MEGATIDAL CONTROLS ON COASTAL GROUNDWATER AND SALTWATER INTRUSION DYNAMICS ALONG DYKELANDS

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NSERC RESNET

BACKGROUND

Saltwater intrusion (SWI), the landward migration of saline water into formerly freshwater zones of coastal aquifers, is one of the most severe global threats to coastal groundwater resources. This process can arise due to both anthropogenic and natural causes and can occur over timescales ranging from hours to millennia. The influence that macro- to mega-tidal conditions exert on SWI dynamics is largely unstudied but is highly relevant to changing coastal groundwater systems. Groundwater flow dynamics in coastal environments are highly complex due to many factors such as tidal influences and variable density that constantly alter the magnitude and direction of flow. In conjunction with these natural conditions, ocean-aquifer interactions are strongly influenced by anthropogenic activities along coastal areas that rely on dykes to protect their resources and infrastructure.

Figure 1. Aerial image of the Wolfville dykelands, NS (looking west). Sewage treatment plant located on the left. Photo taken from a drone June 14th, 2021.

RESEARCH

The Bay of Fundy, Nova Scotia is home to among the highest tides in the world and dykes that date back to the 17th century. Climate change and concomitant sea-level rise is increasingly stressing the dykeland dimensions (coastal squeeze) and threatening coastal groundwater and surface water resources. While the *surface* effects of dyke overtopping have received considerable attention, the *subsurface* effects are largely unexplored.

The town of Wolfville (Fig. 1) is an ideal location for a coastal groundwater observatory as the town relies entirely on groundwater resources and is bordered by several kilometres of dykes that protect crucial infrastructure and agricultural crops from the mega-tidal conditions in the Minas Basin. To investigate the potential for saltwater intrusion above, through, or under the dykes, numerous field techniques were employed to characterize the hydrogeology and evaluate the present and future vulnerability to SWI for the town of Wolfville. These techniques included a series of deep and shallow monitoring wells that were installed and/or instrumented, and paired hydrodynamic monitoring (wave buoy and tidal station, Fig. 2) in the basin to monitor wave dynamics and deeper aquifer-ocean interactions. Additionally, geophysics surveys were conducted to capture the subsurface dynamics in the intertidal zone. These data were used to calibrate and drive a numerical model to simulate the impacts of climate change (e.g., sea-level rise, coastal flooding), which could then be used to develop practical water resources engineering solutions to ensure coastal water security in an age of rising seas.

Figure 2. Wave buoy deployment in the Minas Basin near the town of Wolfville, NS. Photo taken November 17th, 2020.

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RESULTS

The field instrumentation and methodologies used in this study have yielded insight into the local aquifer characteristics and properties, groundwater flow dynamics and conditions, ocean forcing, ocean-aquifer interactions, and most importantly, how each of these processes or conditions can impact or exacerbate SWI. Water level and electrical conductivity (proxy for salinity) readings from the deep coastal well revealed that the mega-tidal controls on the groundwater flow pattern is substantial as evidenced by the ~1.5 m tidal range in the groundwater level at ~100 m inland from the high tide mark at the coast (Fig. 3a, light blue). Additionally, results from the geophysics survey revealed that during a spring flood tide (Fig. 3c), the subsurface intertidal zone is drastically impacted by the mega tides as evidenced by the order of magnitude change in resistivity (proxy for salinity) over a short timespan (Fig. 3b). These findings indicate that the high water levels in the Minas Basin result in dynamic flow of groundwater.

HydroGeoSphere (HGS) is a computer modeling code used in this study to assess the present and future states of groundwater and SWI dynamics for the Bay of Fundy dykelands. The results from HGS indicate that sea-level rise will drive landward movement of saltwater, and mega tides increase the vertical extent of this saltwater in the subsurface. Surge-induced surface flooding results in saltwater infiltrating behind the dyke and shallow soil salinization, contaminating the agricultural area (Fig. 3d).

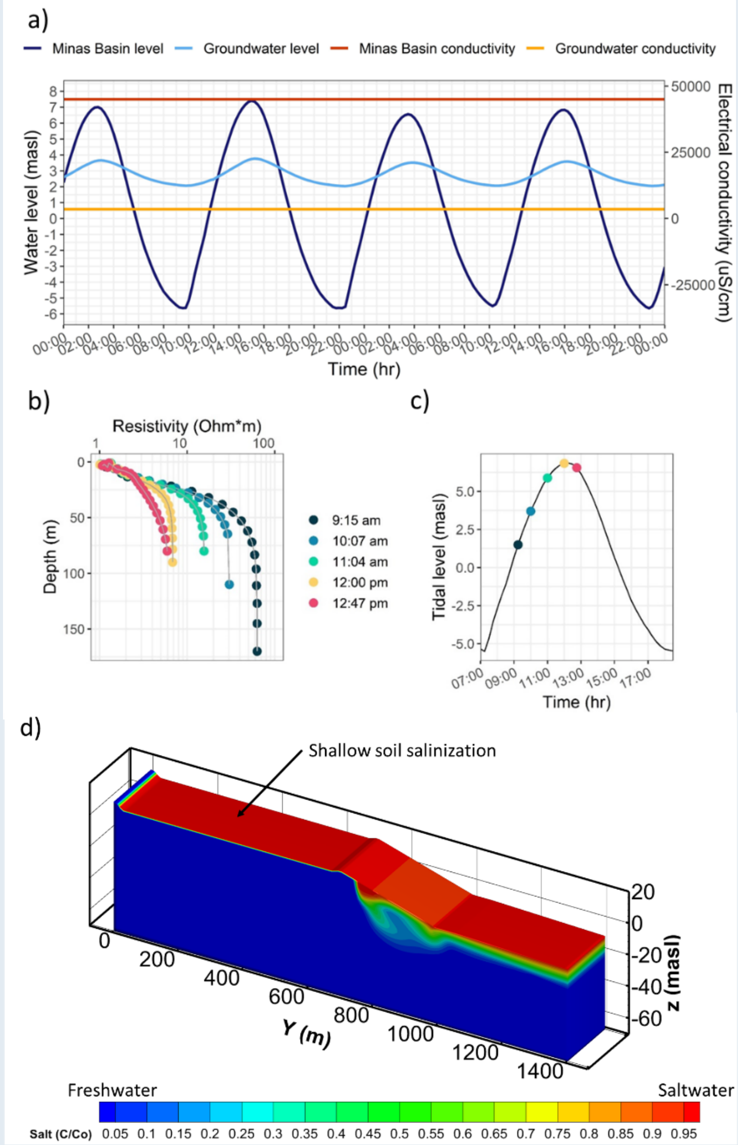

Figure 3. a) Minas Basin (tidal) and groundwater level and electrical conductivity data, b) resistivity point data collected, c) the corresponding tidal stage, and d) salt distribution as a result of a surge projection for 2100 (RCP8.5).

APPLICATION & CONCLUSION

The main overarching results from this study suggest that changes to the mean sea level or tidal range in the Minas Basin will drive SWI into aquifers near the town of Wolfville as these domains are highly interconnected. Climate change will drive landward salt wedge movement which could threaten the deeper groundwater resources that the town relies on for their drinking water supply. Surface flooding over the town's dykes could salinize the shallow soils in this important agricultural region and lead to detrimental impacts on crop sustainability.

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