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Understanding Saltwater Origins and Mechanisms in the Coastal Aquifers of Da Nang Area (Central Vietnam)

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Context

Saltwater intrusion in the rapidly developing city of Da Nang in central Vietnam is currently causing various water-related challenges, including inadequate water supply and water pollution. An integrated SWAT-MODFLOW numerical model was used to investigate the origin and mechanism of saltwater in Holocene and Pleistocene aquifers. Geophysical and isotopic approaches were used to validate the SEAWAT model applied for simulating saltwater intrusion. The results suggest that the ebb and flow of tides, as well as water levels in rivers primarily impact coastal aquifers. During the dry season, groundwater is recharged from higher altitude areas. The current saltwater intrusion mainly occurs along the rivers up to the hydraulic dam. Simulated models, using scenarios of stop abstracting groundwater (GW), but changing to the use of surface water (SW) for drinking water, show that the area of saline water shrinks quickly after 30 years, reducing from 59.6 km^2 to 39.5 km^2 and from 40.2 km^2 to 28.6 km^2 in the Holocene and Pleistocene, respectively.

Objective

Geophysical, hydrogeochemical and isotopic methods were applied to investigate the distribution of saltwater and its origin and mechanism in the coastal aquifers. The status of saltwater intrusion in the Da Nang area was assessed using a coupled SWAT-MODFLOW numerical model. The model was calibrated and employed to forecast potential scenarios of saltwater intrusion, considering the influence of economic and urban development through changes in GW pumping and recharge rates.

Experiment site

The study area is predominantly covered by porous sediments from the Holocene and Pleistocene ages (a blue color, Figure 1). Holocene deposits in the study region are found with thickness varying from 5 m to 29 m and containing sand, silty sand and gravel (light blue, Figure 1). Hydraulic conductivity (Kh) of Holocene aquifer varies from 1.41 to 11.96 m/day, average is 4.6 m/day. Following, there are fine to coarse sand, as well as sand with gravel and pebbles of the Pleistocene (qp) age with a thickness up to 34m, average is about 25m, contains gravel sand to silty sand (dark blue, Figure 1). Hydraulic conductivity (Kh) of qp ranges from 1.9 to 22.6m/day, average is 7.29 m/day.

More than 200 samples have been collected to define the saltwater zones and they show a relation between salt water in aquifer and in the river.

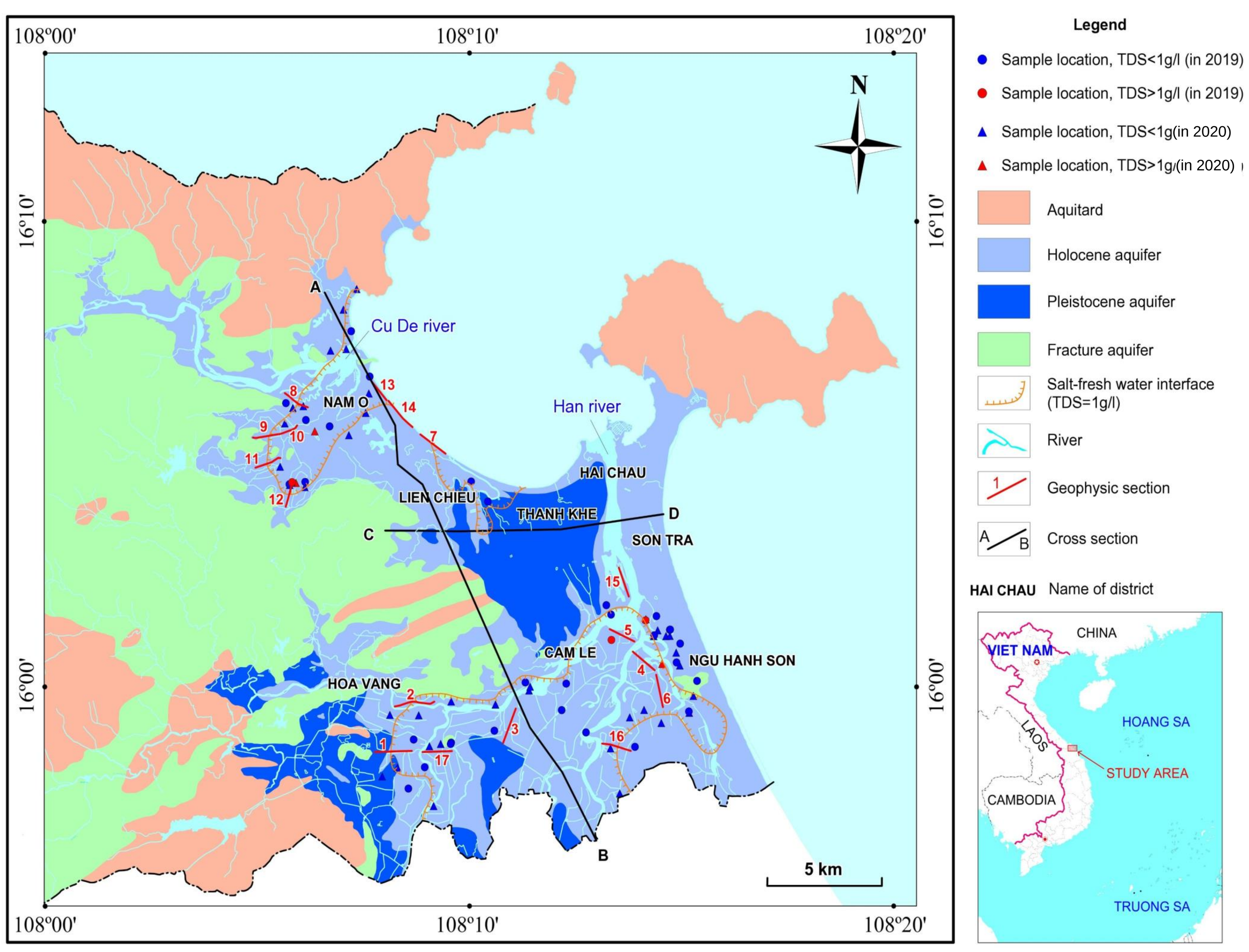

Figure 1. Location of Da Nang coastal plain and its hydrological distribution.

Results

In the rainy season isotopic compositions in GW (open dots in Fig.2) from the study area positioned close to the LMWL indicate that GW in this area is recharged from the local precipitation. The only point positioned below the LMWL, possibly is being affected by seawater making the isotopic signatures in water from that borehole to be enriched.

For the dry season, a quite different trend of the δ2H vs.δ18O relationship for ground-water was observed (solid dots in Fig.3). Oxygen 18 in the water was depleted but deuterium was enriched could explain the recharge area was at a higher altitude for which isotopic compositions in precipitation were depleted.

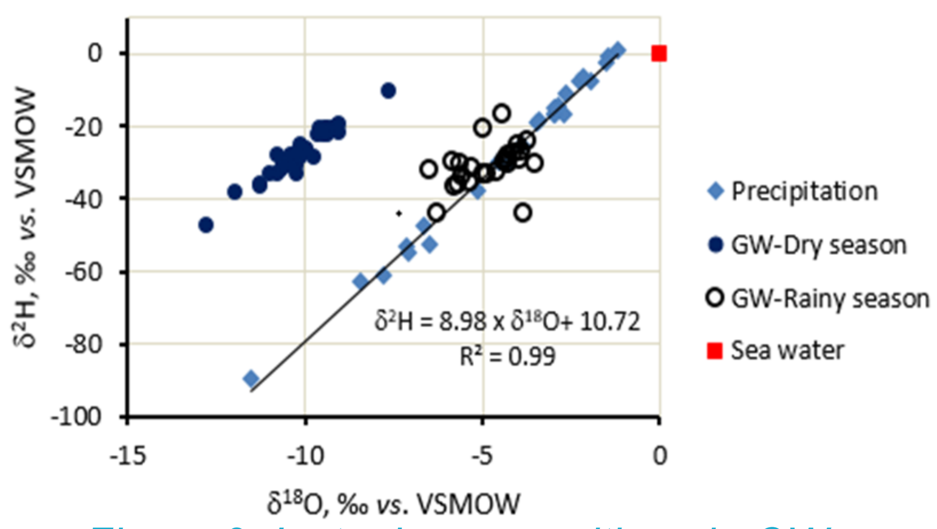

Figure 2. Isotopic compositions in GW samples and the LMWL in Da Nang city

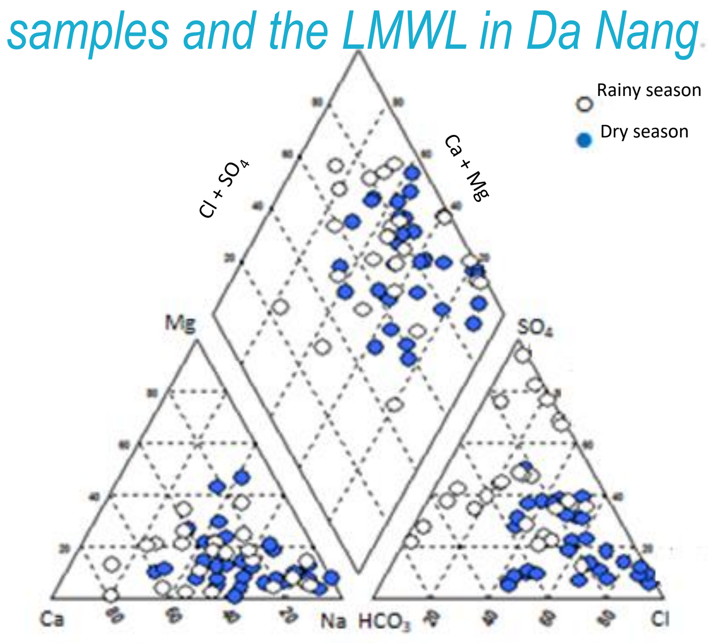

Figure 3. Chemistry of GW in the study area.

As seen from Figure 3, GW in the area is dominated by Na-Ca-Cl-SO4 type. However, some boreholes, e.g. BS1, BS12, BS27 HV40, in the rainy were found to have chloride concentrations that exceeded the national standard for GW quality by up to 4 times. The high levels of chloride in groundwater may be attributed to the ongoing salt intrusion occurring in the study area.

Based on the numerical modeling for saltwater intrusion in the qh and qp from 2016-2020, it was observed that the area of qh aquifer with initial high salinity decreased at a faster rate than that of qp aquifer.

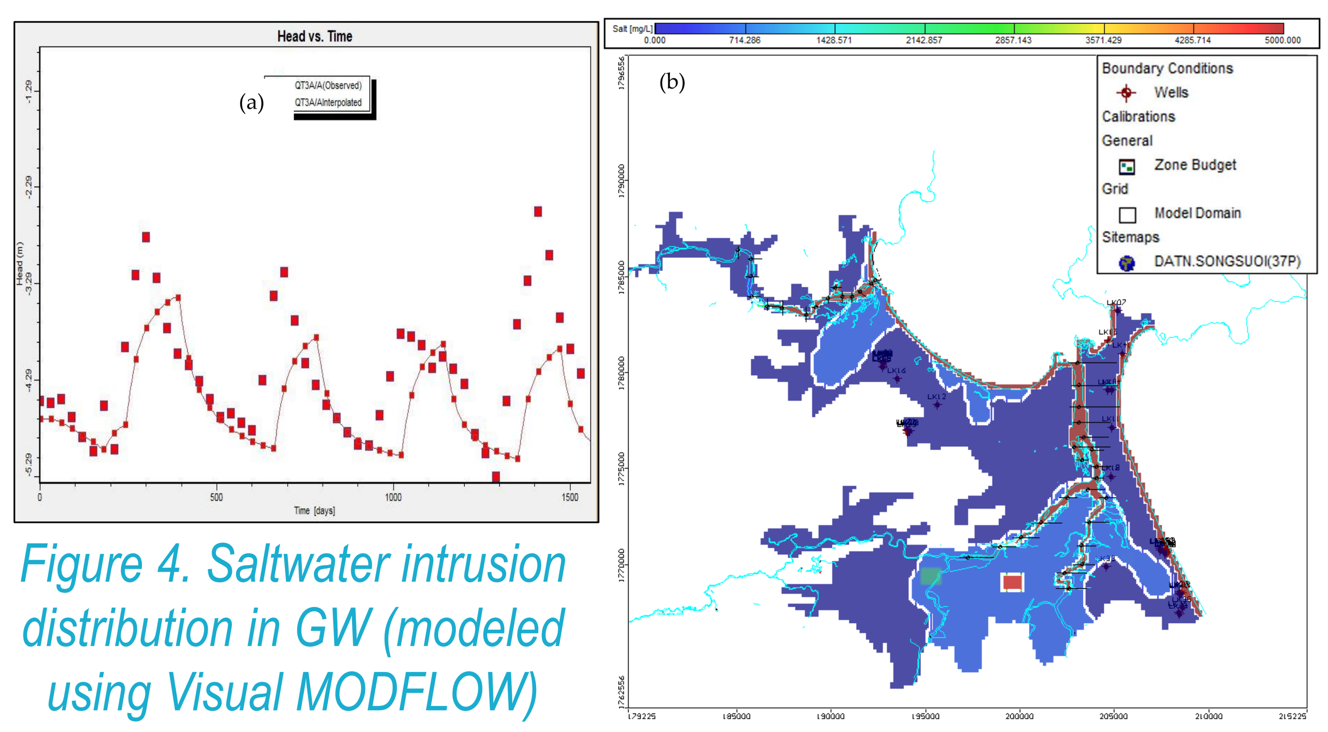

Figure 4. Saltwater intrusion distribution in GW (modeled using Visual MODFLOW)

Conclusion

In Da Nang area, the distribution of saltwater (TDS>1g/l) in Holocene with about 60.3km^2 and in the Pleistocene aquifer with 41.3km^2. Hydro-chemical and stable isotopic data of 35 points from both aquifers demonstrated that in the rain season, GW is recharged from the local precipitation, in the dry season GW is recharged from a higher altitude area and the flow direction of the recharge would be through and beneath a landfill. The replenishment of GW from surface sources is a valuable resource that can reduce the extent of saltwater intrusion in many areas. Along the river downstream up to the hydraulic dams, saltwater in GW mainly recharges by SW from rivers.

Integrated SWAT and MODFLOW model shows that a double pumping rate scenario and no recharge scenario give the same salt intrusion effect to qh and qp aquifers. In this area, GW is an effective resource for water supply to the city, but detailed studies are needed to control saltwater intrusion into aquifers.

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