WVLC
UN Water Virtual Learning Centre

The Arab Regional Center @ AGU

جامعة الخليج العربي
Arabian Gulf University

Feasibility & Health Risk Assessment of Groundwater Recharge by TSE in the Kingdom of Bahrain

Aqeel Ahmed, Waleed Al-Zubari, Alaa El-Sadek, and Mubarak A. Al-Noaimi

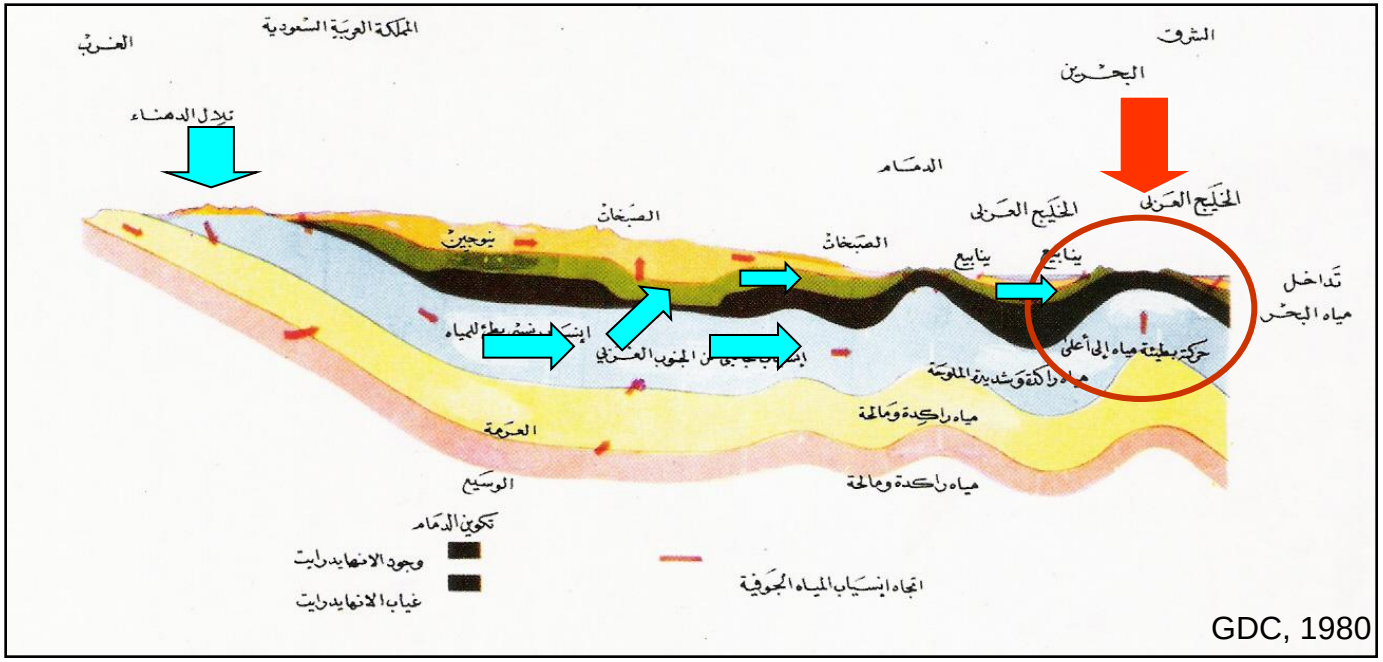
WSTA 10th Gulf Water Conference, Water in the GCC…the Water-Energy-Food Nexus", Doha, 22-24 April, 2012

Overview

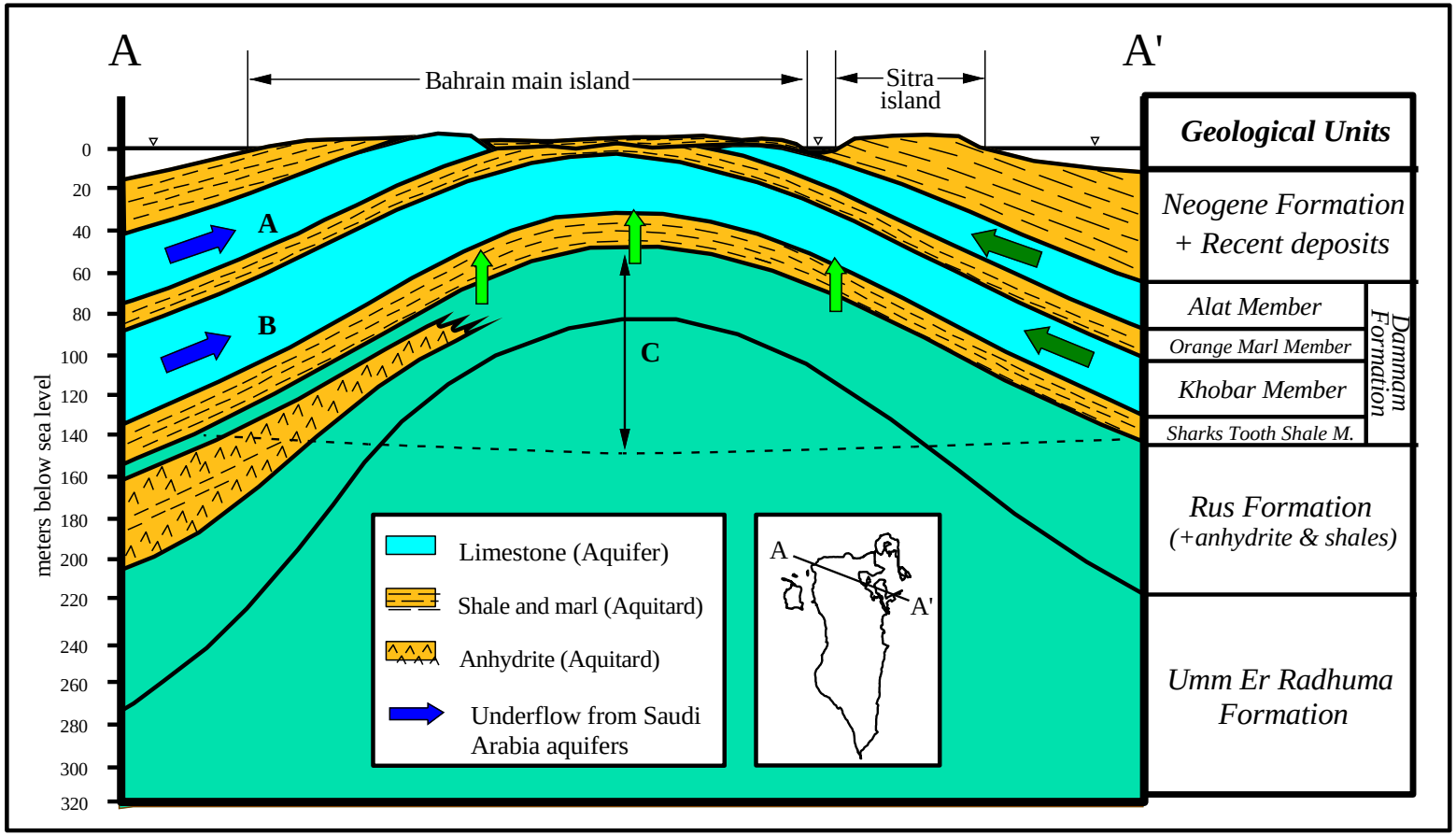
- Introduction
  - Groundwater Resources in Bahrain and Groundwater Development Impacts
- Agriculture, Groundwater, and Tertiary TSE
- Feasibility of Groundwater Recharge by Tertiary TSE
  - Methodology
  - Results
- Conclusion and Recommendations

Introduction

- Groundwater (Dammam Aquifer) is the only natural water resource in Bahrain
- Part of an extensive regional aquifer (the Eastern Arabian aquifer), recharged by underflow

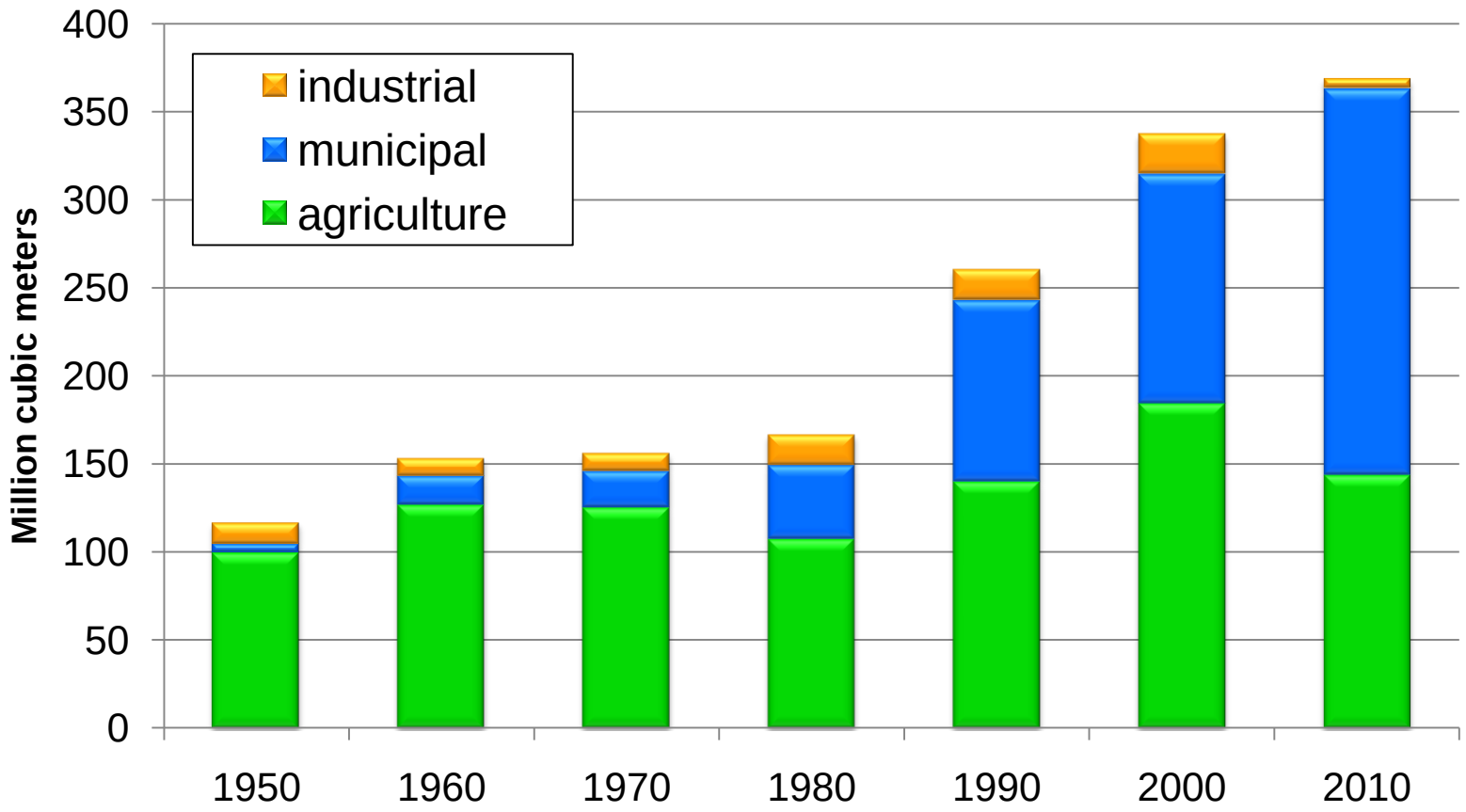


- Two Aquifer units (A & B zones)
- Adjacent to seawater on the east and brackish water (C zone) from the bottom



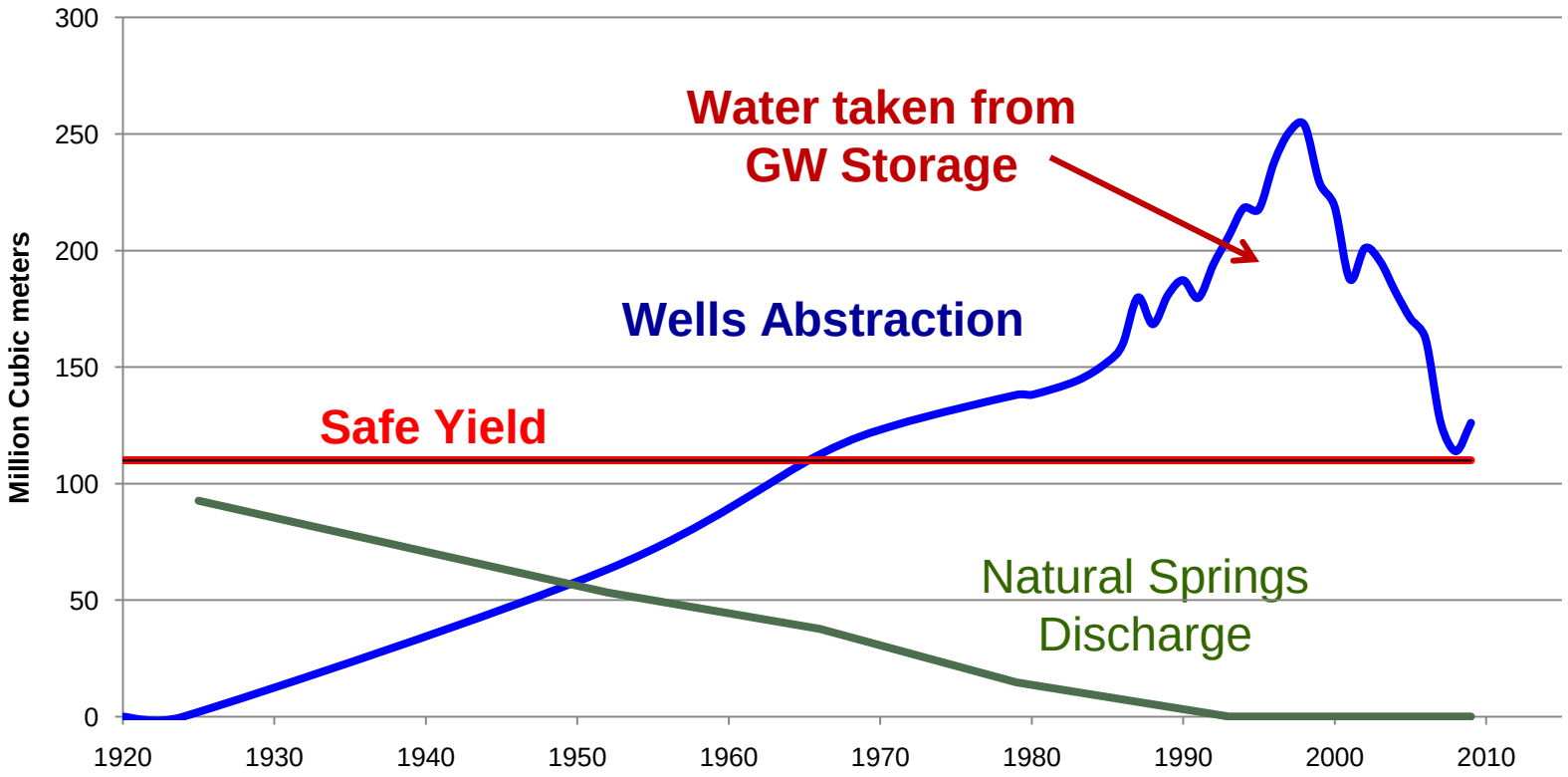
- Significant increase in water demands in past four decades, met mainly by groundwater abstraction

Total Water Requirements in Bahrain, 1950-2010

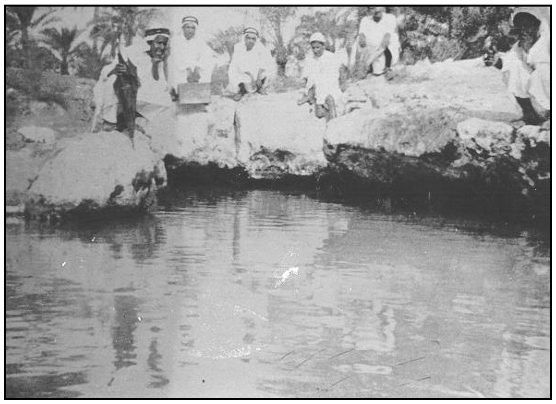
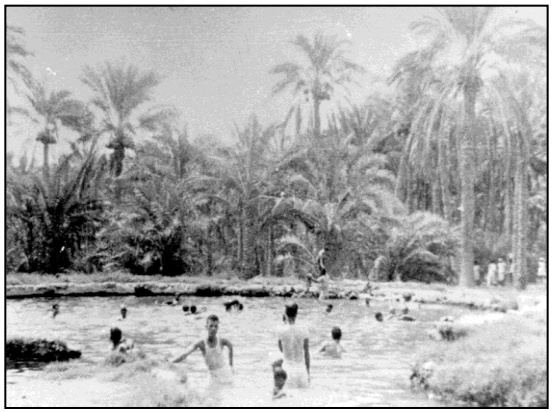


- **Heavy reliance on groundwater and unplanned utilization**
  - Prolonged over-exploitation
    - Potentiometric level decline & Quality deterioration

Development of Dammam Aquifer in Bahrain



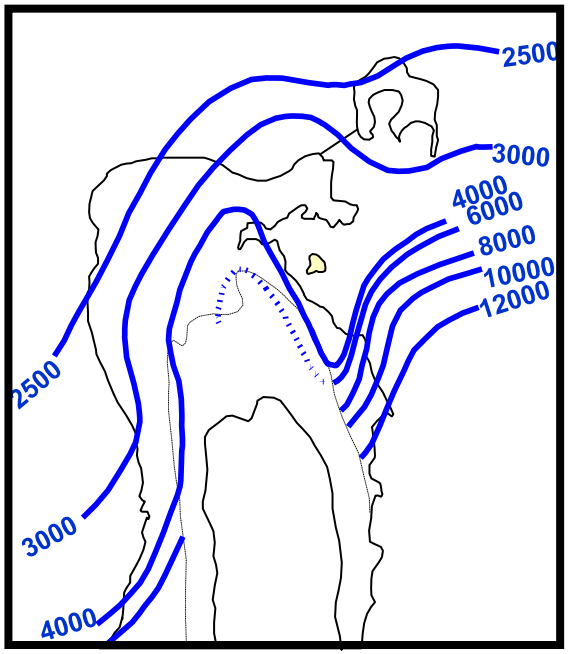
Potentiometric Levels Decline of the Dammam Aquifer in Bahrain

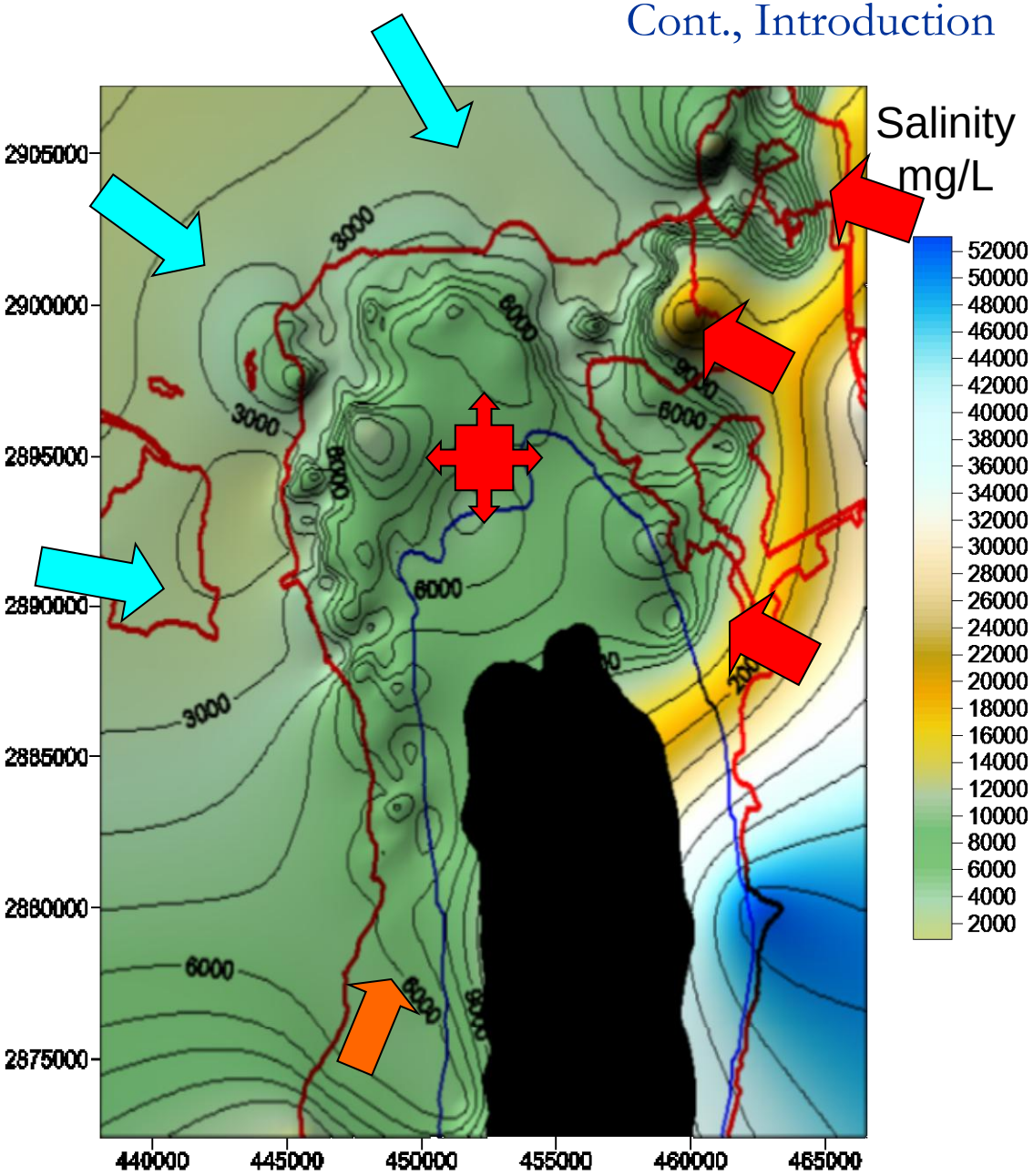
	Al-Shaikh	Al-Safahiyah	Al-Rahah
1940-1950			
1990			

Al-Qusaibi, 1997

Quality Deterioration of the Dammam Aquifer (Salinity)

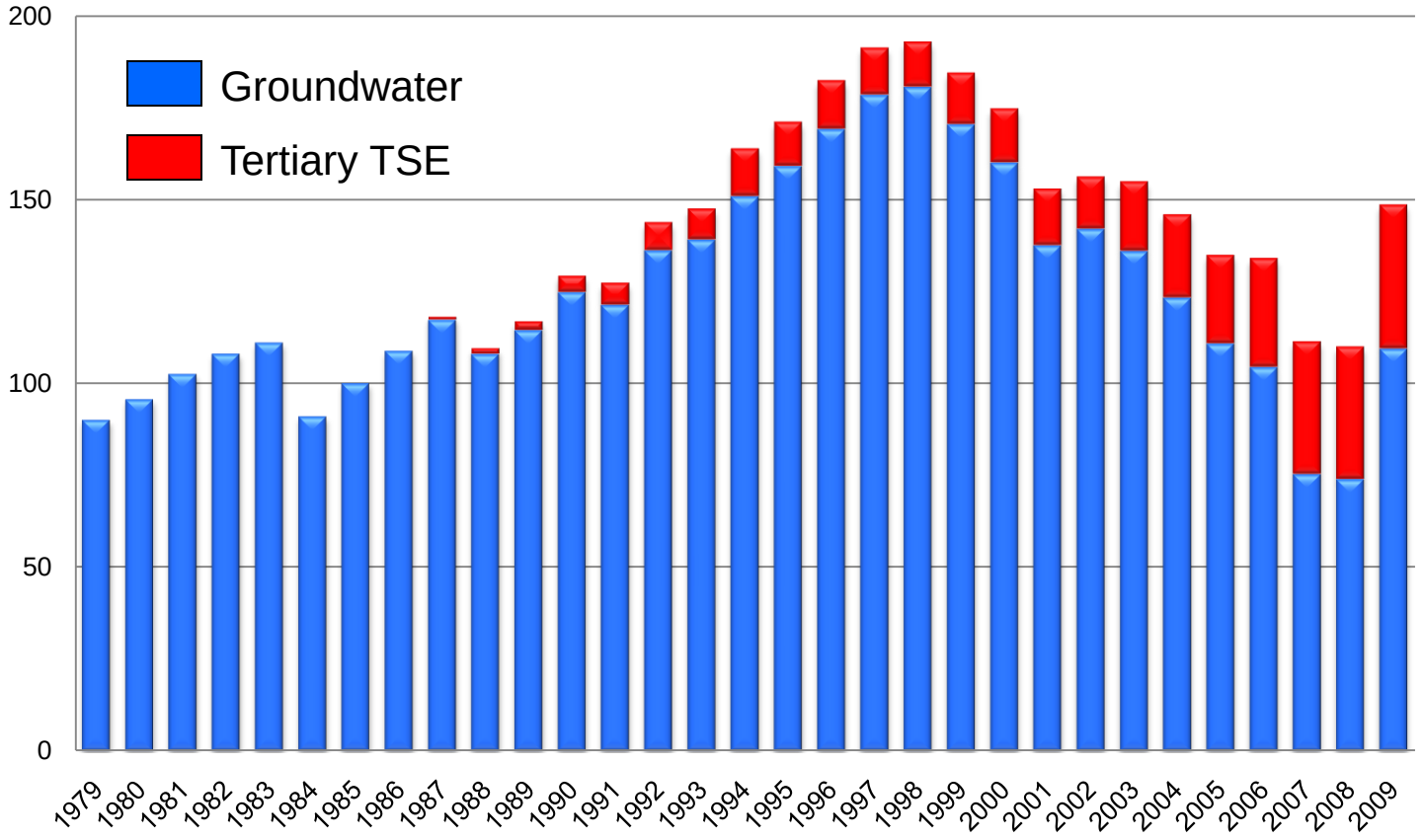
Historical salinity (1965)



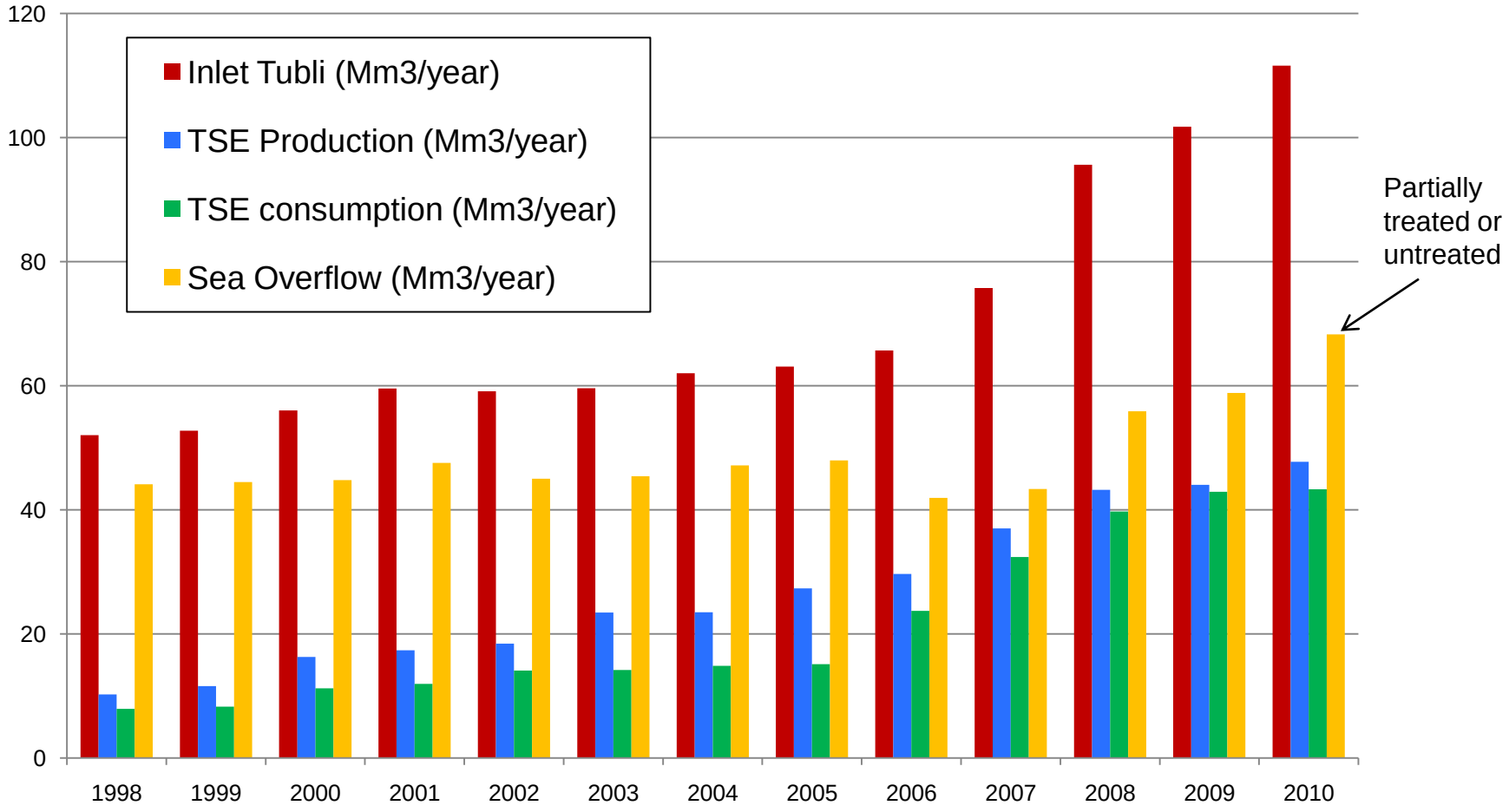


Agriculture, Groundwater and TSE

Agricultural Water Consumption, in Mm^3 (Groundwater &TSE)



TSE Dynamics in Bahrain (Tubli Wastewater Treatment Plant)



System Analysis of the Problem of Tubli Bay Pollution by Wastewater in Bahrain

Drivers

Rapid population growth High consumption patterns

Pressures 1

Increasing rates of municipal water consumption & Increasing rates of wastewater generation

Pressures 2

Increasing inflow rates to Tubli treatment plant (centralized wastewater system & limited capacity)

MAR?

Response

Increasing wastewater treatment capacity
Decentralization
Clean up
Proposed tariff on Wastewater!

State

Increasing carryover rates and pollution

Impacts

Health, Environmental, Ecological, Aesthetics, Financial, economical, political, social losses

Feasibility of GW Recharge by TSE

- **MAR** using Tertiary TSE represents a promising and potential option in the management of water resources in the Kingdom of Bahrain (hydraulic benefits: water levels and salinity)
- However, associated **health risks** need to be assessed thoroughly (among other less concerns) before the implementation of such a scheme
- **Objective**: to evaluate the hydrogeological and environmental feasibility of recharging groundwater with surplus tertiary treated wastewater

Methodology

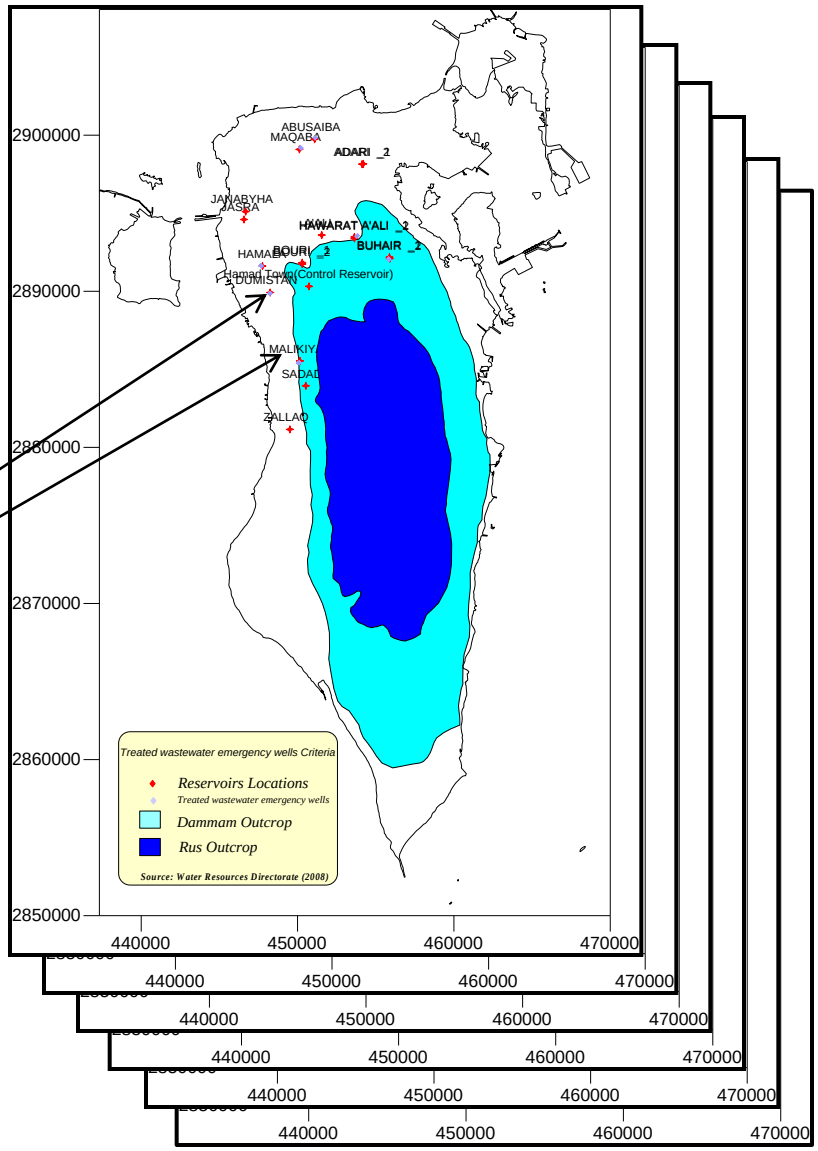
- **Site selection by GIS and Criteria Matrix**
  - Using geospatial data to select the best location for artificial recharge (geometry, transmissivity, quality of groundwater, water supply wells location, TSE distribution network and main reservoirs with possible surplus)/ GIS
- **Simulation Modeling and Analysis of selected sites**
  - Develop a groundwater mathematical model for the surrounding areas of the selected sites; simulate artificial recharge using several scenarios, evaluate the hydraulic efficiency and benefits, and identify the most suitable site for MAR/ MODFLOW and MT3DMS simulation
- **Health Risk Assessment**
  - Use simulation modeling to assess health risks of artificial recharge/ PMPATH and MT3DMS

Results

Site selection by GIS & Criteria Matrix

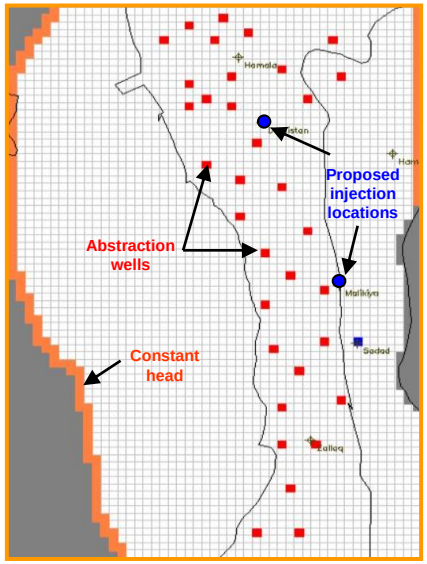
1. Treated wastewater reservoirs tanks locations and capacity
2. Dammam Aquifer Transmissivity (T)
3. Domestic Water wells locations
4. Agricultural areas
5. Aquifer salinity
6. Treated wastewater emergency wells

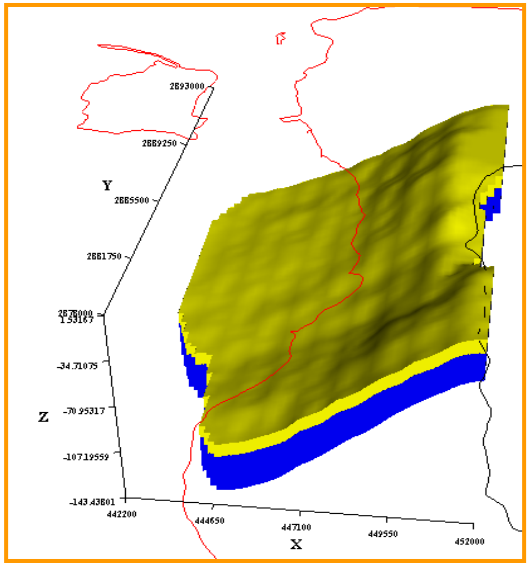
Two Selected Sites
Malikya and Dumistan

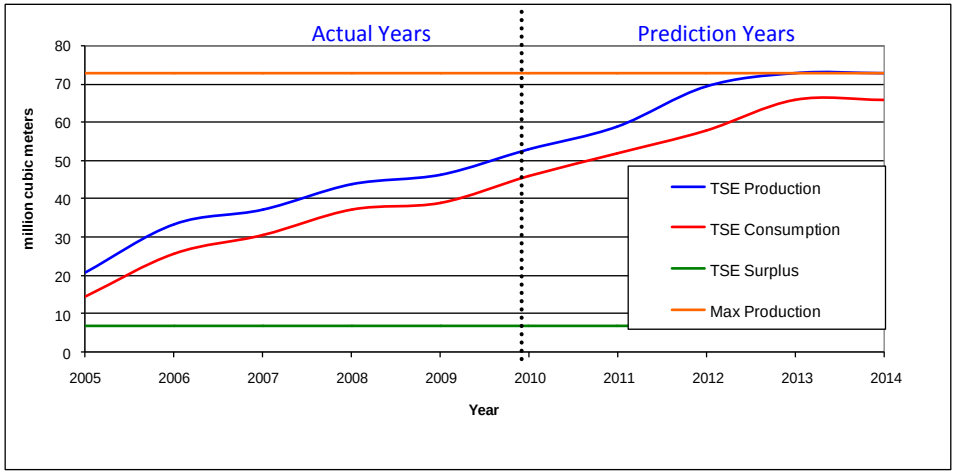


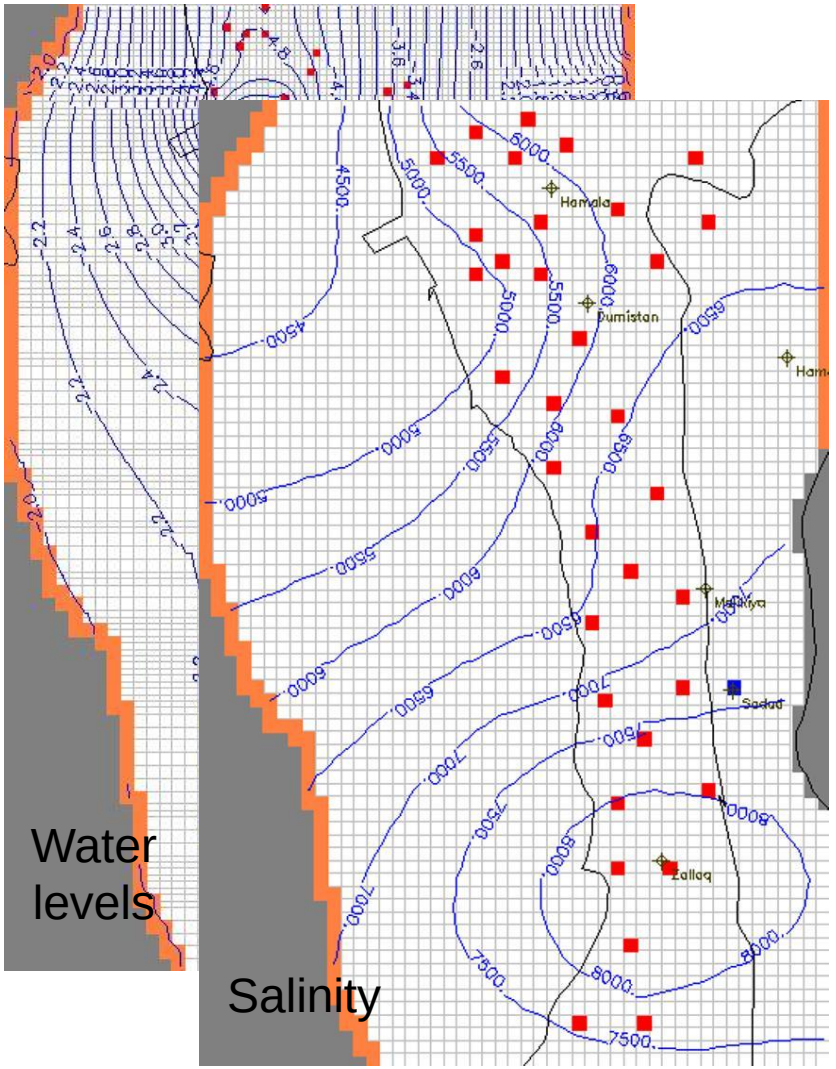
Cont., Results

Simulation modeling and analysis of the two selected sites





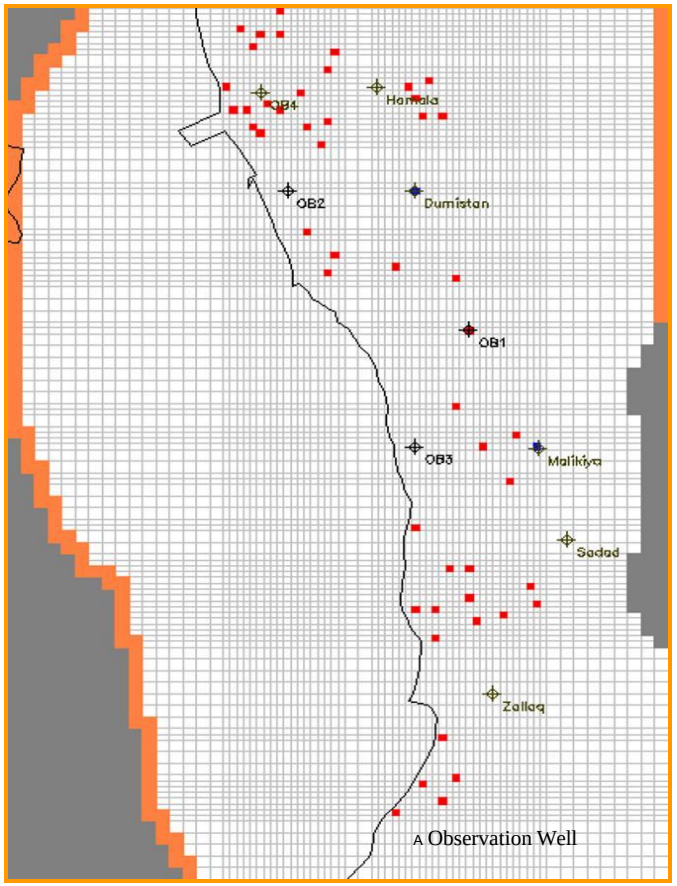


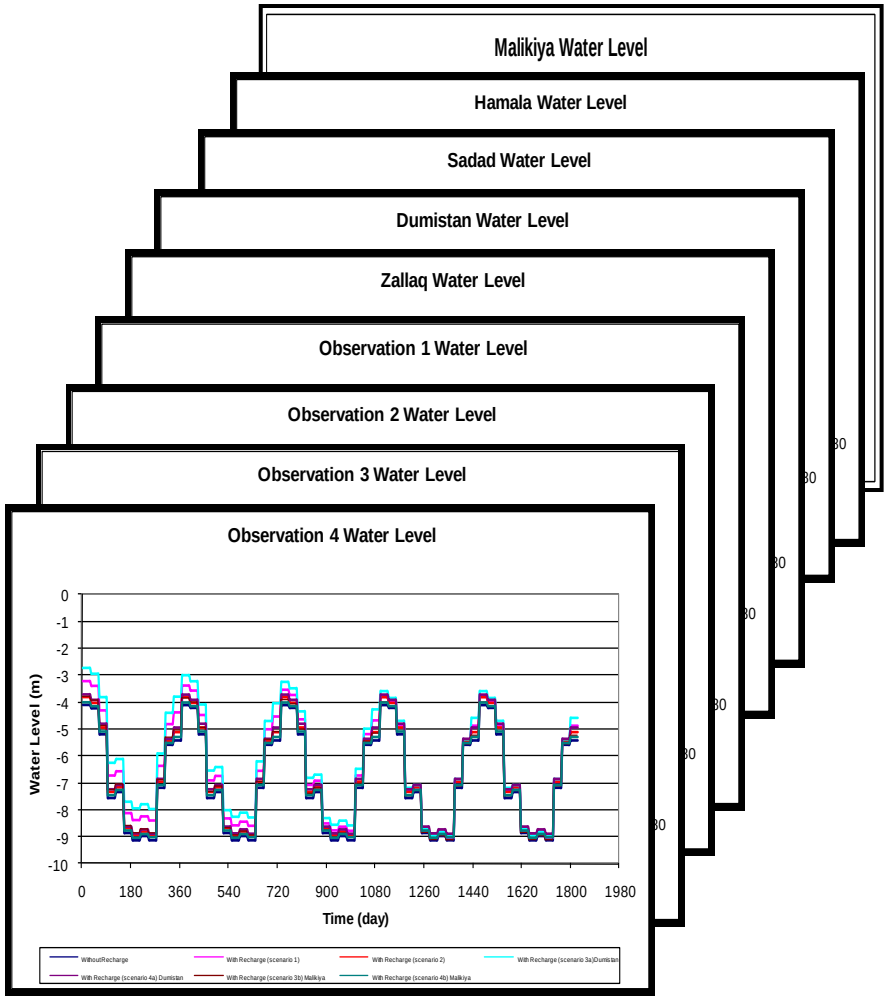


- **Cont., Results**
  - **Six scenarios are developed**
    - **National strategic water storage plan scenario**: [200,000 m^3/day – average daily consumption] / 2 = 77 Mm^3 (38.5 Mm^3 per location)
    - **Surpluses storage Scenario:** 7 Mm^3/year = 35 Mm^3 (17.5 Mm^3 per well)
    - **Inject all the quantities from scenario 1 (77 Mm^3) in one well only:** (3a: Dumistan, 3b: Malikiya)
    - **Inject all the quantities from scenario 2 (35 Mm^3) in one well only:** (4a: Dumistan, 4b: Malikiya).

Cont., Results

- **Simulation modeling and analysis of selected sites (water levels)**

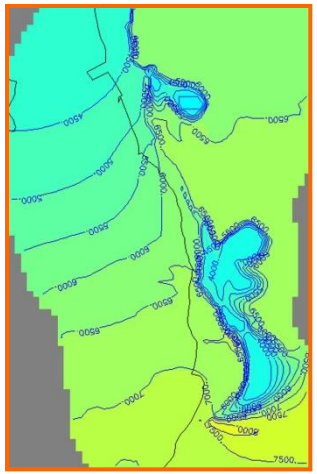




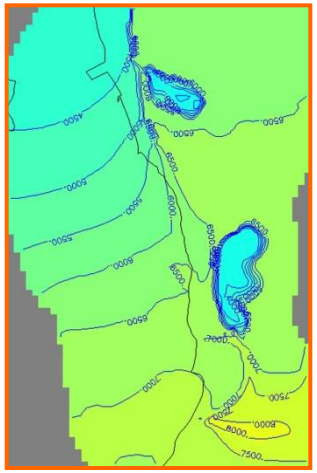
Cont., Results

Simulation modeling and analysis of selected sites (Salinity)

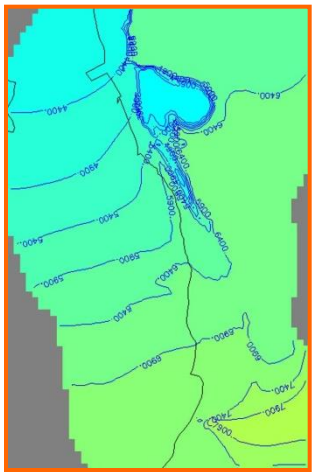
scenario 1



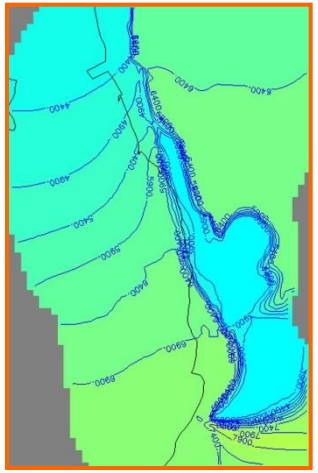
scenario 2



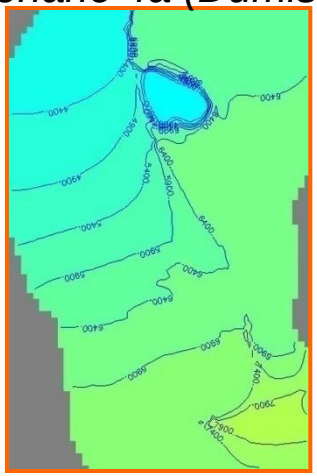
scenario 3a (Dumistan)



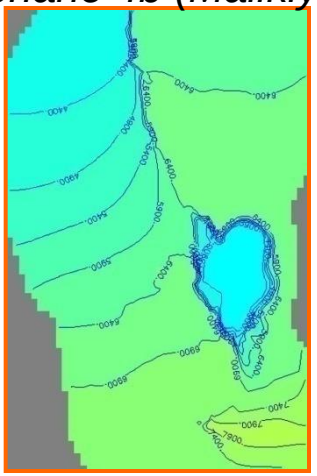
scenario 3b (Malikiya)



scenario 4a (Dumistan)



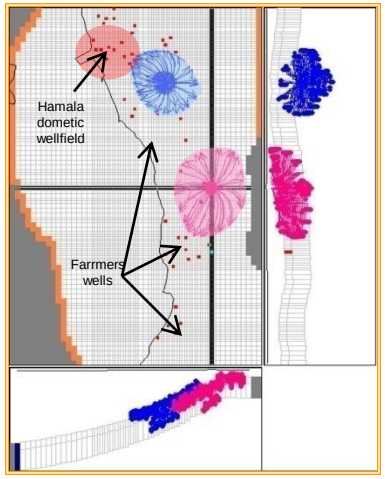
scenario 4b (Malikiya)



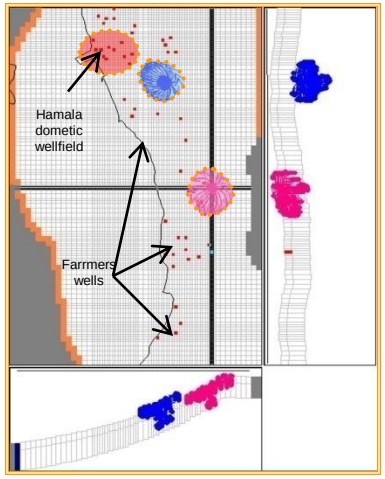
Cont., Results

Health Risk Assessment (Pathogens) using PMPATH

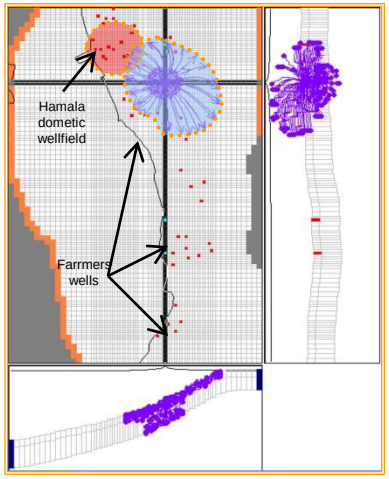
scenario 1



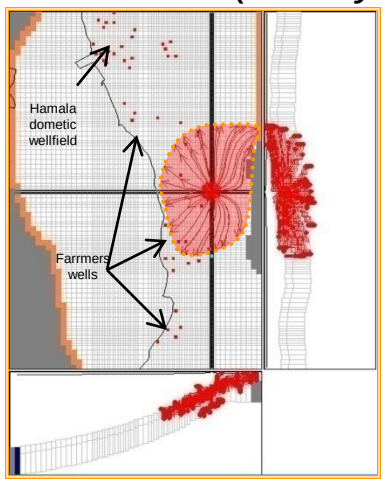
scenario 2



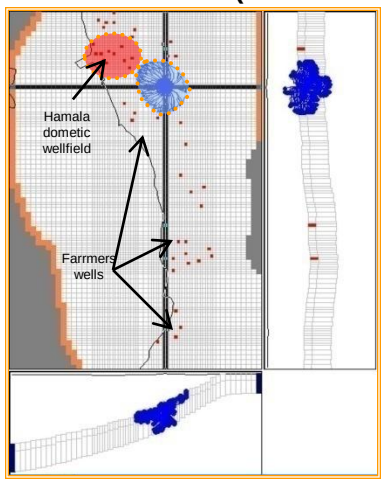
scenario 3a (Dumistan)



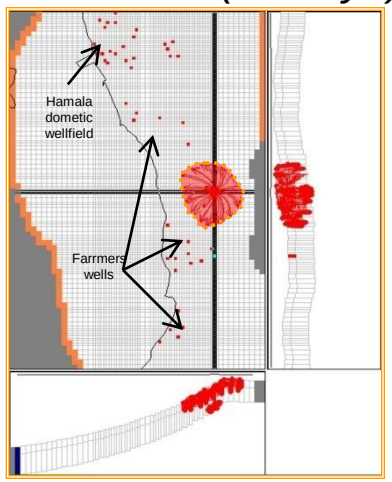
scenario 3b (Malikiya)



scenario 4a (Dumistan)

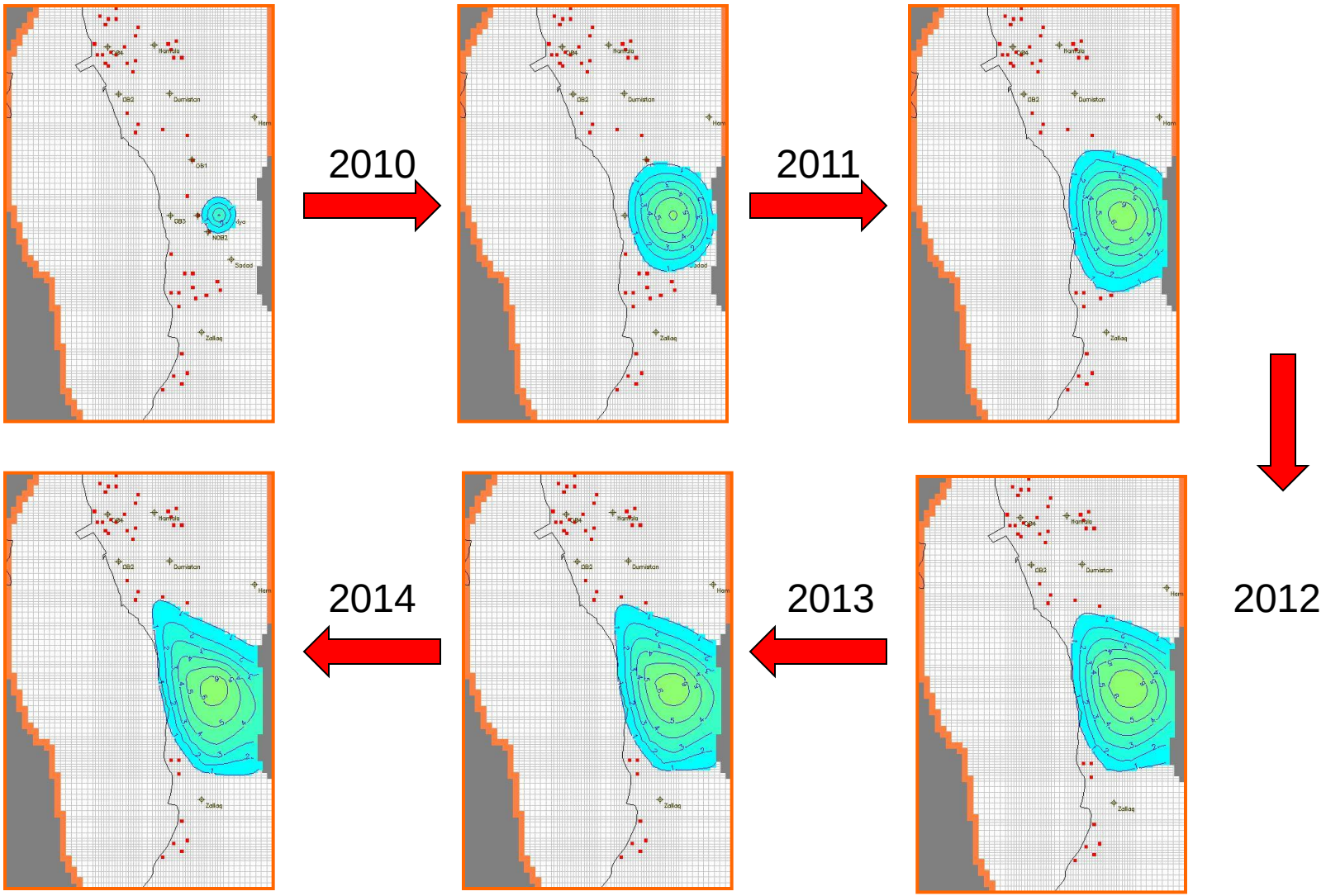


scenario 4b (Malikiya)



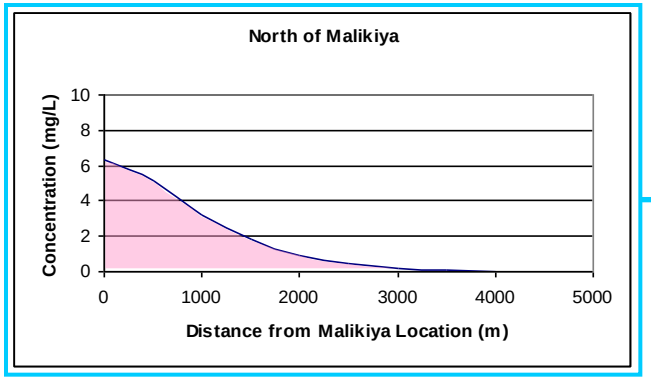
Cont., Results

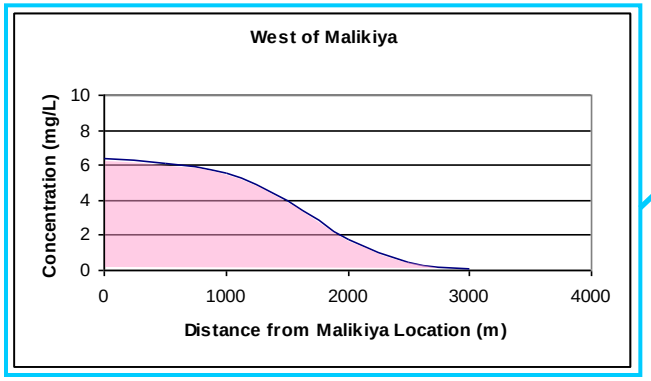
Health Risk Assessment (Nitrates) – Using MT3DMS (S 3b)

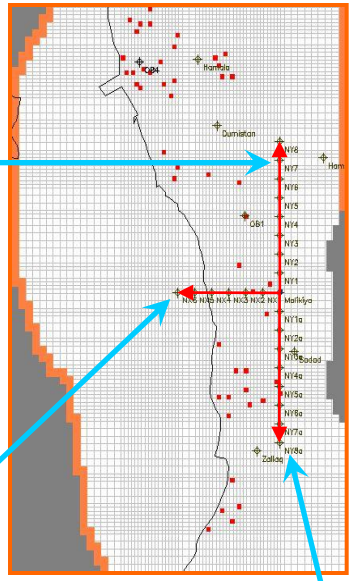


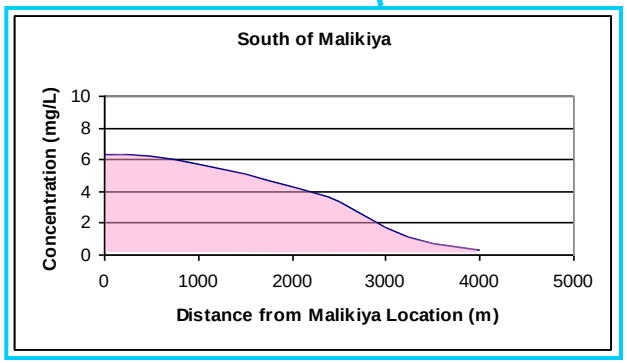
Cont., Results

Health Risk Assessment (Nitrates)









5 Year Simulation of scenario 3b (about 4 Km)

Conclusion and Recommendations

- Groundwater artificial recharge/storage enhancement using surplus tertiary TSE is a viable option for Bahrain at a certain location in western Bahrain, where maximum “hydraulic benefits” and minimum “health risks” can be achieved
- Field pilot study for artificial recharge using tertiary TSE at the selected location to further evaluate the feasibility of artificial recharge and validate the modeling results is a pre-requisite for such plans
- MAR should be looked at as a major component of national water resources management and planning in Bahrain
- To develop a 3D simulation model for Bahrain aquifer system (including C zone), that can be used in the management of groundwater, including the evaluation of artificial recharge

THANK YOU!