Ministère de l'Environnement,
de l'Eau et des Ressources
Halieutiques

REPUBLIC OF CHAD

FEASIBILITY STUDY FOR MANUAL DRILLING

MAPPING OF FAVOURABLE ZONES

PRACTICA FOUNDATION

EnterpriseWorks/VITA
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Introduction

In the framework of its programme focused in supporting the application of low cost techniques of manual drilling in Africa, UNICEF promoted a study having as main purpose the analysys of the existing information at national level for in order to have an initial knowledge of areas where environmental and hydrogeological situation could make hand drilling techniques a potentially suitable low cost and sustainable solution to increase the availability of water for the population.

The study has been carried out through the analysis wit support of GIS systems of a set of data collected from public source of data (mainly web) and the collection of data available in different institutions at national level.

The present study aims to give a general idea and it is extend to the whole country; the results of this study must be used to target specific ares where more detailed analysis are required in order to have a detailed idea of the best strategy and location to support manual drilling.

It takes into consideration the methods and results achieved in a previous study carried out during 2006 (GIS ANALISYS OF EXISTING HYDROGEOLOGICAL INFORMATION AND MAP PRODUCTION AS A SUPPORT FOR THE IDENTIFICATION OF SUITABLE AREA FOR MANUAL DRILLING TECHNIQUES IN UNICEF WATER PROGRAMME IN TCHAD) that focused its attention to 5 regions (Mayo Kebbi, Tandjile, Kanem, Ouaddai, Guera, Batha, Hadjer-Lamis), extending the analysis to the whole country and modifying some of the assumptions on the basis of the direct experience of manual drilling impelement by UNICEF after 2006 in Chad

General context

Geography

Chad, a landlocked country in Northern Central Africa, is bound by Libya on the north; by Sudan on the east; by the Central African Republic on the south; and by Cameroon, Nigeria, and Niger on the west. The extension is 1.284.000 square kilometres.
Chad is dominated by the low-lying Chad Basin, which rises gradually to mountains and plateaus on the north, east, and south. In the east are the plateaus - Ennedi and Ouaddaï, which rise to more than 1000 meters. The greatest elevations are reached in the Tibesti massif in the north, which touches 11,204 ft in height at Emi Koussi. The northern half of the republic lies in the Sahara. The important rivers are the Logone and Chari (Shari) which lie in the southwest and flow into Lake Chad. The lake doubles in size during the rain season.

Climate and environment

Chad has three distinct climatic and vegetation zones:

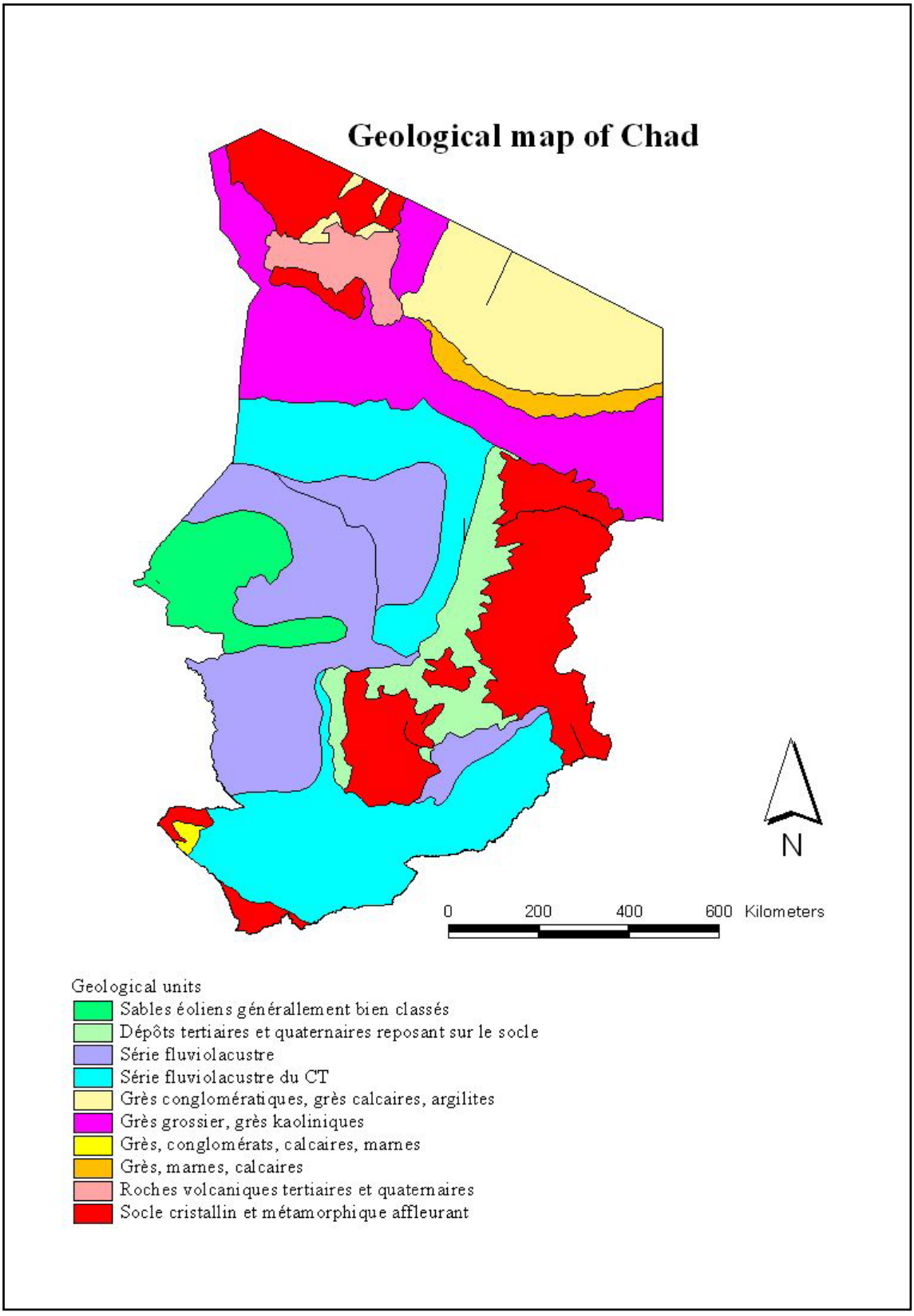
- the northern parts consist of Sahara desert environments
- the central part is bush-covered steppe
- the southern part is wooded savannah

Chad consists of a large peneplain deeply cut by rivers that drain into Lake Chad.

While the northern portion of Chad is hot and arid, the central section has three seasons - hot summers from March to July; from July to October rain, measuring 250 to 750 mm are experienced while the remaining months experience cool weather. The southern section has similar seasons but receives about 1,145 mm of rain in the same four months.

Geology

The geology of Chad is characterized by Precambrian and younger sediments surrounding the central Chad Basin. Precambrian rocks occur in the Tibesti Mountains in the north and consist of undifferentiated granites and gneisses in the eastern part of the country. Lower Paleozoic sandstone sequences in the Kufra Basin in the northeast (at the border with Libya and Sudan) are overlain by Nubian sandstones. The Lower Cretaceous is characterized by continental clastic sequences and the Upper Cretaceous includes up to 400 m thick marine sediments. Tertiary continental sediments cover parts of southern Chad. Lacustrine sediment sequences (the Chad Formation) comprise large parts of the Chad basin.



Geological units of Chad (based on the national hydrogeological map)

Methodology for the identification of suitable area for manual drilling

Source of Information

Main sources of information for this study are:

- Database of water points stored in the Direction de Nationale de l'Hydraulique. This database stores more than 10000 water points distributed in all Chad, with different information.
- the digital map of hydrogeological units, obtained also from Direction Nationale de l'Hydraulique

Choice of criteria to define level of suitability for manual drilling:

The preliminary selection of suitable area was done considering 2 main criteria:

- Suitability according to depth of exploitable water ; it is an estimation of the probability that in a specific zone depth of exploitable water can be reached by manual drilling
- Geological suitability ; it is an estimation of the probability that in a specific zone the shallow rock or sediments layers have favorable characteristics of hardness and permeability for manual drilling (it must be possible to drill with manual techniques ; permeability must be sufficient to give good yield even if the hole has small diameter and no deeper than 30 m)

Suitability according to deptstatic water level

Concerning **depth of exploitable water**, different class of suitability were defined:

Class-ID	Static Water Level	Suitability
swl1	from 0 to 10 m	Highly suitable
swl2	from 10 to 25 m	Moderately suitable
swl3	deeper than 25 m	Unsuitable

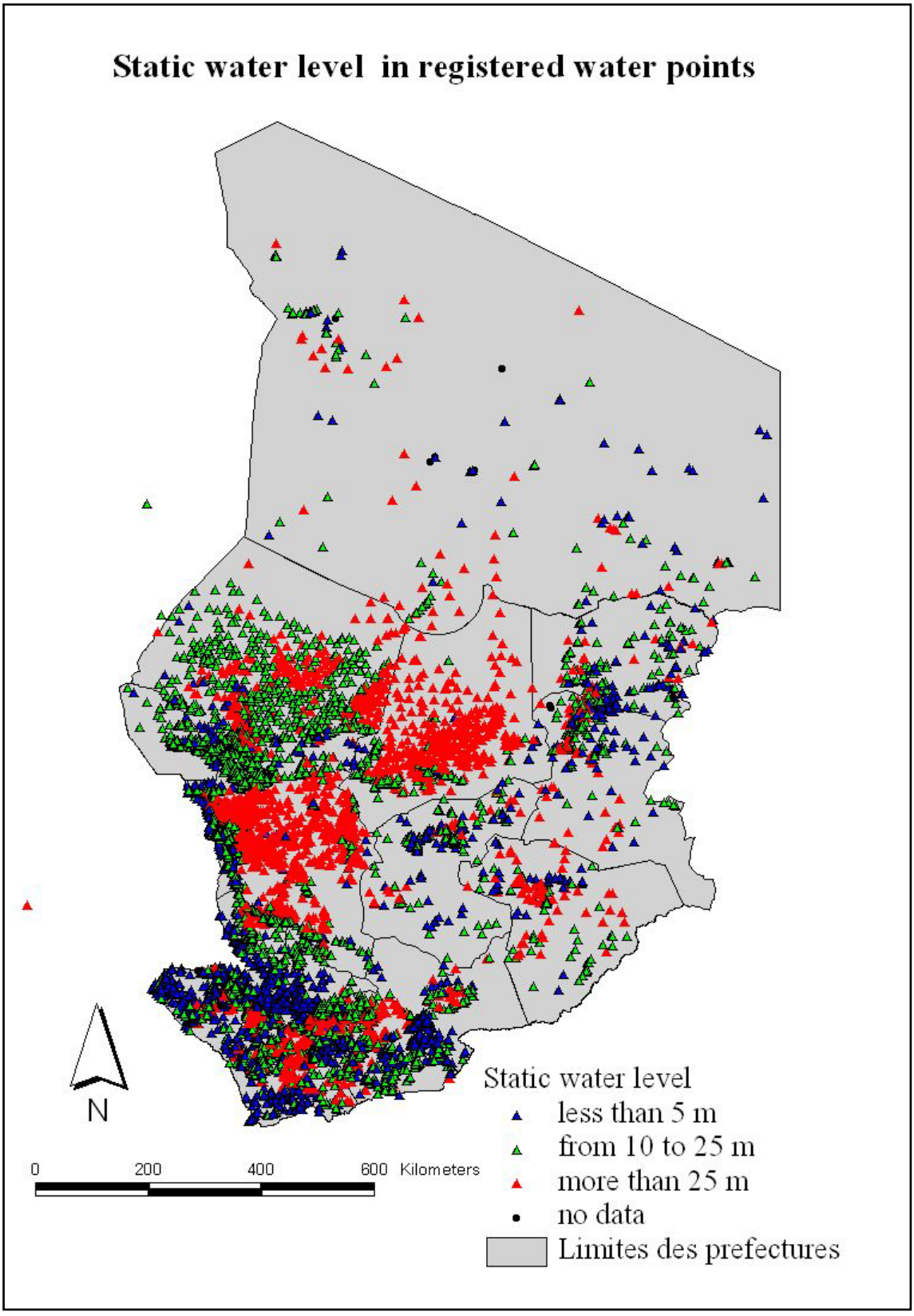
Considering that manual drilling in Chad is used up to 30/40 m deep, we consider unsuitable those areas where most of the existing wells have a static water level deeper than 25 m. Between 10 and 25 m they are considered moderately suitable area (as it is likely that manual drilled wells must be more than 20 m deep, therefore they need good lithological condition in order to be completed and require effort). For static water level shallower than 10 m, conditions are considered optimal (although it is important to protect water from possible contamination from the surface).

To determine the most likely depth of water level in each zone a methodology based on direct visual interpretation of the map of static water level in registered water points by the consultant without using any automatic interpolation procedure; this technique was preferred considering that:

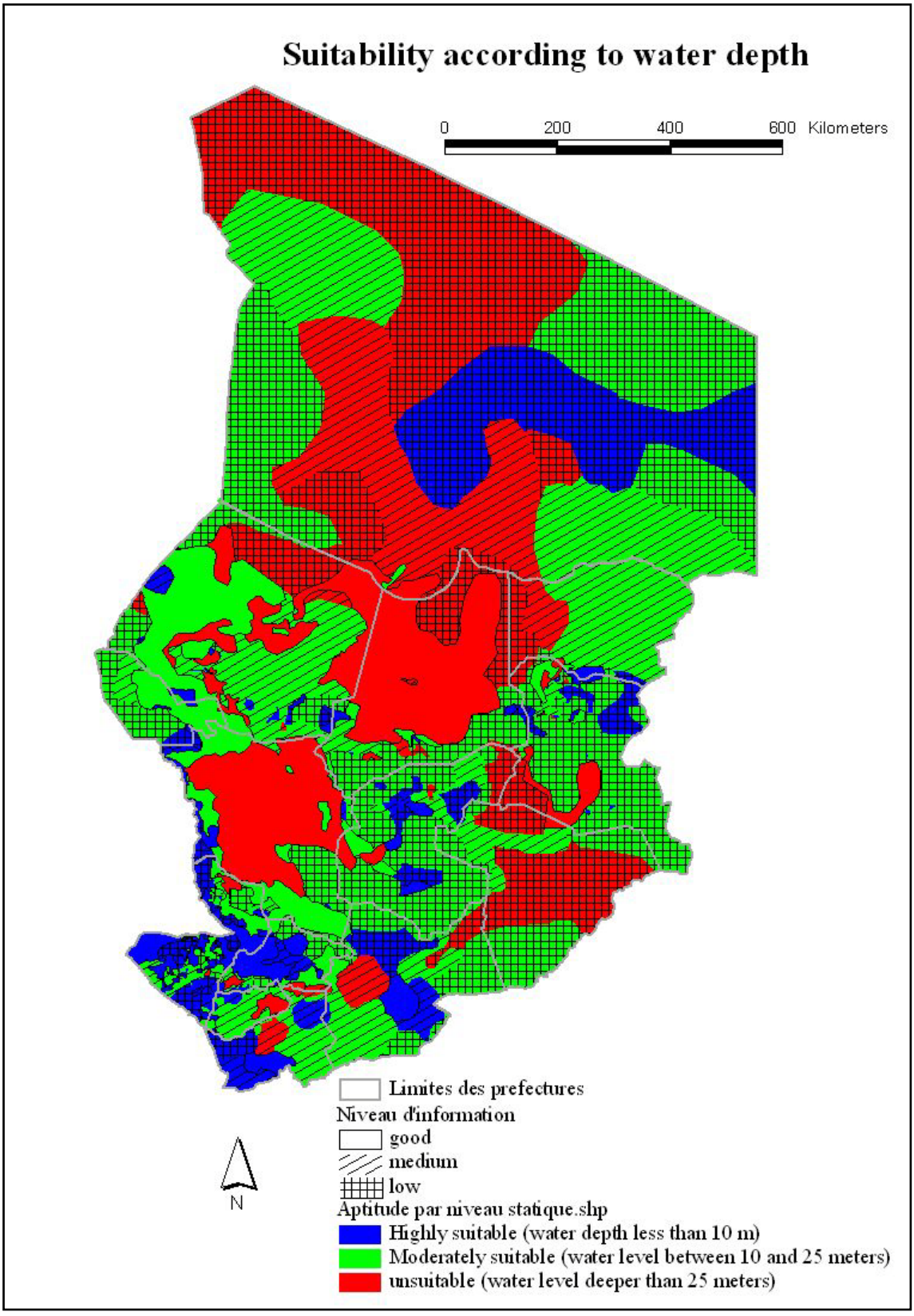
- Density of water points is extremely different from one zone to the other; in some regions there is a huge distance between registered water points and this could lead interpolation algorithms are to give unreliable results. Automatic interpolation procedure is reliable when real data are homogeneously distributed in the whole area and they are not too scarce compared with the dimension of the interpolation grid. Where registered water points are very far – sometimes more than 100 km – interpolation procedures are not reliable
- No precise information regarding the elevation of the water points on sea level was available; therefore it was not possible to calculate the absolute static water level in the water points (elevation of water table referred to sea level). While interpolation between absolute static water level in the same aquifer could give reliable information (as change in water table is expected to be a continuous variable), this could be not true for water depth, as this values is affected by local difference in ground elevation.
- It was difficult to verify if water points in the same area are exploiting the same aquifer or they take water from different rock layers that are nor in hydraulic contact. In this case there can be differences in water level that are not related to change in phreatic water depth.

Direct interpretation was carried out by defining zones having similar depth of static water level in registered water points (considering the 3 classes, less than 10 meters, from 10 to 25 meters, more than 25 meters). For each zone it was indicated not only the predominant class of depth of water level, but also the so called “level of information” (it means that those areas where only few water points are present, or water levels has fluctuations from one well to the other within a short distance, these areas are classified with low level of information; at the contrary where we have good density of water points and water depth is almost constant, in this case level of information will be good)

We must be aware that in case of confined aquifers, static water level cannot correspond to depth of exploitable water; no information about registered depth of water inflow in boreholes is registered, therefore zonification and estimate of suitability was based on static water level. In any case, since hand dug wells are present in most of the regions, we can assume that in their case water intake and static water level are quite similar, since it would be difficult to dig deeper than the water intake if water level is rising; generally hand dug well are more likely to exploit shallow and unconfined aquifers, although this can’t be always sure.



Map of static water level in registered water points



Map of suitability according to exploitable water depth

Geological suitability

Zonification of study area was done through automatic reclassification of the hydrogeological map of Tchad (available in digital format). Each category of the original map was reclassified according to the criteria exposed above (expected hardness and permeability of shallow layers); in this way a specified degree of suitability was assigned to each area.

The following classes of geological suitability were defined

Class-ID	Degree of suitability
hgA-s	Highly suitable, with sandy soil (jetting or percussion recommended)
hgA-c	Highly suitable, with sandy clay soil (sludge recommended)
hgB	Moderately suitable
hgC	Unsuitable

Each hydrogeological unit defined in the hydrogeological map of Tchad was assigned to a specific class of suitability, according to the following classification:

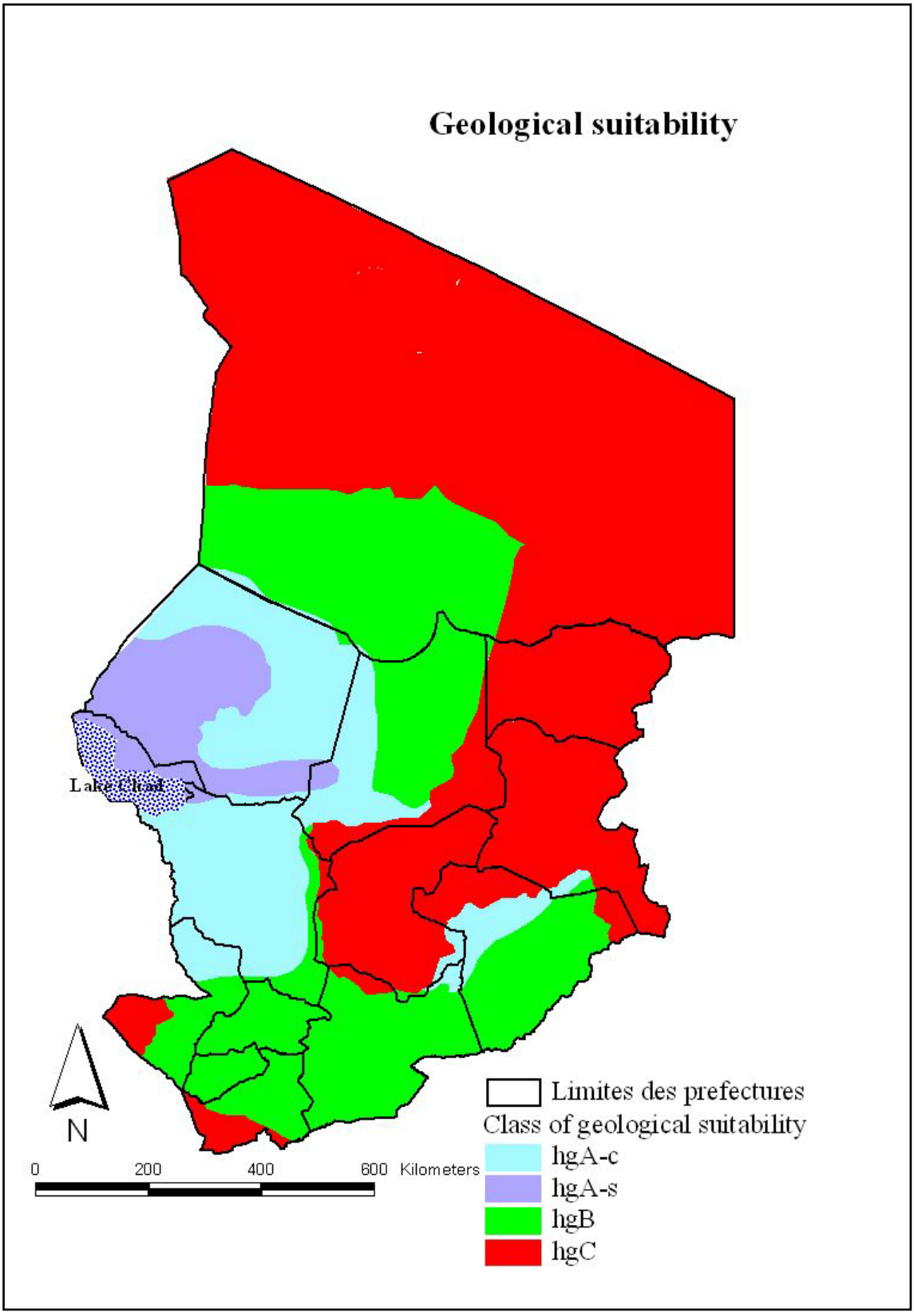
Hydrogeological Units	Class of suitability	Degree of suitability
Sables Eoliens - Quaternaire	hgA-s	Highly suitable, with sandy soil (jetting or percussion recommended)
Fluviolacustre - Quaternaire	hgA-c	Highly suitable, with sandy clay soil (sludge recommended)
Fluviolacustre - Pliocene	hgB	Moderately suitable
Fluviolacustre - CT (Oligocene)	hgB	Moderately suitable
Gres conglomeratiques, Gres calcaires, argilites	hgC	Unsuitable
Gres, conglomerats, calcaires, marnes	hgC	Unsuitable
Gres, marnes, calcaires	hgC	Unsuitable
Gres grossier, Gres kaoliniques	hgC	Unsuitable
Depots tertiaires et quaternaires reposant sur le socle	hgC	Unsuitable
Roches volcaniques tertiaires et quaternaires	hgC	Unsuitable
Socle cristallin et metamorphique affleurant	hgC	Unsuitable

In this classification we made the following assumptions:

- All lithology formed by hard rock (gres, volcanic roks, basement) or by discontinuos tertiary and quaternary laying on the basement are considered unsuitable for manual drilling

- Quaternary sand sediments are highly suitable for manual drilling, but specific techniques must be applied to avoid collapsing of the hole (recommendation done by Practica after their first missions)

- Fluviolacustre sediments are mainly composed of sand and clay; they are considered highly suitable if they are recent (quaternaire) while they are considered moderately suitable if they are older (as they could be more compact and more difficult to drill). In Fluviolacustrine sediments sludge method is recommended (Practica recommendation)



Map of geological suitability

Cross-analysis of static water level and geological suitability. Final suitability for manual drilling.

This map was produced through an automatic process of intersecting polygon features of the two maps of suitability (suitability for depth of water and geological suitability). To each specific combination of parameters in the resulting polygons it was assigned a specific class of general suitability.
Five classes of general suitability were defined:

Class-ID	Degree of suitability	Description	Class name in final map
A	Highly suitable	Both suitability for water level and geological suitability are highly suitable	Très favorable
B	Suitable	One of the two parameter is highly suitable, while the other has intermediate suitability	Favorable
C	Moderately suitable	Both parameters are moderately suitable	Partiellement favorable
D	Unsuitable, except in small zones with unconsolidated sediment	The geological formation is classified as unsuitable, while water depth is highly or moderate suitable. In this situation it is possible to have limited deposits of unconsolidated sediment (mainly around temporary water stream) that can be exploited if they have sufficient thickness to reach the water table	Peu favorable, seulement dans les zones limitées avec sédiments pas consolidés
E	Unsuitable	Water depth is to high, therefore it can't be reached with manual drilling	Pas favorable

The final class of suitability was assigned to each combination of suitability for depth of water table and geological suitability as follows:

	Class of suitability for depth of water level		
	from 0 to 10	from 10 to 25	more than 25
	swl1	swl2	swl3
Class of geological suitability			
HgAs	A	B	E
hgAc	A	B	E
hgB	B	C	E
hgC	D	D	E
	FINAL SUITABILITY		

During the process of zonification in different class of suitability for manual drilling, it was also evaluated the level of information that could be obtained from the analysis of water wells database obtained from Direction de l'Hydraulique. Level of information was classified as follows:

Good: attribution to a specific class of suitability can be considered quite reliable, as there are sufficient and mostly homogeneous data of existing wells that give us information regarding static water level in the area. However, it is recommended to analyze more in details the existing data in surrounding villages before starting manual drilling in a selected location.

Medium: existing wells are not providing sufficient information that can indicate in a reliable way an homogenous and defined depth of groundwater. Further information must be collected, if available, to confirm the estimation of static water level. Geophysics could be used to fill the gap of information obtained from data of wells.

Low: level of information contained in the existing database at Direction Nationale de l'hydraulique is limited, and the estimate of the predominant static water level cannot considered sufficiently motivated to affirm that the area is suitable for manual drilling. Field survey, hydrogeological observation, local knowledge and eventually geophysics must be considered in order to have a more clear idea of the condition of groundwater.

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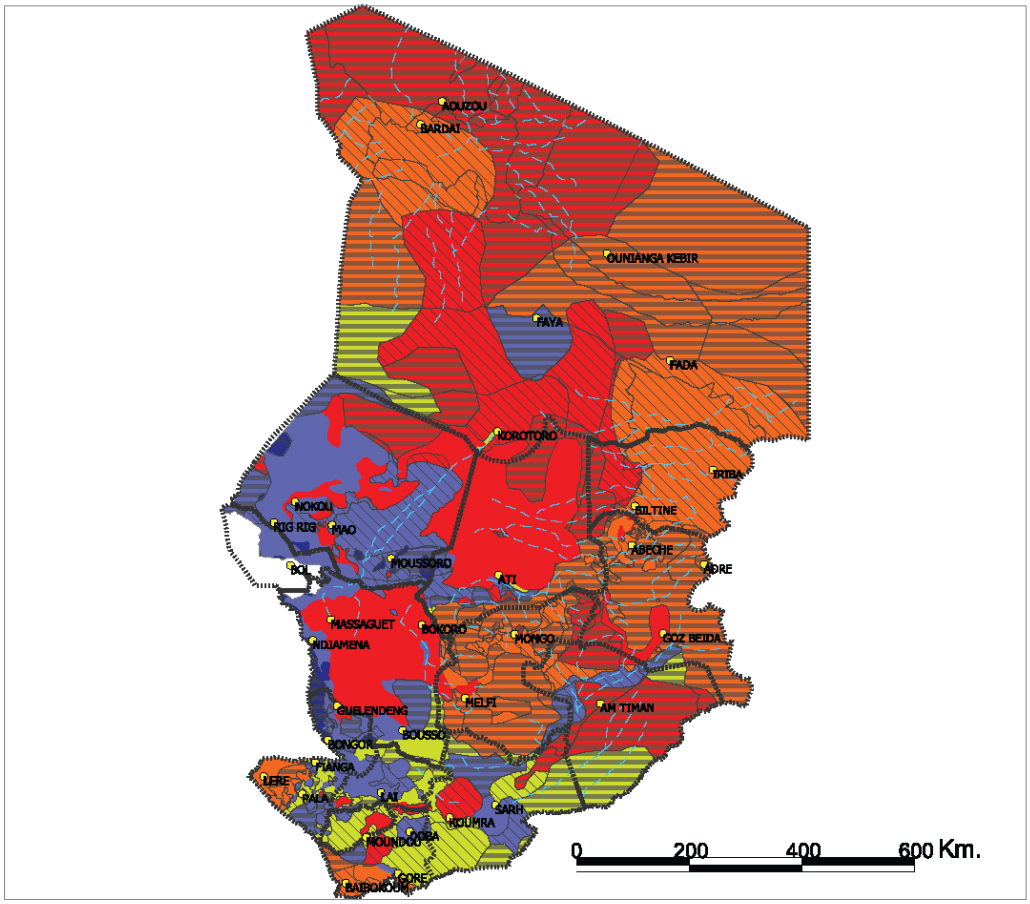
ETUDE DE FAISABILITE DES TECHNIQUES DE FORAGES MANUELLE

APTITUDE AUX FORAGES MANUELS - REPUBLIQUE DU TCHAD



Légende

villes principales

Limites des préfectures

Oaudi

Niveau d'information sur la profondeur de l'eau

bon

moyen

faible

Classification d'aptitude aux forages manuels

Très favorable

Favorable

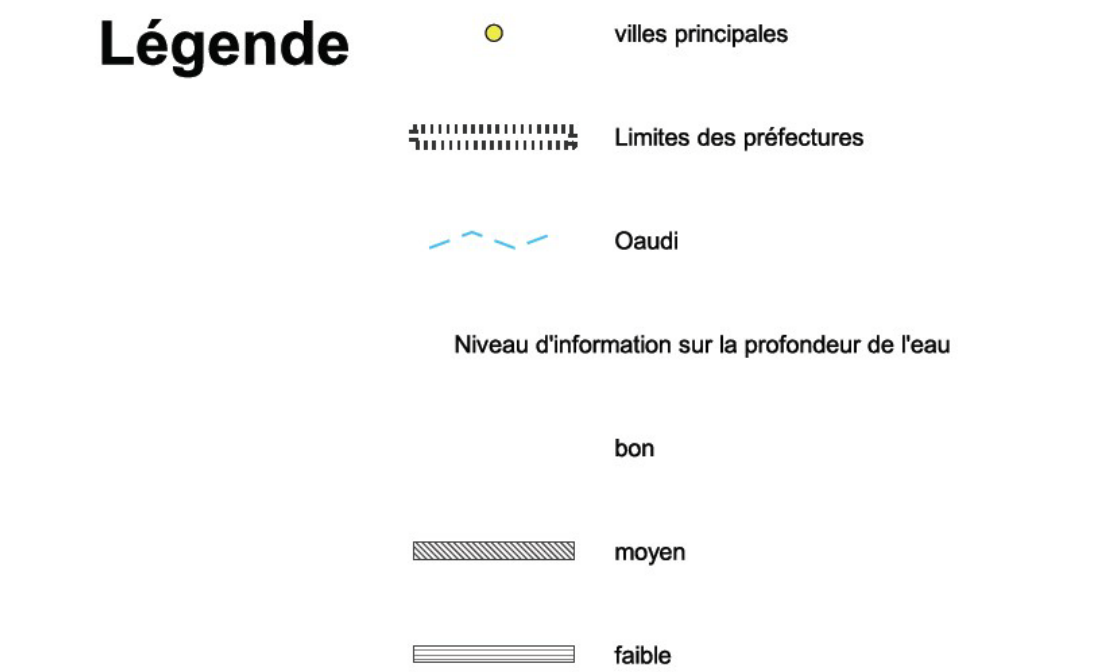
Partiellement favorable

Peu favorable, seulement dans les zones limitées avec sédiments pas consolidés

Pas favorable

N
W E
S

Map of final suitability to manual drilling



Legend of the final map of suitability to manual drilling

Comment to final results and recommendations

From the geological point of view, Chad is generally highly or moderately suitable in the western and southern part, where the territory is covered by the sediments of the huge aquifer of continental terminal and more recent unconsolidated sediments layer. On the other hand, northern and eastern parts of Chad have generally hard rock formations covered by thin and discontinuous sediments in specific geomorphological position

Concerning the depth of groundwater, it appears that favorable or moderately favorable conditions are present in a large portion of the country in the western, southern and eastern part, while the central region and part of the northern are not favorable, particularly in the mountainous zones; it must be underlined that with the exception of the western and southwestern part, density of water points in all the rest of the country is so low that estimation of water depth on the basis of registered water points can't be considered fully reliable and all the estimates have to be cross checked with experience of local technicians and population, as well as direct field observations.

Considering these two distribution of geological and hydraulic conditions, the result shows that western and southwestern part are favorable to manual drilling; in these zones we have the highest concentration of population in the prefectures of Chari Baguirmi, Mayo Kebbi, Lac and Kanem, and in consideration of the low acces to drinkable water we can consider manual drilling as a good and suitable solution to improve water access, particularly in rural remote areas.

In the eastern side of the country it could be possible to promote hand drilling in those areas where small layer of sediment are concentrated around temporary water stream (and positive experience of UNICEF and PRACTICA have been done in the last years); these favorable zones are quite limited, since in general geological conditions are dominated by outcrops of hard rocks; to pinpoint them it is necessary to make an analysis at a more detailed scale compared with the present study, make use of indirect indicators (like presence of vegetation, distribution of villages, detailed drainage mapping in rainy season, etc) and make direct observation of existing wells, in terms of their characteristics and availability of water in dry season.

	Très favorable	Favorable	Partiellement favorable	Peu favorable	Pas favorable
Prefecture					
BILTINE	0.0%	0.0%	0.0%	76.7%	23.3%
OUADDAI	0.0%	2.3%	1.2%	78.9%	17.5%
BATHA	0.7%	8.9%	0.4%	16.2%	73.8%
CHARI BAGUIRMI	4.3%	24.4%	8.9%	1.8%	60.7%
MAYO KEBBI	8.7%	48.8%	16.1%	23.9%	2.5%
TANDJILE	0.0%	49.0%	44.0%	0.0%	7.0%
LOGONE ORIENTAL	0.0%	18.1%	36.0%	32.6%	13.3%
LOGONE OCCIDENTAL	0.0%	13.2%	69.4%	0.3%	17.0%
MOYEN CHARI	0.0%	26.9%	52.7%	4.5%	15.8%
GUERA	0.0%	3.7%	2.3%	84.8%	9.3%
SALAMAT	0.0%	9.0%	22.8%	14.9%	53.3%
LAC	3.8%	95.7%	0.0%	0.0%	0.6%
KANEM	3.5%	63.3%	0.0%	0.0%	33.2%
BET	0.0%	2.9%	3.8%	48.2%	45.2%

Disitribution of class of suitability for prefecture

Prefecture	Percentage of the territory with suitability highly favorable or favorable
LAC	99.4%
KANEM	66.8%
MAYO KEBBI	57.5%
TANDJILE	49.0%
CHARI BAGUIRMI	28.6%
MOYEN CHARI	26.9%
LOGONE ORIENTAL	18.1%
LOGONE OCCIDENTAL	13.2%
BATHA	9.6%
SALAMAT	9.0%
GUERA	3.7%
BET	2.9%
OUADDAI	2.3%
BILTINE	0.0%

Percentage of territory with favorable conditions, by prefecture