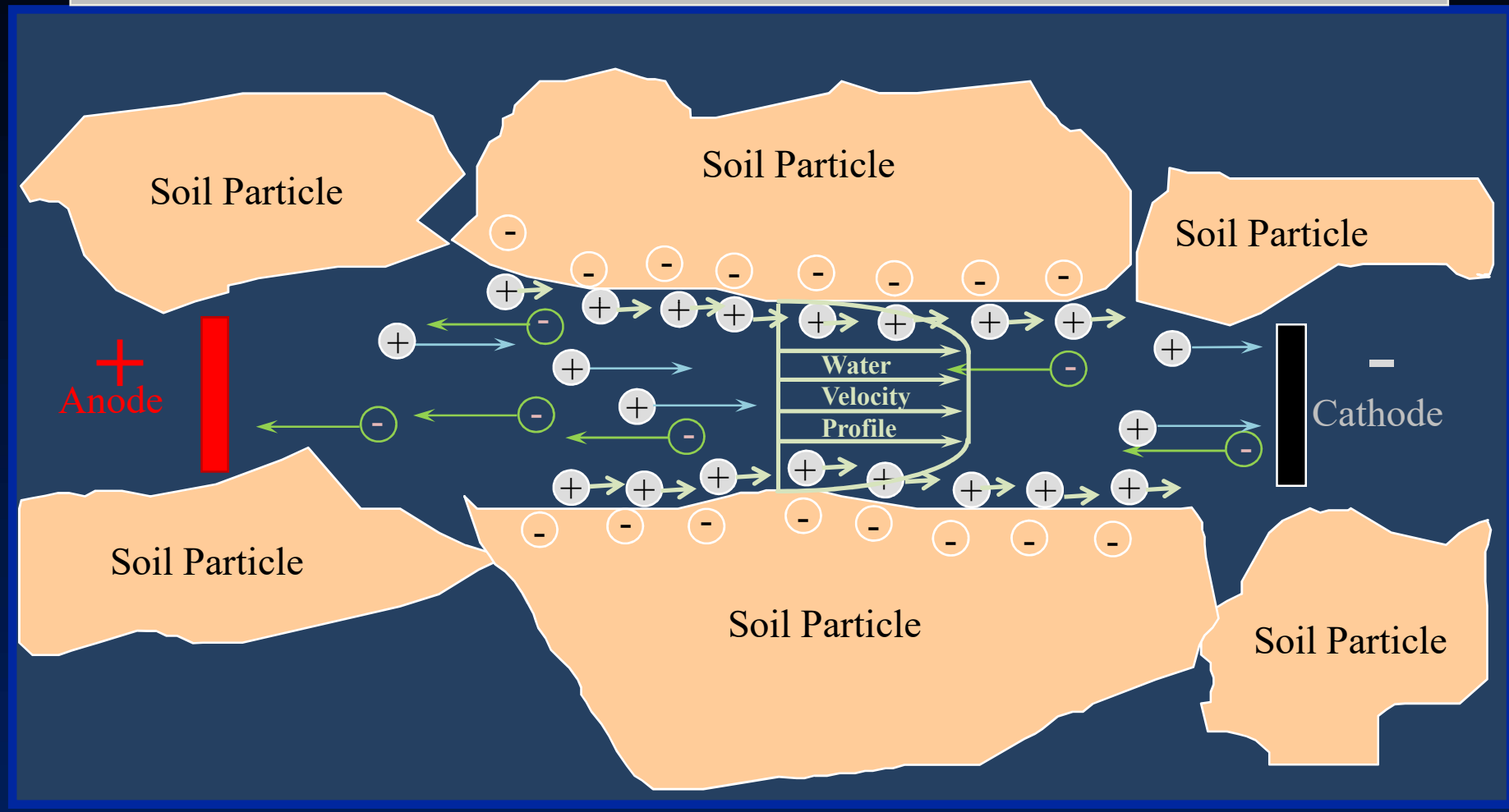
Electrokinetics

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

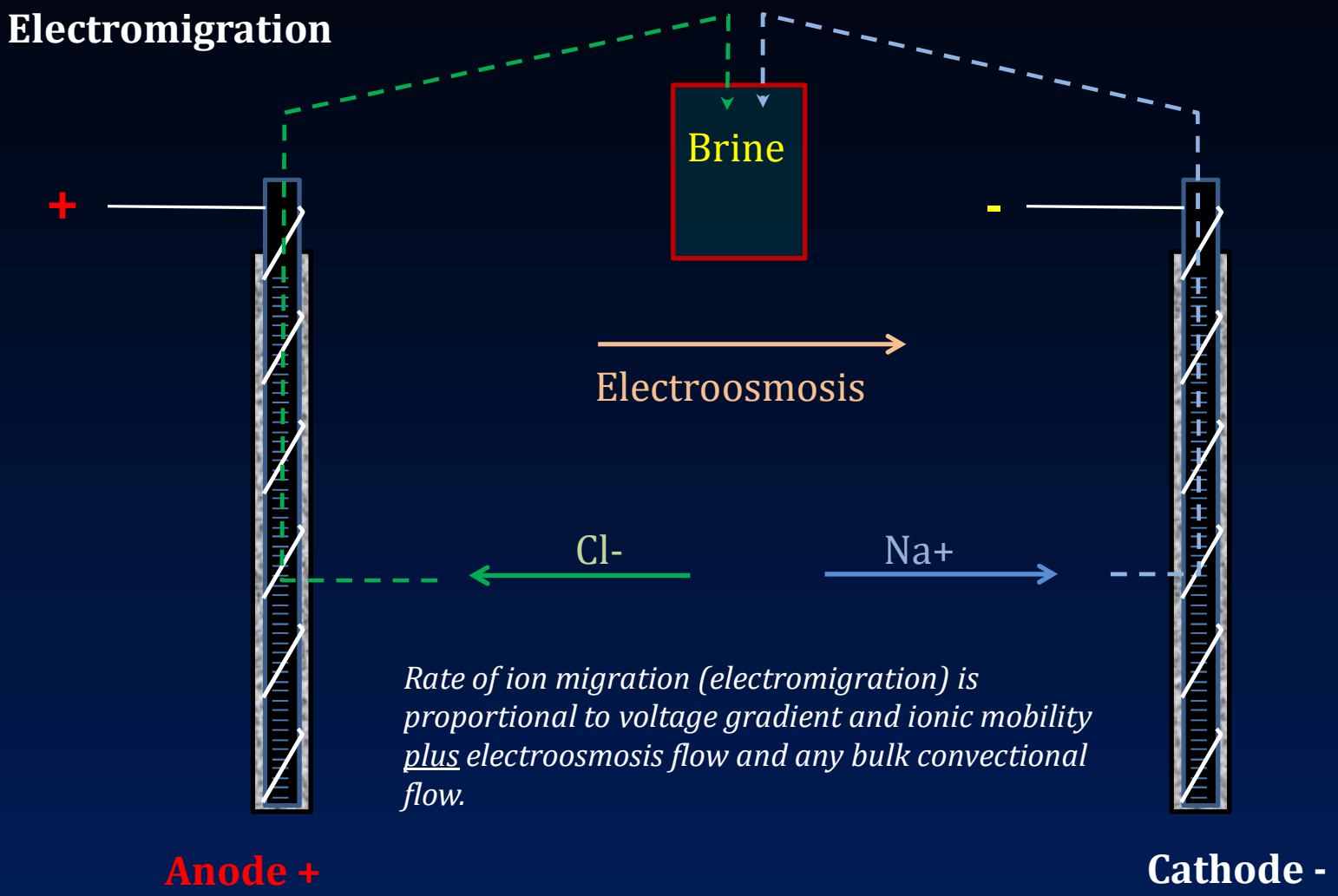
- **Electromigration – Migration of ionic species toward respective electrodes (anions toward anode, cations toward cathode) by electrical attraction**
  - **EM ~ 10 x EO, depending on size and charge**

Principles of Electrokinetics

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

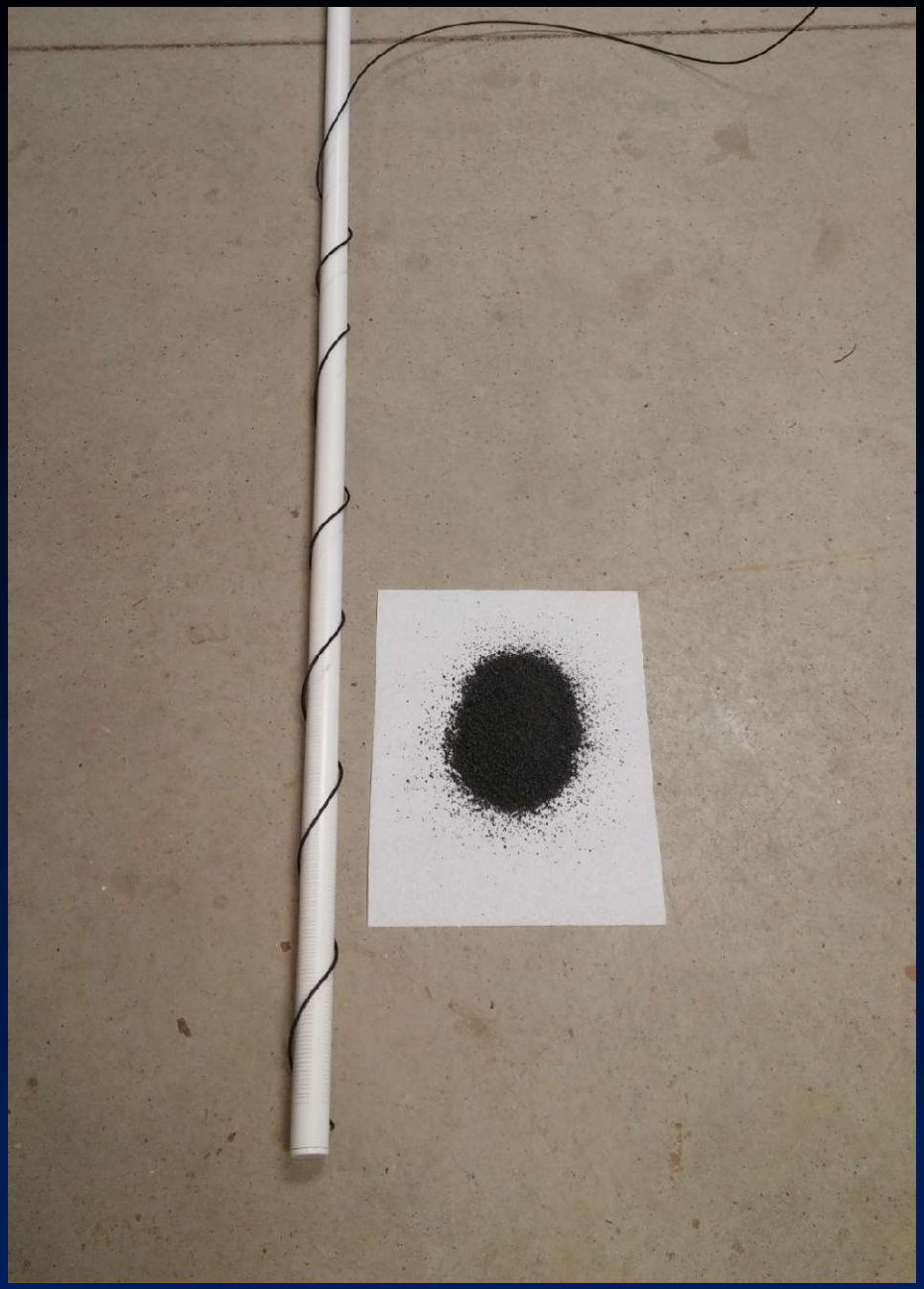


EK Desalinization Application

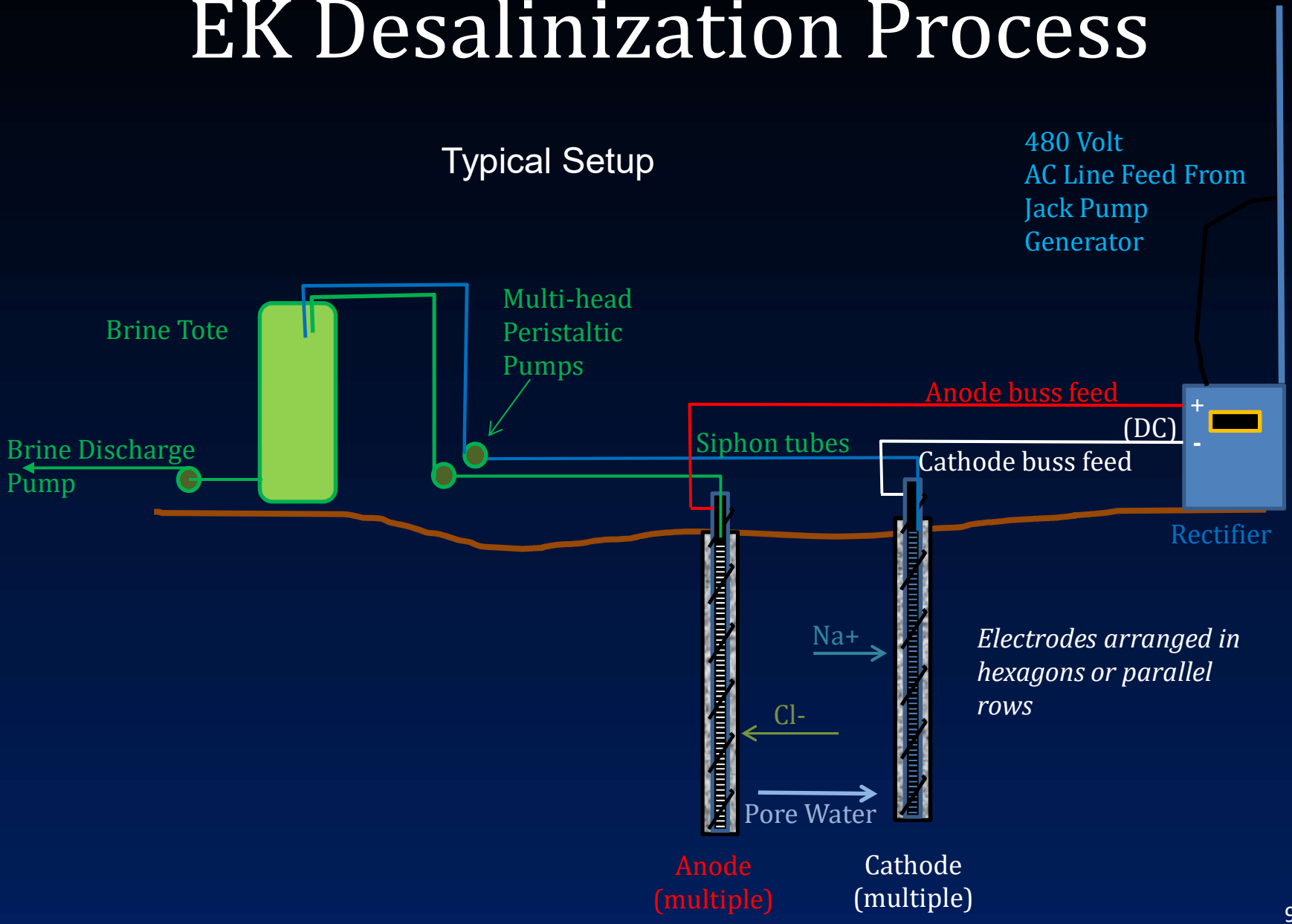


Field Scale Design

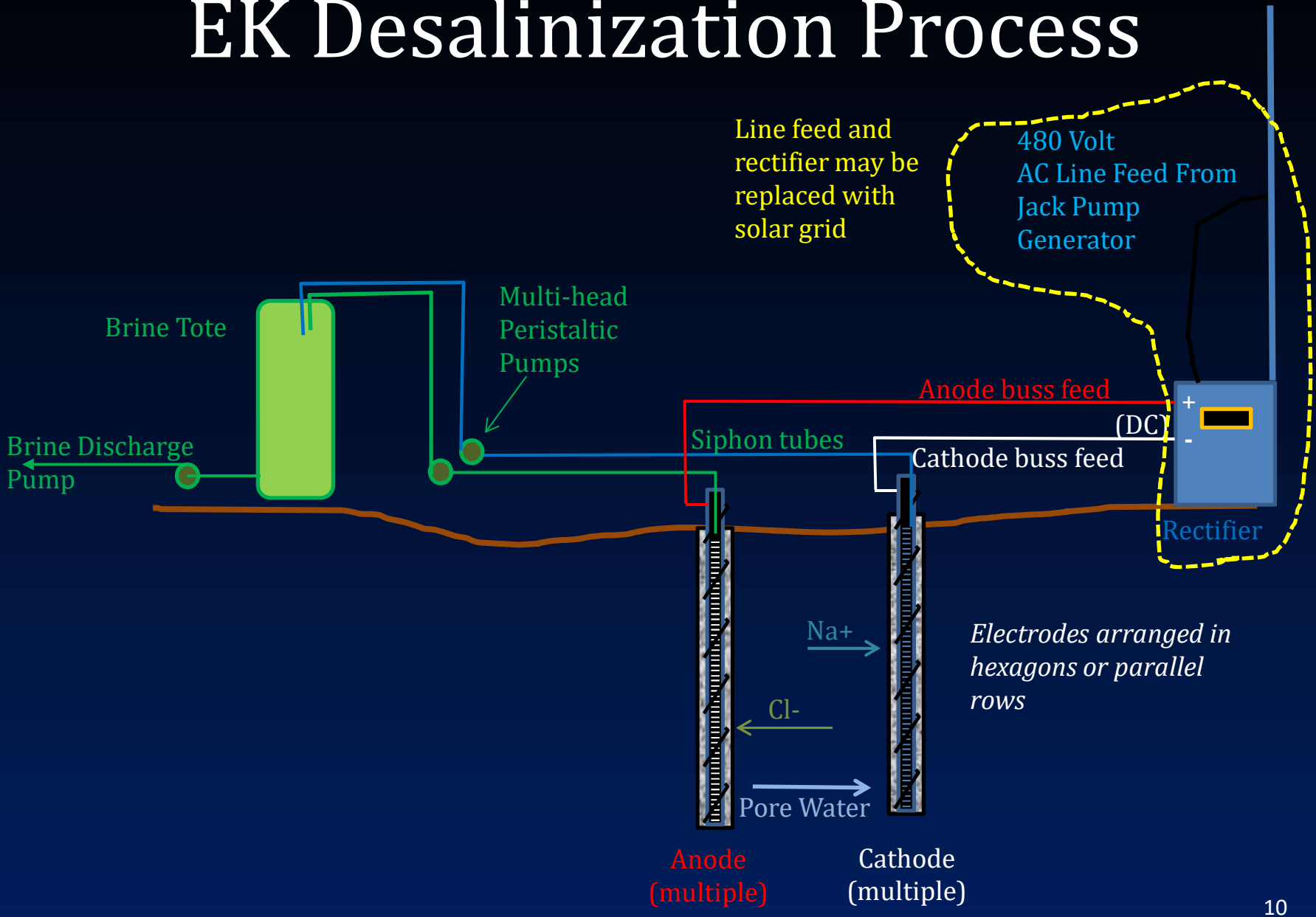
- Readily available equipment and parts (lowest costs)
- Electrodes are installed like miniature wells
  - Slotted 1” PVC well screen (24 cathodes, 69 anodes)
  - DSA wire wrapping as primary electrode
  - Backfill annulus with conductive backfill material (example-Loresco SWS®)
  - Installed with hydraulic push (Geoprobe®) or small drill rig
- Extraction equipment is multi-head peristaltic pumps (peristaltic) operated on a timer
- Passive as possible operation



EK Desalinization Process



EK Desalinization Process



Electrode/Wells are pushed in using a Direct-Push system

Installed EK system at the Connie Site

Lessons Learned to Date

- Small amount of chlorine gas generated at anode (expected) due to oxidation of chloride
- Choose materials and pump equipment wisely
- Rectifier sensitive to “noisy power” from well head generator

Current Status

- EK desalinization is working at the demonstration site *(and some valuable lessons learned)*
- Regulators and Corporate on board
- Next step is to incorporate solar power

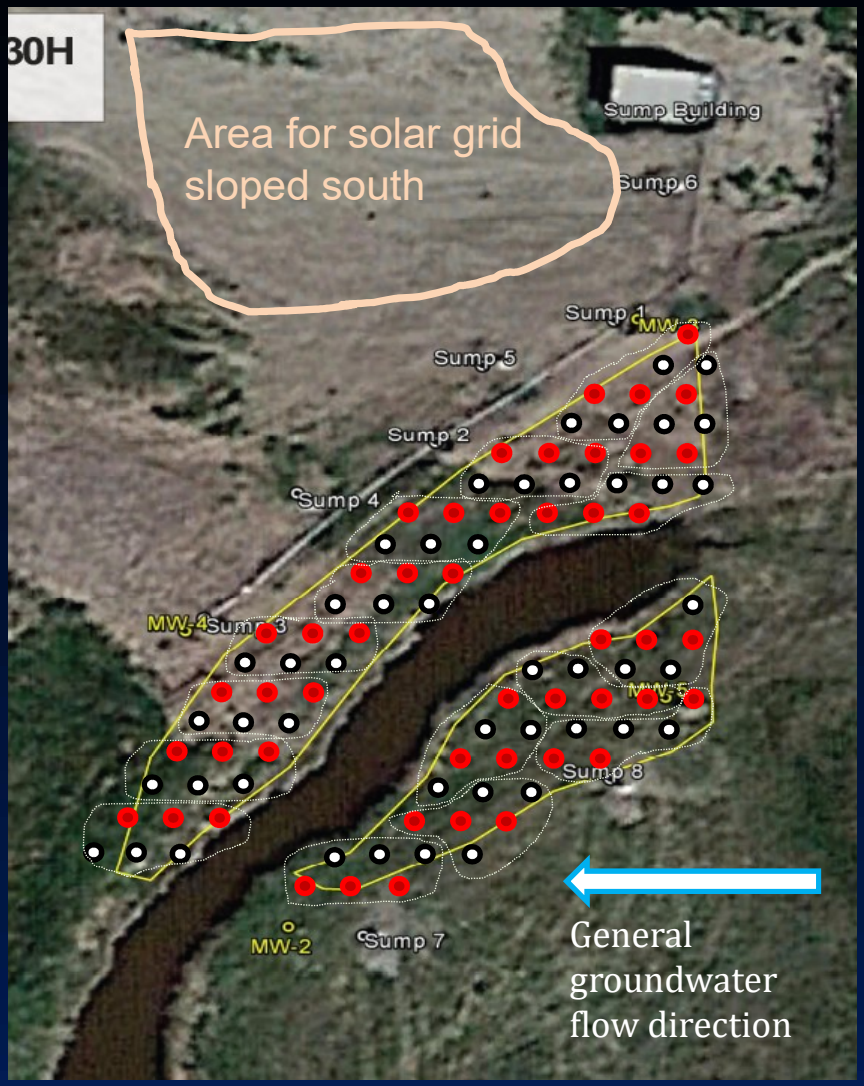
Schmitz Site

Schmitz Site Layout

Naturally south sloping area nearby for solar grid

48 Anodes and 48 Cathodes aligned parallel with groundwater flow to deflect chloride and sodium ions toward electrode wells

16 Sub grid area of 2 KW each serviced by 8 250W panels – 128 total panels



Sodium & Chloride Removal

- Model predicts 2 summers for the chloride to reach anodes
- System to be operated from late spring to early fall each year
- Operations coincide with peak solar incidence. Siphon pumps and tubing will need to be removed during winter months
- Removed ion-rich water will be monitored for conductivity as operations guide

Project Associated Expense	NDIC's Share	Applicant's Share (In-Kind)
Site Investigation and Prep - Direct	$0	$0
Investigation and Prep - Labor	$0	$0
System Design - Labor	$0	$0
Equipment/Materials	$102,960	$0
Installation - Direct	$0	$68,000
Installation - Labor	$12,000	$38,160
Operations - Direct	$0	$30,000
Operations -Labor	$30,000	$0
Monitoring - Direct	$0	$40,000
Monitoring - Labor	$5,000	$0
Demobilization - Direct	$0	$20,000
Demobilization - Labor	$0	$0
TOTALS	$149,960	$196,160

Budget

- Installation requires:
  - Equipment
    - Multi-head peristaltic pumps
    - Electrode wells (96)
    - Wire and tubing for each well
    - Data system
    - 32KW Solar Array + infrastructure
  - Labor – Electrical hookups and plumbing
  - Direct – Well installation and drilling

Budget

- Operation requirements:
  - Oversight and data management (Terran)
  - Fluids management (Oasis subcontractor)
  - Sampling and analysis (Oasis + subcontractor)

Budget

- Management and Reporting:
  - Required summaries and updates
  - Annual report and evaluation

Summary

- EK Desalinization shows promise
- Solar appears to be a natural fit
- The Schmitz site lends itself a good test case with back-up provisions available

- **Ideal outcome**:
  - Oasis gets a cleaned site
  - Terran develops a proven remediation tool
  - North Dakota has a viable option for remote brine release sites