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Hydrologic Implications to Produced Water Spill Response and Remediation

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Petroleum reservoirs typically produce a mixture of hydrocarbons and saline water. Due to past operational practices, accidental spills, or pipeline breaks, produced water has been released to the environment. Salt-affected soils and groundwater are perhaps the single most common environmental problem faced during land reclamation by the upstream petroleum industry.

Research on infiltration and salt transport was conducted at an abandoned upstream oil and gas facility with salt-affected soils and groundwater near Edmonton, Alberta. The primary objective was to improve understanding of shallow groundwater flow and salt transport to a remedial tile drain leachate collection system. The design and operation of leaching systems is based on a model of single permeability flow in a porous medium. Conceptual models of tile drain flow have historically assumed lateral flow into the tile drains away from the water table mounded between the tiles.

Tile drains were installed to collect saline leachate from shallow soils (0 to 2 m) and remove it from the rooting zone. The tile drains were installed in a fine-grained silt layer, above a sequence of dense, weathered to unweathered glacial till deposits interlayered with fine to medium-grained sand. A multi-year irrigation experiment was performed to investigate major solute transport paths operating within and below the tile-drained soil.

A chemical tracer was applied in high concentrations to the surface of a 20 m by 20 m test plot during the 2009 irrigation season. During 2009 and 2010, tracer concentrations were monitored every few hours in tile drain effluent and monthly in the monitoring well network screened at three levels within and outside the test plot. Results from the tracer test indicate relatively rapid breakthrough to the tile drains, on the order of one day; and breakthrough to the sand lense at 4 m depth on the order of weeks. This contrasts with results from the salt remediation experiment, which indicate relatively slow salt transport.

Mechanisms for rapid solute transport include flow through vertical macropores and fractures with high hydraulic conductivity; and, sand layers acting like lateral drains. Interpretation of temporal variation in solute concentrations indicates multi-rate transport processes are occurring. This has significant implications to the relative rate of transport of salt from produced water releases. For cases of recent spills, salt can be transported rapidly to depth through high hydraulic conductivity macropores in low hydraulic conductivity soils. However, as time passes, the salt diffuses into the soil matrix and matrix flow and diffusion control salt transport. This generally results in long remediation times for fine-grained soils.