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Electro-Osmotic Recovery of Salinity Impacts in Low-Permeability Soils

Field Demonstration and Technology Advancement through Industry-Academic Collaboration

Trevor Carlson & Robin Turri

The Project Team

A collaborative team moving electrokinetics from concept to field

Industry need, academic research, applied engineering and leveraged public funding combined to advance the technology.

COLLABORATIVE EK/ EO PROGRAM

research • field pilots • scale-up

Imperial

Industry sponsor • field sites • operational direction

Geosyntec consultants

engineers | scientists | innovators

Project Concept and Field Execution

UNIVERSITY OF CALGARY

Research leadership • modelling • laboratory optimization

NAIT

Applied research • system fabrication • field-scale integration

The Project Team

LEAD

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Nael Yasri

Ted Roberts • retired

One program, four complementary roles: client direction + research + technology development + field delivery

Project Origin

Can an electric field mobilize and recover chloride impacts where groundwater barely moves?



WHY REMEDIATION IS DIFFICULT

The legacy

Historical produced-water releases left chloride and dissolved-salt impacts in soil and shallow groundwater.

The geological constraint

Western Canadian sites commonly include fine-grained, heterogeneous glacial till where hydraulic conductivity is very low.

The remedial gap

Conventional flushing, injection and pumping cannot readily contact or recover salt retained within tight pore networks.

The research question

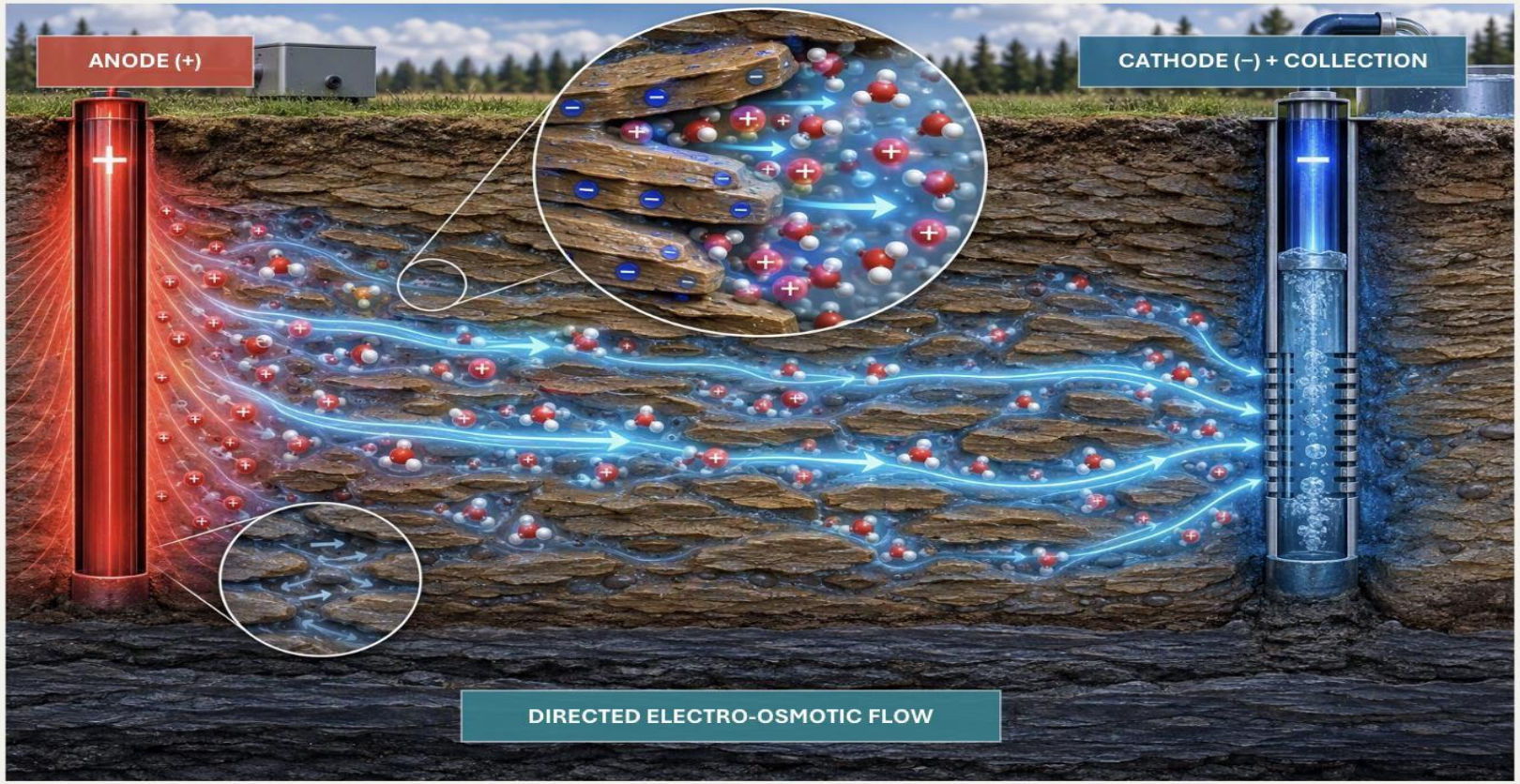
Could electro-osmosis move porewater while electrokinetic processes mobilize ions toward engineered recovery zones?

Electro Osmosis – What's all about

ELECTROKINETIC REMEDIATION | CONCEPTUAL MECHANISM

Electro-osmosis moves porewater where pumping cannot

A direct-current electric field mobilizes the water-rich diffuse layer around clay particles and creates directed bulk flow toward a cathode collection zone.



HOW THE PROCESS WORKS

1. **Establish the field**
   Low-voltage DC is applied between an anode and cathode installed across the treatment zone.
2. **Mobilize the diffuse layer**
   Clay surfaces are commonly negatively charged. Hydrated cations in the diffuse double layer migrate toward the cathode and drag adjacent water.
3. **Create bulk porewater flow**
   Momentum transfers from the mobile water film into the pore fluid, producing a near plug-like flow through fine pores.
4. **Capture and manage**
   Water and dissolved constituents are directed to a cathode recovery zone for extraction, treatment, recirculation or disposal.

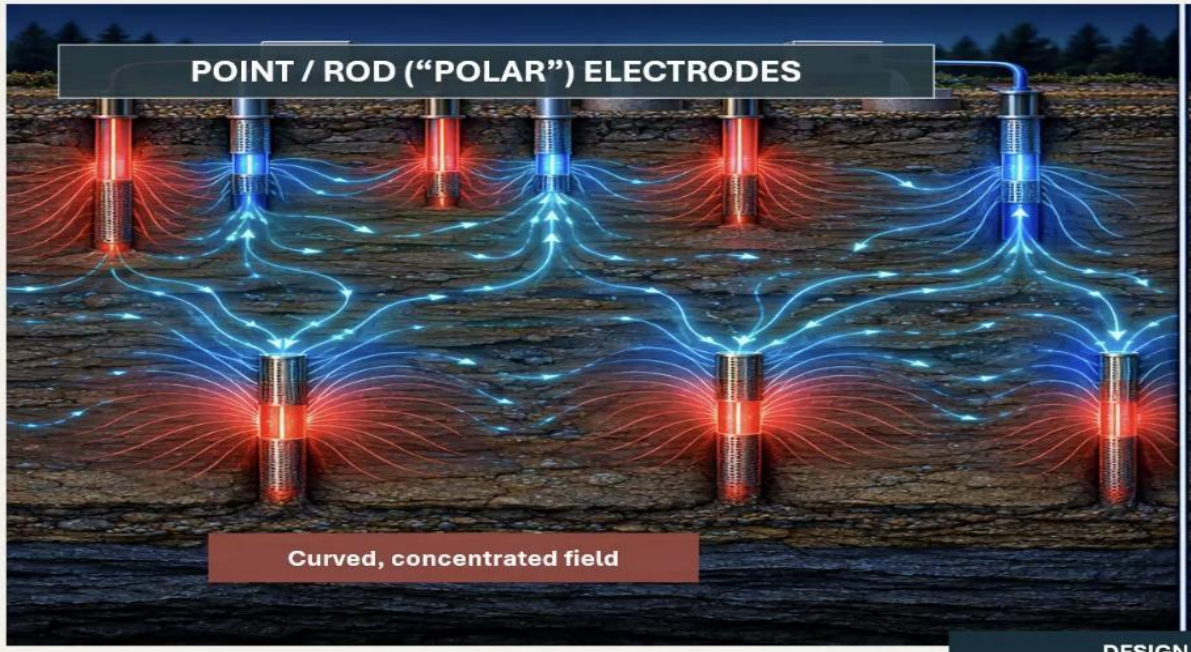
WHY IT MATTERS **Electro-osmotic flux is driven by electrical potential rather than hydraulic conductivity, making it especially useful for clays and silts where conventional injection or pumping is slow and spatially uneven.**

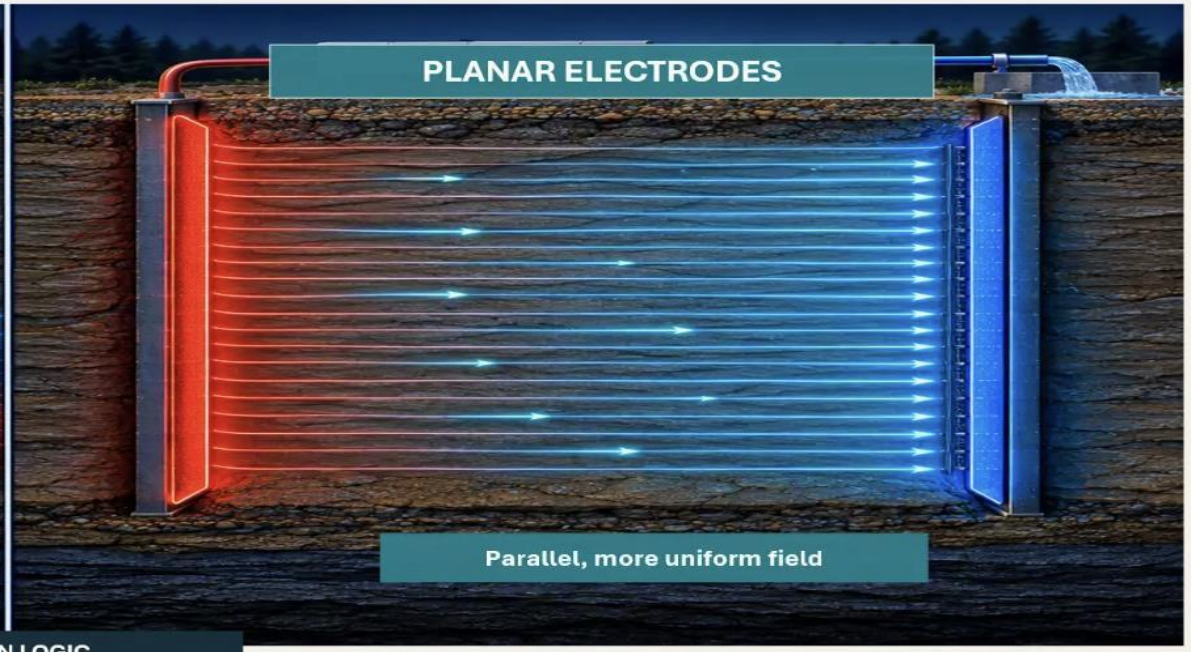
Electro Osmosis – Polar vs Planar Electrodes

ELECTRO-OSMOSIS | ELECTRODE GEOMETRY

Planar electrodes distribute the driving force across the treatment zone

Electrode geometry controls where voltage is lost, where water moves, and how completely recovered porewater can be captured.





DESIGN LOGIC

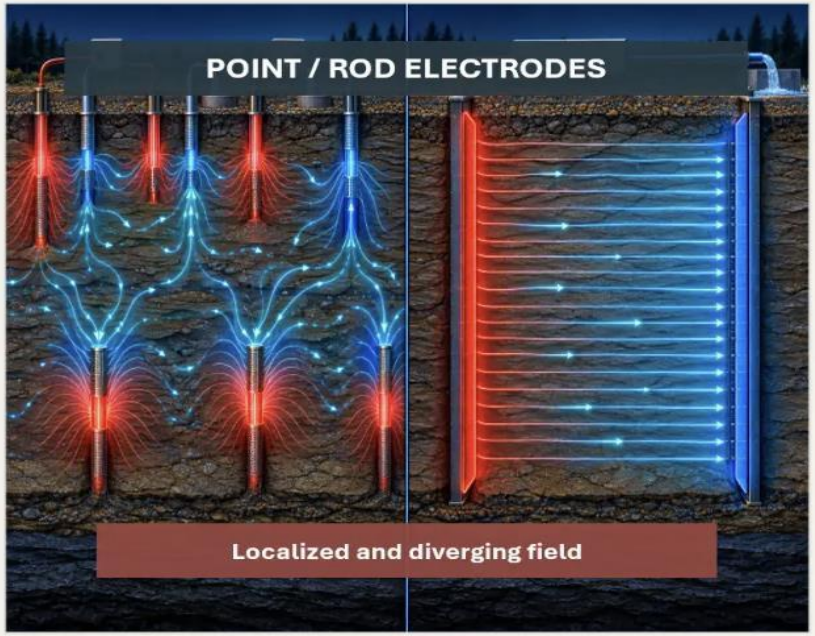
	POINT / ROD (“POLAR”) ELECTRODES	PLANAR ELECTRODES
FIELD	High gradients near rods; weaker zones between them.	Broad opposing surfaces approximate a consistent gradient.
ENERGY	Current concentration and non-uniform field use more input to cover the full soil volume.	More of the applied potential contributes to useful, directed transport.
RECOVERY	Flow converges toward discrete sinks, producing uneven capture.	A distributed cathode collects water across a broader treatment face.

Electro Osmosis – Why electrode type matters

ELECTRO-OSMOSIS | ELECTRODE GEOMETRY AND EFFICIENCY

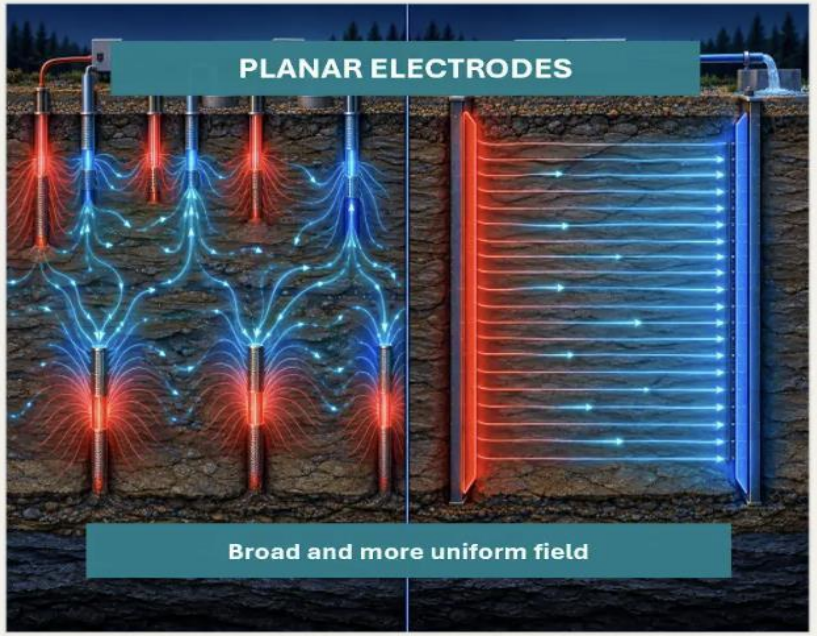
Why planar electrodes can be substantially more efficient

The advantage comes from how the electrode geometry distributes the electric field, current density and water-recovery boundary.



WHY PLANAR IS MORE EFFICIENT

1. **More uniform field**
   Parallel facing surfaces reduce intense near-electrode gradients and weak-field gaps.
2. **Lower current density**
   Current is distributed across a larger interface, reducing localized electrochemical losses.
3. **Better field utilization**
   More of the applied electrical input contributes to the desired treatment field.
4. **Distributed recovery**
   A broad cathode provides a larger collection face for mobilized porewater.



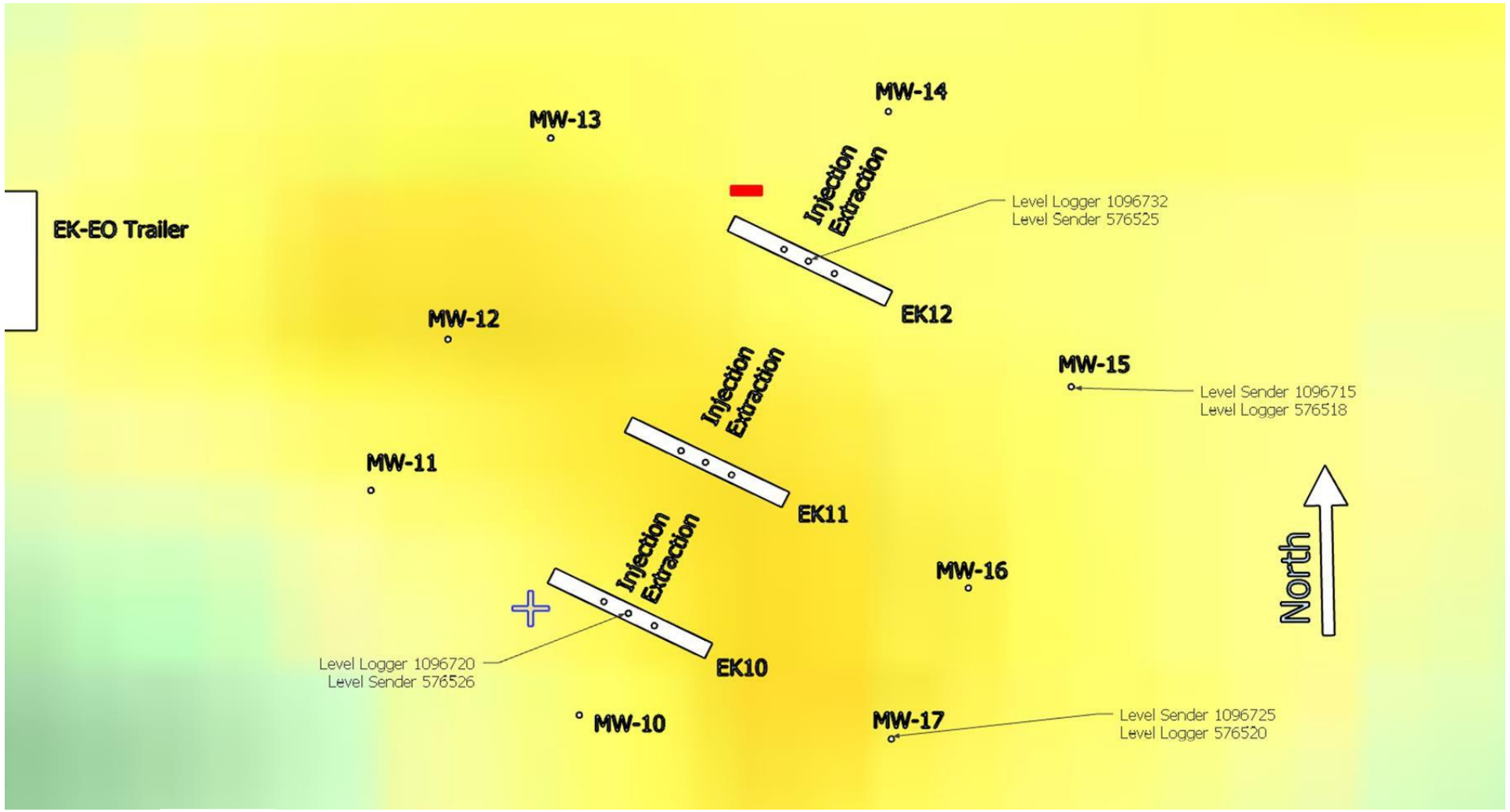
DESIGN TAKEAWAY

Planar electrodes can be much more energy efficient because they create a more uniform and useful electric field across the treatment volume, while avoiding excessive current concentration around discrete electrodes.

The broad cathode also supports more uniform water recovery, helping align the electrical driving force with the intended hydraulic collection zone.

GEOSYNTEC CONSULTANTS

Electrodes Prior to Installation



Electrodes Prior to Installation



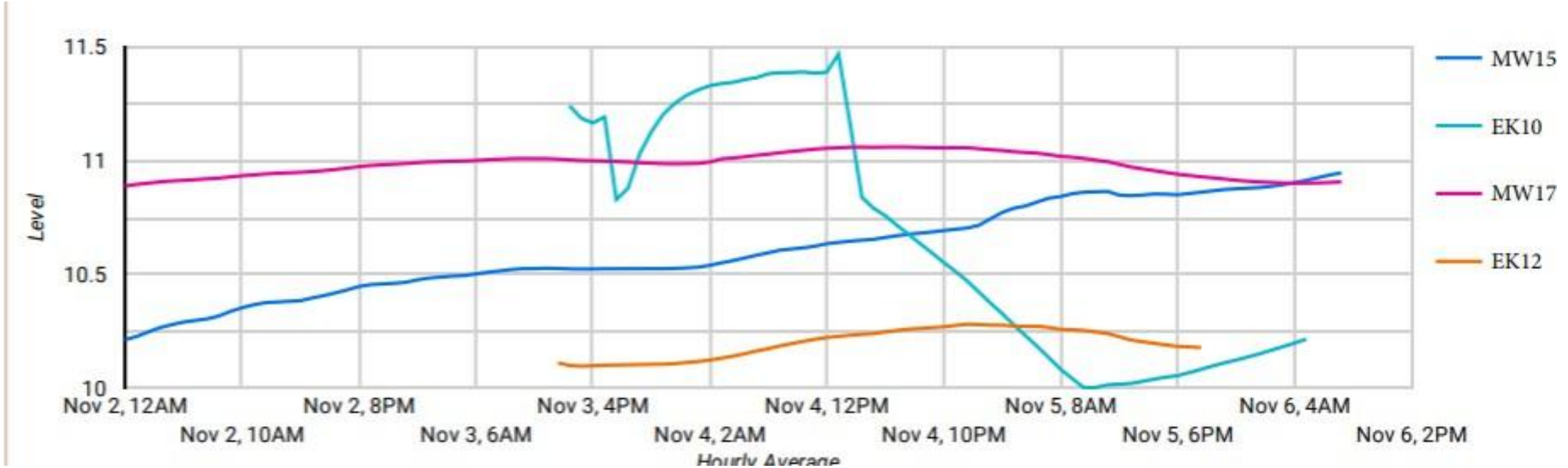
System Installed and Operational



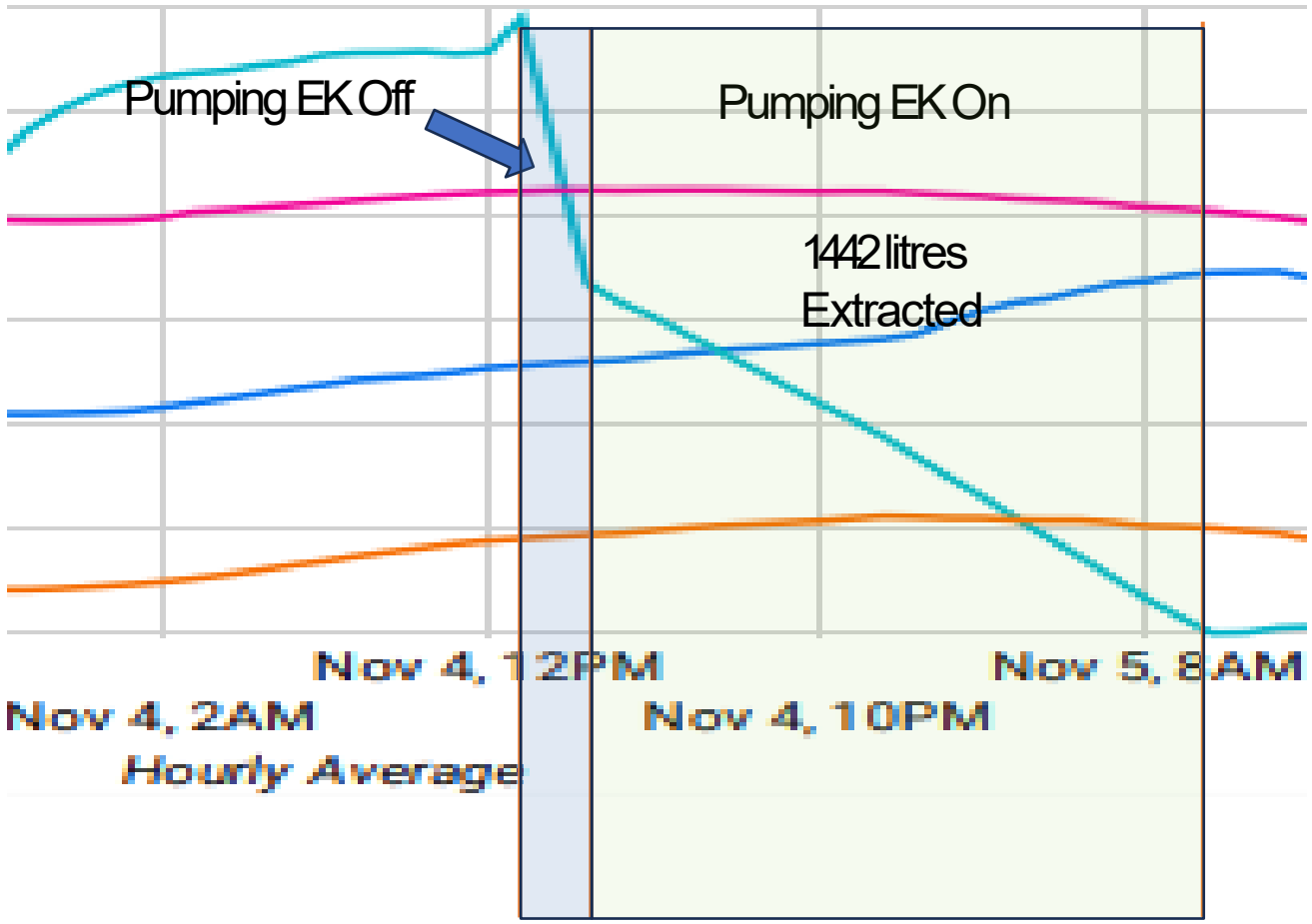
System Installed and Operational



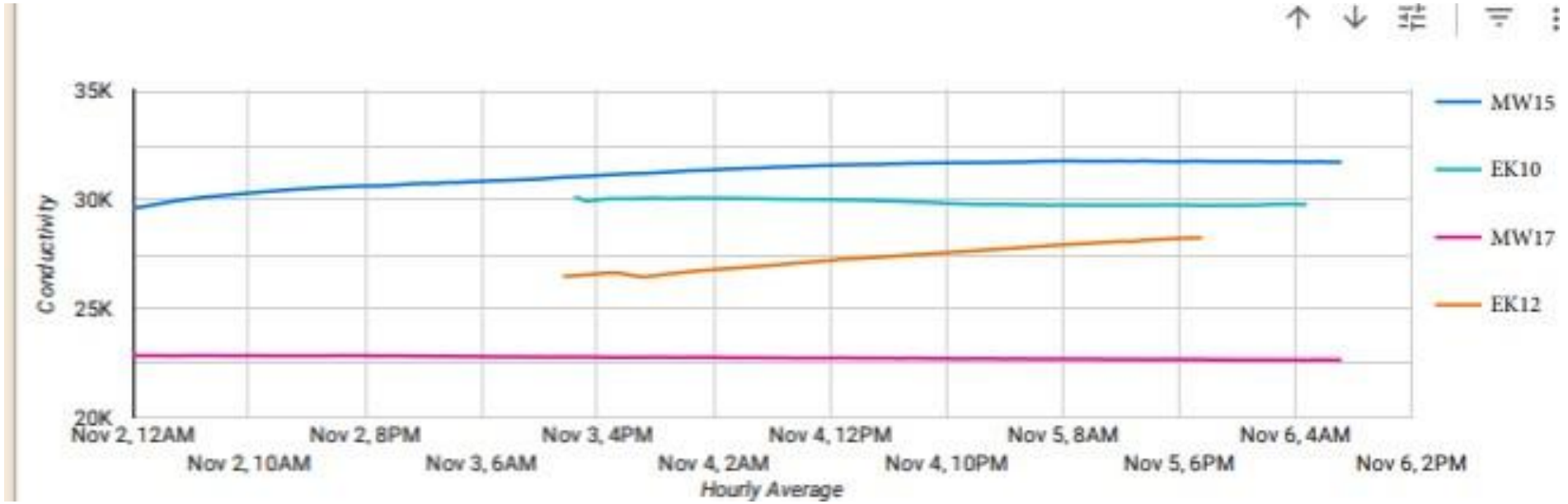
Hydrographs



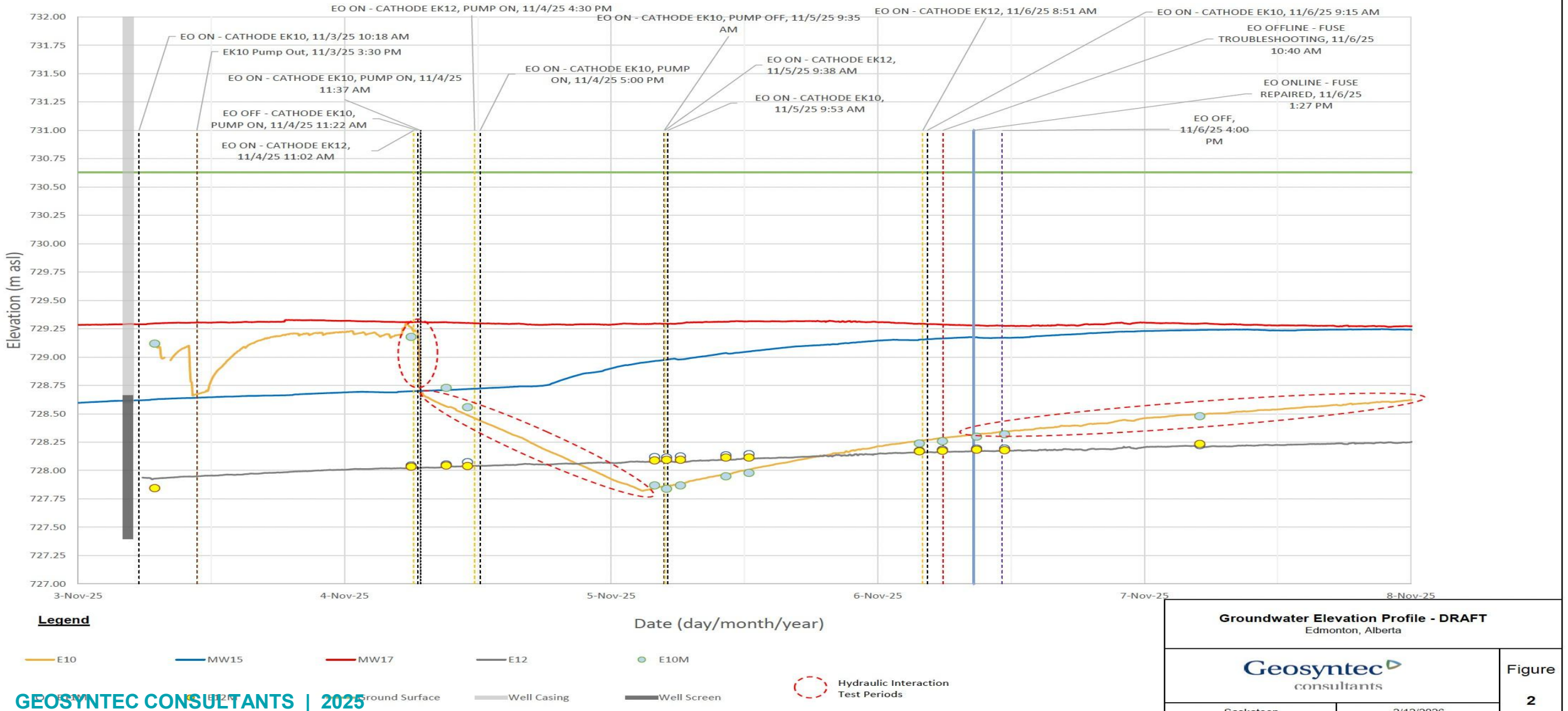
Test Results



Results outside EO Field



Groundwater response



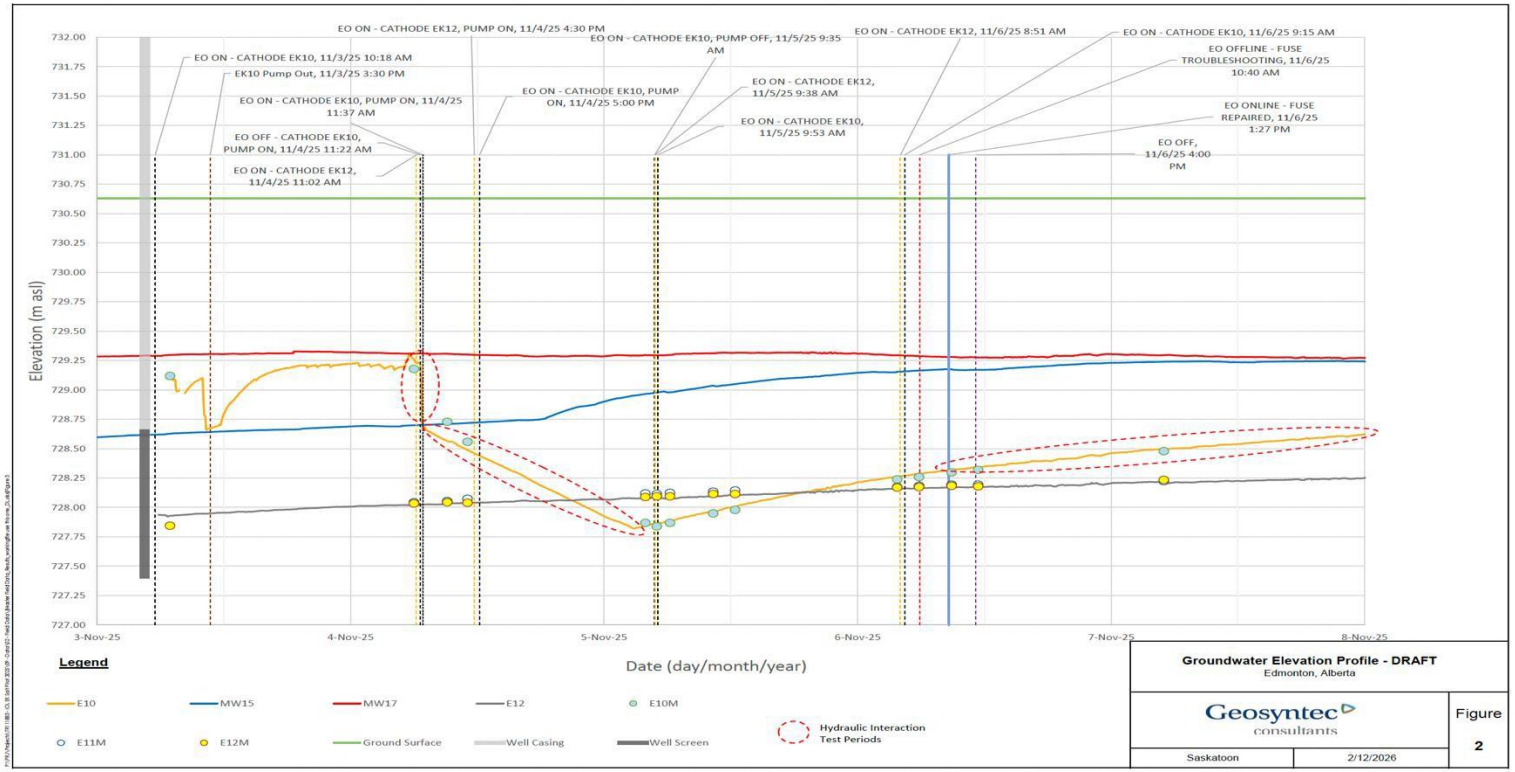
Groundwater Elevation Profile - DRAFT
Edmonton, Alberta

Geosyntec consultants

Figure 2

Saskatoon | 2/12/2026

Groundwater response

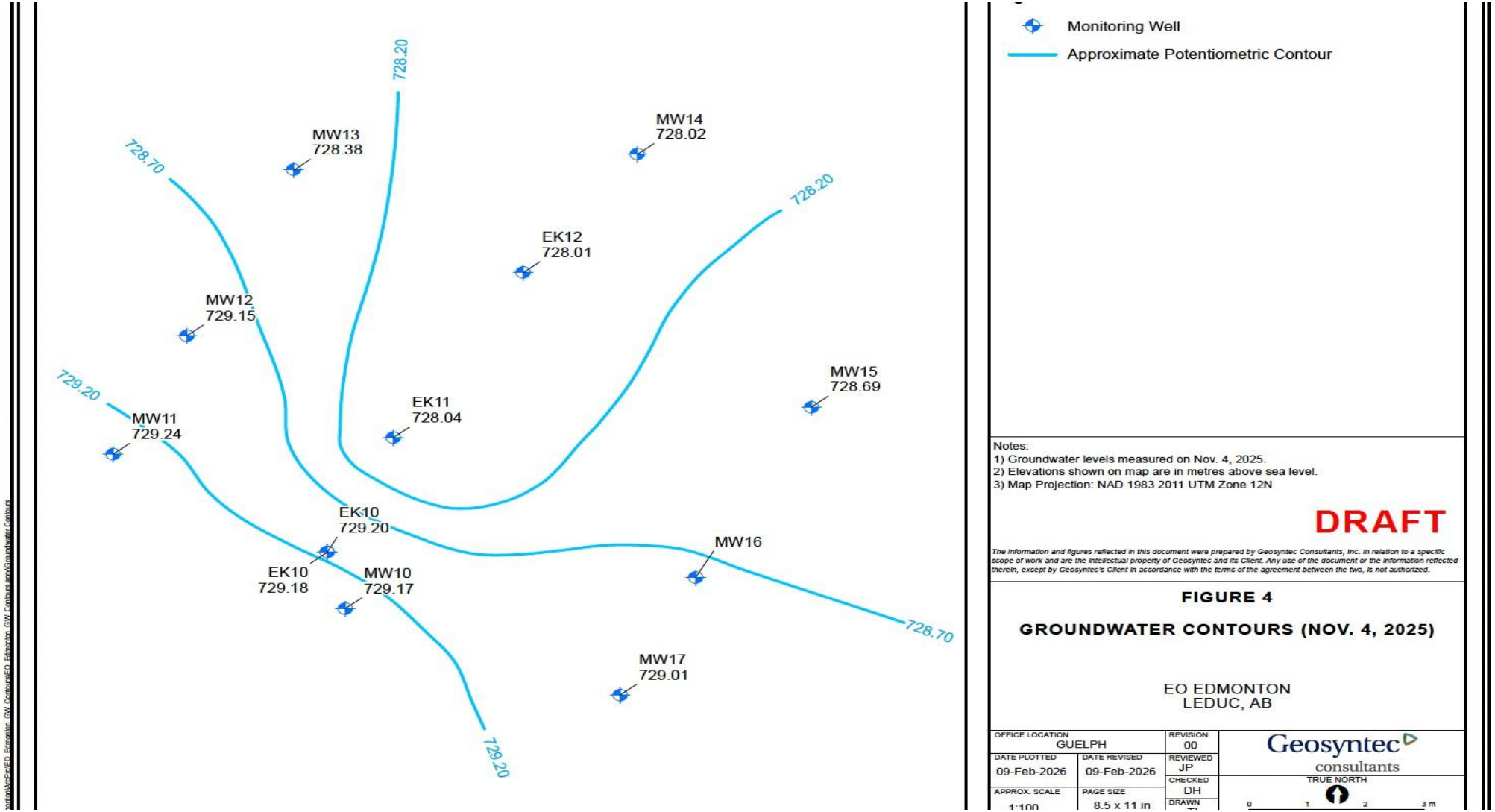


From 11:37 a.m. on November 4, 2025, to 7:37 a.m. on November 5, 2025, analysis of hydraulic gradients yielded an apparent hydraulic conductivity of 1.28×10^{-4} m/s.

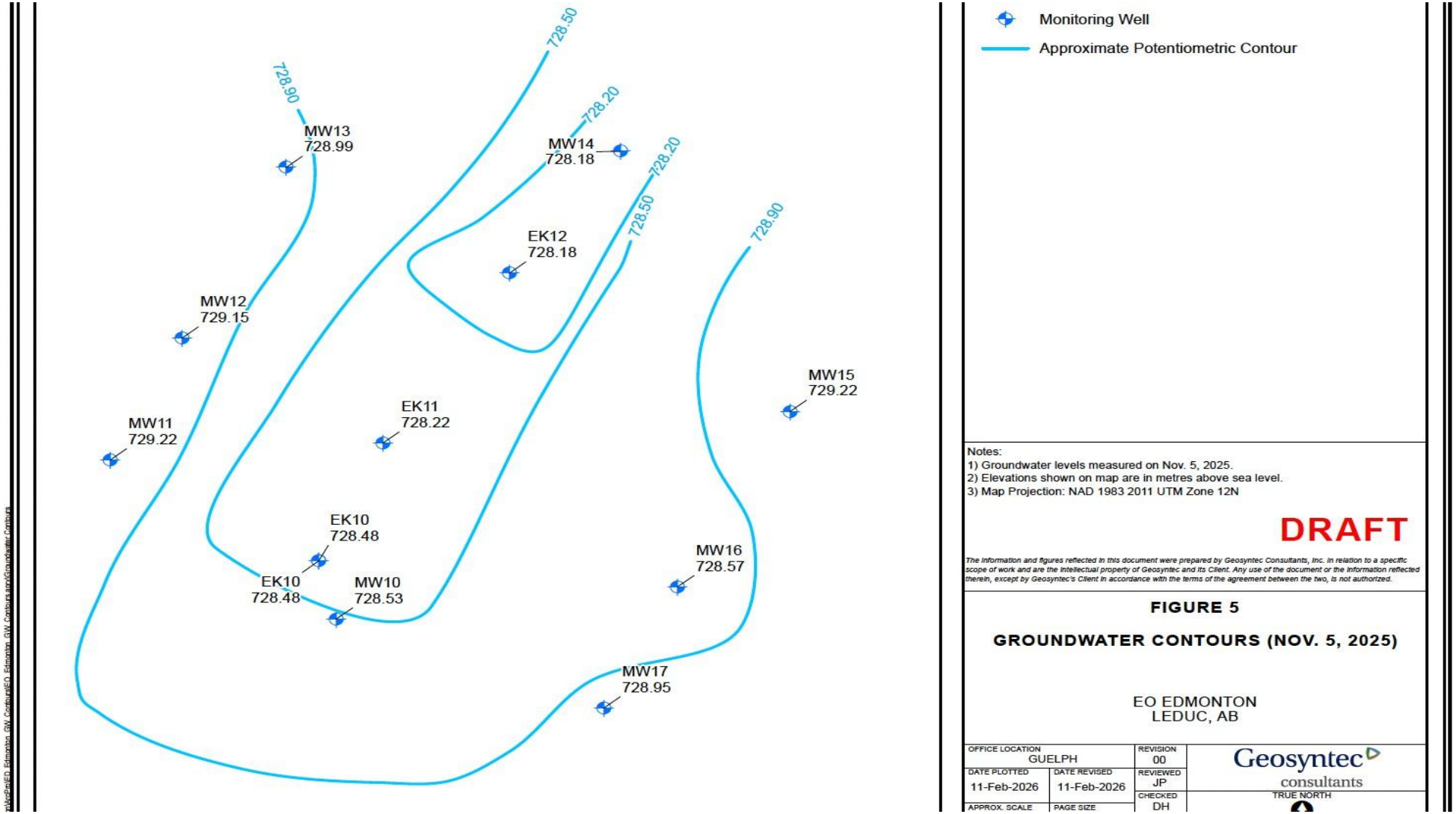
The hydraulic conductivity for shallow groundwater at the Site was calculated to range from 7×10^{8} to 9.3×10^{8} m/s

Approximately 1300 times more conductive in the presence of the electrical field

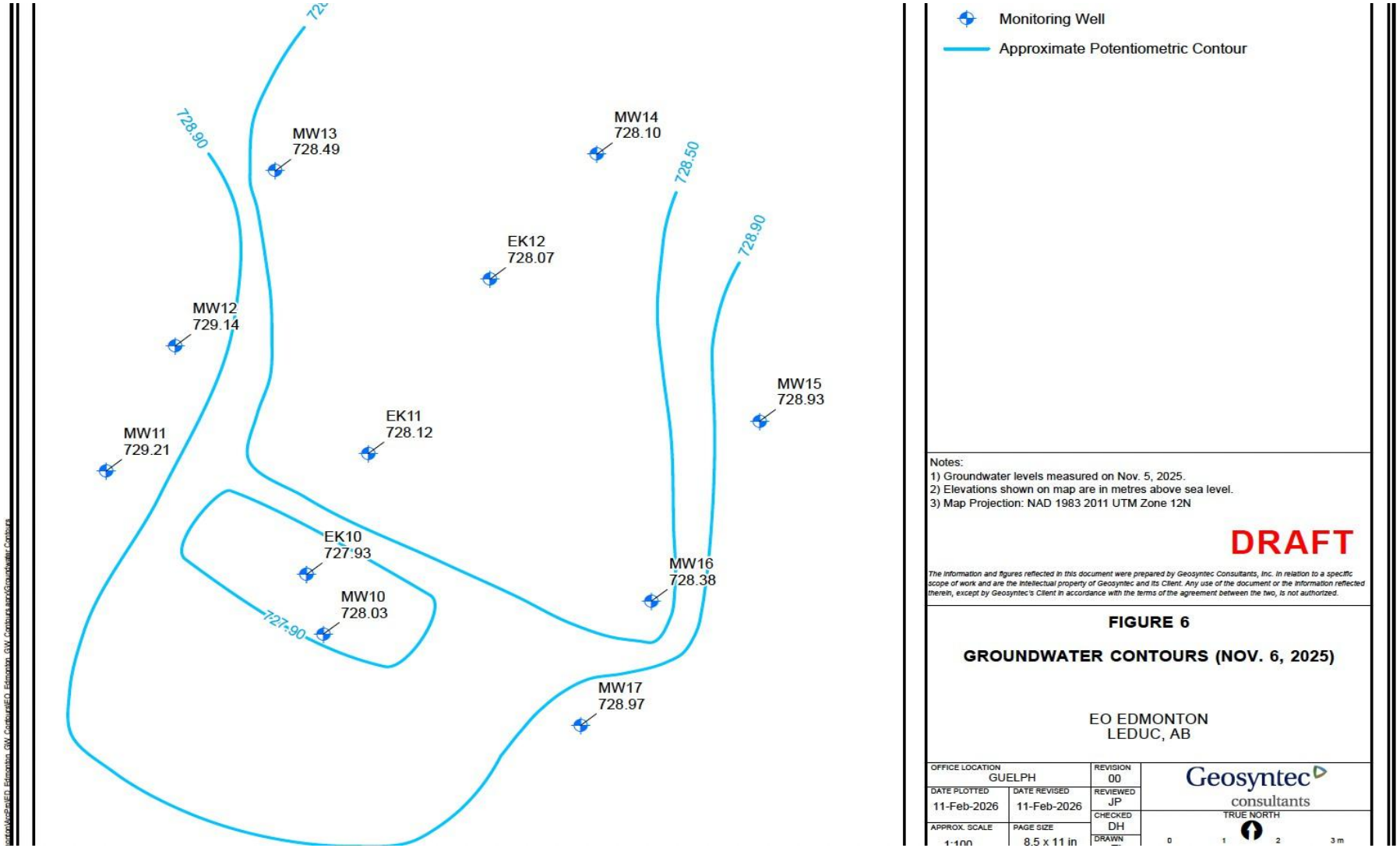
Groundwater response over time



Groundwater response over time



Groundwater response over time

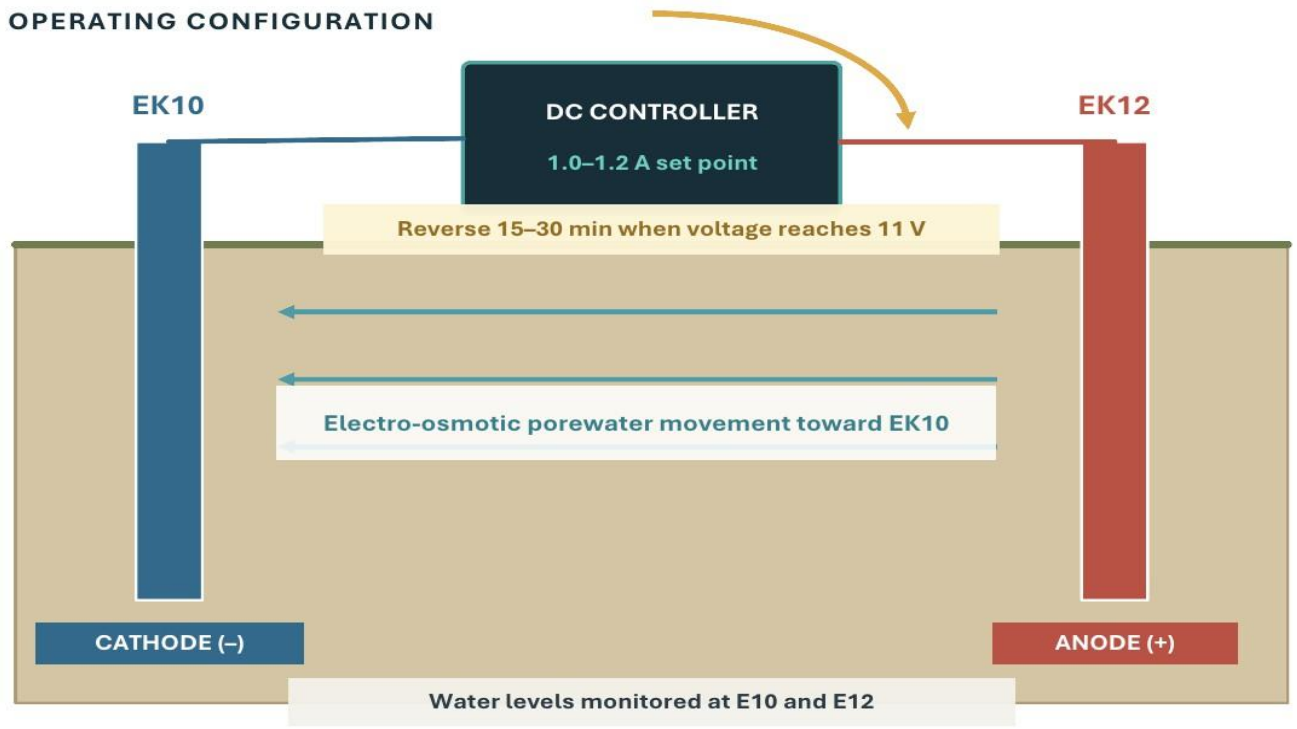


System Power Consumption

ELECTRO-OSMOSIS FIELD PILOT | INITIAL OPERATING PERIOD

EO system operation: controlled current with periodic polarity reversal

Days 0–4 focused on whether low-current DC operation produced measurable water-level responses consistent with enhanced groundwater transport.



PURPOSE OF THE INITIAL TEST

Assess whether the applied DC current changed water levels in E10 and E12, providing an indication of enhanced groundwater transport by electro-osmosis.

WHY REVERSE POLARITY?

Temporarily regenerate the cathode, limit precipitation buildup and help maintain electrical conductivity.

ELECTRICAL DEMAND AT 11 V

11.0–13.2 W

instantaneous power

0.264–0.317 kWh/day

if operated continuously at 11 V

P = V × I | Daily energy = P × 24 h ÷ 1,000

Because voltage increased beyond the 11 V reversal trigger, these daily energy values represent an upper-bound estimate; actual logged energy would require integration of V × I over time.

System Power Consumption

ELECTRO-OSMOSIS FIELD PILOT | LOW-POWER OPERATION

The EO pilot operated at a power level comparable to a car battery

At only 11–13 W near the 11 V operating limit, the electrical load was small enough to support practical standalone DC power concepts.

ILLUSTRATIVE 12 V BATTERY



≈ 600 Wh nominal stored energy

12 V × 50 Ah

LOW-VOLTAGE DC

EO SYSTEM DEMAND

1.0–1.2 A	11–13 W
operating current	upper-bound power

WHAT THAT MEANS

Theoretical runtime from a 50 Ah battery

50 Ah ÷ 1.2 A = 42 h
50 Ah ÷ 1.0 A = 50 h

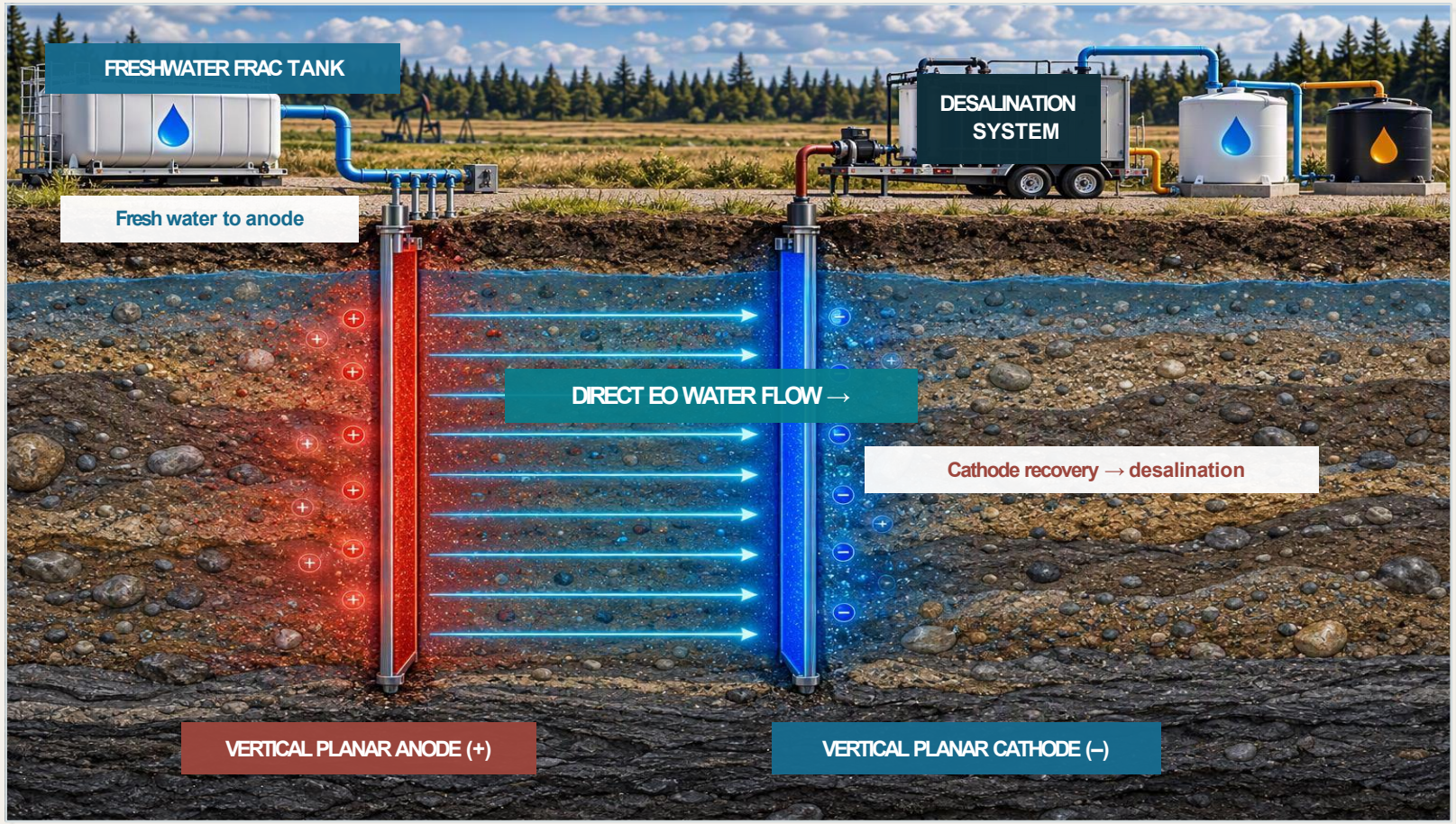
≈ 1.7–2.1 days

A conservative 50% discharge limit would provide roughly 21–25 hours before recharge.

The power demand is small enough for battery-based field operation, although a regulated supply and a deep-cycle battery would be preferable to directly using an automotive starting battery.

2026: Moving from proof of transport to integrated chloride removal

The currently underway 2026 program repeats the EO experiment with improved water balance, active soil washing and treatment of the recovered saline water.



WHAT CHANGES IN 2026

1. **Maintain water balance**

   Supply fresh water from a frac tank directly to the vertical planar anode, replacing water recovered at the cathode.

2. **Test in-situ soil washing**

   Drive water directly across the treatment zone from the vertical planar anode to the facing planar cathode.

3. **Treat cathode discharge**

   Pump cathode recovery water through the desalination system, producing separate treated-water and brine-concentrate streams.

4. **Advance toward integration**

   Track three distinct water inventories: freshwater feed, desalinated water and concentrated brine.

SUPPORTED BY

Imperial Oil • NSERC • Alberta Innovates • Emissions Reduction Alberta

Research and delivery partners: University of Calgary • NAIT • Geosyntec



Questions?