جامعة الإمارات العربية المتحدة
United Arab Emirates University

UAEU Faculty of Engineering

Managed Aquifer Recharge in the UAE

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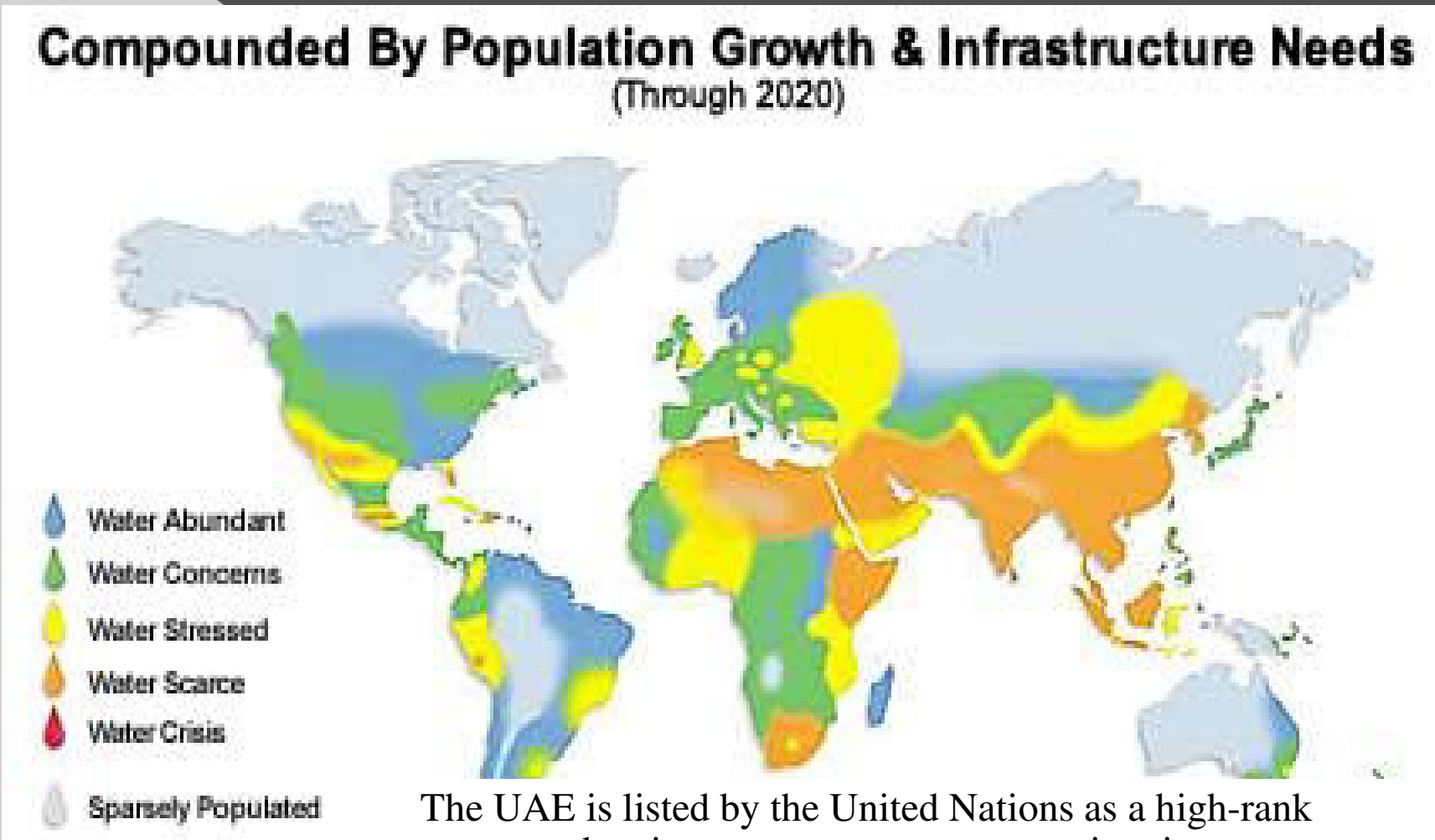
Water Resources in UAE

- UAE occupies an area of about 85,000 km²
- Water demand is 26 times renewable resources
- The Emirate has an arid climate with less than 100 mm/yr average rainfall, a very high evaporation rate (2-3m/yr).

- Low groundwater recharge rate and no reliable surface water resources
- Groundwater is the only conventional source with about 80% share.

Precipitation (P) & Evapotranspiration (ET)

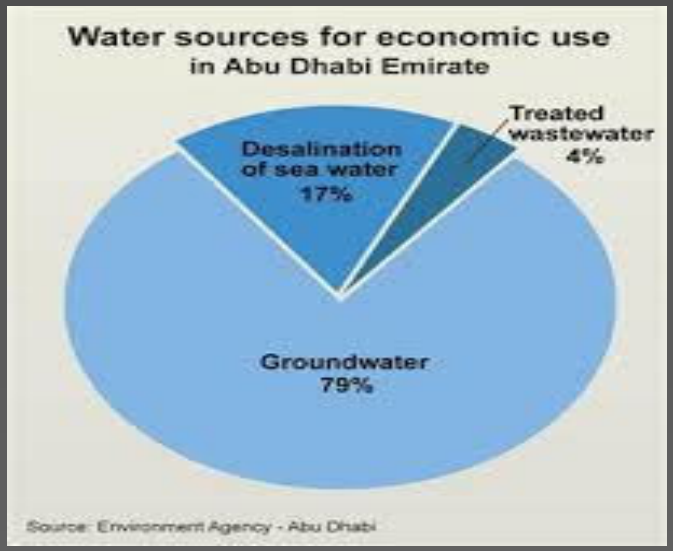
Water Scarcity and Stress



The UAE is listed by the United Nations as a high-rank country when it comes to water stress, a situation which occurs when the availability of water is not in balance with the demand for water

Water Resources in AD

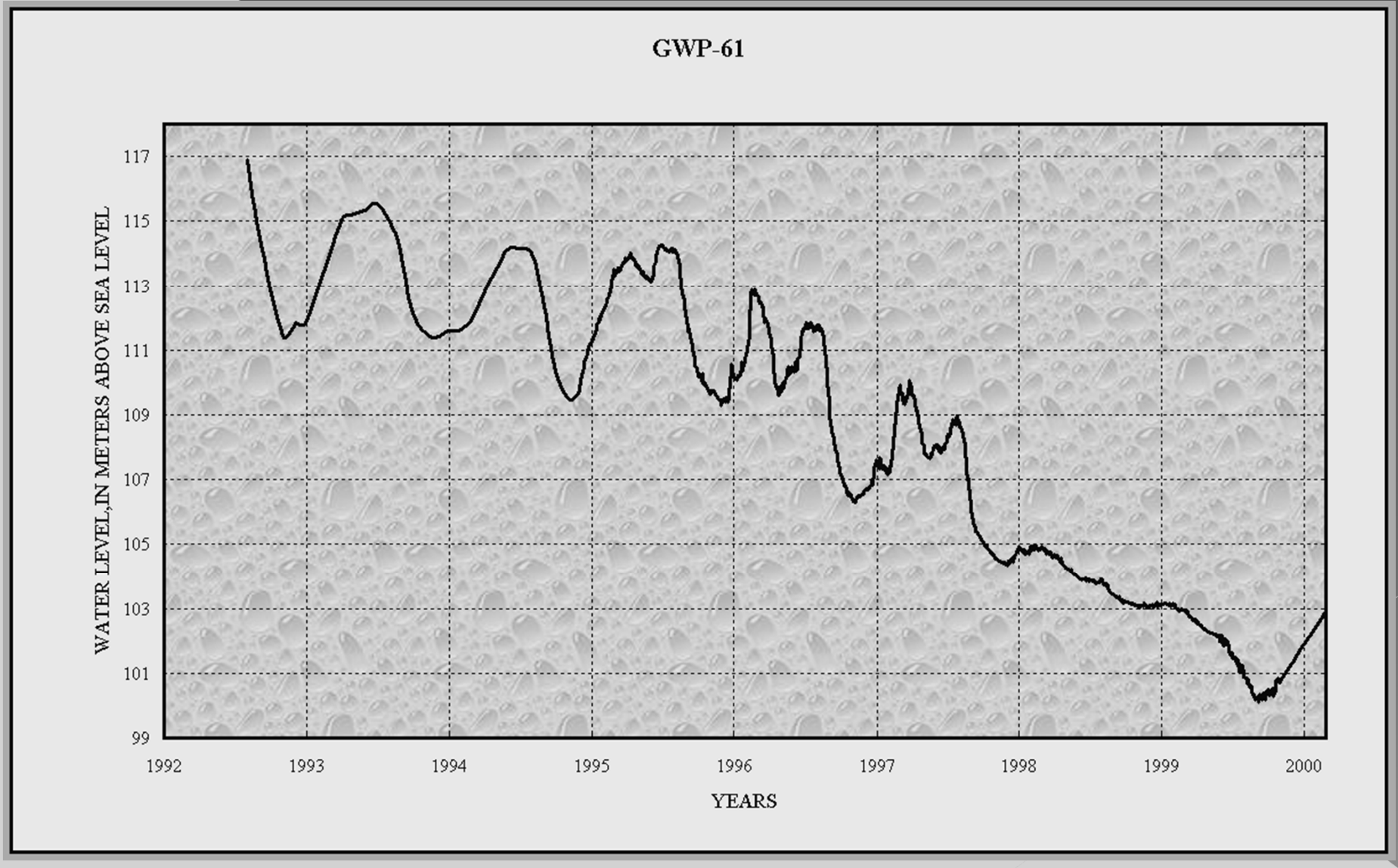
- **In 2013, the water demand was estimated as 5,400 MCM with annual growth of about 10%**
  - 79 % Groundwater
  - 17 % Desalination
  - 4 % Treated Sewage



Water Source 2007	Water using sector and water use (Mcm/year)							
	Agriculture	Forests	Amenity	People	Livestock	Industry	Lost	Total
Groundwater	1413	579	51		20			1,816
Desalination	76		91	366	183	46	94	856
TSE		130					51	182
Faljs			25					25
Total	1489	709	167	366	203	46	145	3125

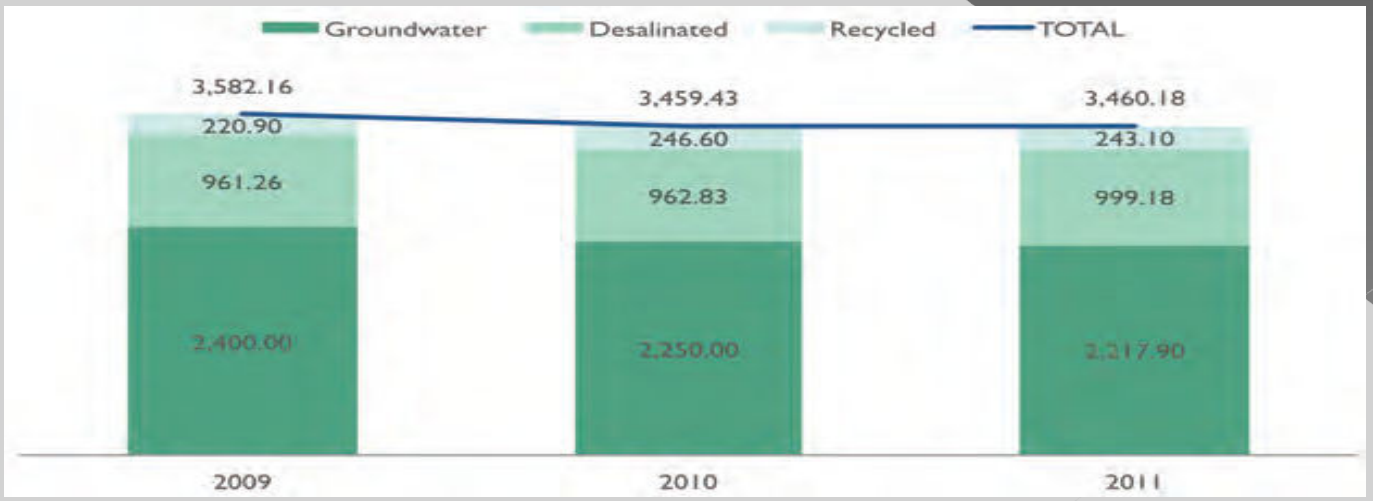
Source: ICBA based on EAD, ADWEA and USGS data and information

Groundwater Levels (before 2003)

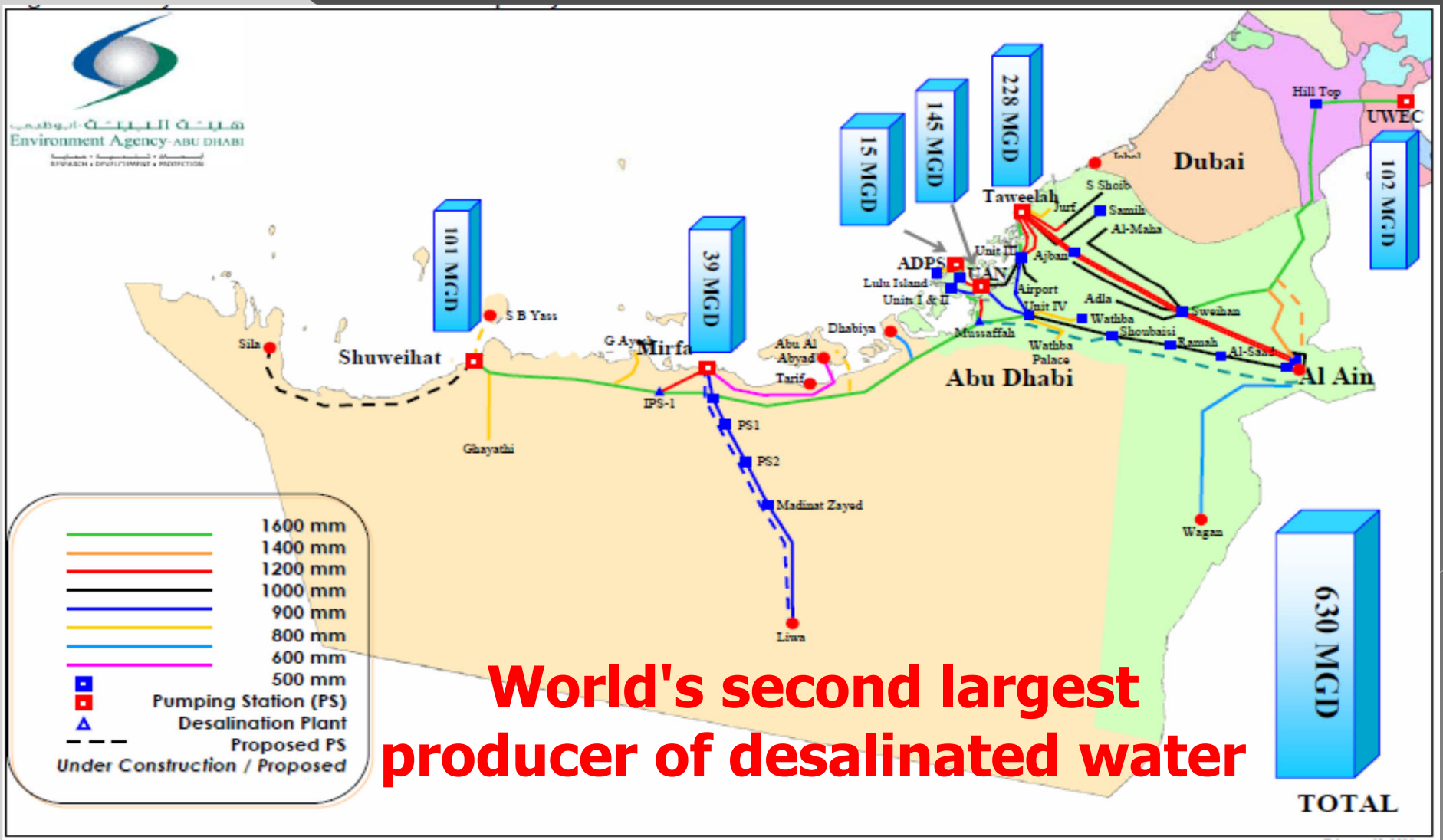


Groundwater Use

- **641km^3 groundwater** resources available in AD, mostly **non-renewable**, less than **3% is fresh**
- Based on current abstraction rates, both fresh and brackish reserves will be **depleted within 50 years**
- Abu Dhabi **groundwater intake** has been **decreasing** at annual rate of **6%**.



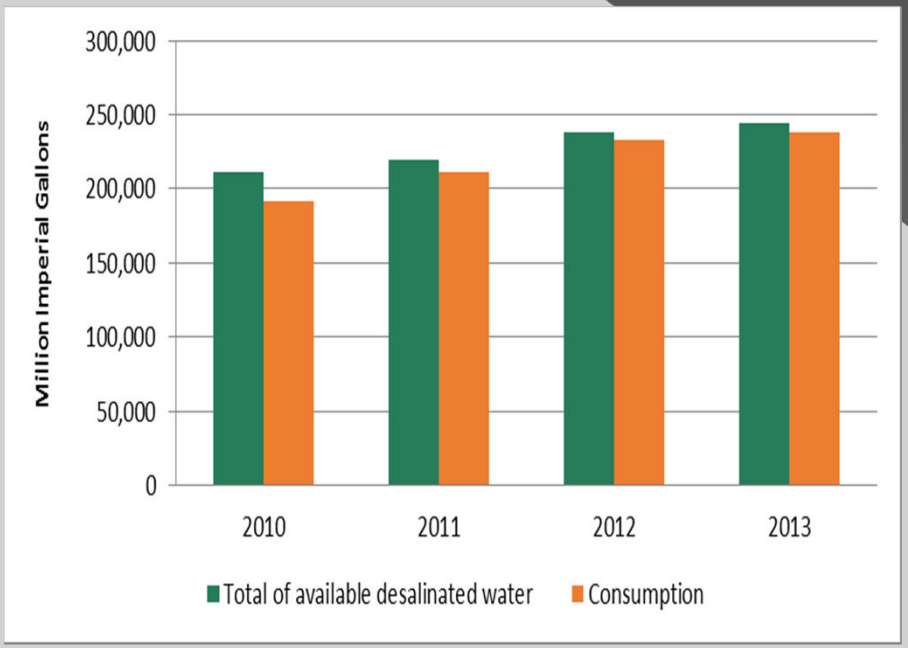
UAE Desalination Capacity

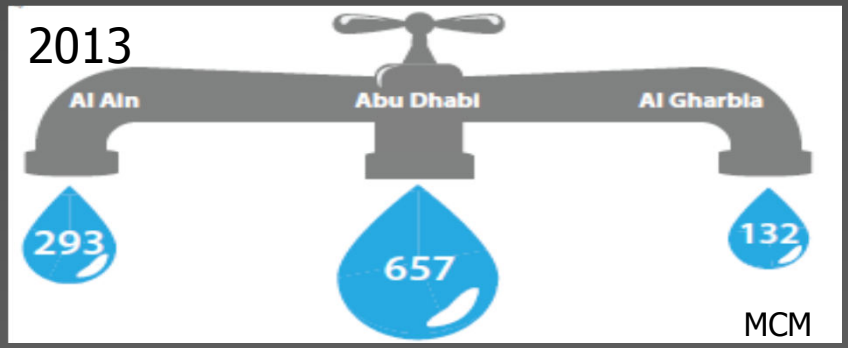


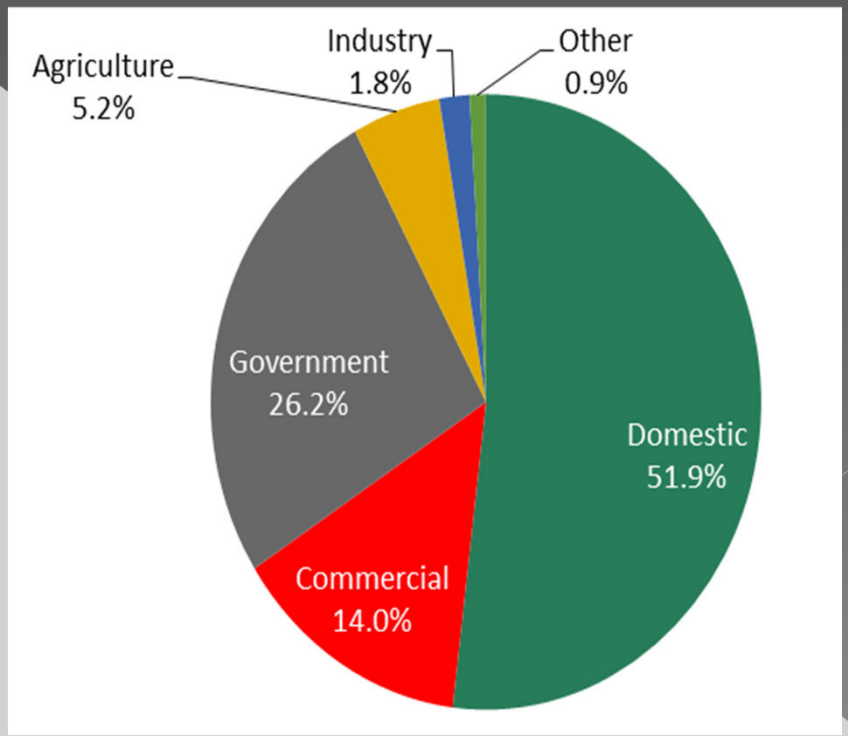
Water Distribution System in Eastern AD

- The water desalination plants are the only source of drinking water
- The water is delivered by TRANSCO from:
  - Taweelah through twin 1,200 mm diameter pipelines, with boosting provided at pumping stations at Ajban and Sweihan;
  - Abu Dhabi through a 1,000 mm diameter pipeline boosted at the Shobaisi and Remah pumping stations; and
  - Fujairah via twin 1,600 mm diameter pipelines
- 3,900 km of pipelines, from 80 mm to 800 mm diameter
- 8 pumping stations
- The average supply to Alain 293 MCM per year

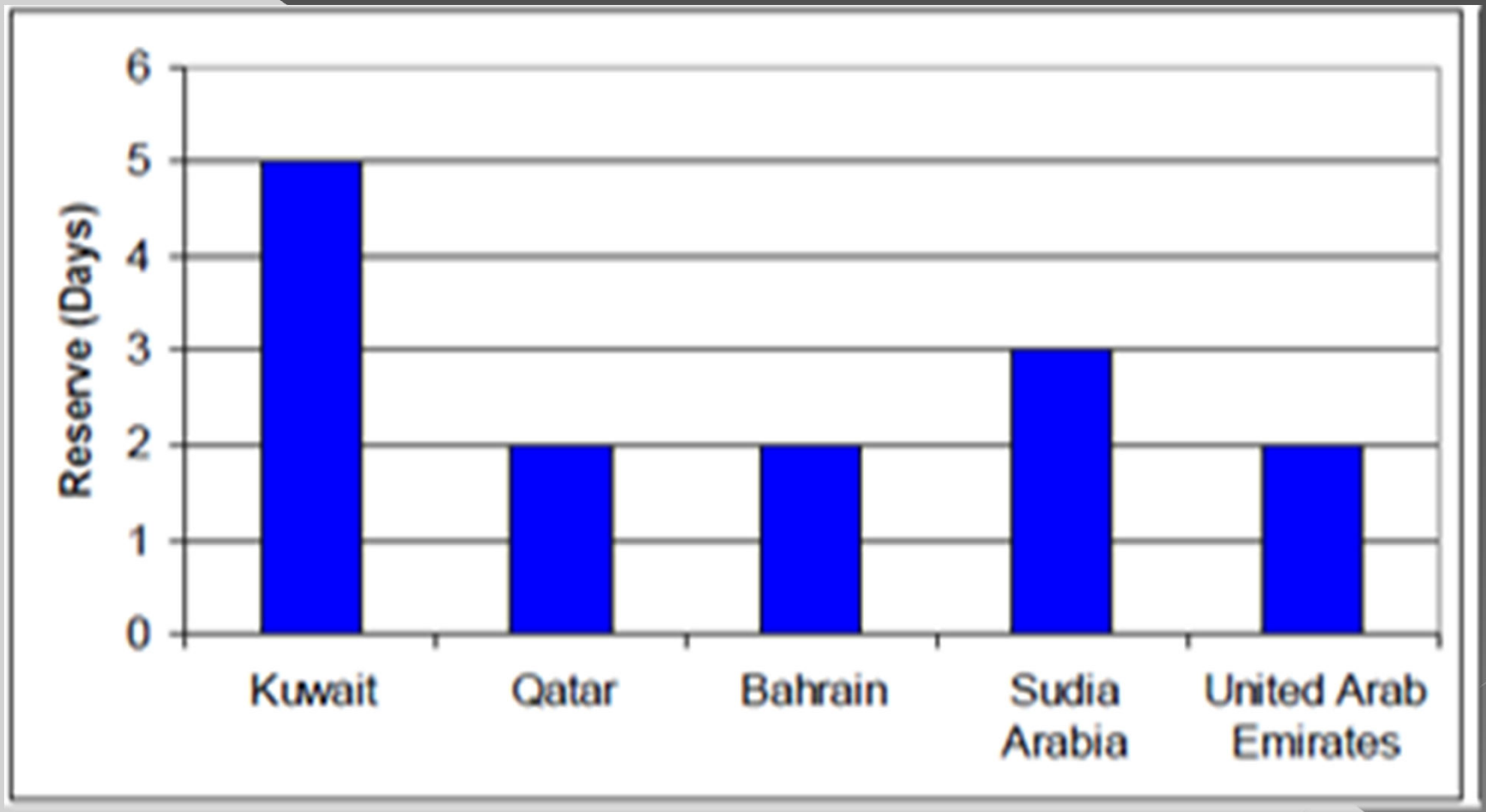
Desalination Production in AD





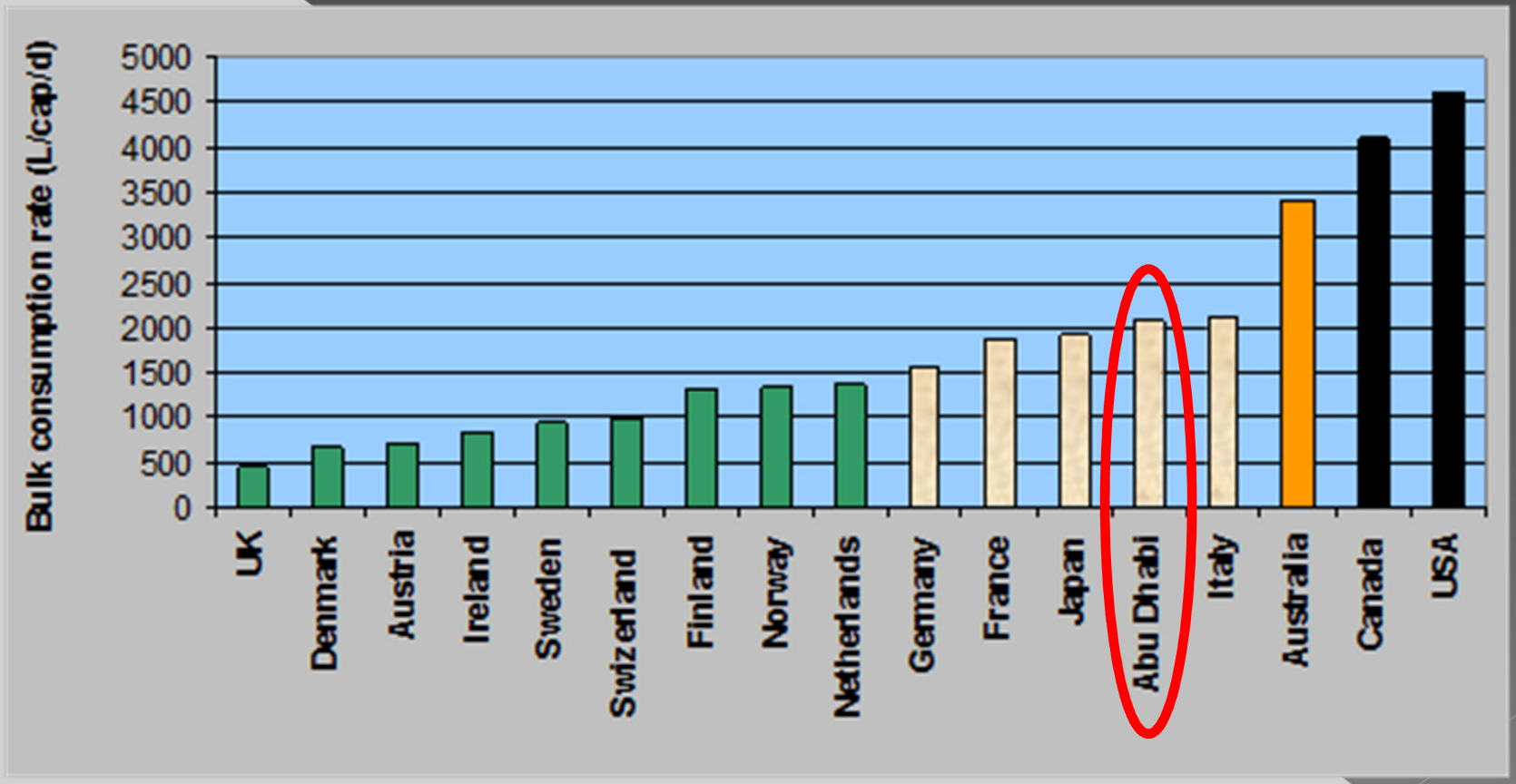


Storage capacity for emergency water in GCC countries



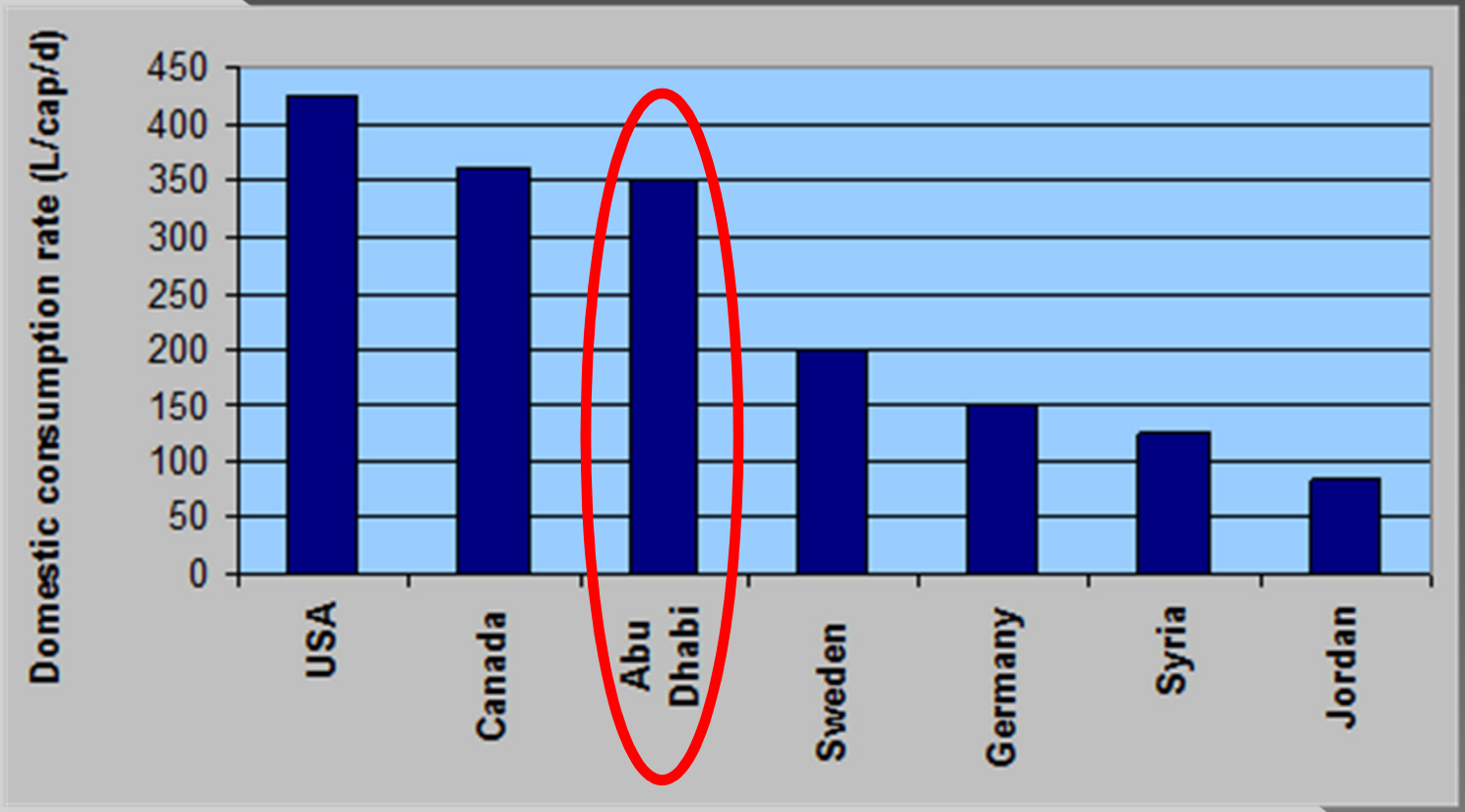
Dawoud, 2005

Water Consumption in Abu Dhabi Emirate



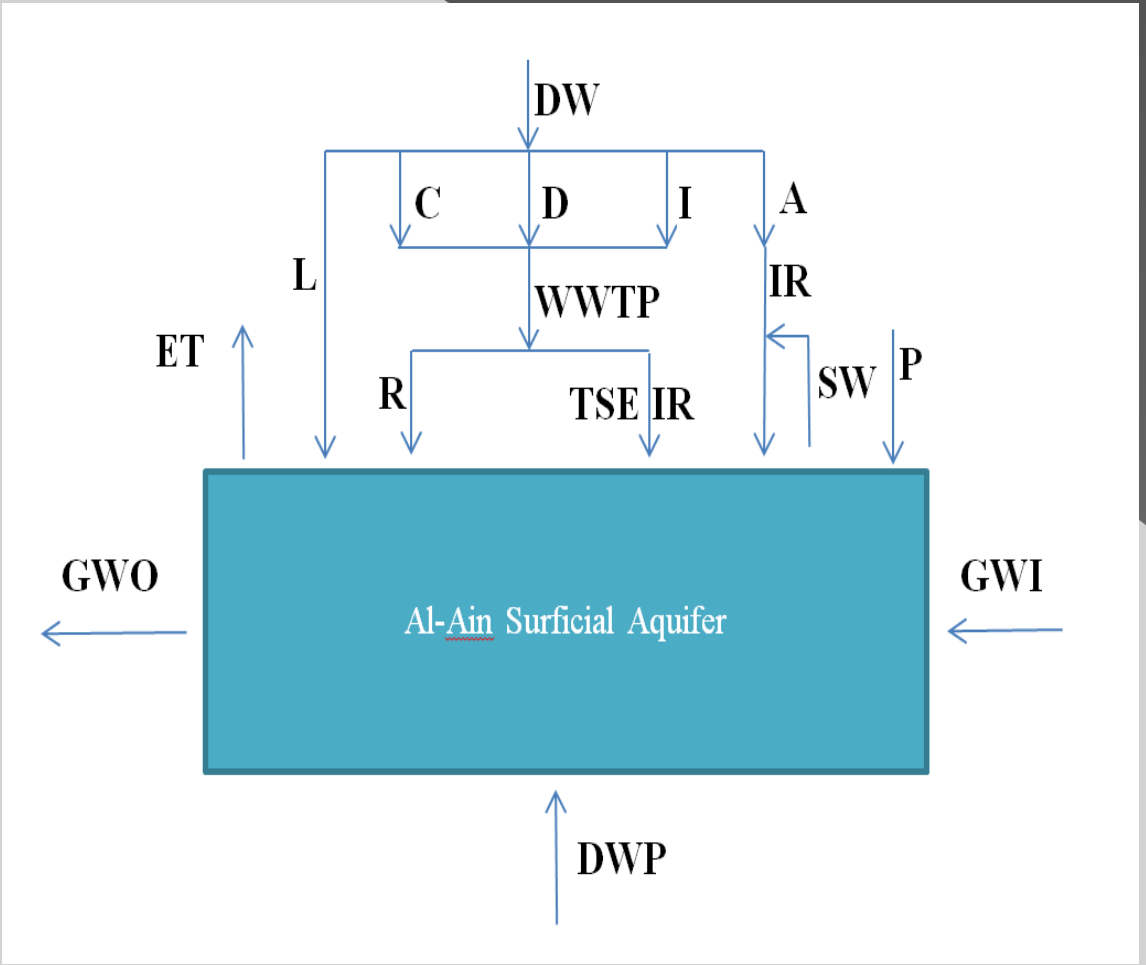
Bulk per capita water consumption in Abu Dhabi Emirate and some developed countries (data for developed countries were adopted from Conference Board of Canada (2008)).

Water Consumption in Abu Dhabi Emirate



Domestic per capita water consumption in selected countries (EAD, 2007)

Water Use in Eastern UAE



Components	Mm^3/year
INFLOW	
GWI	1.0
P	100
IR	142.4
TSEIR	49
R	5.5
L	21.9
DWP	35.5
Total Input	354.9
OUTFLOW	
ET	175
GWO	0.8
Total Output	175.8
Balance	179.5

Water use patterns in eastern UAE (Mohamed et al., 2013)

Treated sewerage effluent discharge

~ 55 Mm^3/year of sewage water generated annually in AlAin

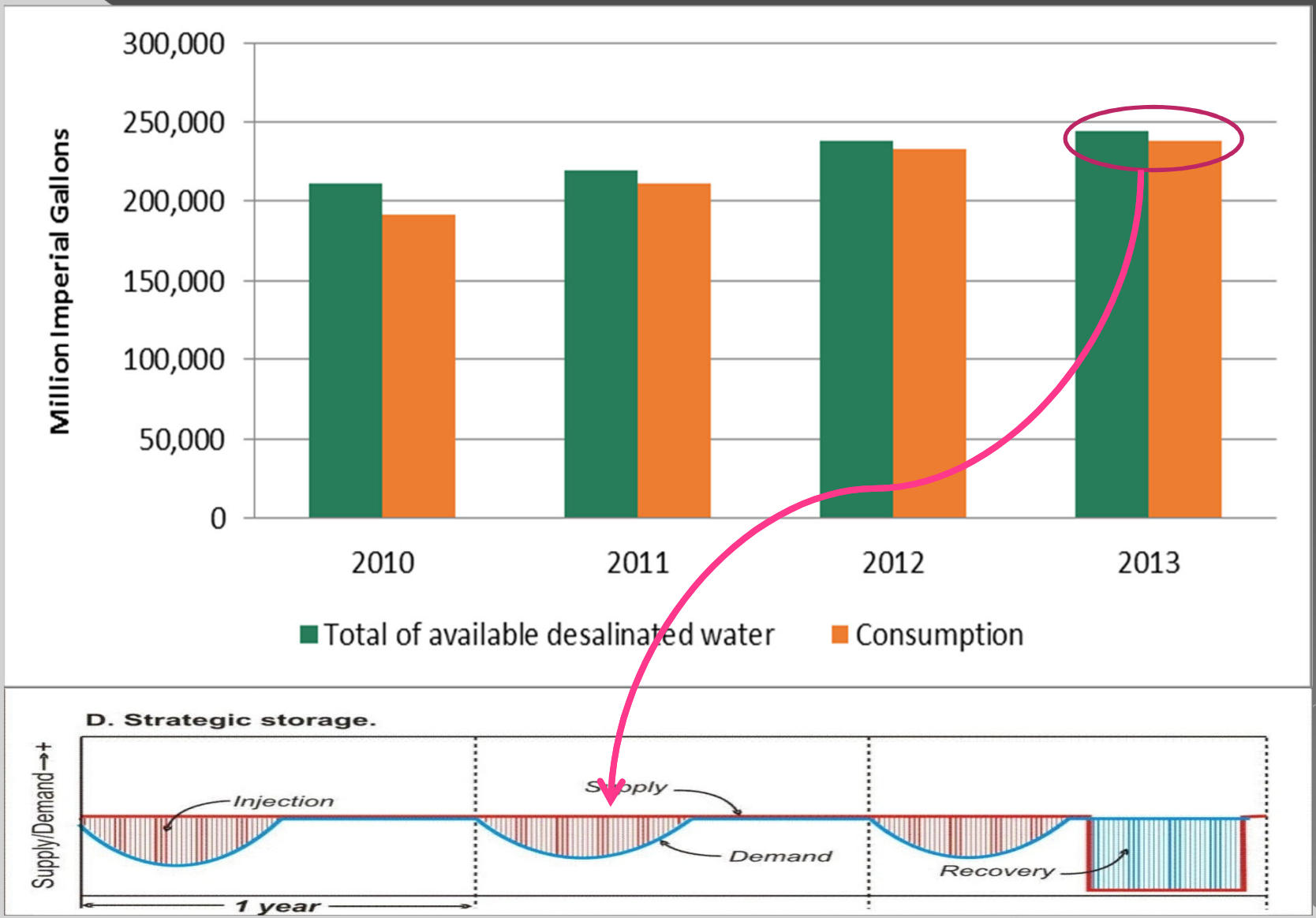
~200 Mm^3/year of sewage water generated annually in Dubai

~200 Mm^3/year of sewage water generated annually in Abu Dhabi

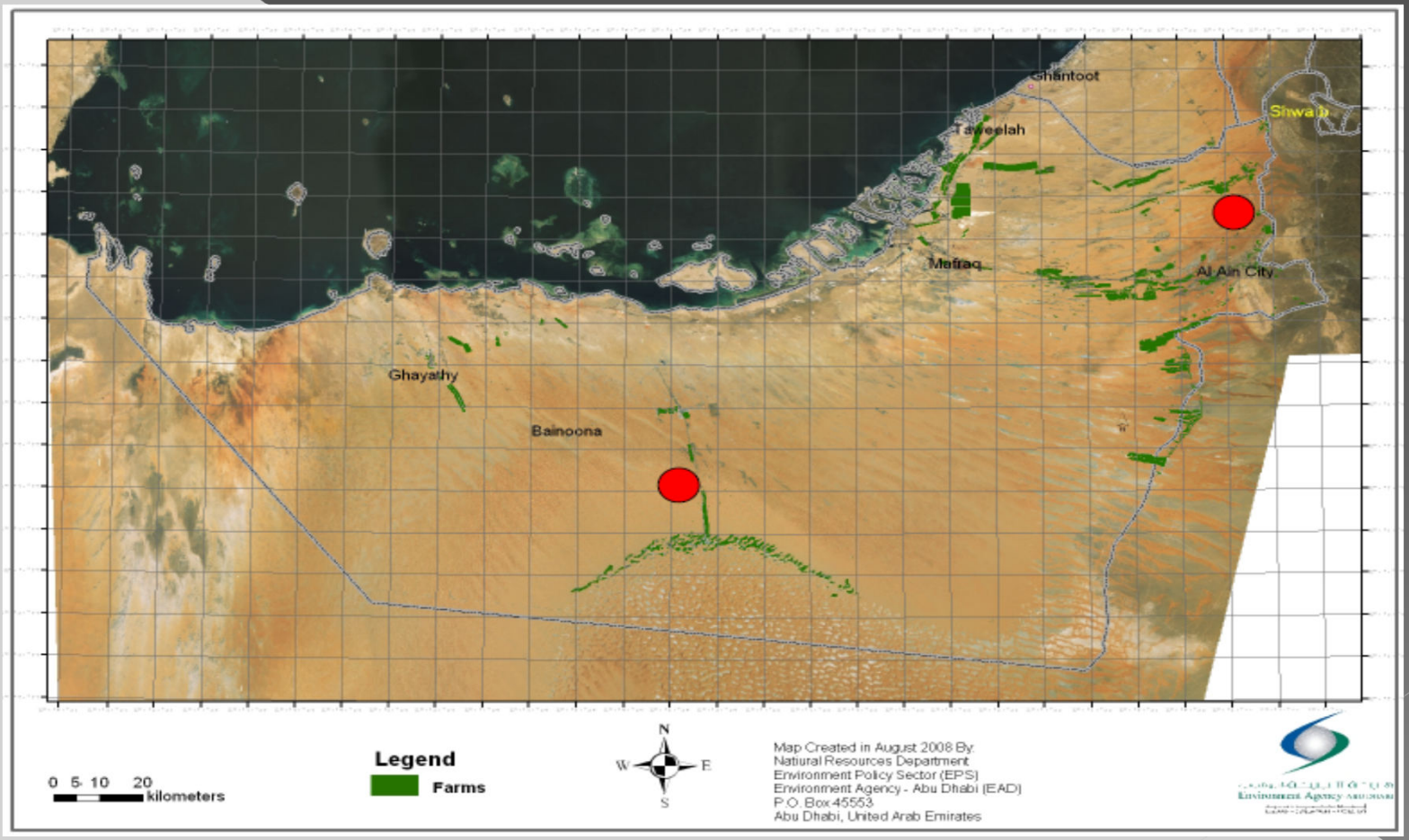
Objective

Enhance National Strategic Groundwater Reserves via Managed Aquifer Recharge with Recycled Water

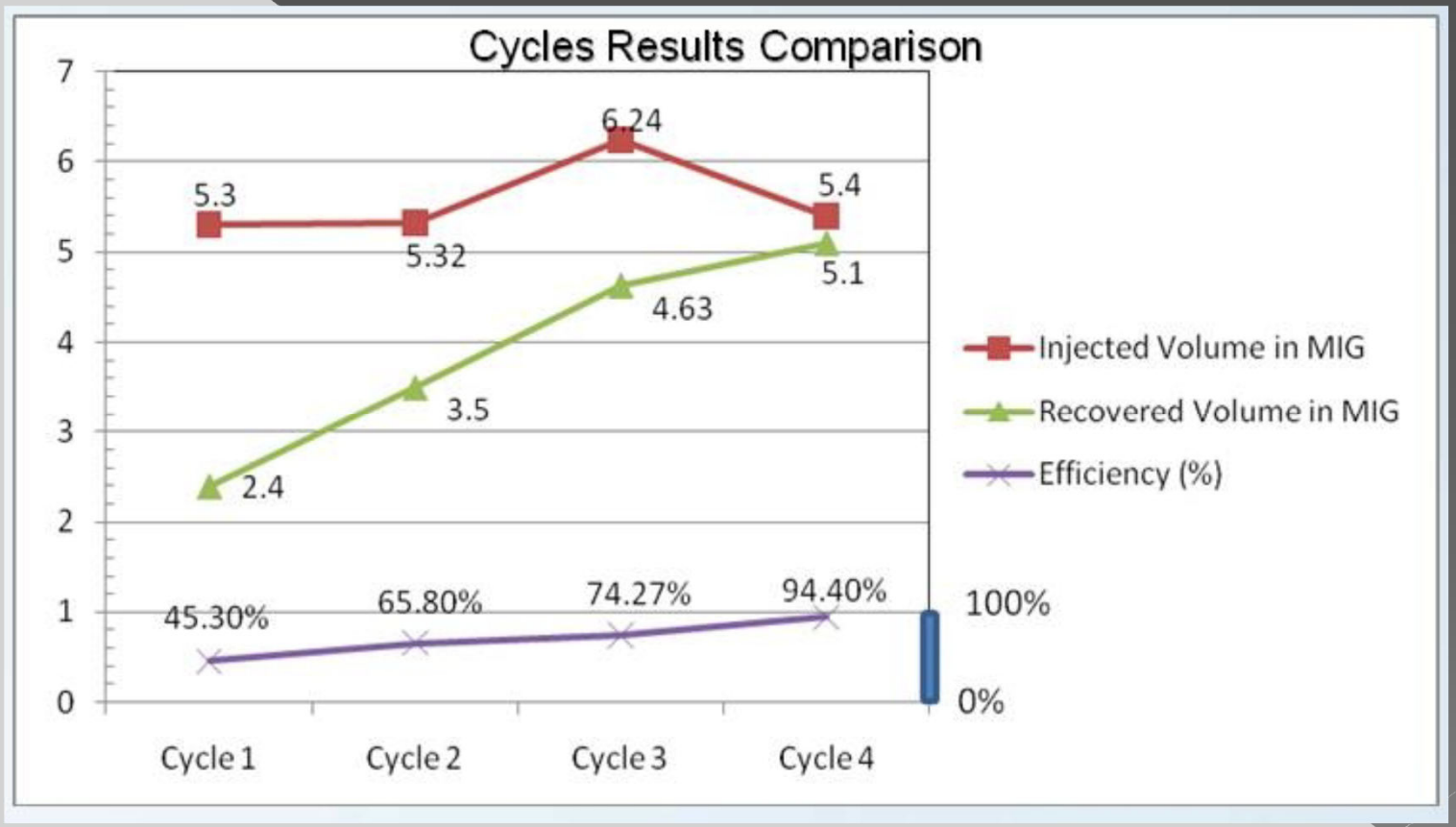
Storage and Recovery in UAE



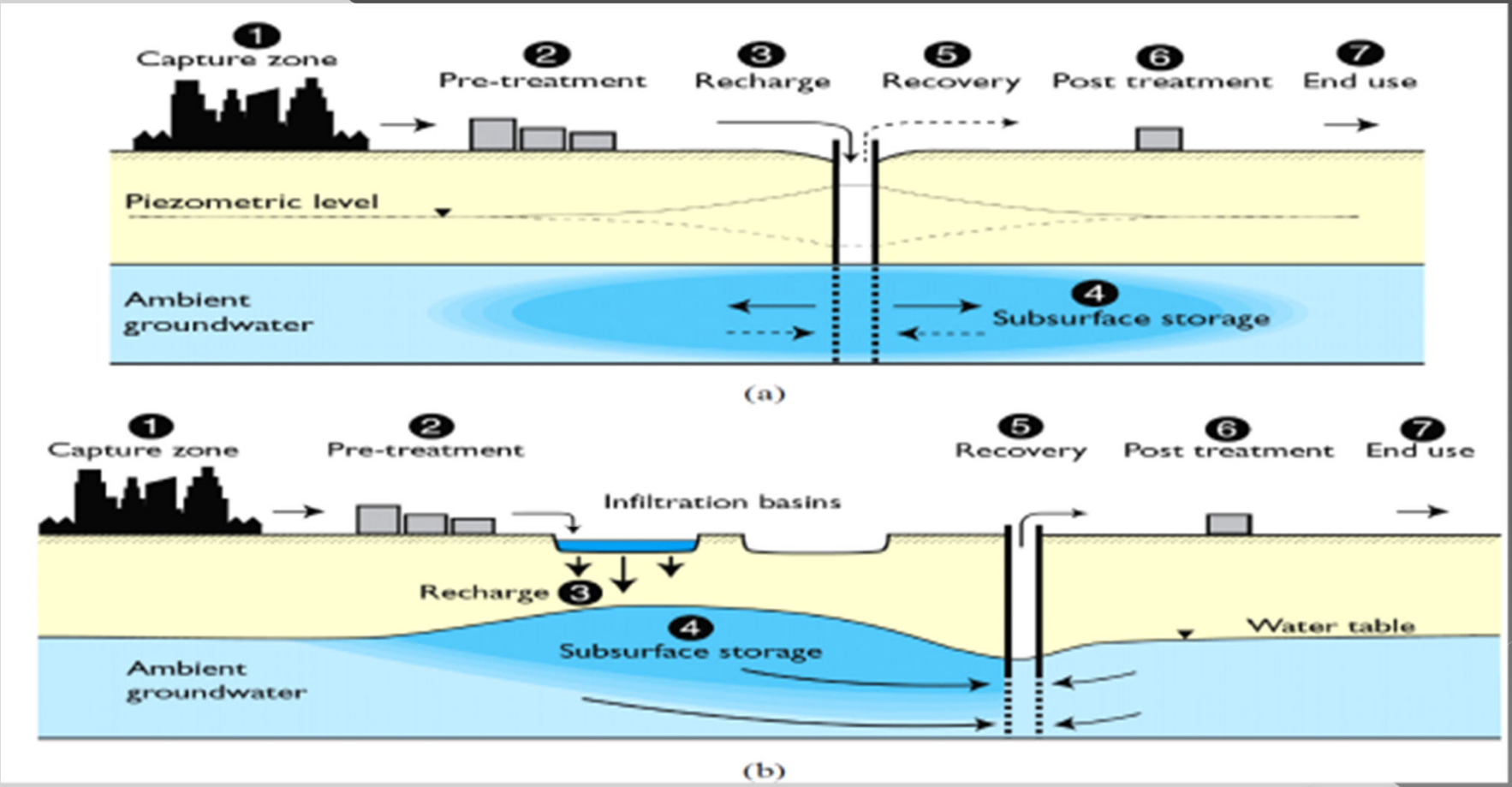
Two ASR projects in AD



Sharjah Project in Nizwa



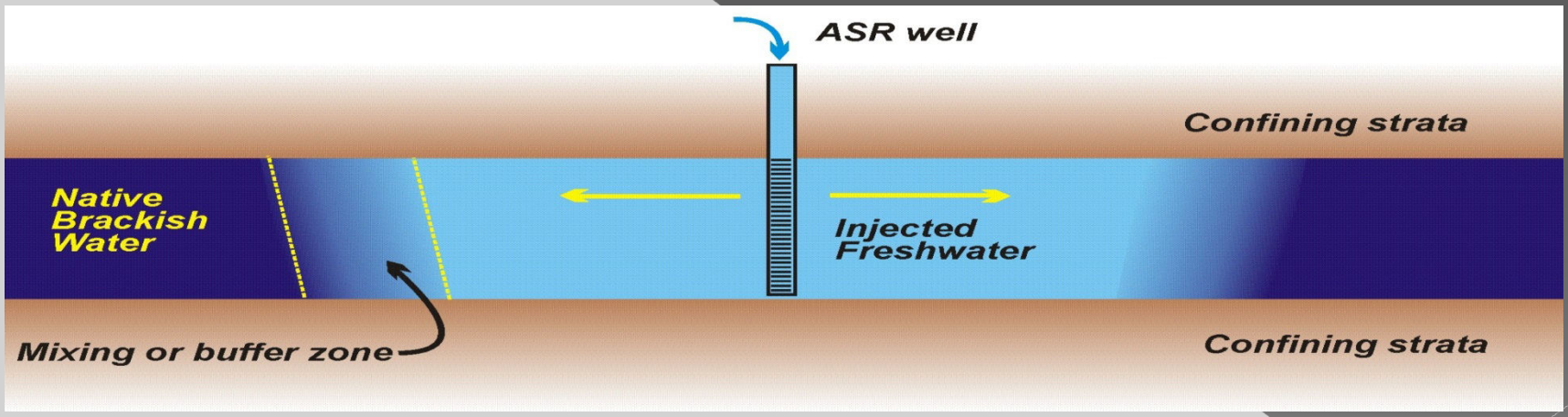
Common Elements of MAR



The seven elements common in MAR systems (a) injection wells, and (b) infiltration basins (Pyne 2005)

ASR technical issues

- **Physical storage** – increase amount of water in storage in an aquifer.
- **Chemically bounded** – injected freshwater displaces water of lesser quality.



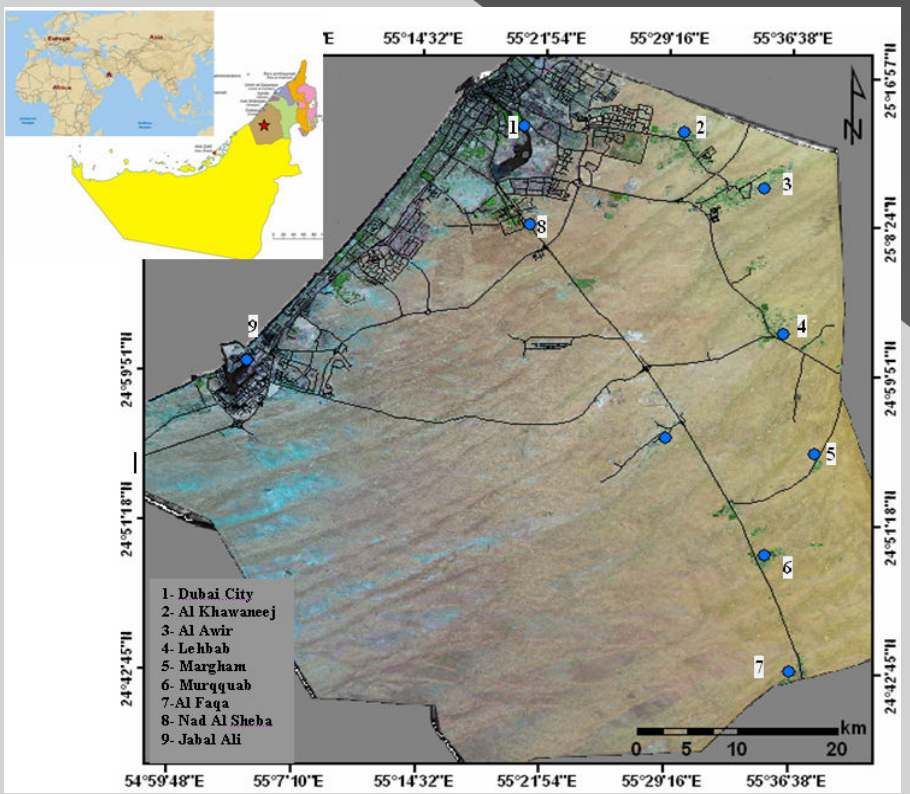
- **Regulatory storage** (water banking) – injection confers the right to later withdrawal water.

SWS, 2010

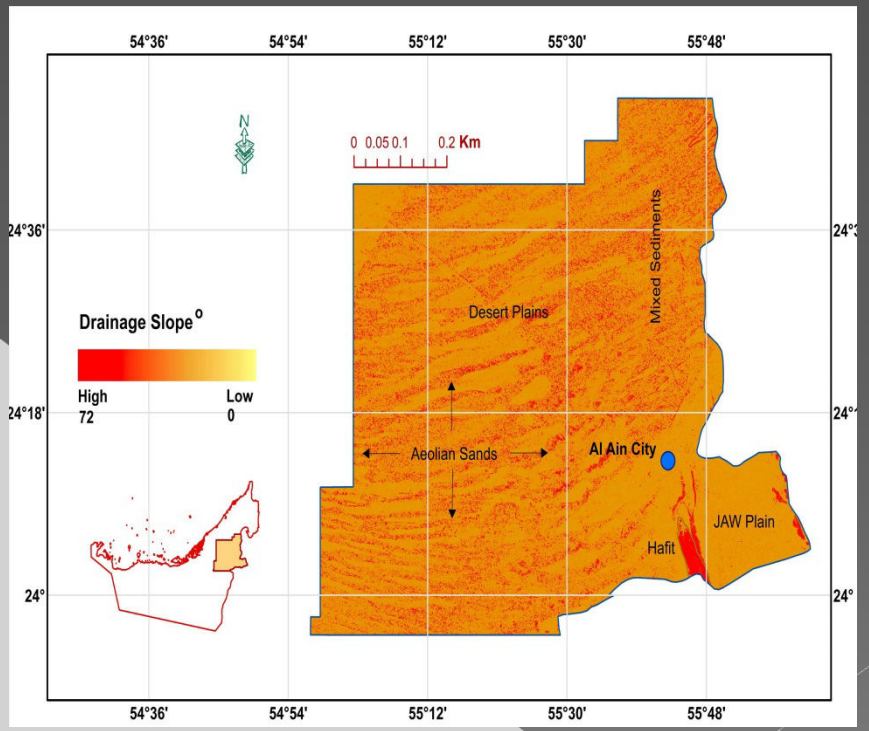
MAR Phases

- Feasibility study (current project)
- Exploratory program
- Pilot MAR study
- Full-scale MAR implementation
- Maintenance and adaptive management

Study Areas



Study area 1



Study area 2

Meeting with Stakeholders

Several meeting were conducted with delegates from:

- Ministry of Environment and water
- Al-Ain distribution company
- National Drilling company
- Al-Ain municipality
- Abu Dhabi Sewerage Services Company
- Environmental Agency of Abu Dhabi

Data Considered

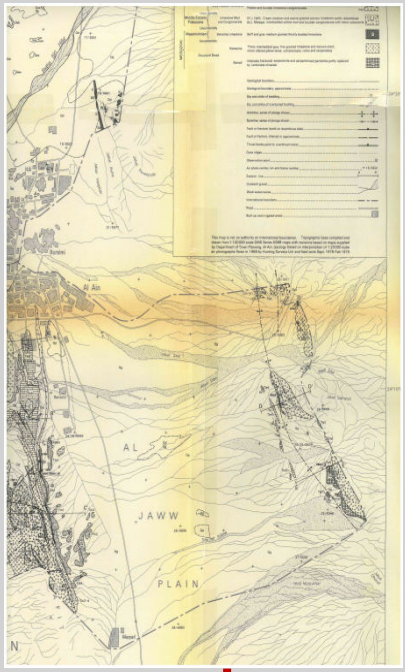
- Depth to GW
- GW Aquifer
- Hydraulic Conductivity
- Soil Type
- Land Surface Topography
- Impact of Vadose Zone
- Land Surface Slopes
- Land Use Distribution
- Distance from source

Ranking

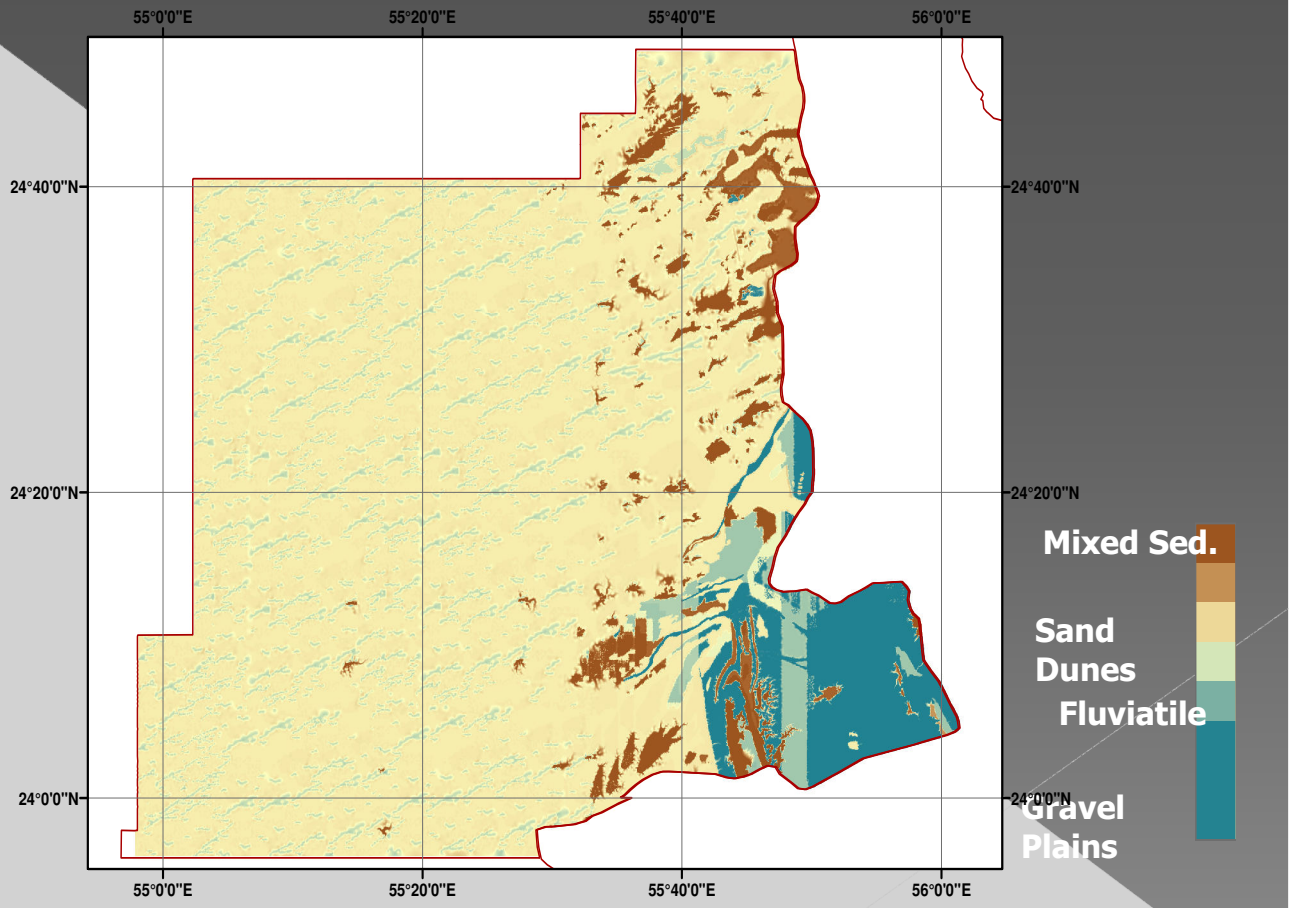
Ranks		Influence for identifying artificial recharge sites
5		Very good
4		Good
3		Moderate to Good
2		Moderate
1		Poor

Parameter	Class	Rank	Wt.	Parameter	Class	Rank	Wt.
Geology	Gravel Plain	4.8	4.5	Rainfall	130 mm	1	2
	Desert Plain	4.1			100 mm	1	
	Fluviatile Sediments	4.5			70 mm	1	
	Sand Dunes	4.3			40 mm	< 1	
	Limestone and Marl	1			< 10 mm	< 1	
Slope	0 – 1 o	5	1	Storativity	Gravel	4	4
	1 – 3 o	4			Coarse Sand	4.2	
	3 – 7 o	3			Fine Sand	4.5	
	7 – 15 o	2			Silt	5	
	> 15 o	1			Rock	2	
Morphology	Pediment zones	4.75	3.5	Soil	Alluvial Gravels	5	3
	Structural hills	4			Fluviatile sandy soil	4	
	Desert	3			Brown Soils (Desert Sands)	3.5	
	Inter-dune Areas	2.8			Fine sand - Silt	3	
	Mountains	1			Hills (Bare Bedrock)	1	
	Plateau	3 – 3.5					
Water Level	< 6 m	1	6	Land Use	Buildup Area	1	3.5
	6.1 – 12 m	2			Agriculture	3.5	
	12.1 – 18 m	3			Rangelands and Grazing lands	2.5 - 3	
	18.1 – 24 m	4			Forestry and wooded parklands	4	
	> 24 m	5			No Vegetation - Rocks	1	

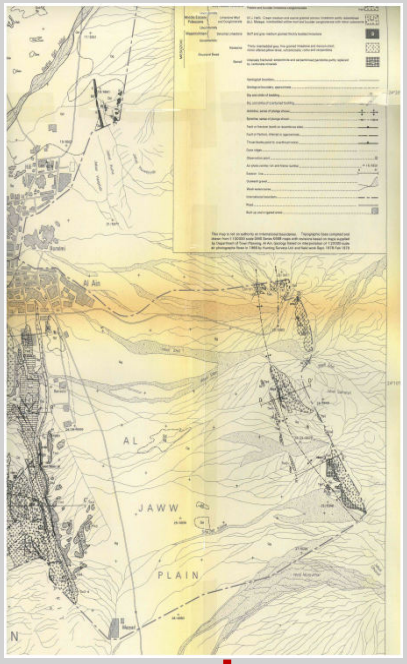
Geology



Processing



Hydraulic Conductivity



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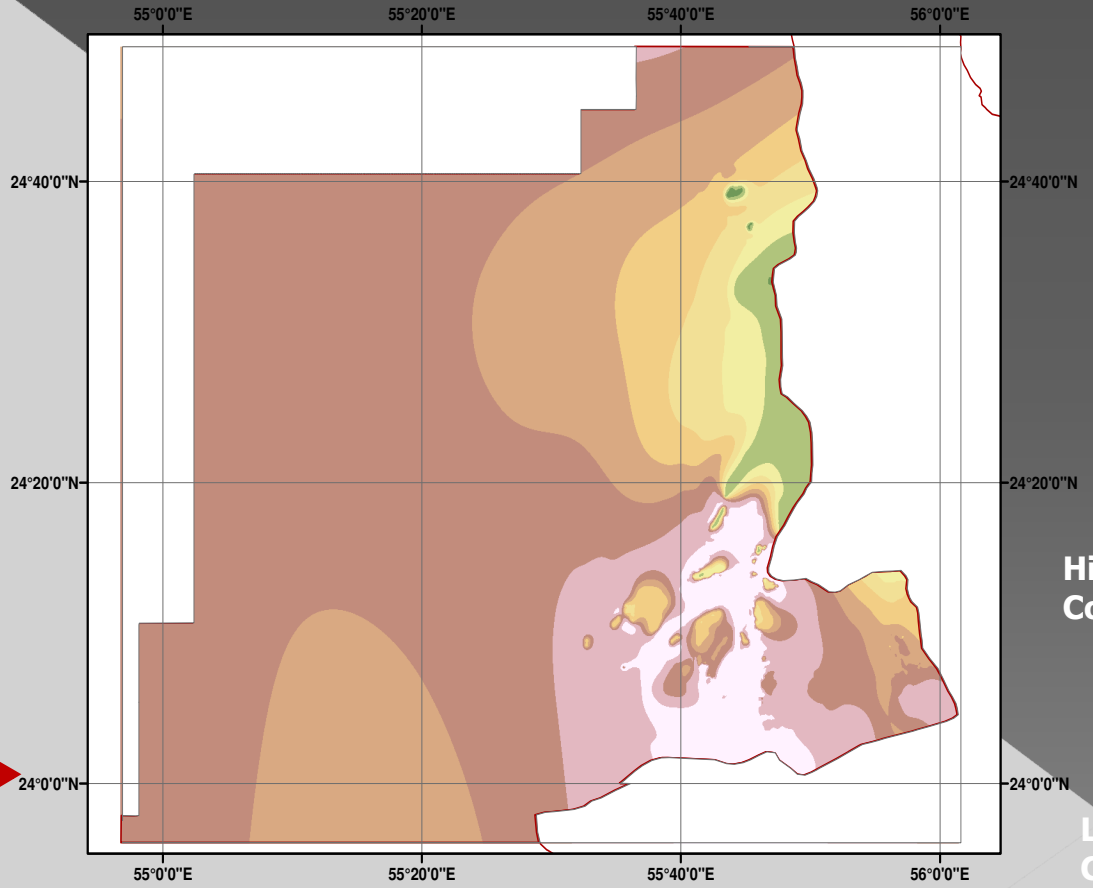
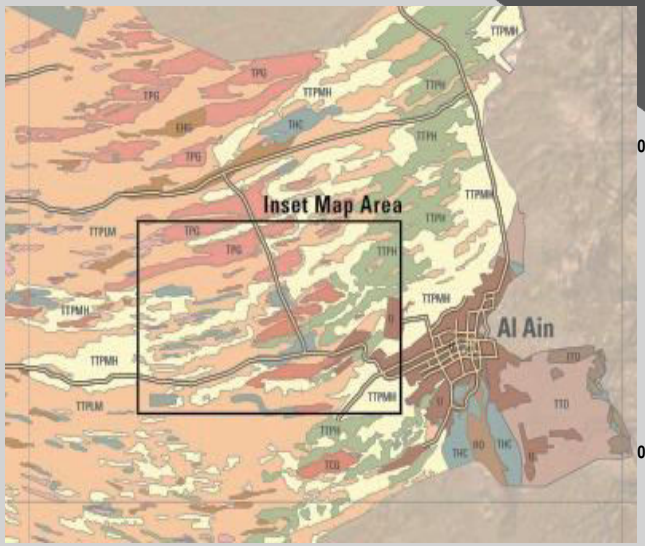


High Conduc.

Low Conduc.

Soil Type



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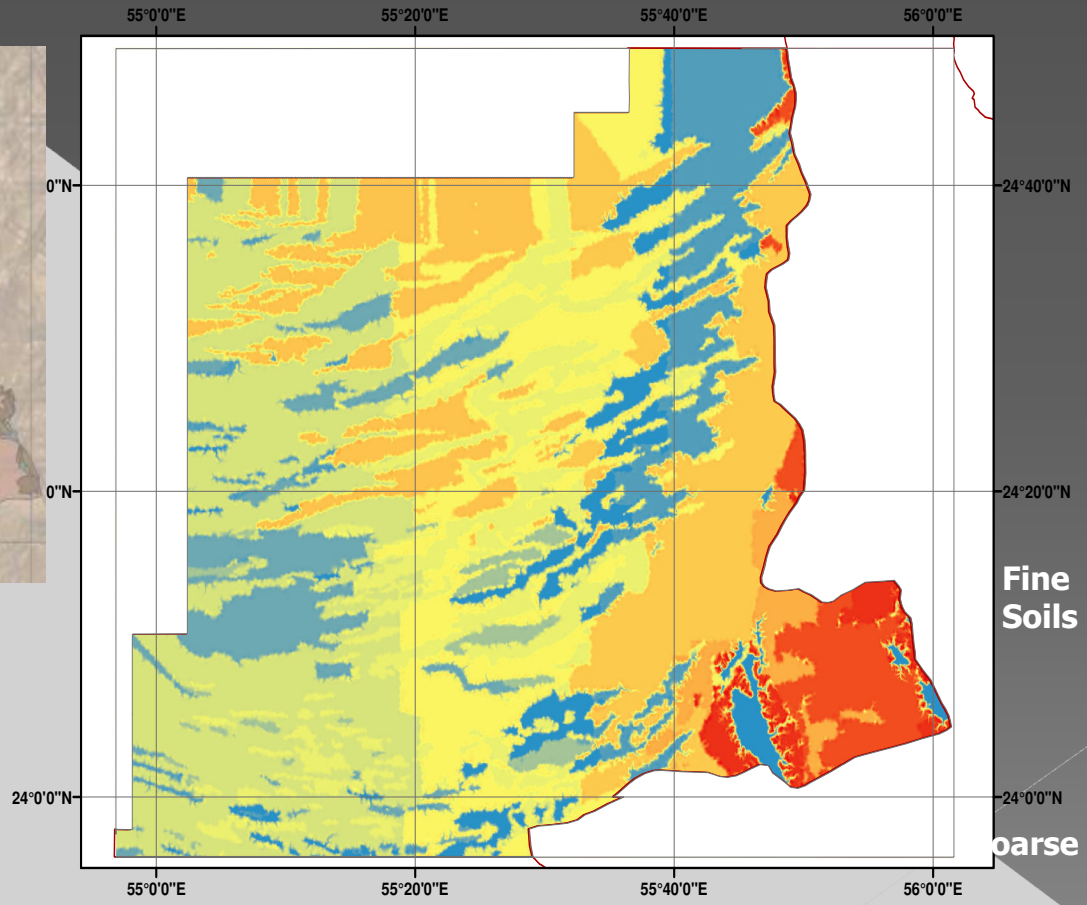
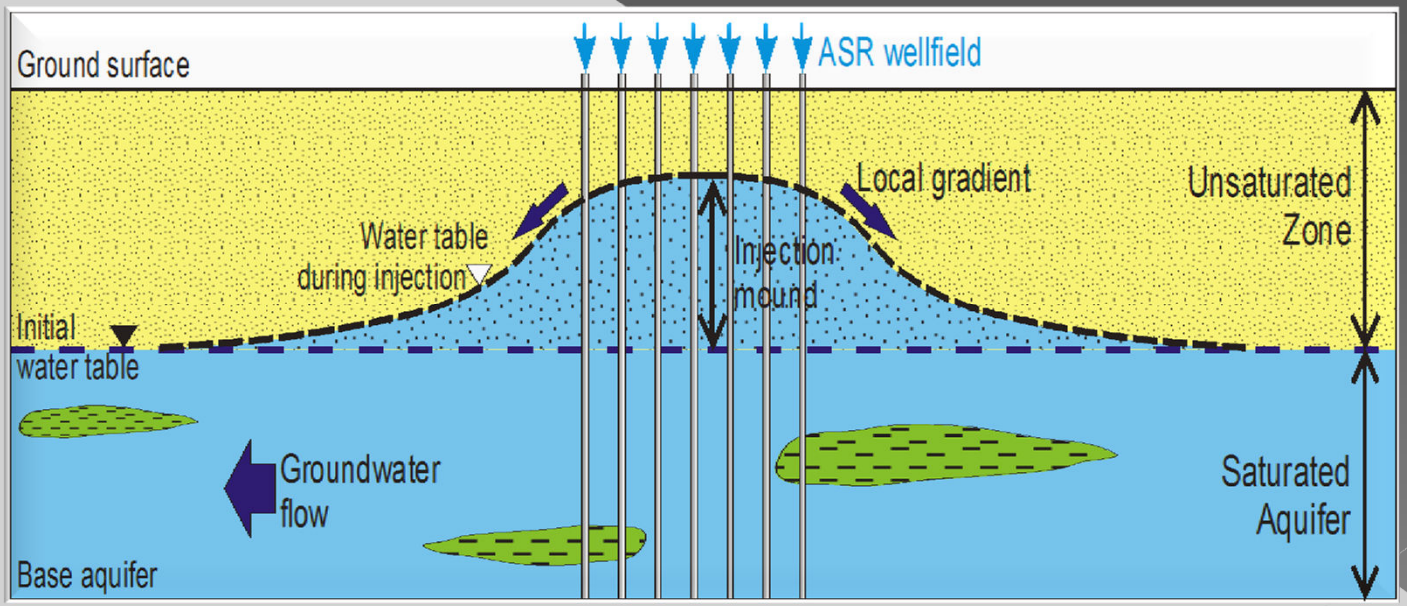
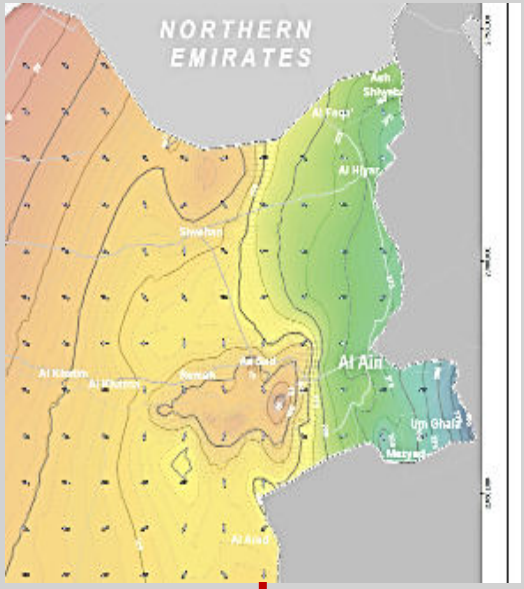


Unsaturated Zone Properties

water saturation, capillary pressure, relative permeability, hydraulic conductivity, effective porosity



Depth to GW



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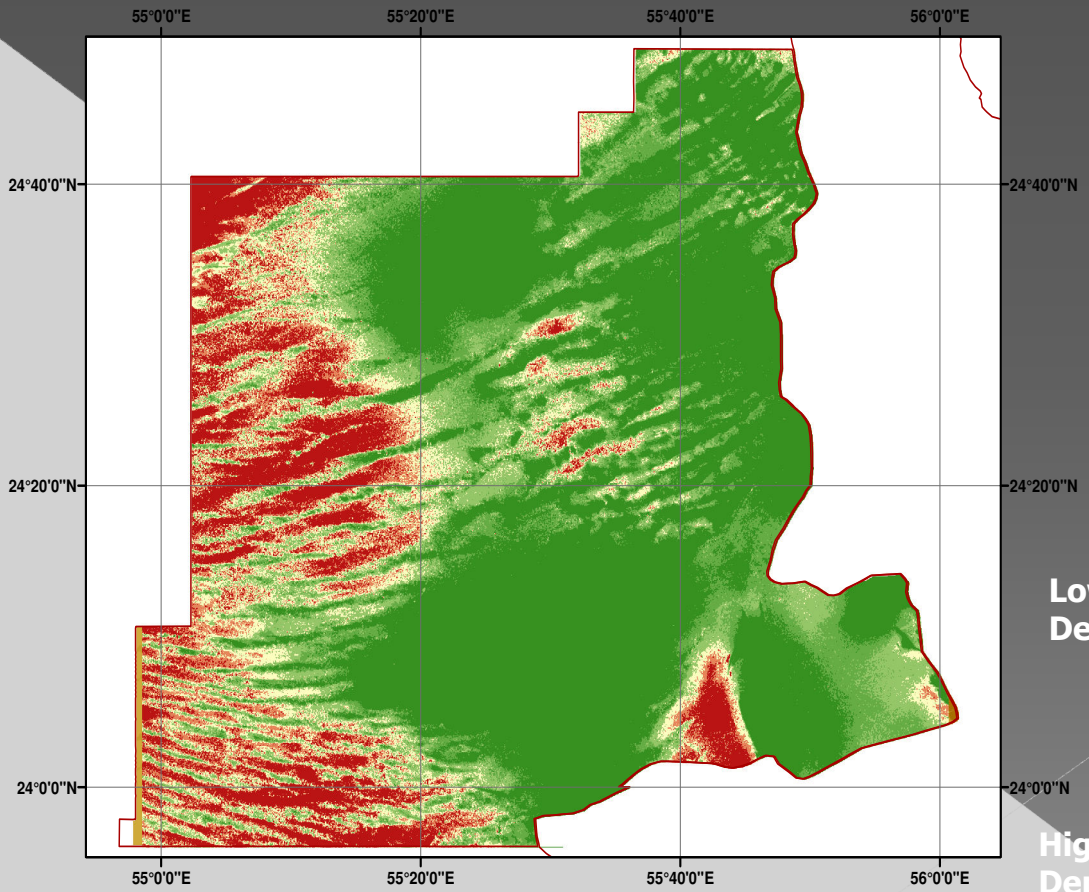
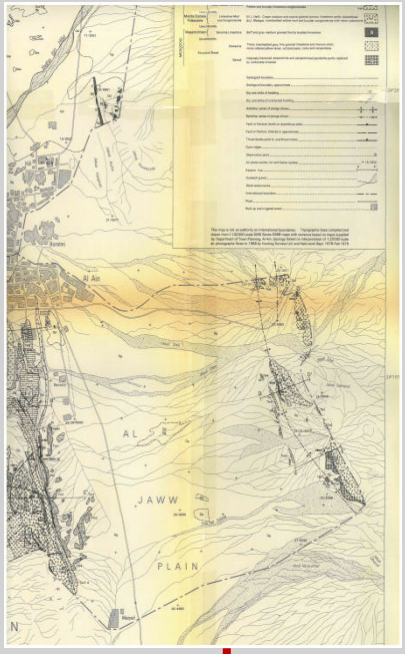


Properties of Vadose Zone



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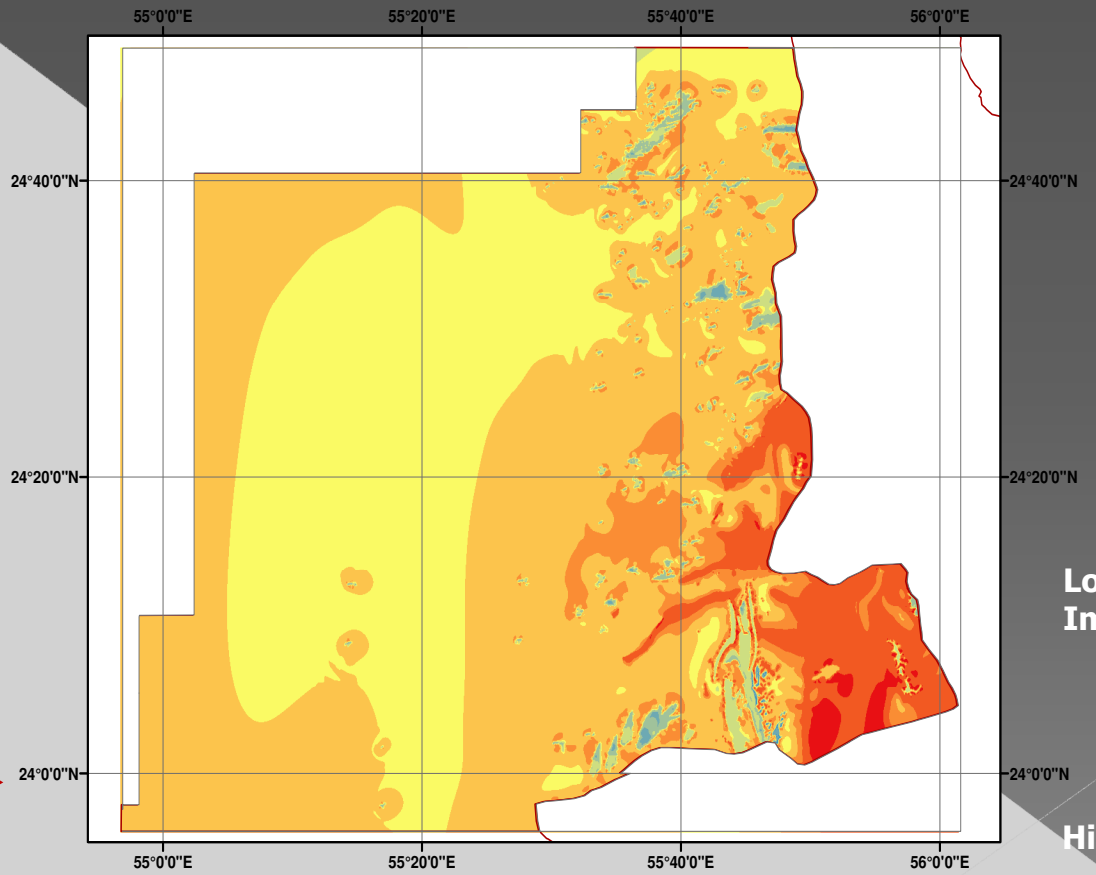
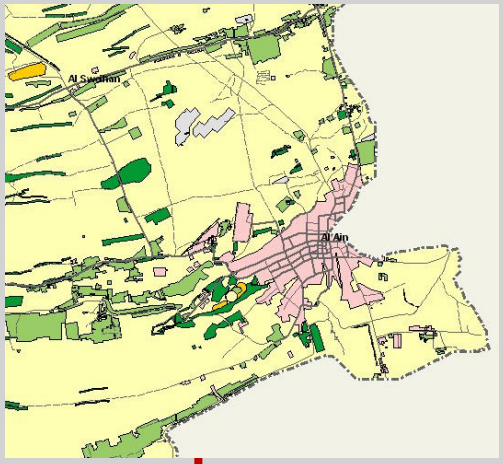


Land Use



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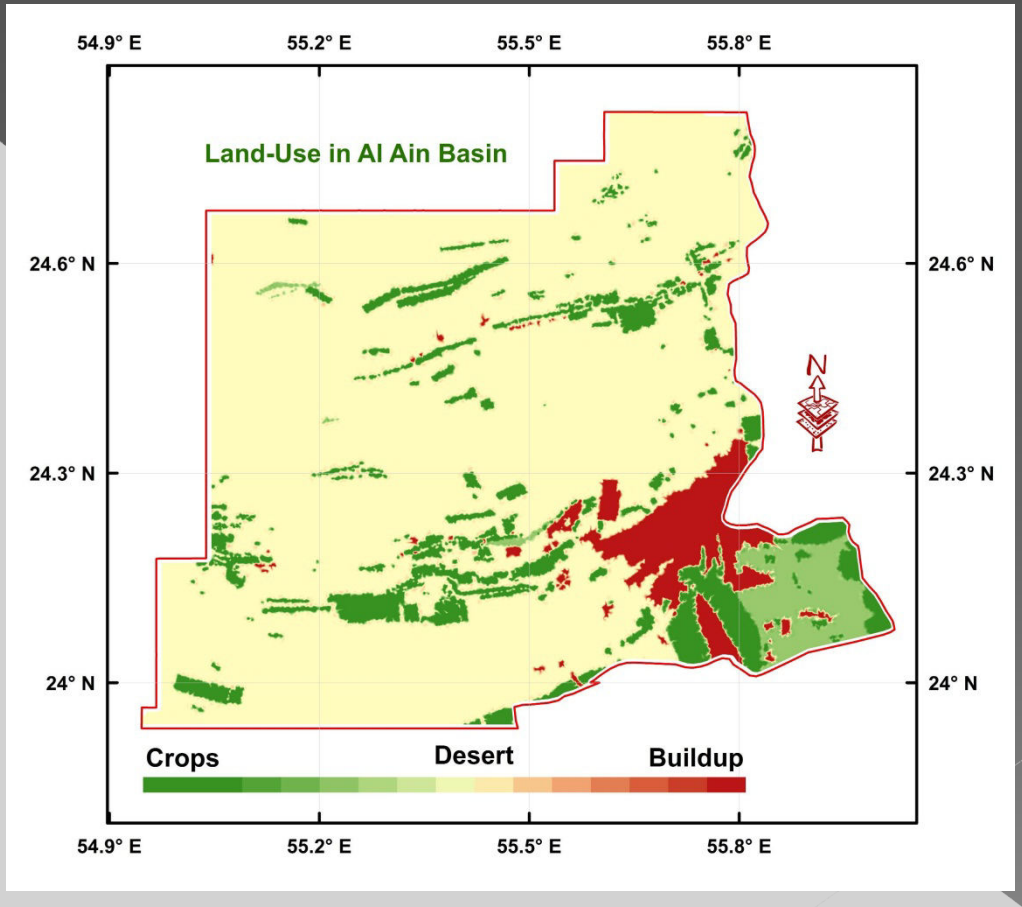

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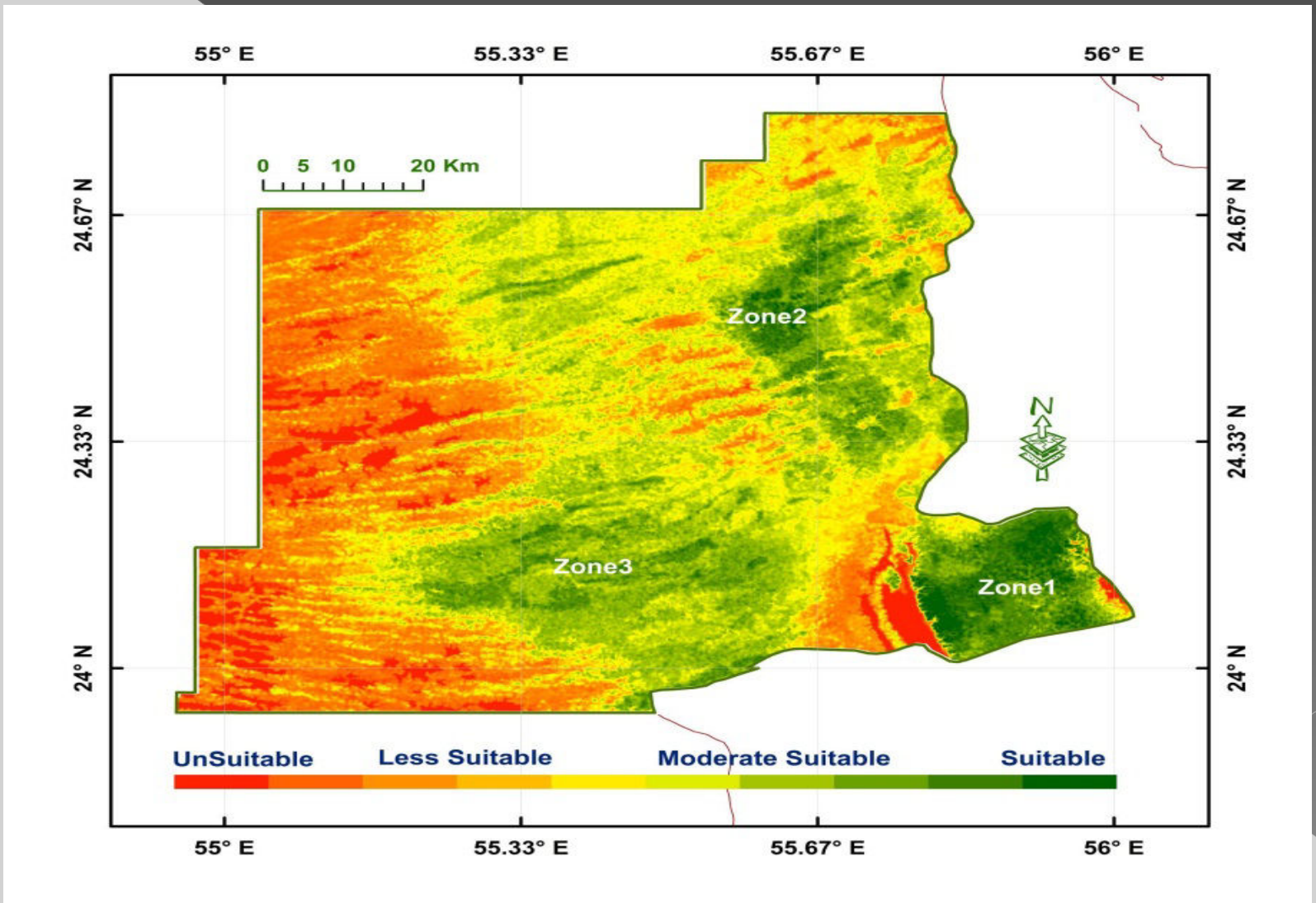
GIS-based MAR site selection



MAR Phases

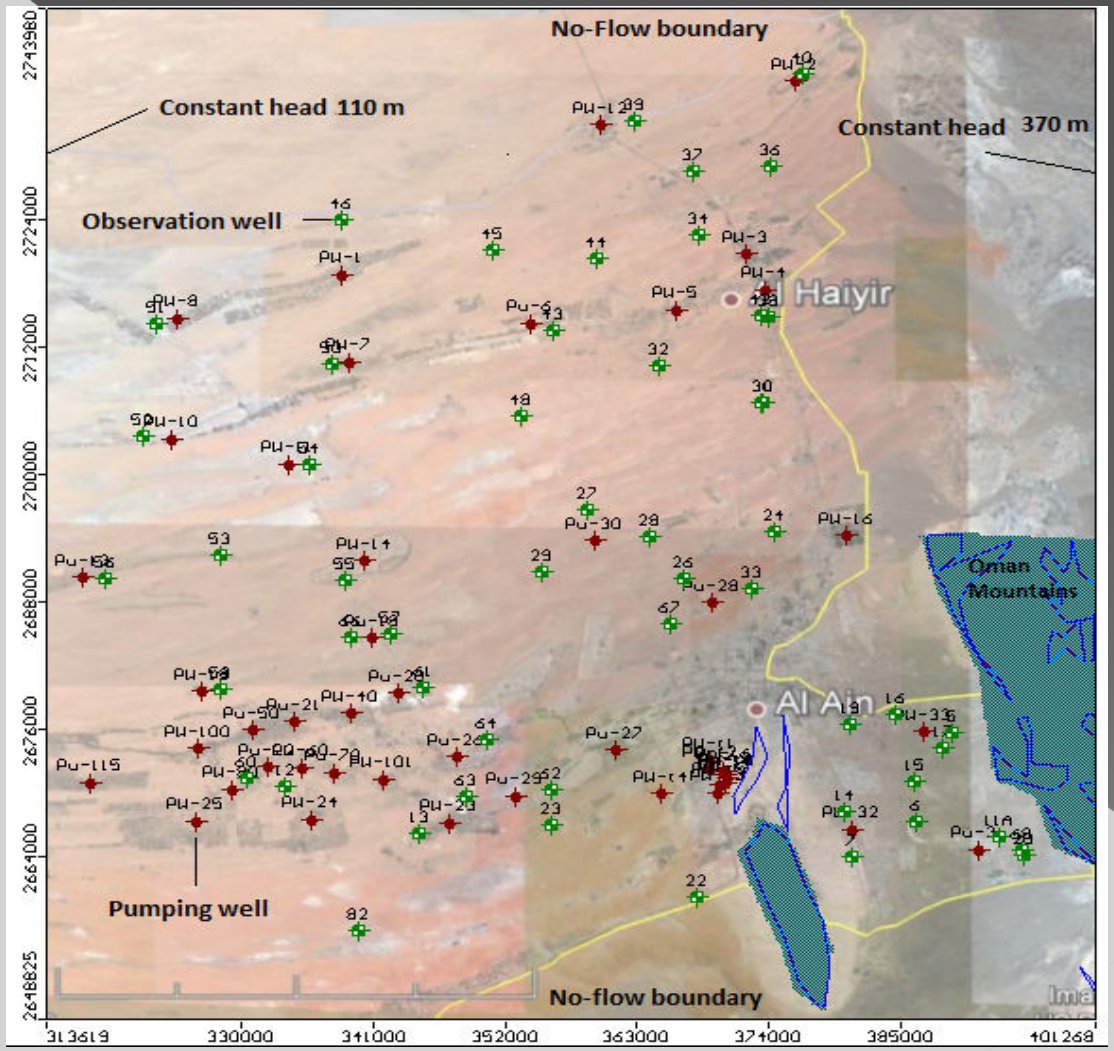
- Feasibility study (current project)
- Exploratory program (2nd phase)
- Pilot MAR study (3rd phase)
- Full-scale MAR implementation
- Maintenance and adaptive management

Geophysical survey

Groundwater samples

Groundwater samples

Groundwater Model



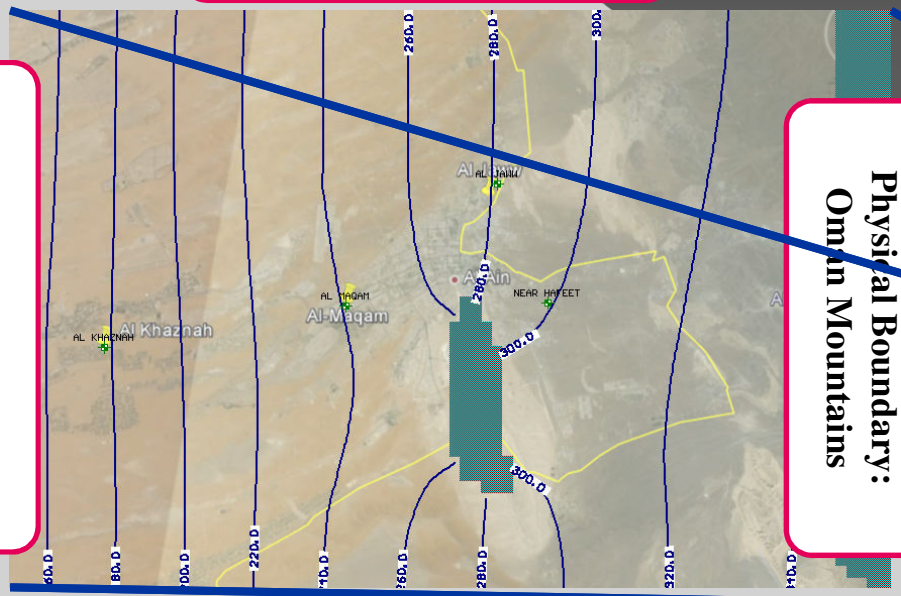
Groundwater Model

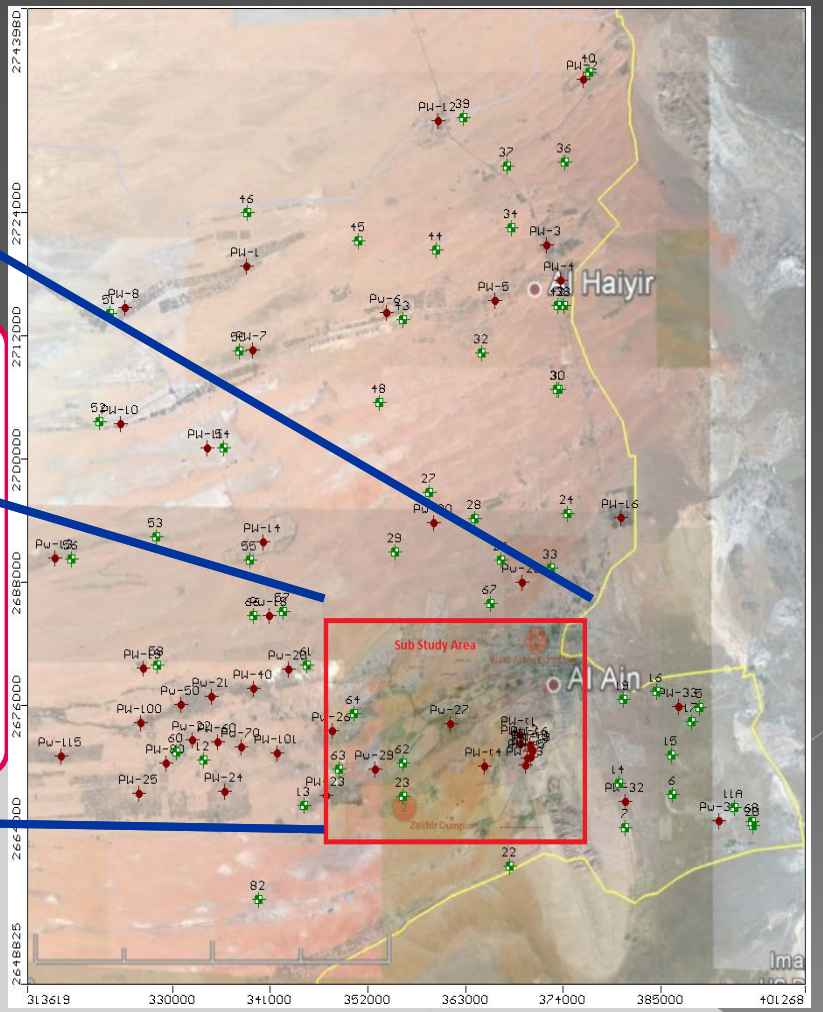
Hydraulic Boundary: No Flow

Hydraulic Boundary: Constant Head

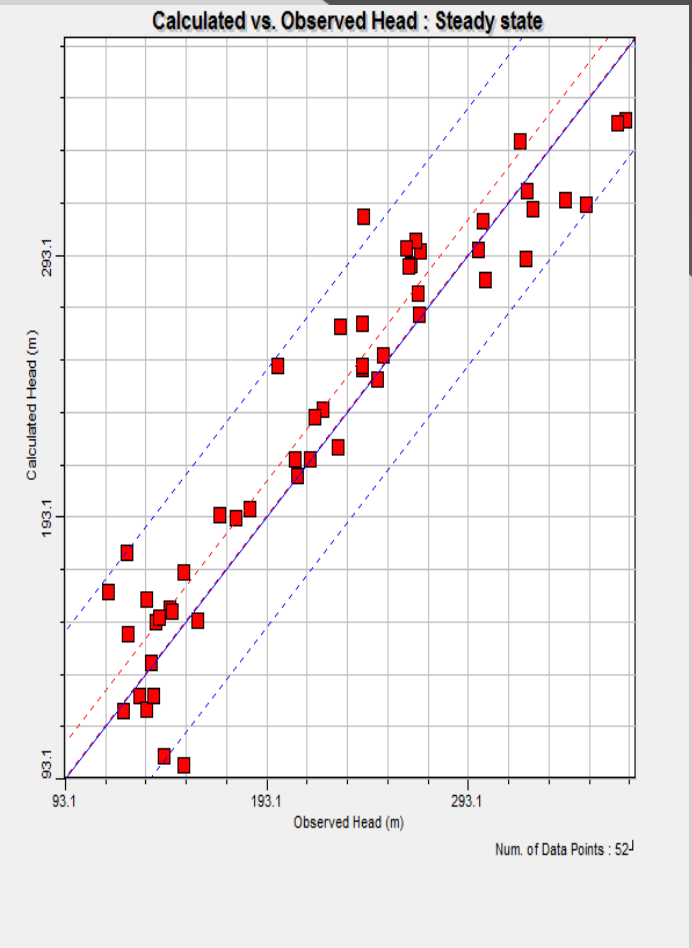
Physical Boundary: Omān Mountains

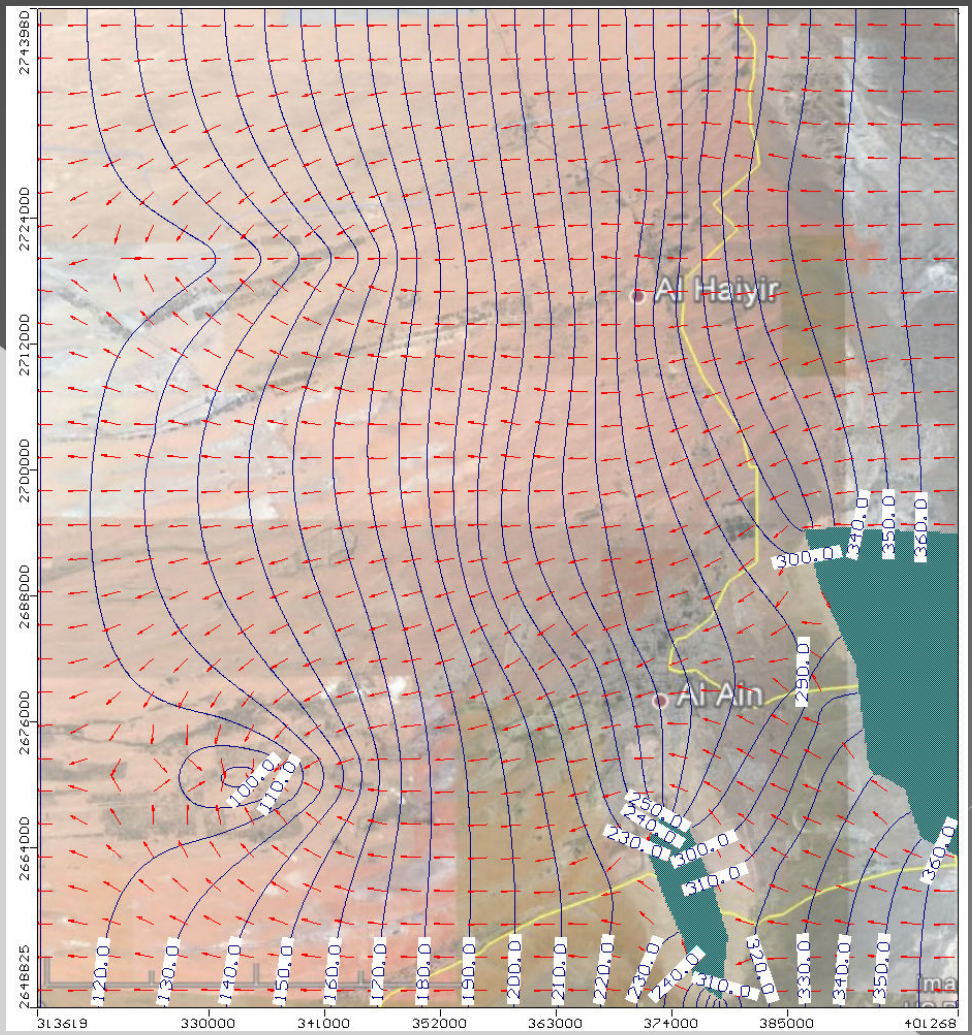
Hydraulic Boundary: No Flow



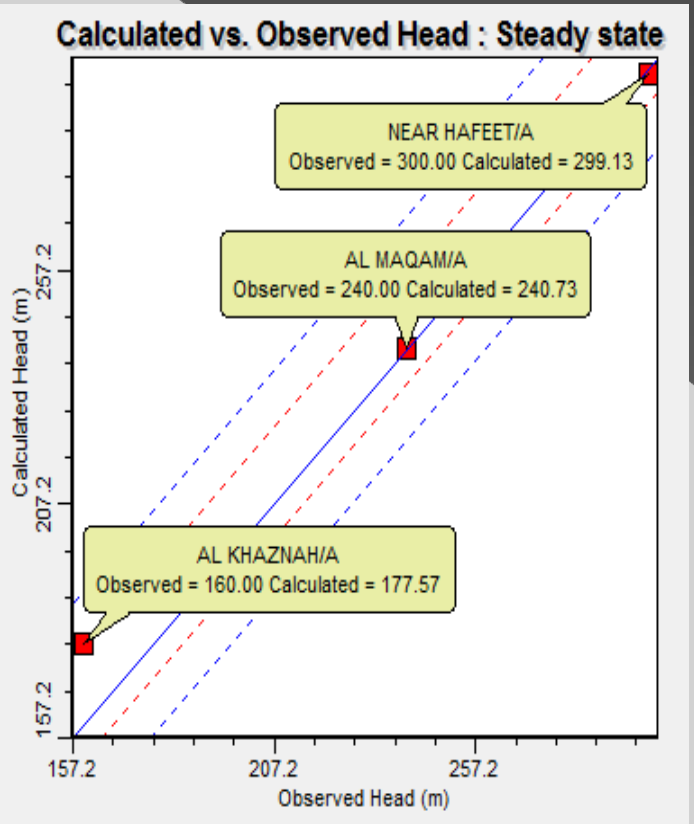


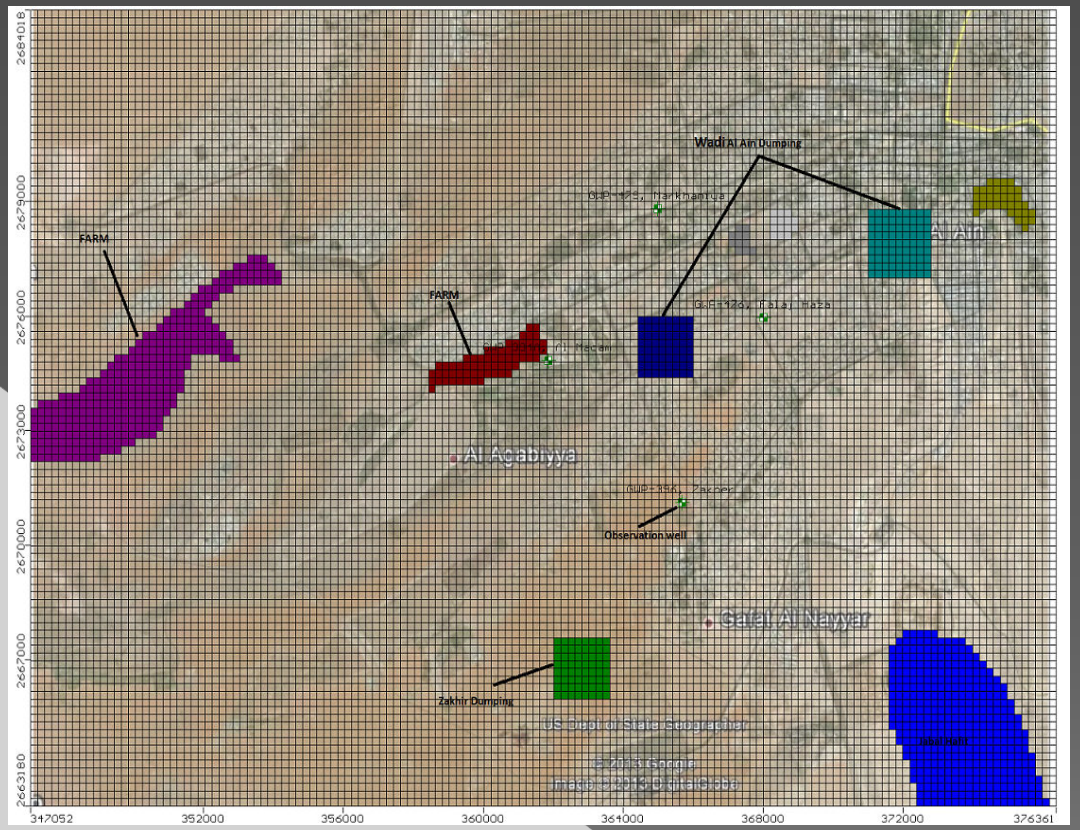
Model Calibration





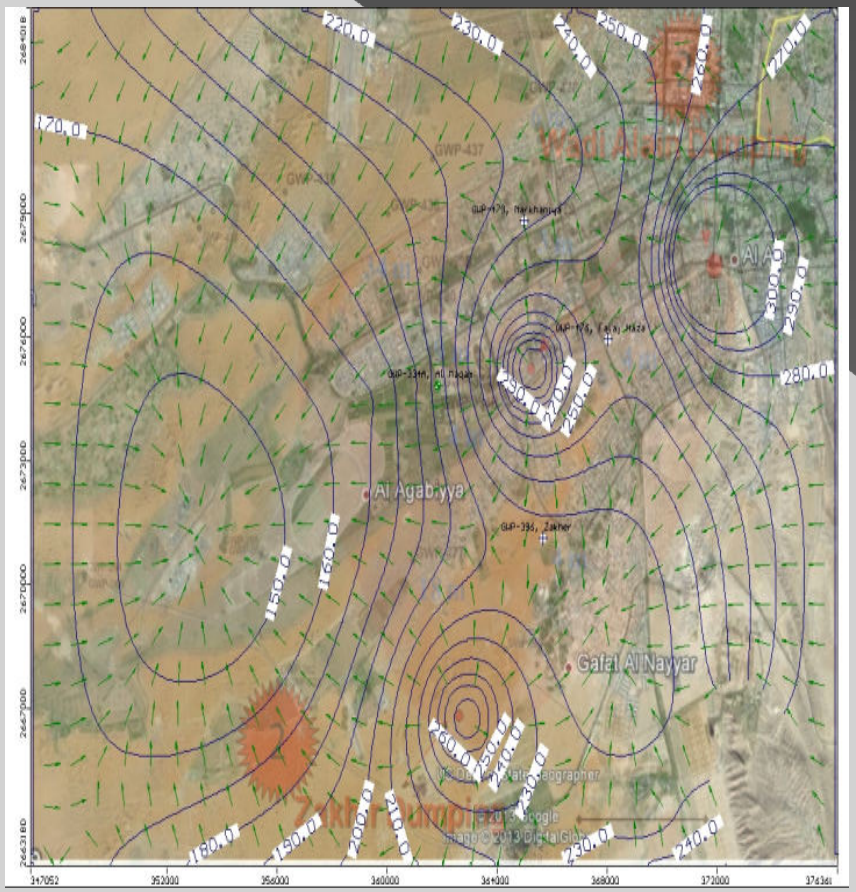
Groundwater Model



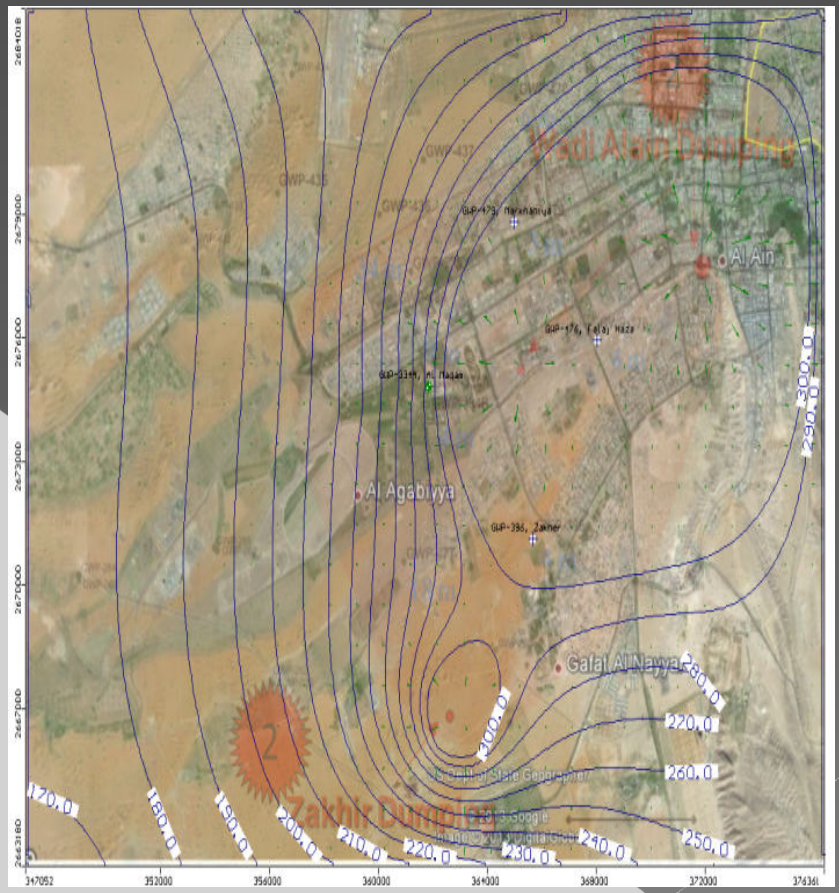


Observation location	Observed Head(m)	Simulated Head(m)	Head Difference (m)	Error %
Al Maqam	240	240.73	0.73	0.30
Al Jaww	280	281.42	1.42	0.51
Near Hafeet	300	299.13	0.87	0.29

Groundwater Model



After 5 years



After 20 years

MAR Phases

- Feasibility study (current project)
- Exploratory program (2nd phase)
- Pilot MAR study (3rd phase)
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- Maintenance and adaptive management

Conclusions

- Currently, about 50% of sewage water generated is diffused after purification.
- If this water is wisely recharged into groundwater aquifers, it can help building a back-up reservoir to face potential threats of shortage in freshwater supply in emergency cases.
- Ultimately, upon completion, this project could lead to replenishing the aquifers with 25 and 100 MCM of TSE water generated annually in Al-Ain and Dubai.
- The advantages of ASR are compelling – very large volumes of water can be stored underground at a fraction of the cost of other storage options.
- However, Inadequate aquifer characterization can cause the ASR system to fail.


Thank You