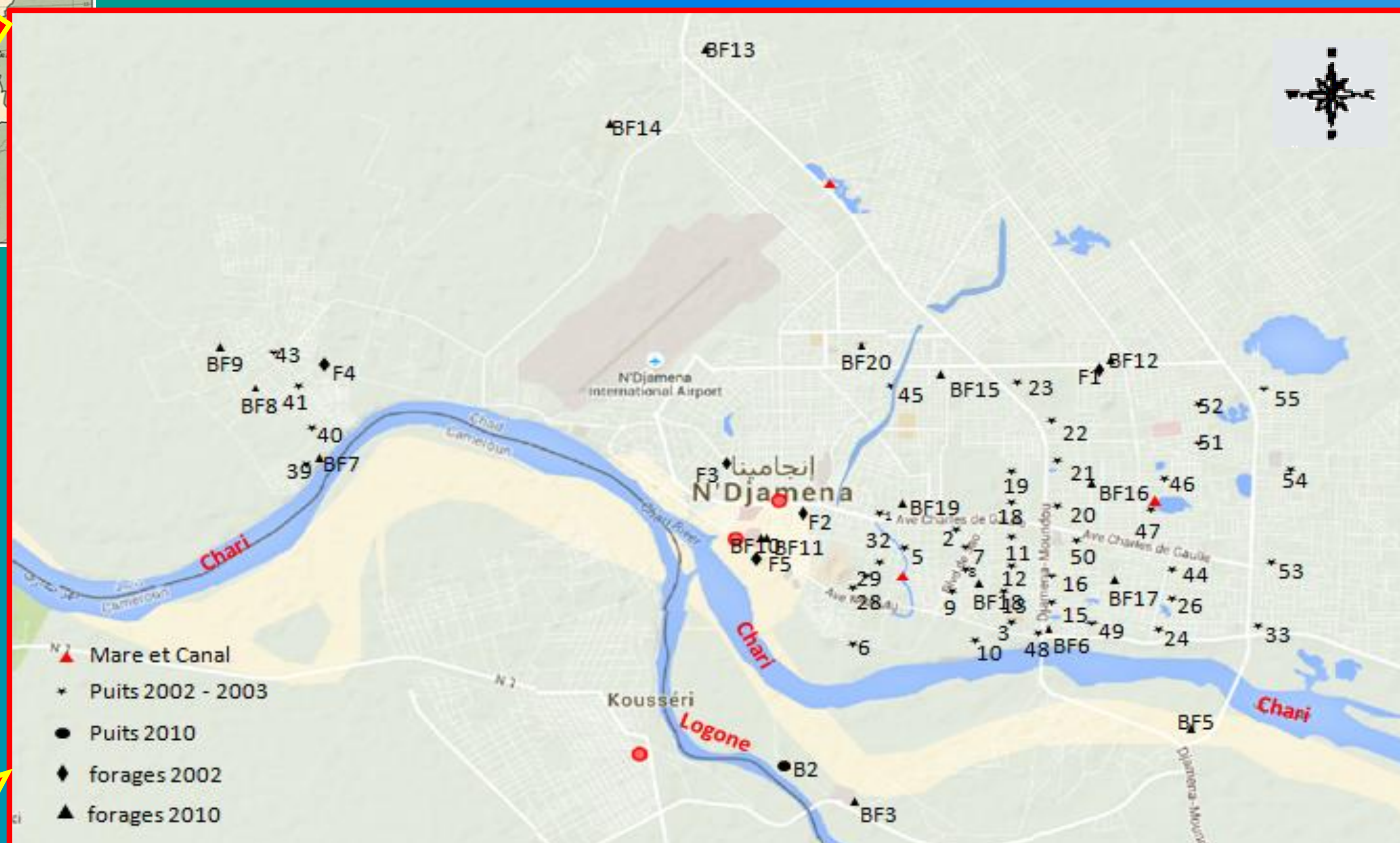
Groundwater recharge and vulnerability of shallow aquifers under a Sahelian metropole: N’Djamena (Chad Republic)

Edith KADJANGABA [1]
Mahamat Ahmat ANNADIF[2]
Frédéric HUNEAU[3]
Yves TRAVI[4]
Daïra DJORET[1]
Yaya MAHMOUT[1]

1 : University of N,Djamena, B.P. 1027 , N’Djamena, Chad
2 : Ministry of Rural Hydraulics; N’Djamena, Chad
3 : University of Corsica, CNRS UMR 6134 SPE, Corte, France
4 : University of Avignon, UMR EMMAH, Avignon, France

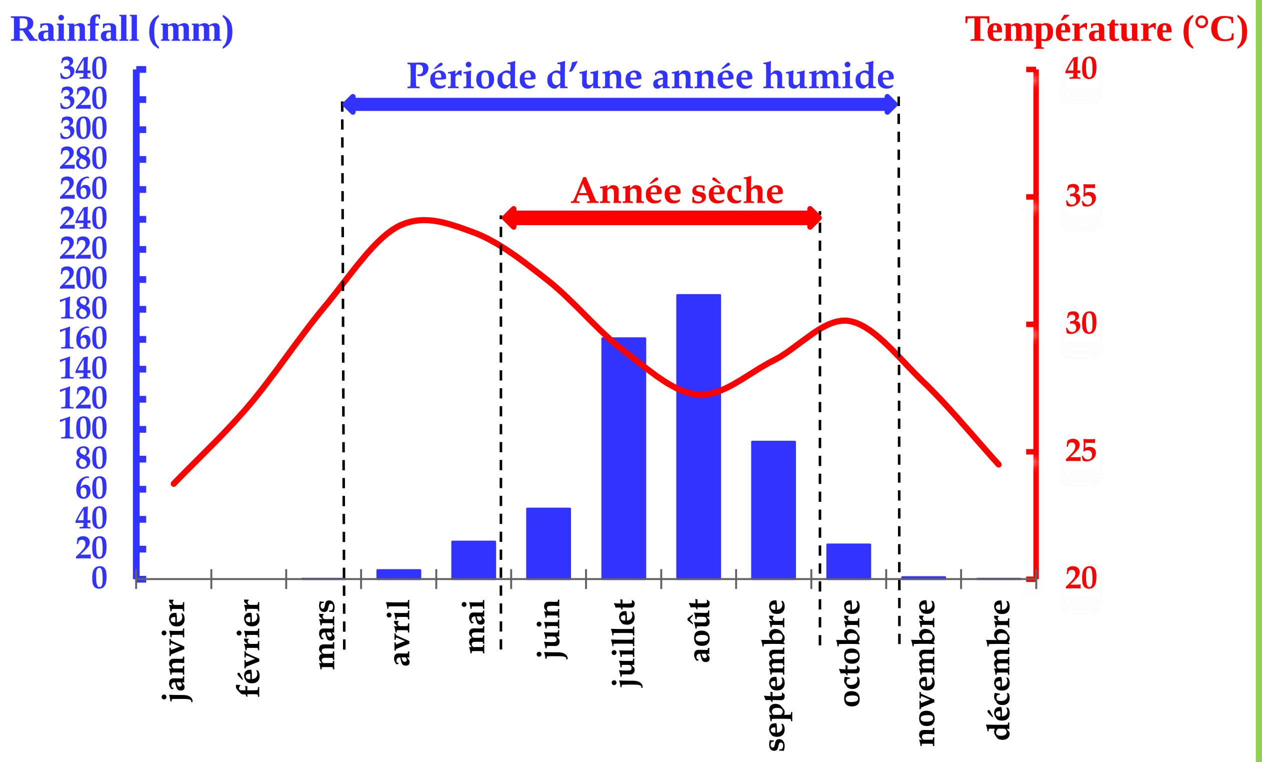
CONTENT

Location city of N'Djamena (CHAD)



I- The study area

Climatic context



Precipitation and average temperatures in the N'djamena Airport station 1984 - 2014

- **Rainfall:**

- Alternating dry season and wet season

- Change the duration of the rainy season

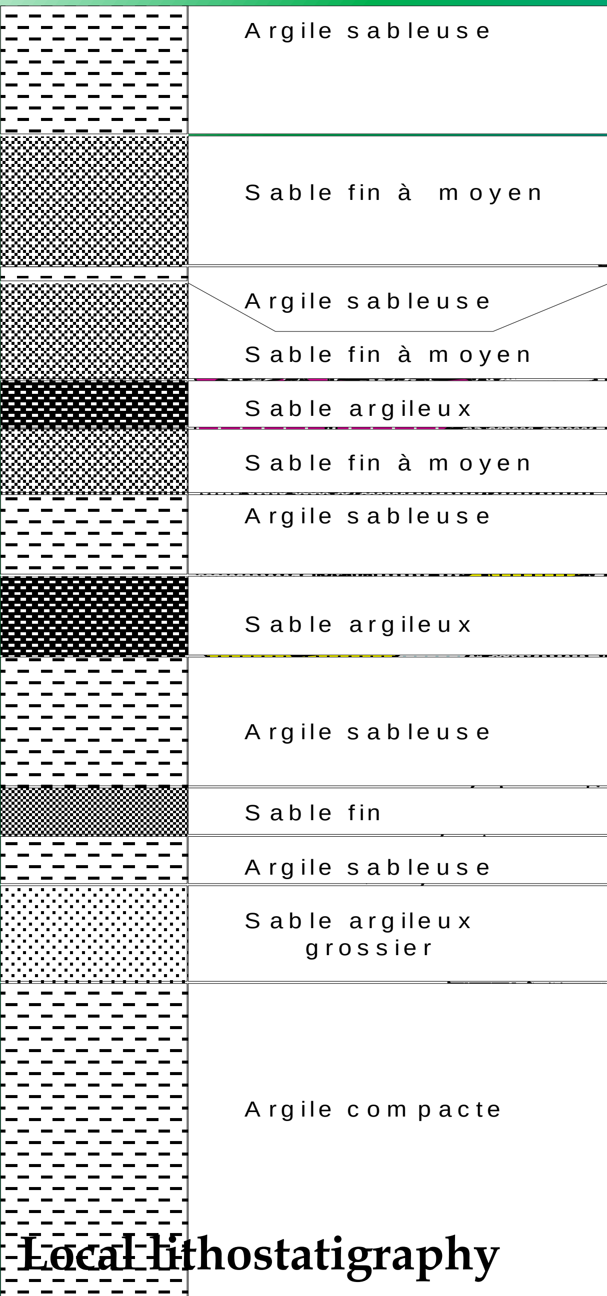
- **Température:**

- Minimum 2: rainy and cold season

- 2 maxima end of the dry season and the rainy season

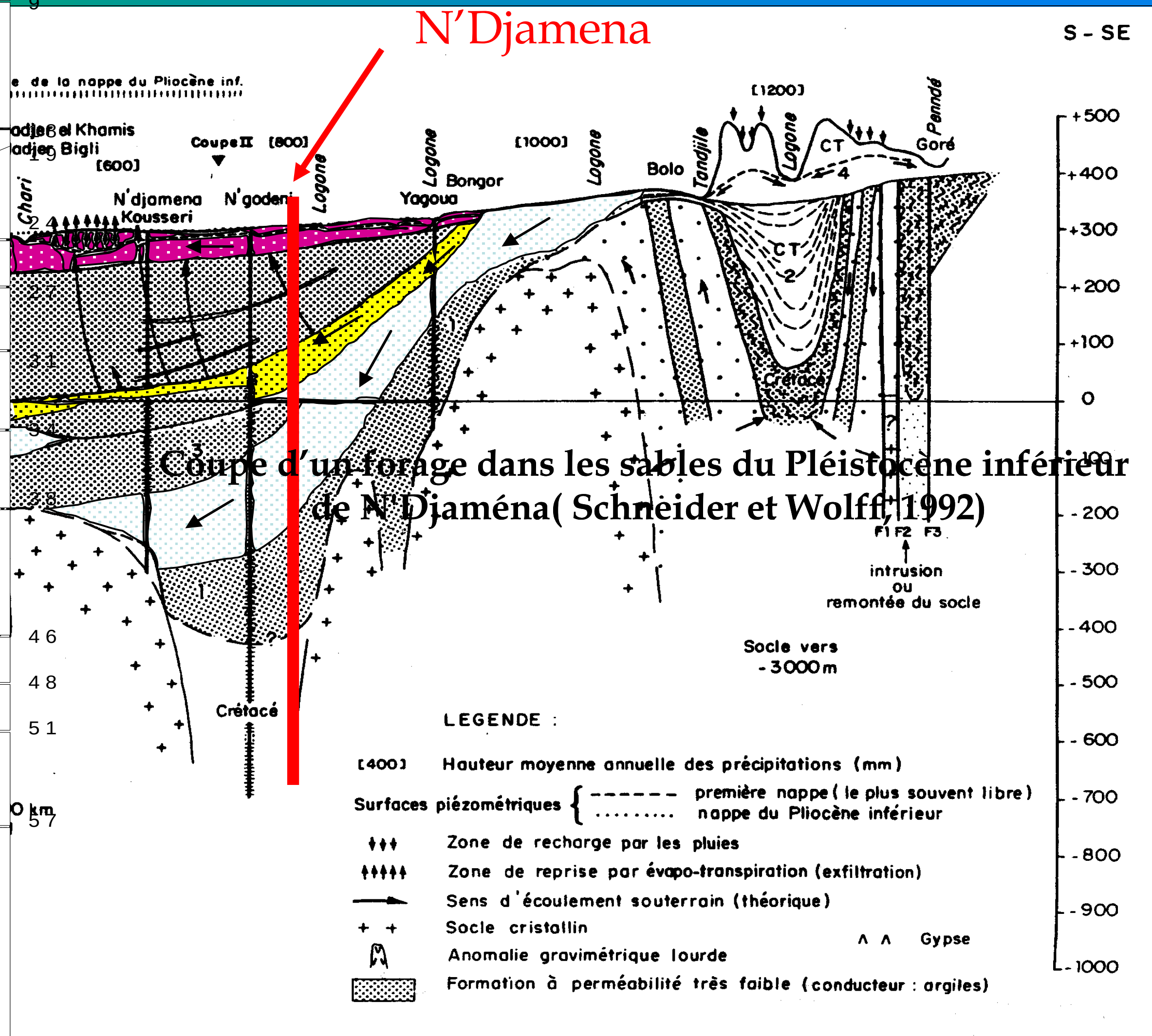
I -The study area

geology and hydrogeology of the Chad basin



Coupe d'un forage dans les sables du Pléistocène inférieur de N'Djaména(Schneider et Wolff, 1992)

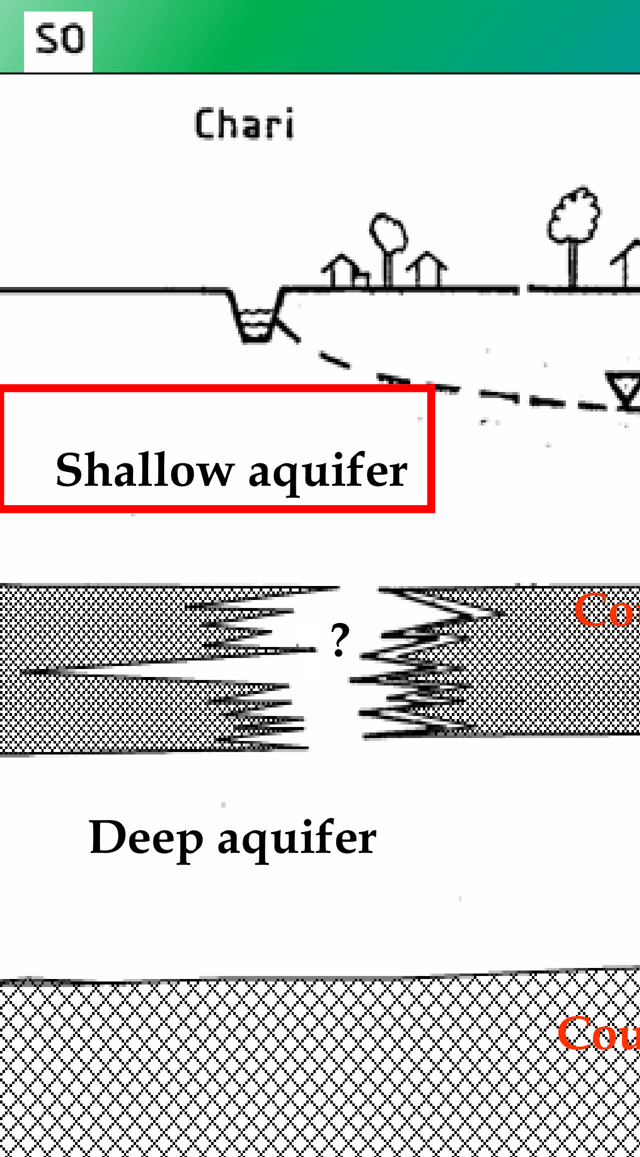
Local lithostatigraphy

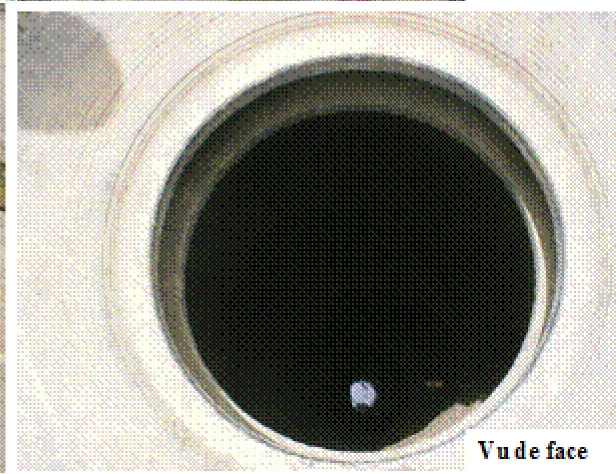


Cross section of the Lake Chad Basin between Rig Rig and Gore (Schneider and Wolff, 1992)

I- The study area

geology and hydrogeology of the Chad basin

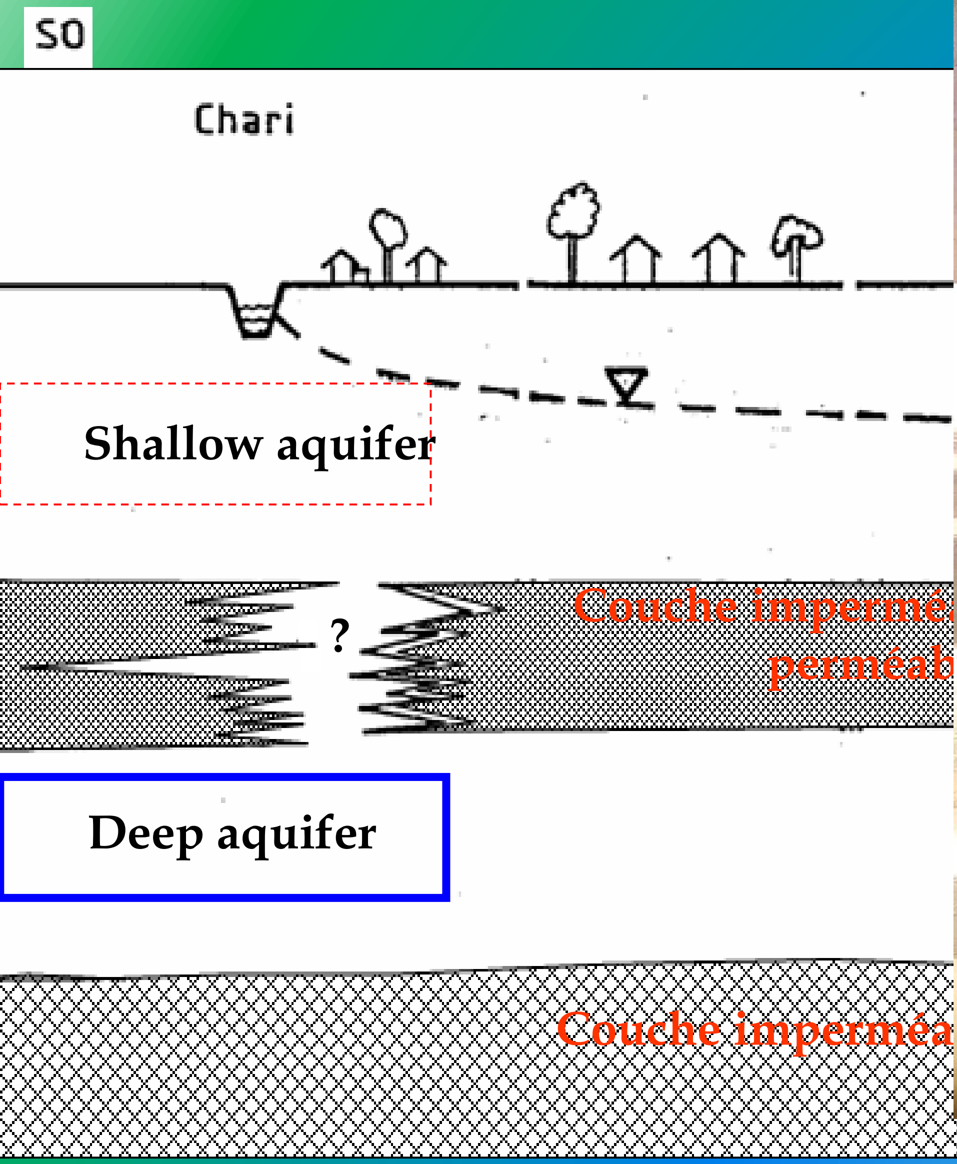




traditionnal wells exploiting the shallow aquifer

I- The study area

geology and hydrogeology of the Chad basin



Borehole exploiting the deeper aquifer

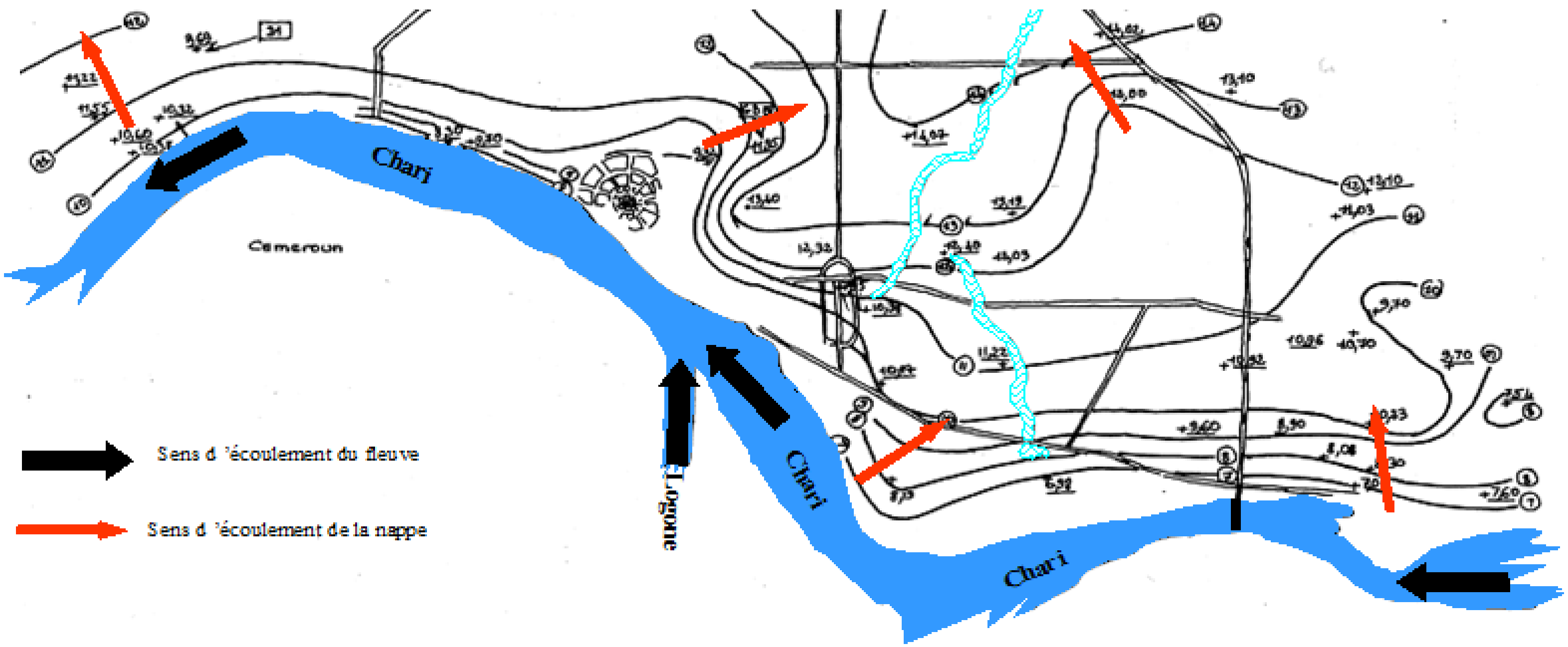
I- The study area

Synthetic piezometric map of the shallow aquifer (BRGM 1988).

groundwater flows from the southeast to the northwest and in the center it tends to flow from the southwest to the northeast

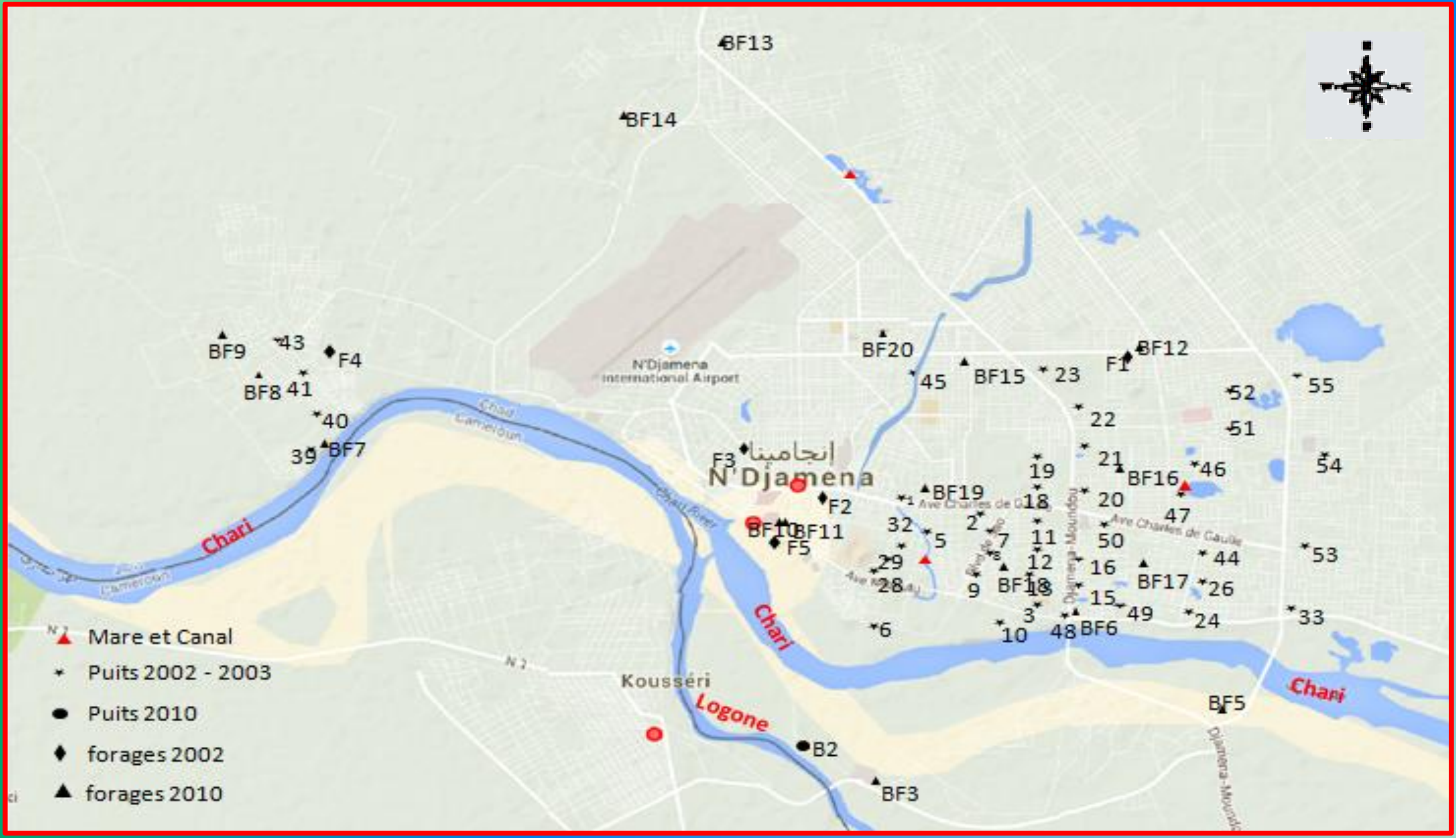
The table depth when the distance from the river increase

we see tighter isopièzes curves near the river, thus highlighting its strong influence on the tablecloth.

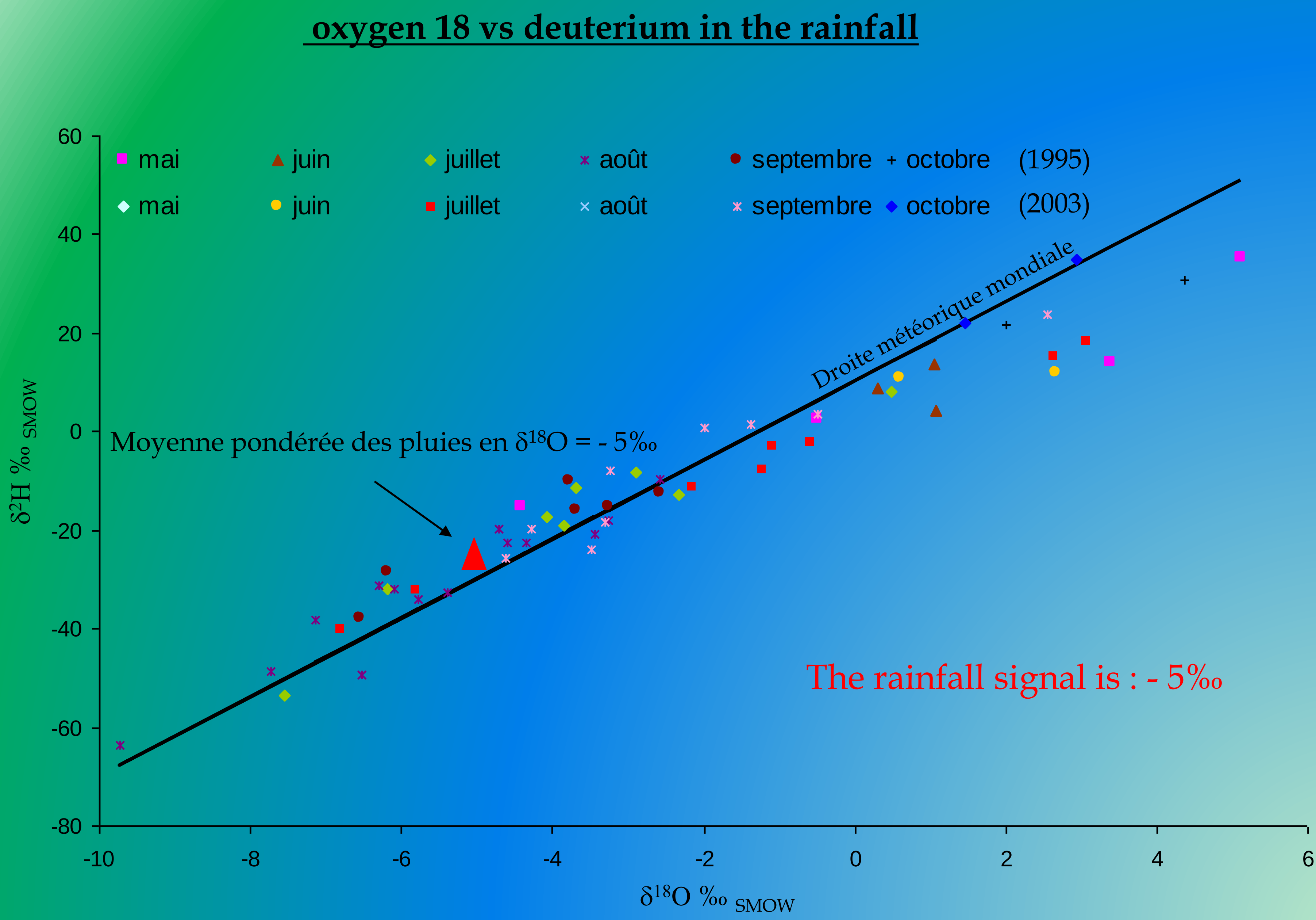


I-The study area

Location of the sampling points

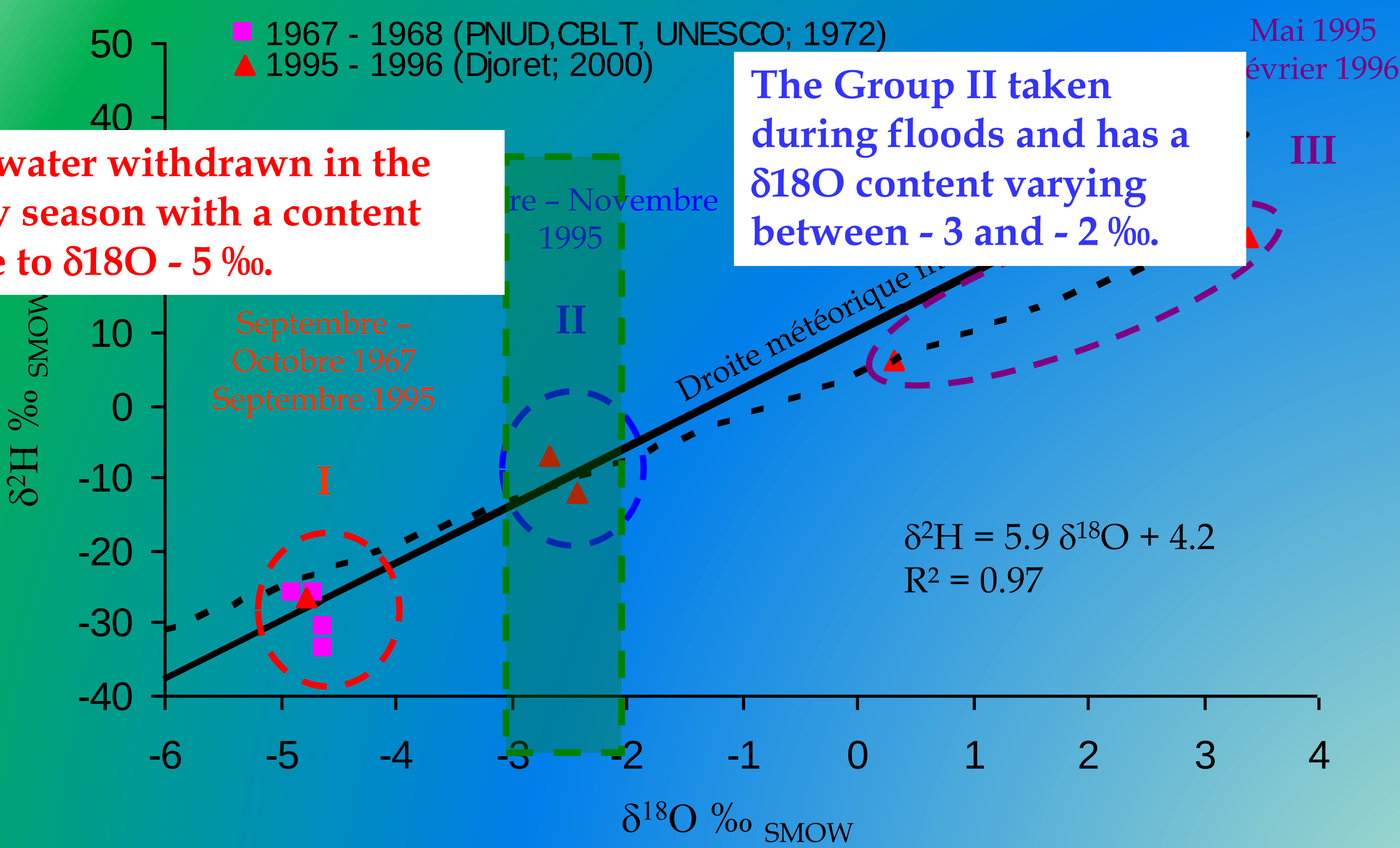


II - Input signal rainfall and Chari River



II - Input signal rainfall and Chari River

<u>$\delta^{18}O$ vs $\delta^{2}H$ in the Chari River water (between 1967 – 68 and 1995 – 96)</u>



the water withdrawn in the rainy season with a content close to δ18O - 5 ‰.

The Group II taken during floods and has a δ18O content varying between - 3 and - 2 ‰.

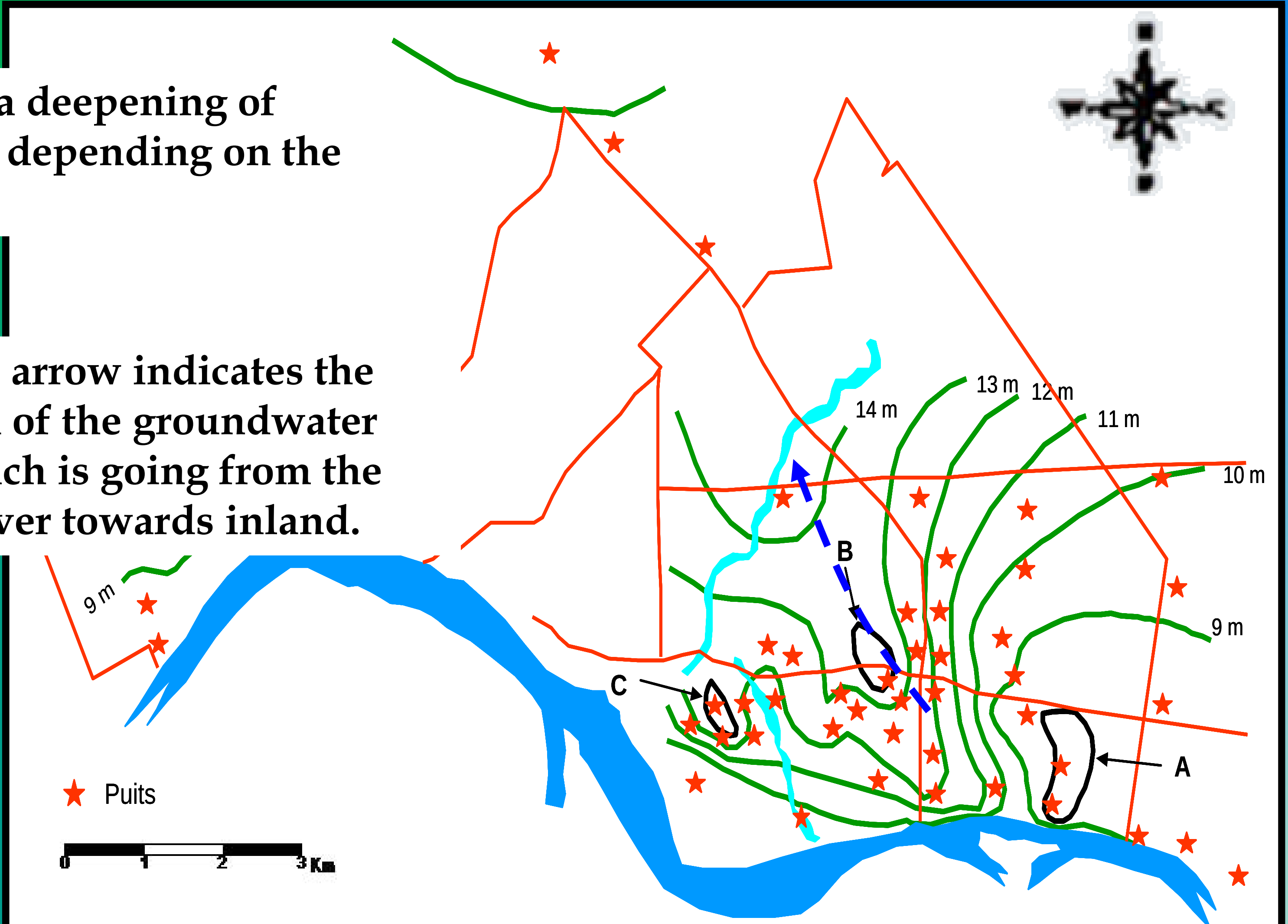
the result gives isotopic chemistry - 5 ‰ in d18O SMOW for rainfall and between -3 ‰ - 2 ‰ in d18OSMOW to the river.

III - Recharge location based on map of deph and isotope tracing

Map of the corrected depth of the shallow aquifer of N'Djamena (september 2001).

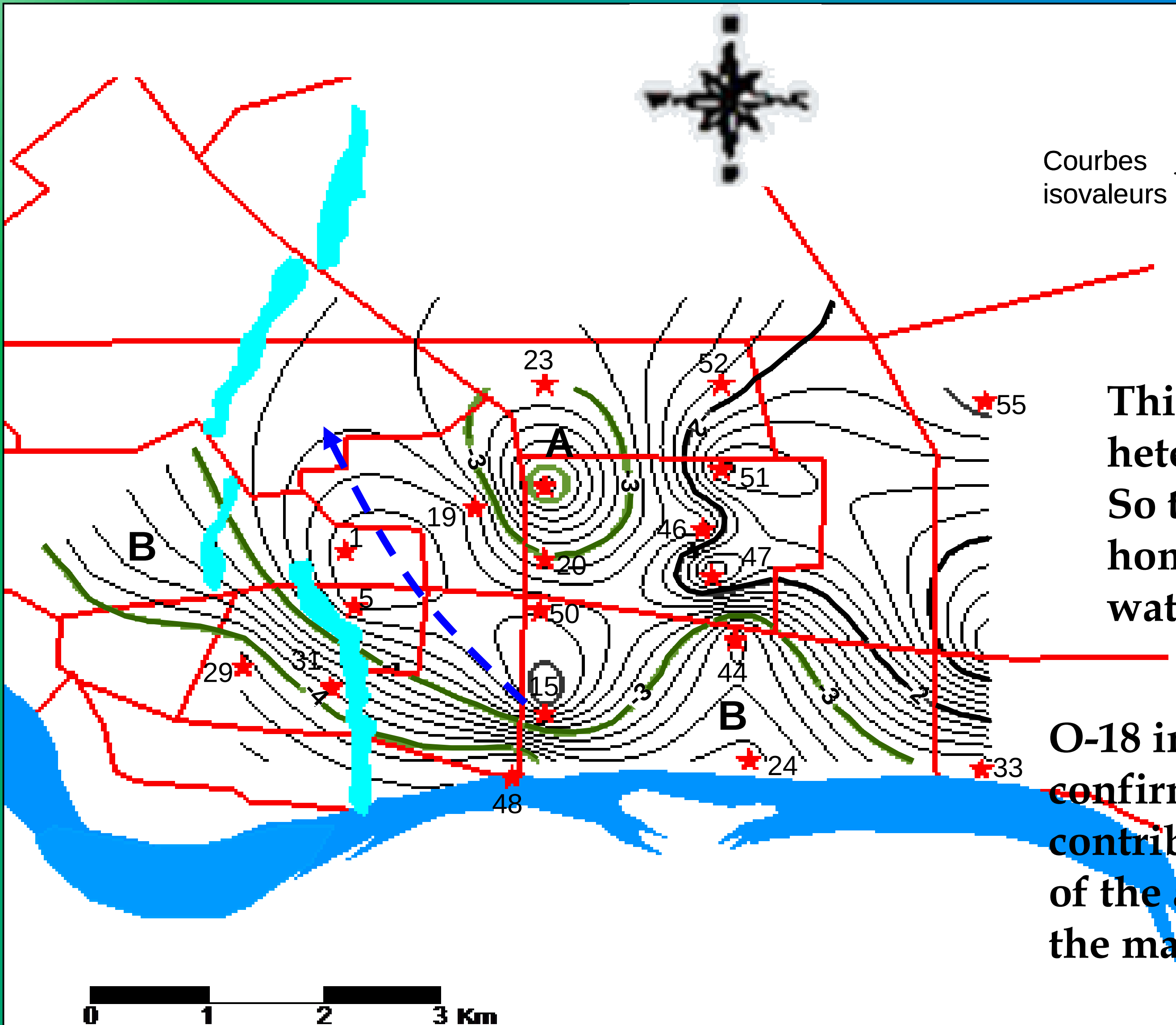
There is a deepening of the table depending on the distance

The blue arrow indicates the direction of the groundwater flow which is going from the Chari River towards inland.



III - Recharge location based on map of deph and isotope tracing

oxygen - 18 in shallow groundwater



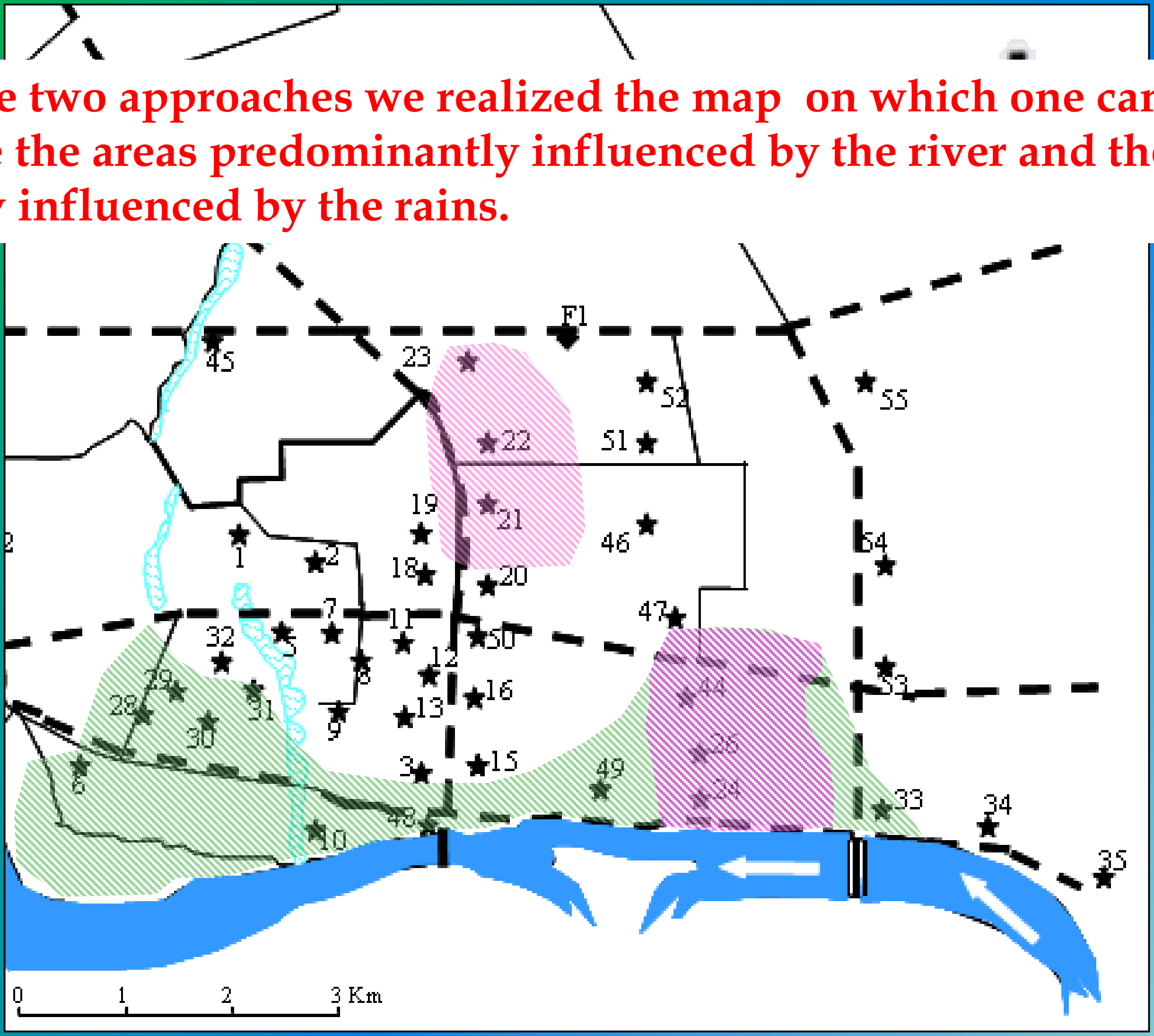
This map show great heterogeneity. So there is no rapid homogenization of the water

O-18 in groundwater confirms the river water contribution to the feeding of the aquifer and shows the main contribution areas

III -Recharge location based on map of deph and isotope tracing

Potential recharge zones

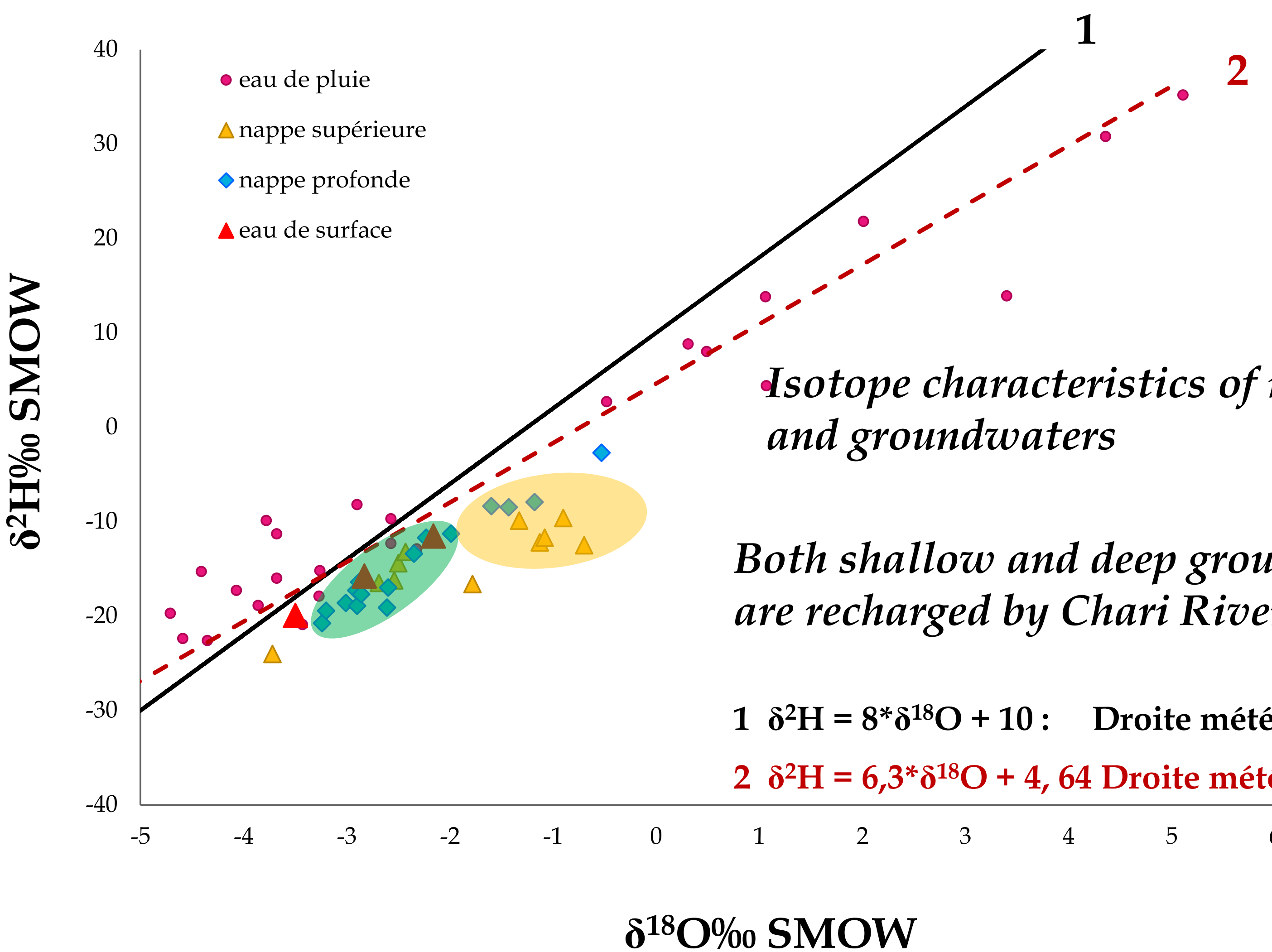
Coupling the two approaches we realized the map on which one can differentiate the areas predominantly influenced by the river and those that are significantly influenced by the rains.



Influence of the River

Influence of the rain water direct infiltration

III -Recharge location based on map of deph and isotope tracing



Isotope characteristics of river waters and groundwaters

Both shallow and deep groundwaters are recharged by Chari River waters

1 $\delta^2H = 8*\delta^{18}O + 10$: Droite météorique mondiale

2 $\delta^2H = 6,3*\delta^{18}O + 4, 64$ Droite météorique locale

IV - Quality of groundwater

		T°C	pH	c25°C	HCO_3^- (mg/l	Cl^- (mg/l)	NO_3^- (mg/l)	SO_4^{--} (mg/l)	Ca^{++} (mg/l)	Mg^{++} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	8O (± 0,15 / SMOW	H (± 1‰ / SMOW
shallow aquife	min	29,00	6,13	205,00	55,20	1,05	0,00	0,12	11,82	0,47	5,41	2,23	-4,40	-24,02
	Max	31,80	7,59	**2450,00**	808,80	**253,00**	**284,70**	99,45	143,24	33,62	517,40	46,34	-0,17	-9,60
	moy	30,61	6,93	497,22	200,63	21,42	28,07	9,84	41,84	9,02	34,01	8,12	-2,46	-14,33
	ecart-type	0,54	0,31	349,96	101,48	39,17	48,73	16,77	22,92	6,42	63,29	6,20	0,95	3,89
	n	67	67	67	67	67	67	67	67	67	67	67	67	67
deep aquifer	min	29,00	6,88	71,00	40,00	0,60	0,46	1,40	22,07	4,53	9,32	3,55	-3,24	-20,76
	Max	31,40	7,30	**596,00**	325,00	10,46	13,20	34,99	55,15	13,55	24,90	6,78	-0,53	-2,70
	moy	30,35	7,05	268,71	148,09	5,12	4,58	12,06	33,92	7,17	18,58	5,42	-2,35	-14,31
	ecart-type	0,82	0,18	133,55	70,66	4,20	5,88	13,21	14,51	3,75	6,05	1,35	0,79	5,32
	n	21	21	21	21	21	21	21	21	21	21	21	21	21
Water surface	min	29,10	7,33	39,00	23,00	0,57	0,00	0,51	1,92	0,96	2,04	2,49	-3,50	-19,93
	Max	32,80	7,96	**1535,00**	544,00	177,35	62,80	2,08	67,82	20,10	170,36	88,88	-2,16	-11,52
	moy	31,03	7,60	416,25	154,75	44,89	31,40	1,08	18,78	5,81	44,78	24,25	-2,83	-15,73
	ecart-type	1,72	0,28	745,84	259,50	88,31	44,10	0,74	32,70	9,53	83,72	43,09	0,67	4,21
	n	4	4	4	4	4	4	4	4	4	4	4	4	4

Strong nitrate content in shallow groundwater

		B (µg/L)	Al (µg/L)	Cr (µg/L)	Mn (µg/L	Co (µg/L)	Ni (µg/L	Cu (µg/L	Zn (µg/L)	As (µg/L)	Rb (µg/L)	Sr (µg/L)	Ba (µg/L)	Pb (µg/L)
Shallow aquifer	min	4,89	1,49	0,10	1,62	0,04	0,81	0,20	0,81	0,10	1,84	128,36	153,03	0,02
	max	69,95	480,61	3,25	593,55	3,65	24,48	5,80	**1335,10**	1,65	12,02	703,00	1134,70	2,56
	moy	14,98	45,85	1,25	163,70	0,77	4,88	1,78	124,29	0,67	4,92	418,08	453,52	0,37
	ecart-type	16,89	130,76	0,91	153,12	0,96	6,74	1,38	364,90	0,57	3,36	186,29	350,45	0,67
	n	13	13	12	13	13	13	13	13	13	13	13	13	13
deep aquifer	min	4,86	0,50	0,01	5,28	0,02	0,23	0,06	5,01	0,08	1,95	52,84	42,71	0,01
	max	13,24	1,32	0,68	435,40	1,26	1,11	0,43	**2586,00**	5,21	6,70	929,40	300,30	0,25
	moy	8,52	0,78	0,21	127,38	0,26	0,44	0,18	444,86	1,27	4,17	306,65	154,15	0,09
	ecart-type	2,69	0,35	0,29	131,15	0,30	0,21	0,12	674,36	1,39	1,54	223,48	80,53	0,08
	n	16	16	16	16	16	16	16	16	16	16	16	16	16
surface water	min	3,80	15,40	0,14	0,28	0,03	0,64	1,40	0,81	0,04	2,87	23,04	26,95	0,02
	max	89,40	301,90	2,45	367,65	1,29	3,70	1,69	9,52	2,21	51,57	401,73	68,37	0,32
	moy	25,81	105,13	0,79	94,23	0,37	1,48	1,51	3,85	0,61	16,10	124,59	38,46	0,12
	ecart-type	42,40	133,20	1,11	182,30	0,61	1,49	0,13	3,87	1,07	23,68	184,91	20,00	0,14
	n	4	4	4	4	4	4	4	4	4	4	4	4	4

Heavy metals ; Mn; Ni; Zn; Hg can be high in some wells and boreholes

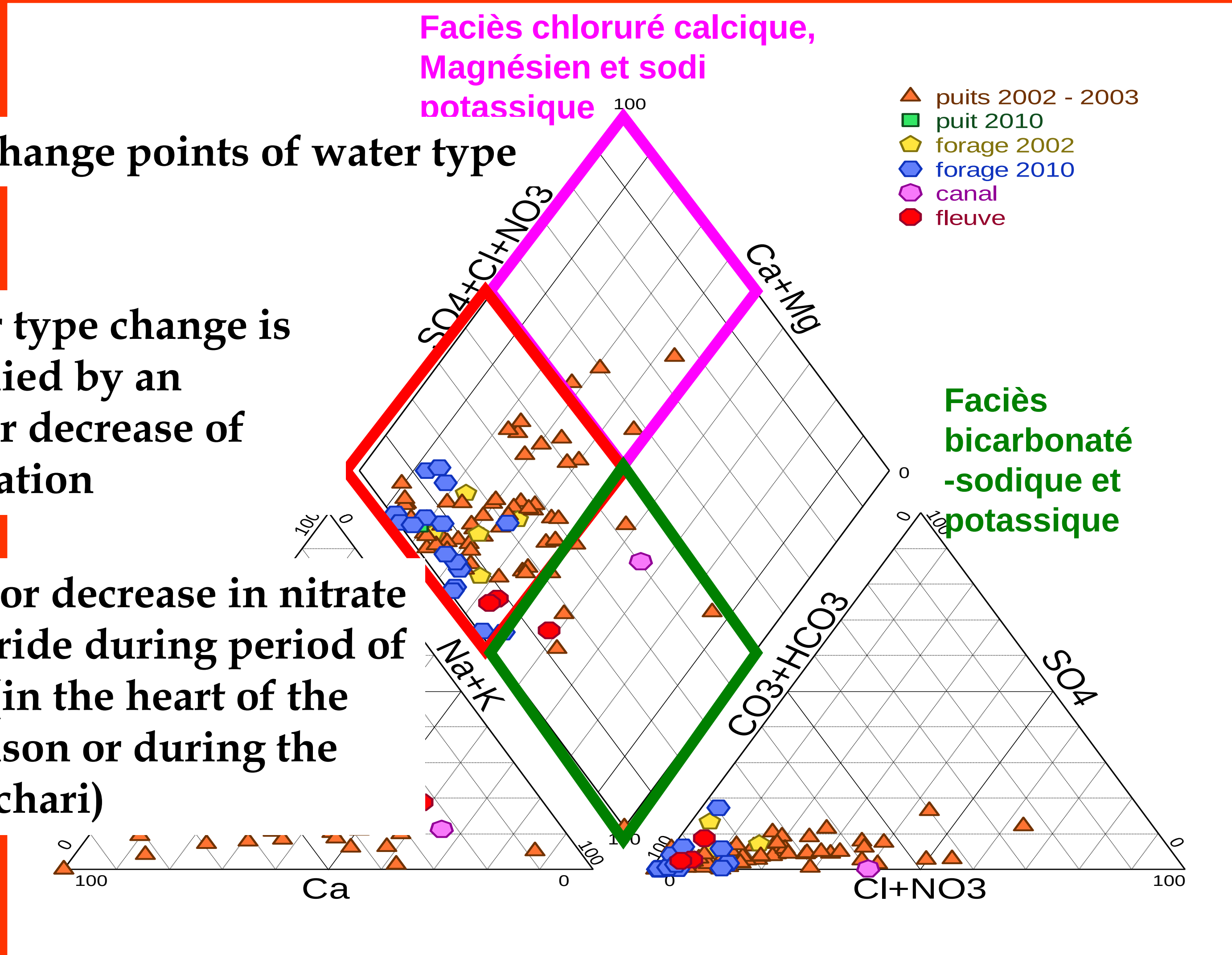
IV - Quality of groundwater

Water types

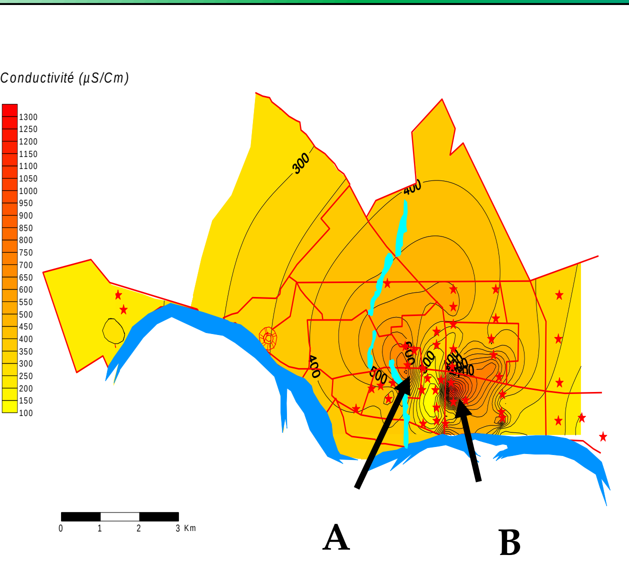
some exchange points of water type

The water type change is accompanied by an increase or decrease of mineralization

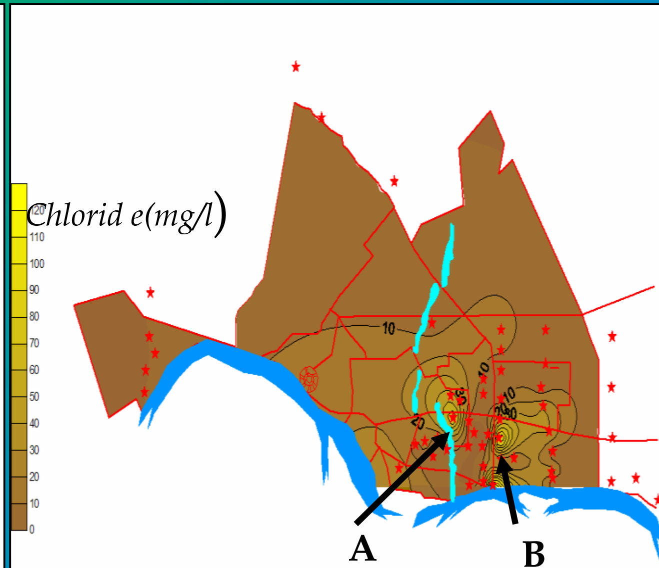
Increase or decrease in nitrate and chloride during period of rechage (in the heart of the rainy season or during the flood of chari)



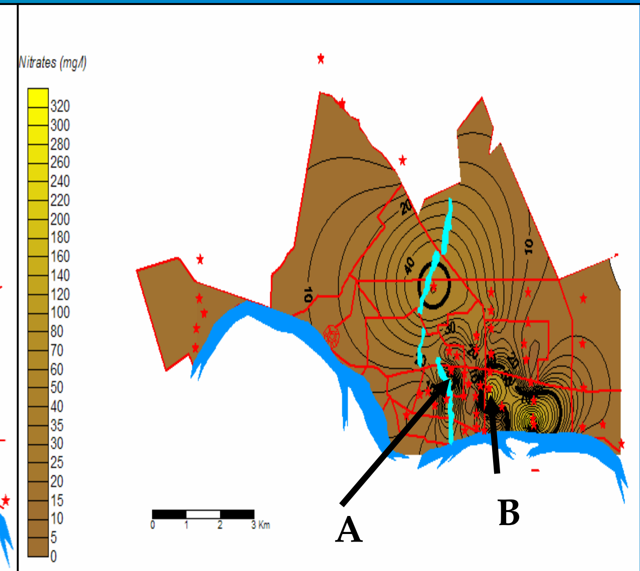
IV - Quality of groundwater



Spatial evolution of electric conductivity



Spatial evolution of chloride concentrations



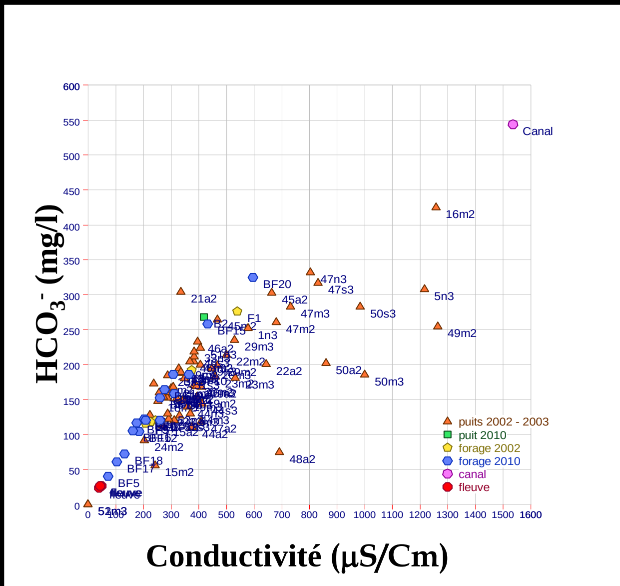
Spatial evolution of nitrate concentrations

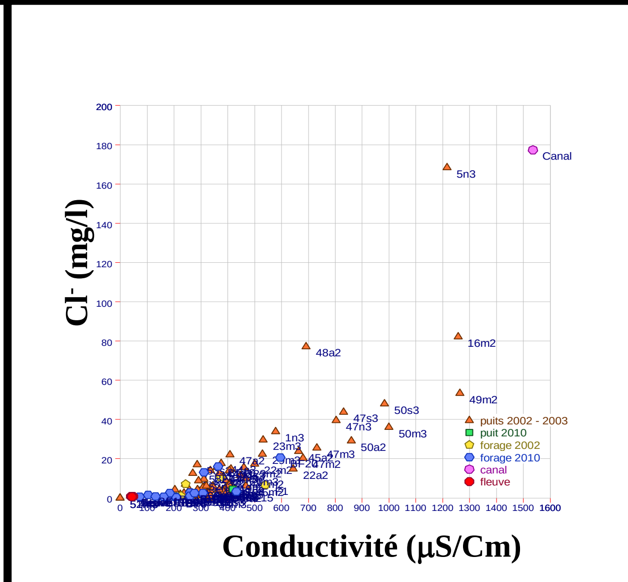
areas with high concentrations of chloride and nitrate associated with conductivities (area A and B)

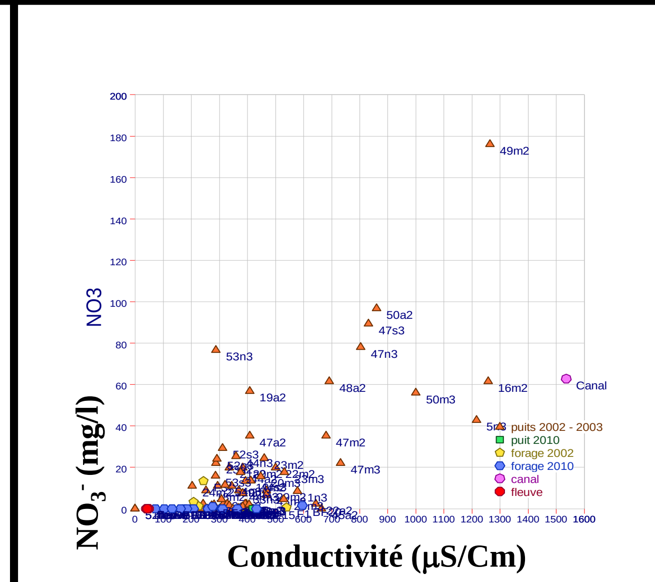
there is a spatial heterogeneity of conductivity, chloride concentrations and nitrate concentrations this may be related to the heterogeneity of the recharge

IV - Quality of groundwater

Evolution of bicarbonates; chloride and nitrate







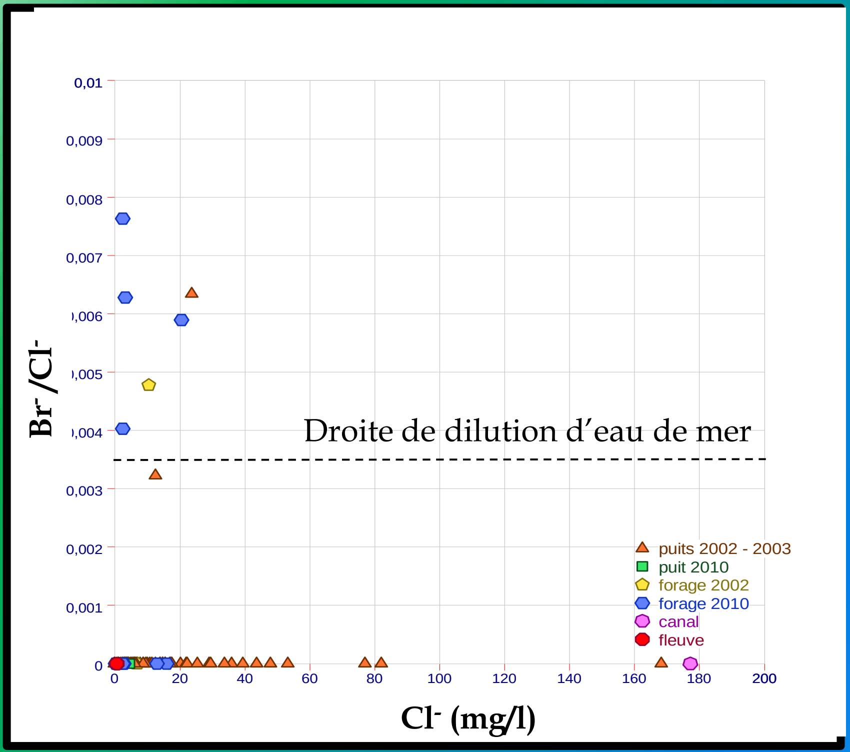
bicarbonates increase linearly with the conductivity.

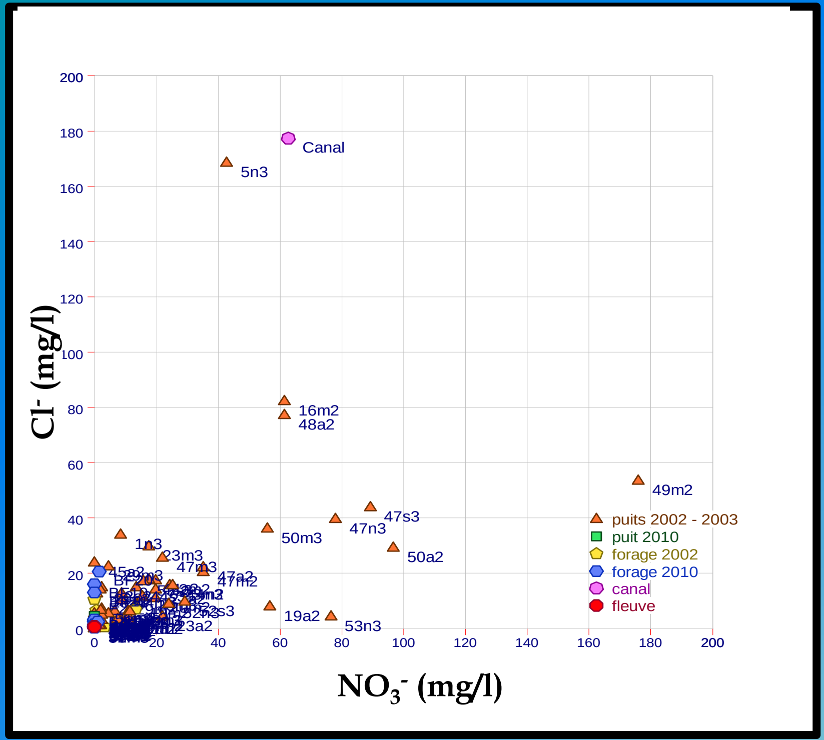
However, some relatively mineralized points, belonging mainly to the upper layer does not follow this logic as if the conductivity was controlled by other parameters.

They are influenced by nitrate or chloride.

IV - Quality of groundwater

O-18 vs nitrate and chloride concentrations

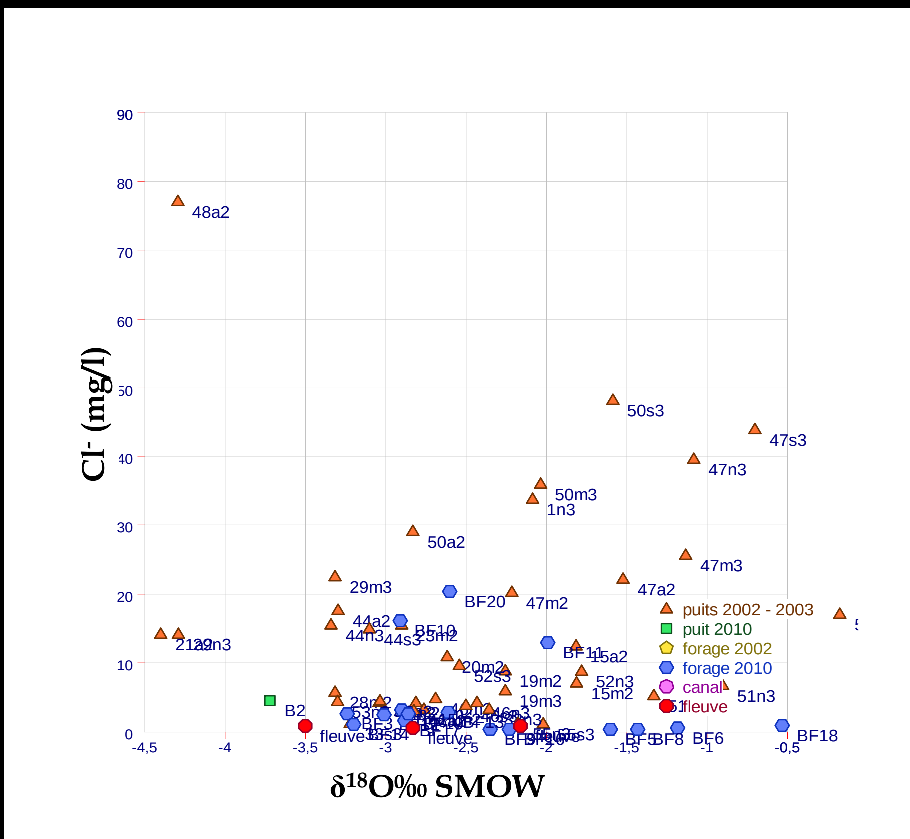


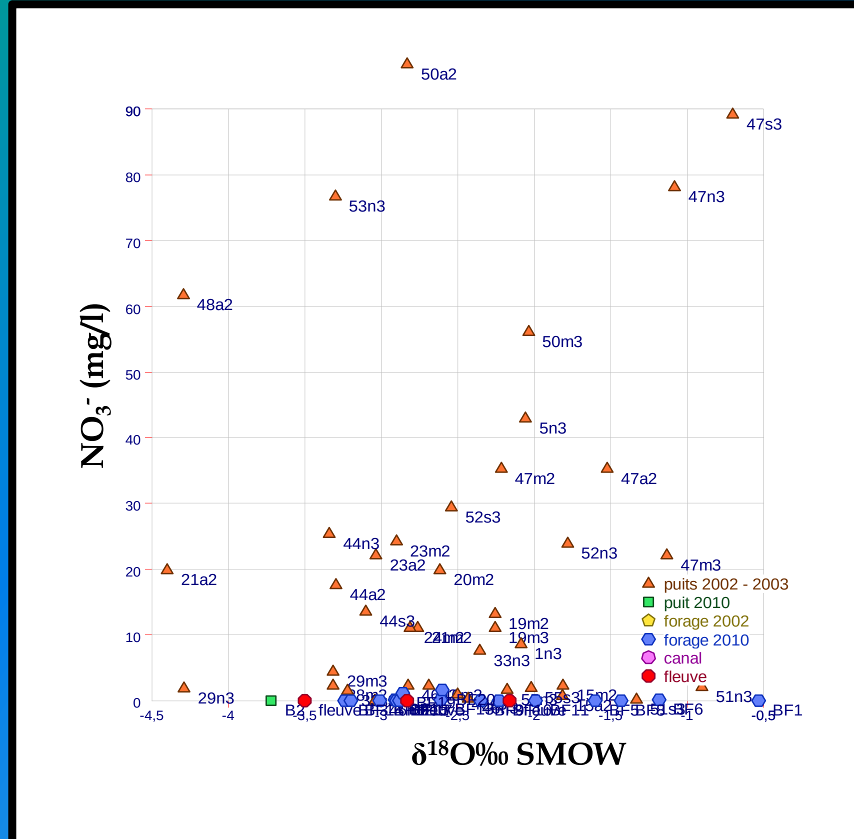


Origin of chloride :

Water is relatively depleted in bromide, suggesting : Chloride are mostly comming from latrines and sewage .

IV - Quality of groundwater





Groundwater from wells shows strong dispersion of isotopic characteristics and nitrate and chloride concentrations.

There are a also heterogeneity of recharge

there are waters which show an increase of the two components showing that in addition to evaporation those waters are under anthropogenic stresses.

Conclusion

Groundwater are under a permanent and almost generalized Chari river

Increases in mineralization are linked to anthropogenic processes, but might also be linked to evaporation

The results also reveal that the deeper part of the Quaternary aquifer is still relatively well preserved despite anthropogenic pollution on the surface.

Nevertheless, this aquifer layer remains vulnerable in case of over exploitation that might drain polluted surface water to deeper levels.

Thank you for your attention