Assessment of Groundwater Recharge in an Arid Zone Using Several Approaches

By

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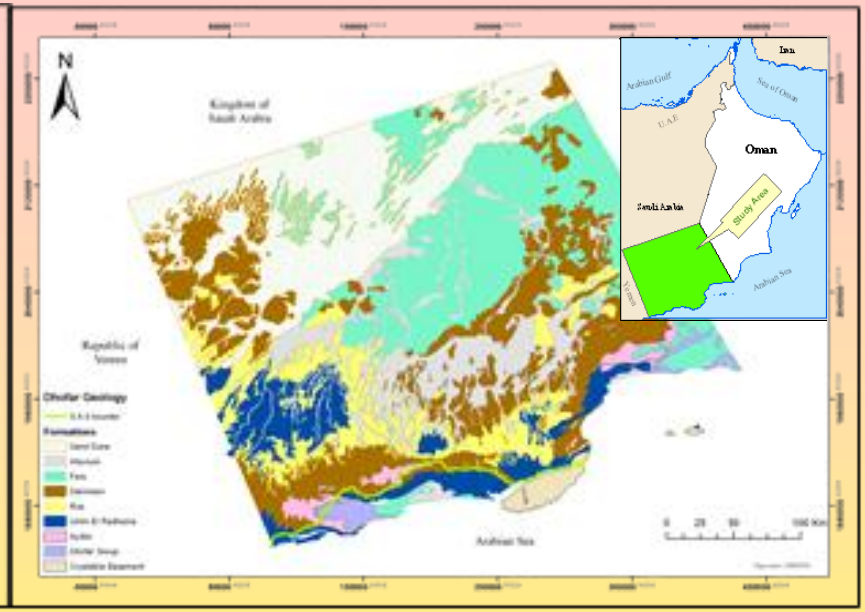

The study area geologically formed by two groups:

- Fars
- Hadhramout :

Dammam, Rus, Umm Er Radhuma (UER)

These formations mainly consists of marine limestone of Tertiary age.

Summary of hydrogeological characteristics of Najd area

Aquifers:
A → semi confined
B,C & D→ confined

Age			Group	Formation	Aquifer	Average Thickness (m)	Lithological description
~~ unconformity ~~~~~~~~~~~~~~~~							
Cenozoic	Tertiary	Oligocene to Miocene	Fars	Marsawdad	A	20	Interbedded reddish to yellowish siltstone and grey silty limestone
				Shisr			Reddish conglomerates, siltstones and limestone.
				Montasar			Grey to white micritic limestone, and places of brecciated limestone.
				Dawqah			Brecciated and lacrustrine limestone.
		~~Pre-Neogene Unconformity ~~				~~Pre-Neogene Unconformity ~~	
		Eocene	Hadhramaut	Damman		30	Massive and thin bedded nodular limestone with marl, yellow to orange shale with marl and limestone.
				Rus		113	Breccia, chalky dolomite, marl and laminated gypsum.
				Upper UER	B	102	Grey to brown dolomitic limestone, very weak white and brown biomicrite and blue-grey shale. Brown granulated and fossiliferous limestone at base.
		Paleocene		Lower UER	C&D	297	Moderately weak olive, sparry limestone interbedded with brown fossiliferous limestone.
				Shammar Shale		?	Grey brown, dark grey limestone and blue shale. Green mudstone interbeds.
~~ unconformity ~~~~~~~~~~~~~~~~							
Mesozoic							

(After GRC,2008)

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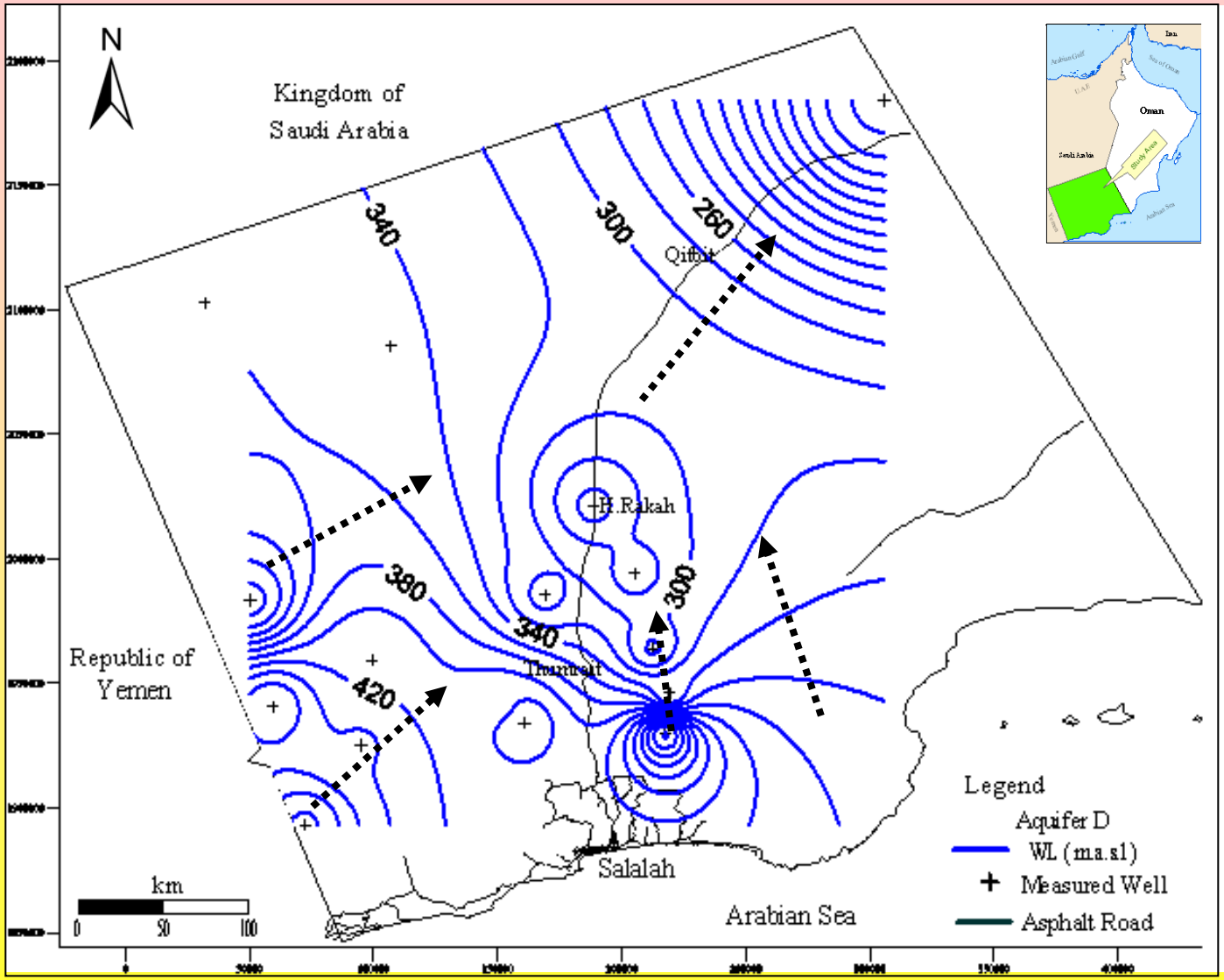
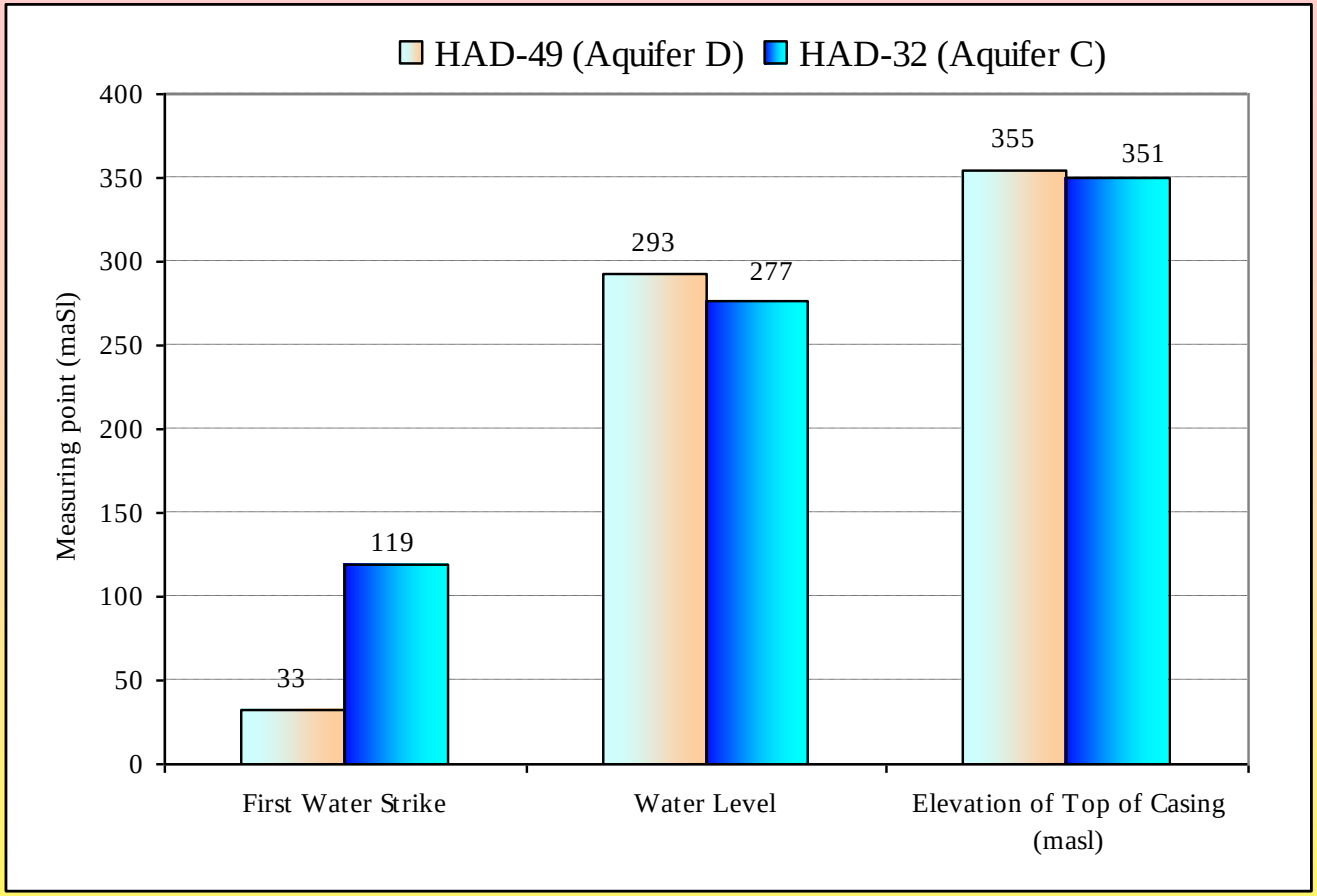
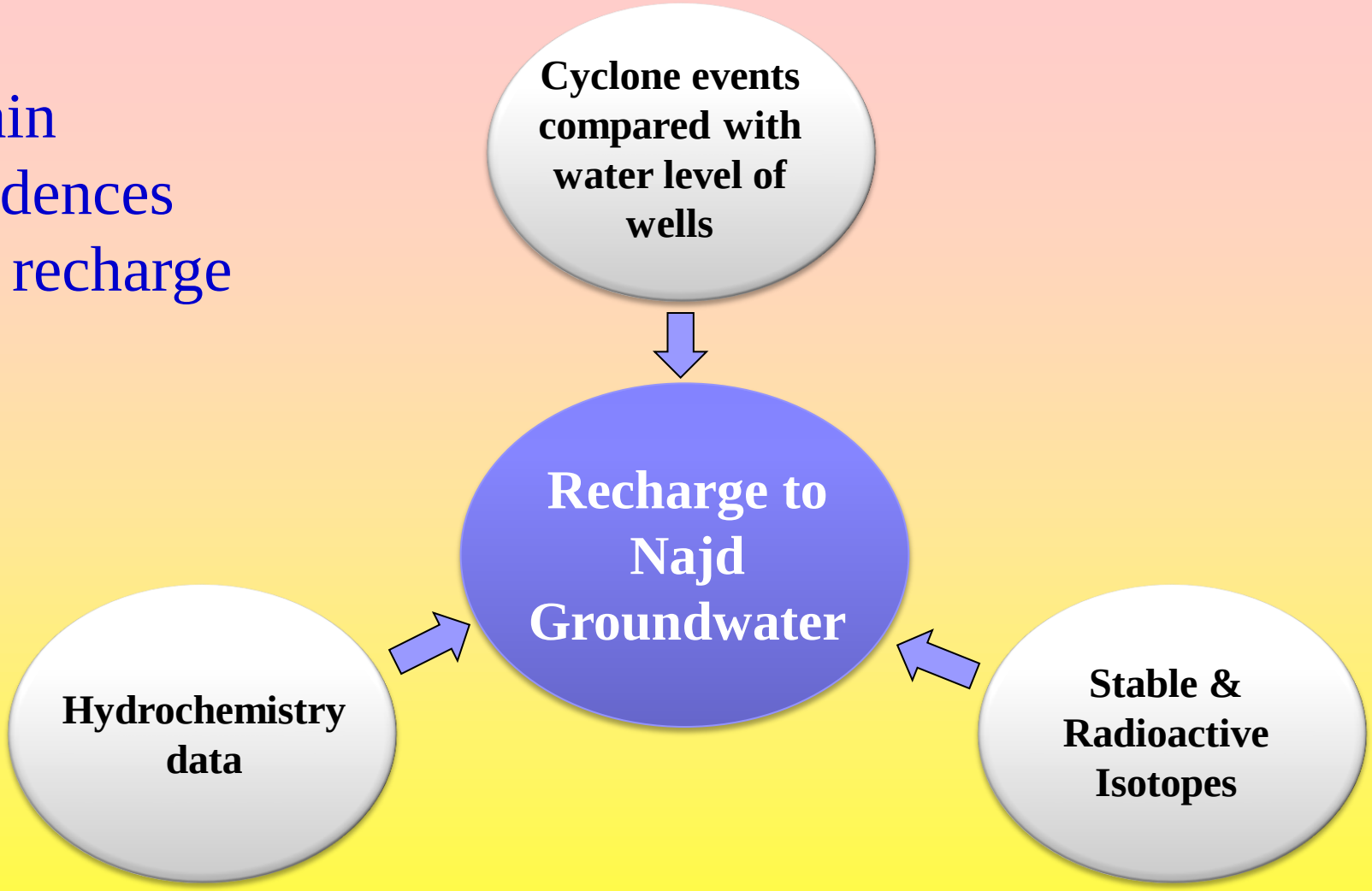
Groundwater flow direction (arrows) in aquifer D from south and south west to north and northeast



Comparison between aquifers C and D



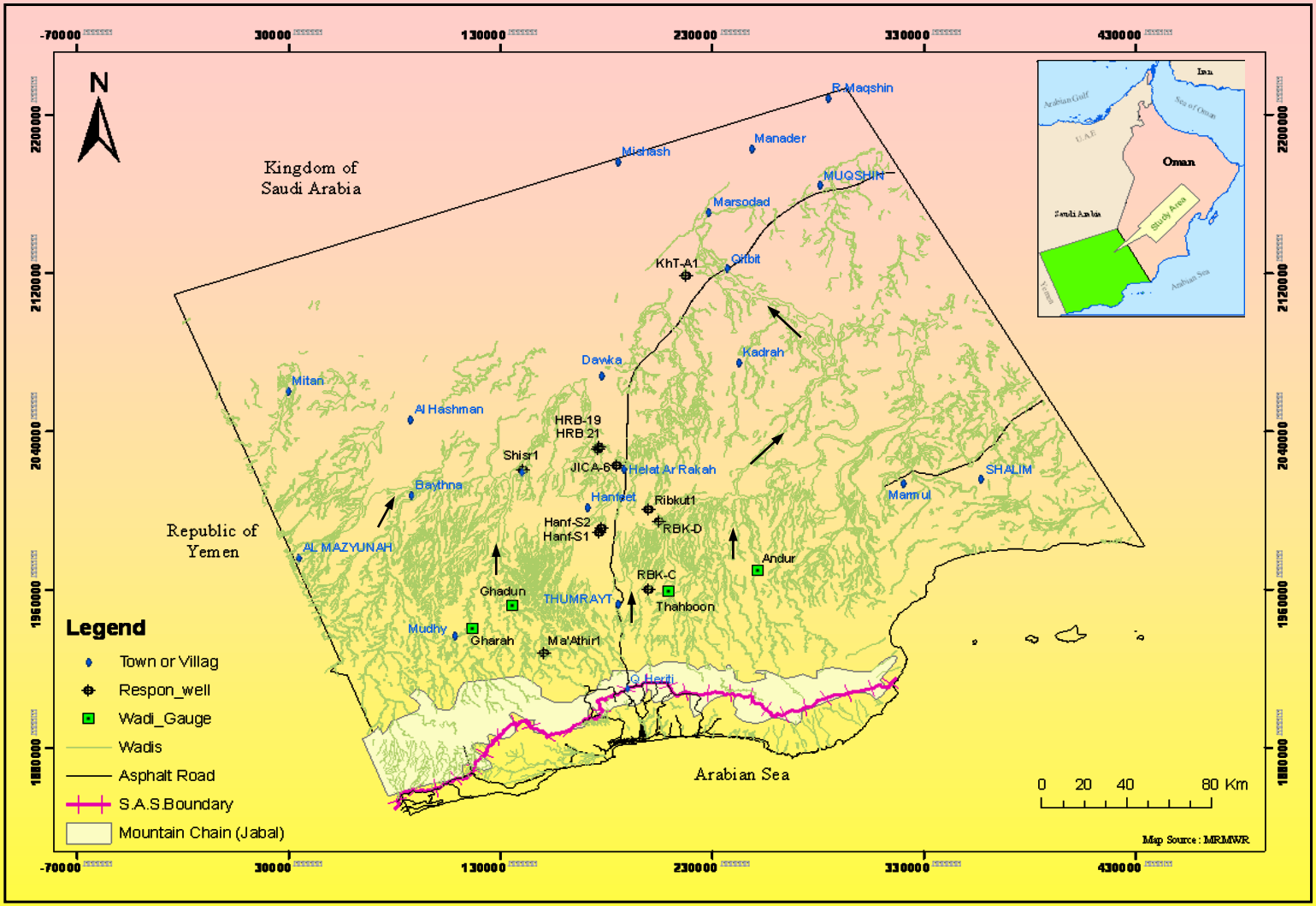
Main evidences for recharge



Locations of
- Wadi gauges
- Boreholes responding with flood events

and

Wadi flow direction (*dark arrows*)



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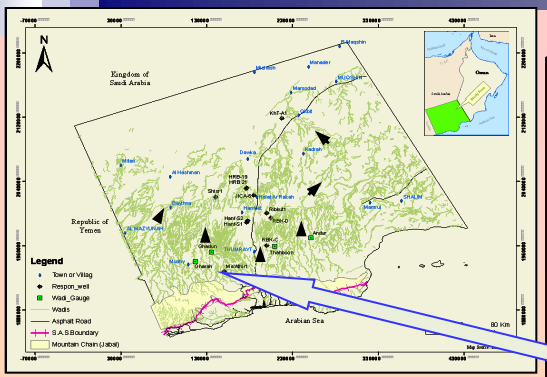
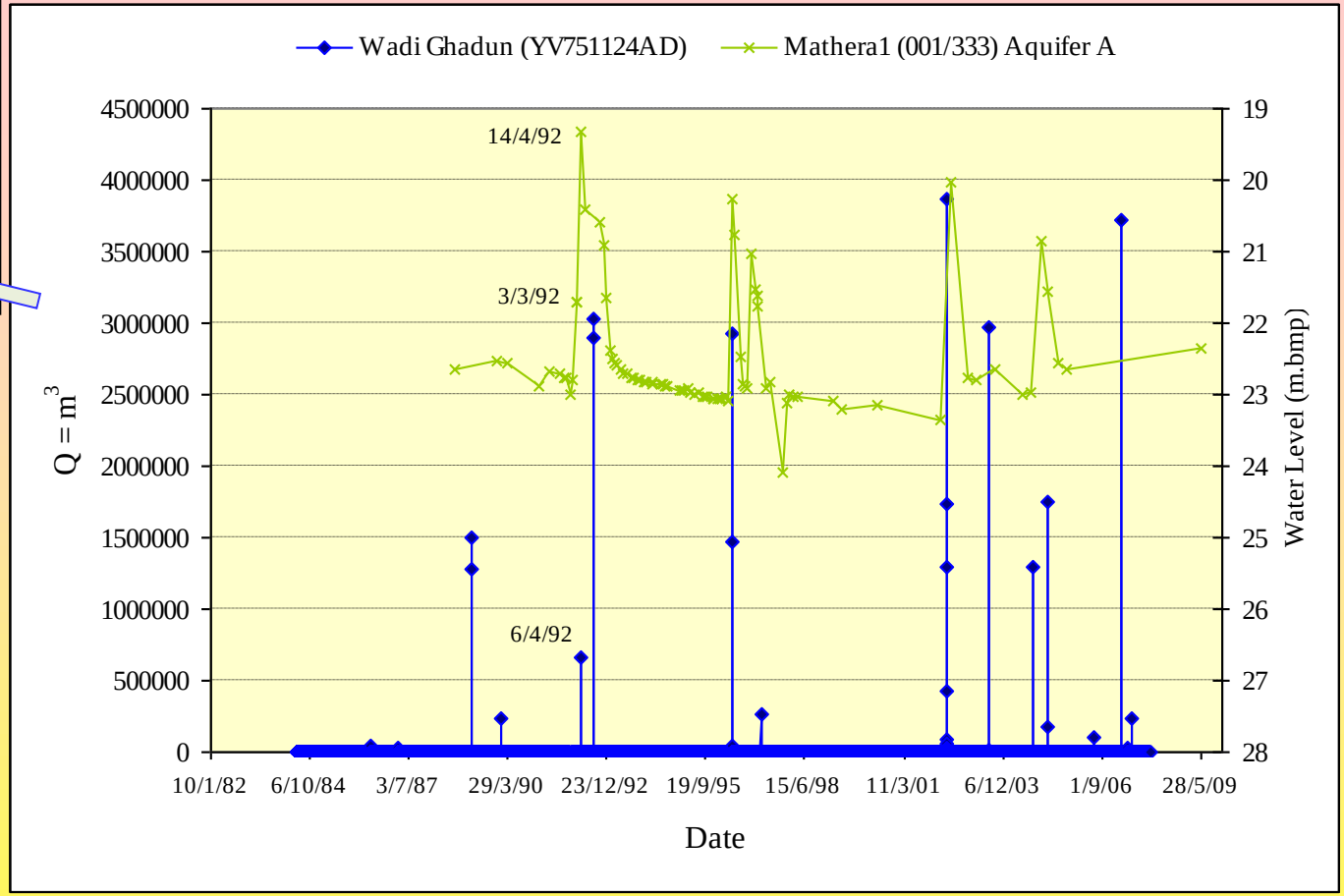
The shortest recharge travel periods observed :

~ 7 days in aquifer A
< 3 months in aquifer B
< 28 days in aquifer C

Well Name	NWI	Aquifer	Flood Period……	Water level responding with flood events (mbmp)					Travel Period
				WL Before Flood	Date	WL After Flood	Date	WL Rises	
Mathira1	001/333	A	6-8/4/92	21.7	3/3/92	19.33	14/4/92	2.37	~7 days
Shsir 1	001/007	B	30/09/04	34.38	21/9/04	32.96	21/12/04	1.42	< 3 months
RBK-C		C	10-12/5/02	167.57	14/4/02	166.72	8/6/02	0.85	< 28 days
Ribkut 1	001/283	C	10-12/5/02	69.55	19/3/02	66.39	23/6/02	3.16	< 1.5month



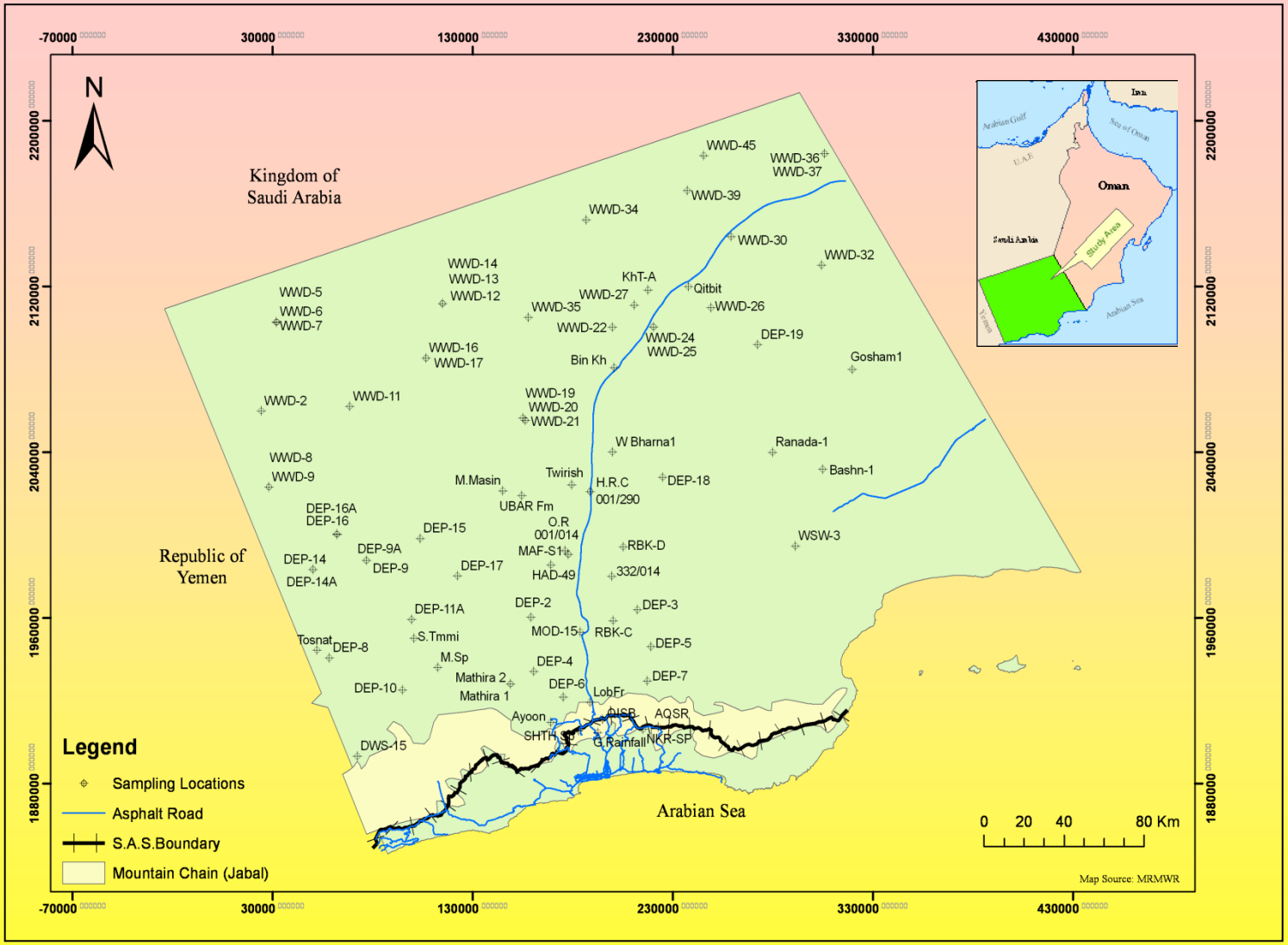


Wadi Ghadun flood event and water level responding at well Mathera-1 in aquifer A →~7 days

Monsoon influences is difficult to detect from the hydrograph even though it can not be ignored

Sampling locations from all aquifers

(selection priority was given for MRMWR wells)



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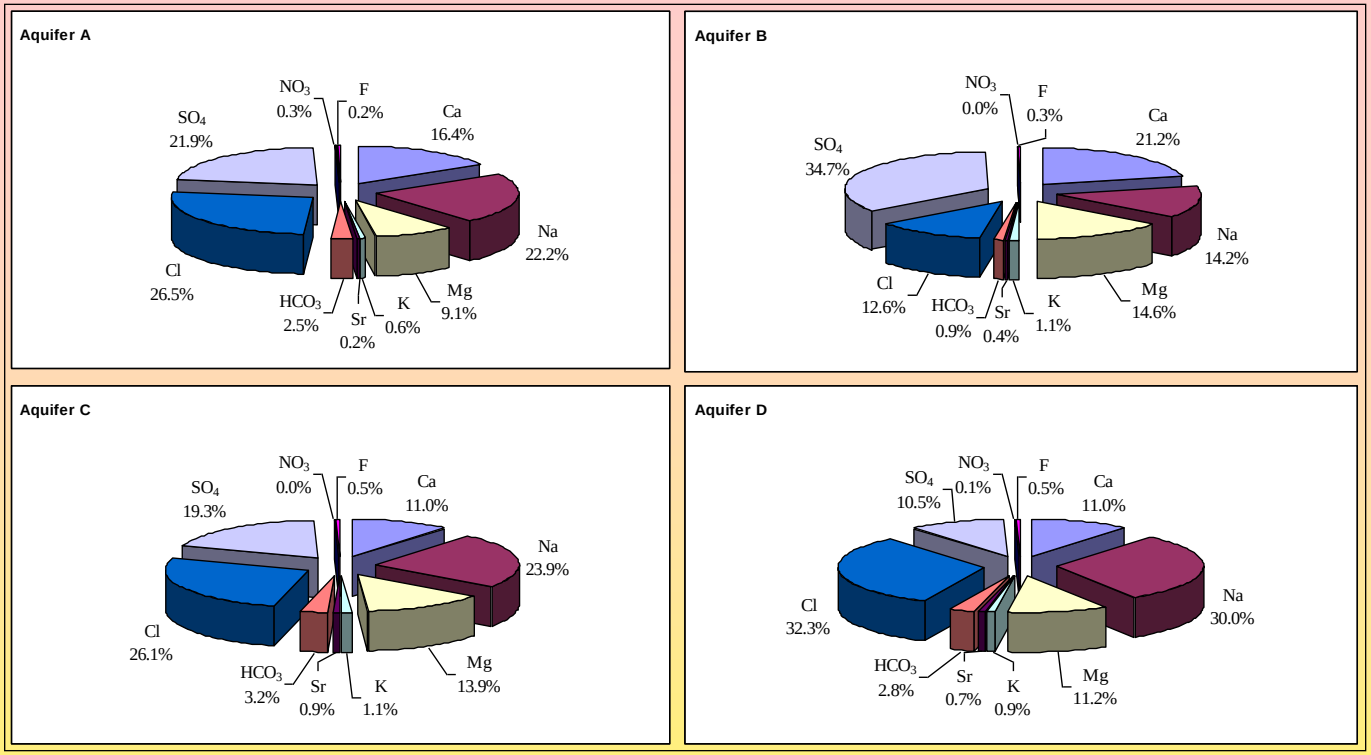
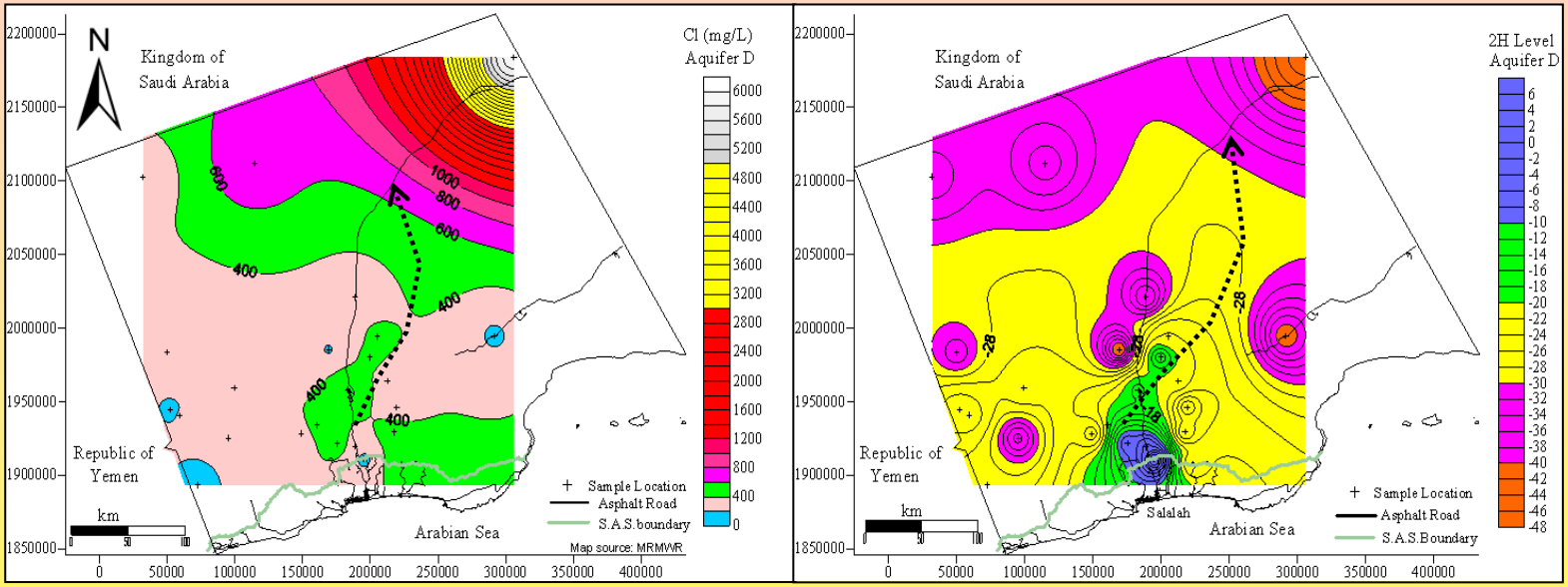
Predominant ions:

- Ca, SO_4 in aquifer B.
- Na, Cl in aquifers A, C & D.
- Bicarbonate, strontium, nitrate, and fluoride (<5%).



Aquifer	Water type
A	Na-Ca-Cl-SO_4
B	Ca-Mg-Na-SO_4-Cl
C	Na-Mg-Cl-SO_4
D	Na-Ca-Mg-Cl-SO_4

Chloride and δ^2H (‰) distribution in aquifer D along flow direction (dot lines)



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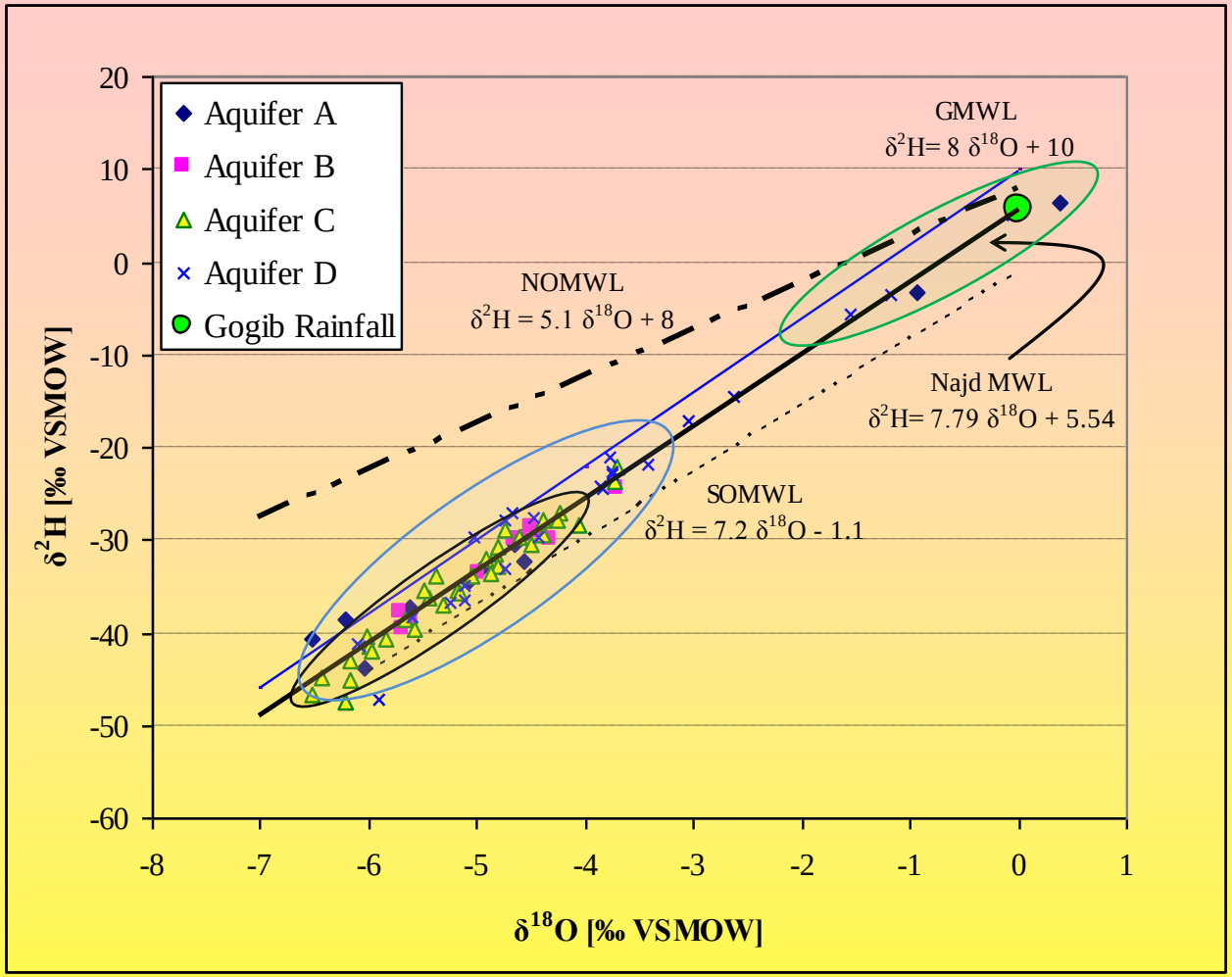
δ^2H vs $\delta^{18}O$

Groundwater, spring water, and precipitation from the Dhofar region (after Al-Mashaikhi et al., Env. Earth Sci 2011).

Legend: green: modern water – monsoon recharge; blue: modern water – cyclones; fossil water – precipitation under humid conditions.



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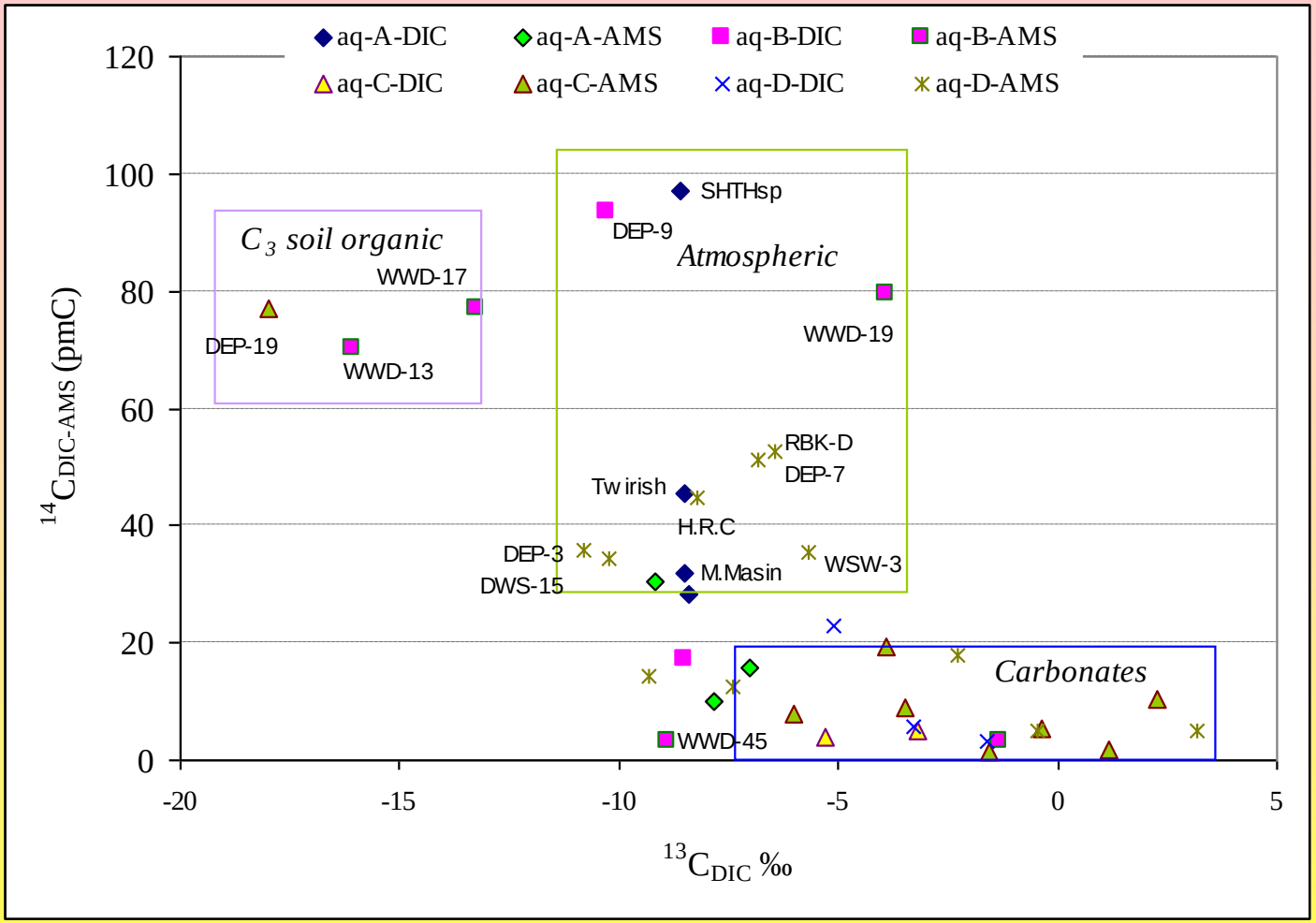
^{13}C and ^{14}C show three types of influences:

- Soil organic CO_2
- Atmospheric CO_2
- Carbonate

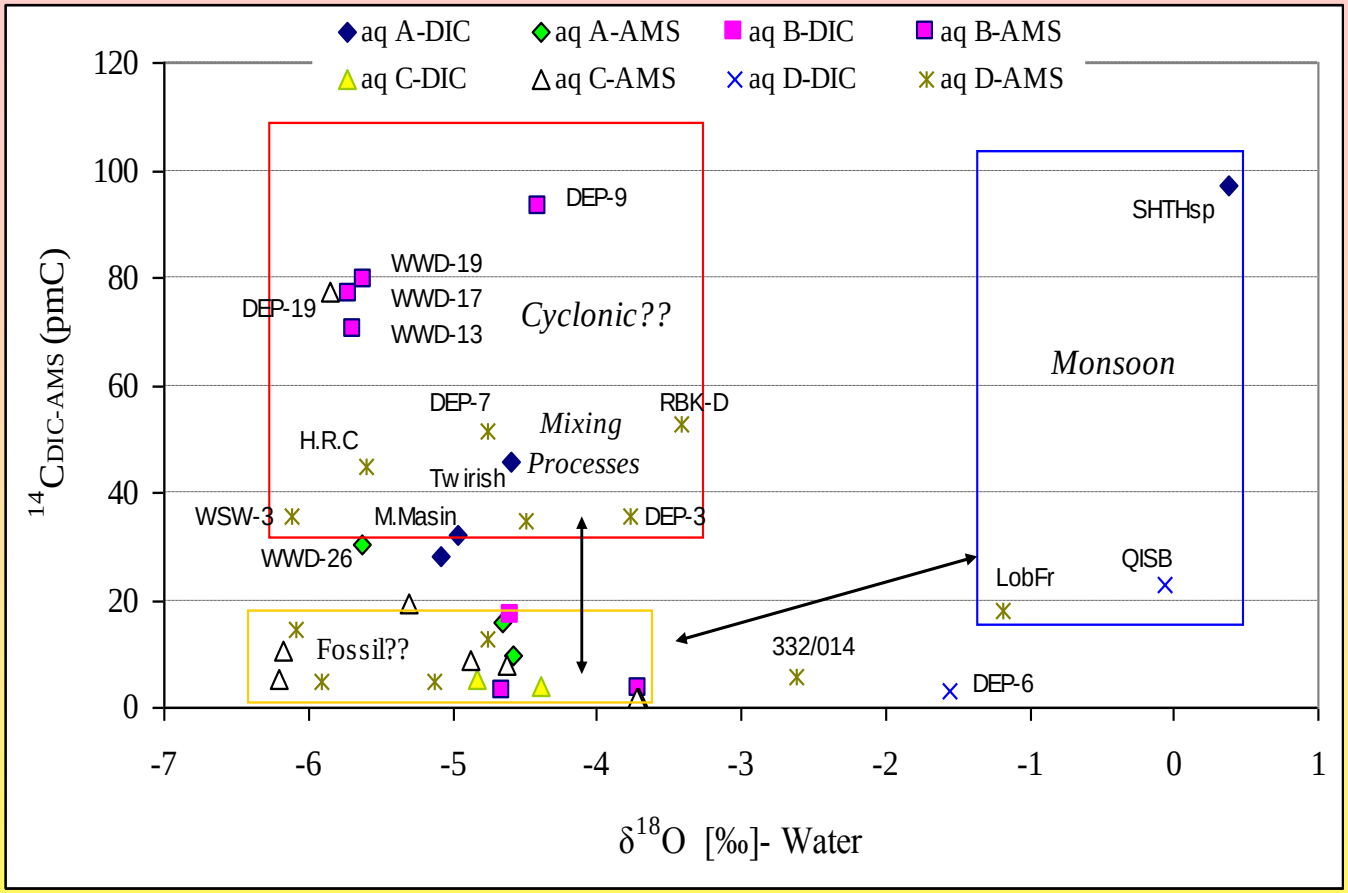


(**^{14}C values were estimated by DIC procedure and beta-scintillation as well AMS) (after Al-Mashaikhi, 2011)**

$\delta\ ^{13}C_{soil\ CO2}$ -14 to -20‰, $\delta\ ^{13}C_{carb}$ = -7 to +3.5‰, atmosphere $\delta\ ^{13}C_{CO2}$ -7 to -8‰

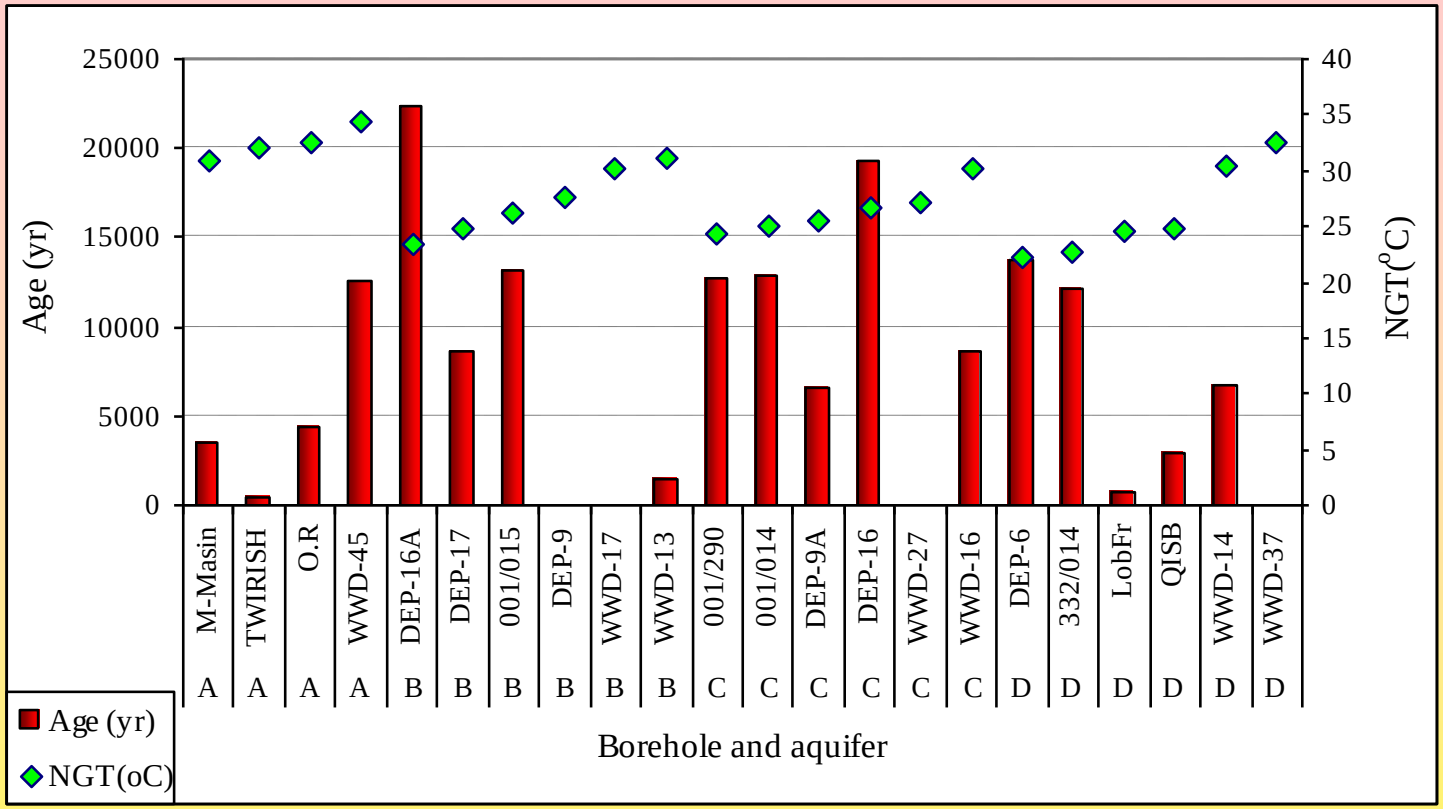
^{18}O of water vs ^{14}C classified the origin of groundwater in Najd to three sources:

- Monsoon
- Cyclonic
- Fossil

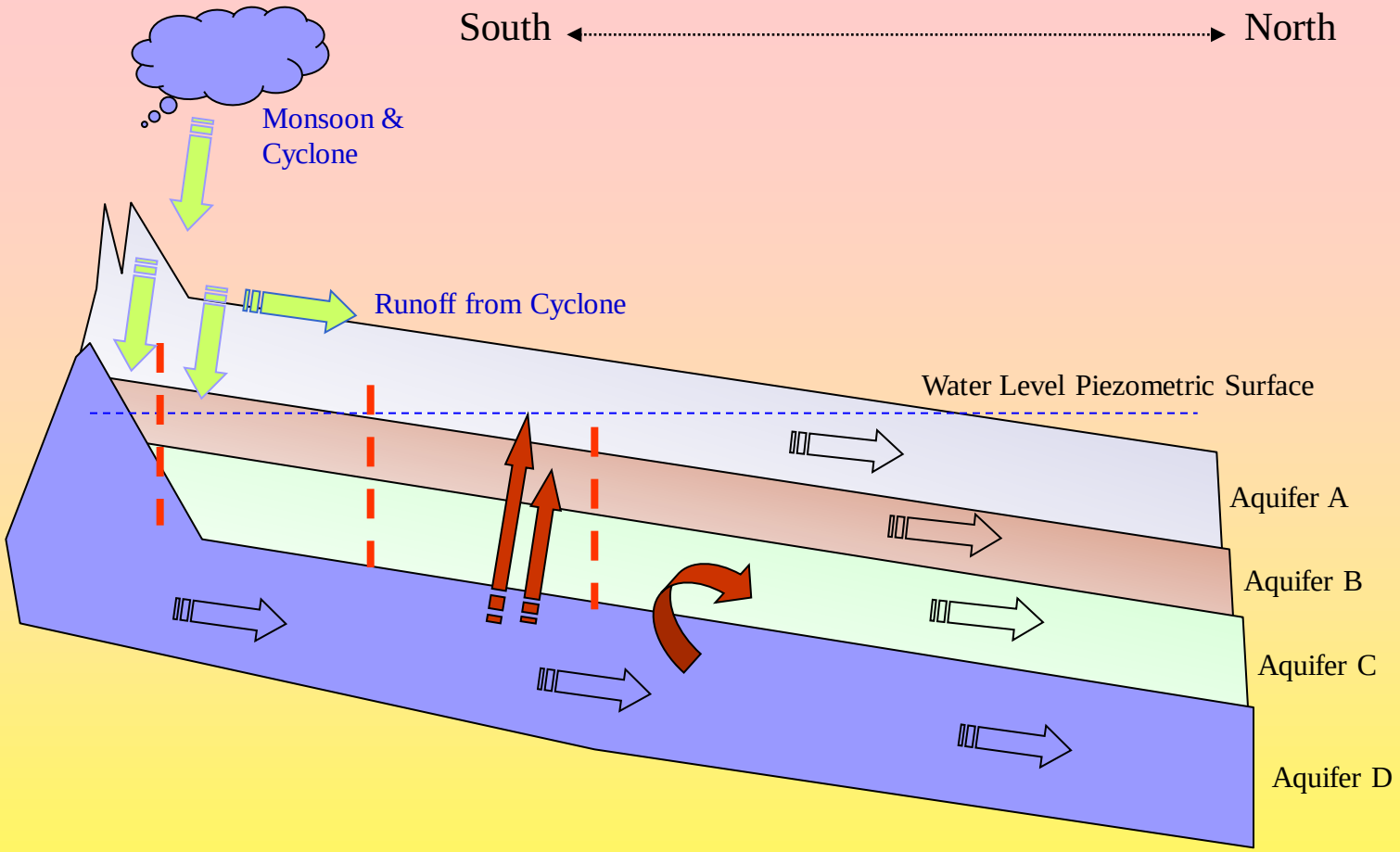


(where: ^{14}C analyzed = DIC and AMS, aq = aquifer)

Groundwater age compared with NGT for different aquifers



Groundwater age Modern to >22,000 Years



Recharge processe initially started in aquifer D, then feeding the other aquifers as follow:

- firstly aquifer C was filled with Paleo-water (early Holocene)
- secondly aquifer B and A later with mixing of fossil and modern water

Conclusion

- Three main recharge processes should be taken into account for the investigation area: (i) modern water by monsoon events, (ii) runoff and recharge by cyclonic events, and (iii) interactions between the aquifers by hydraulic exchange

- Aquifer D is the dominant aquifer and basically all above aquifers C to A are dewatering among this aquifer, and due to high abstraction in aquifer C the mixing processes between old and modern groundwater in aquifer D will be accelerated farther north.

- Cyclone events are the main source of recharge to Najd aquifers whereas Monsoon is the second resource of recharge

- Stable isotopes depletion as well as mineralization increases are following the groundwater flow direction from south/southwest towards north and northeast.

- Two directions of recharge confirmed; by using Cl and ^{2}H data in aquifer D though Thumrait (MOD-15) and Poultry farm (332/014)

- By using, ^{18}O and ^{14}C data, three source of groundwater origin were defined; monsoon, cyclone and fossil water, however the fossil groundwater is concentrated in aquifer C

Thank you for your attention

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