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WATER AND SANITATION DEPARTMENT

EVALUATION OF THE CHOICE OF HAND DUG WELL/BOREHOLE CASE STUDY OF NIMBA COUNTY

Action Contre la Faim for ECHO, 2006

1. INTRODUCTION

The OFDA/ECHO ACF water and sanitation rehabilitation Nimba county project was scheduled from September 2005 to May 2006. The activities included construction of 24 boreholes and 9 hand dug wells as well as the rehabilitation of 25 non functioning water points.
Before the inception of the OFDA/ECHO 2006 water and sanitation project, ACF carried out technical assessments on the existing water points in Nimba County. The main findings of the assessments are presented in the frame below:

The efficiency and effectiveness of hand dug wells are mainly questioned.

- Among 40 existing wells in 15 towns in Tappita district assessed in May 2005, 60% of them are not functioning throughout the dry season.
- In the meantime, among 11 boreholes identified in 9 towns in Tappita and Zoegeh districts, **45%** required rehabilitation. These boreholes were drilled between 1999 and 2000. 40% of them were drilled with the 201 ACF PAT which is not able to reach the fractures in the hard rock (limited depth around 60 meters with 6"$^{1/2}$ diameter). The needed rehabilitation for this type of boreholes concerns their redevelopment (flushing), which required specific kit such as air compressor not available at community level.

Following this assessment, ECHO requested from ACF a comparative study report between hand dug well and boreholes implementation, following various criteria such as:

- cost efficiency
- unit cost considering the depths, time and resources required for the campaign
- maintenance constraints
- site of the water point
- water quality
- yields of the reservoir
- and suitable area for hand dug wells and/or boreholes implementation.

2. OBJECTIVE OF THE STUDY

This study aims at contributing to the improvement of water facilities implementation in Nimba County.
It gives indicators on comparative advantages and disadvantages of hand dug wells and boreholes and can therefore help:

- **in site selection**
- **in the evaluation of cost/time constraints**
- **to analyse geo hydrological information on different districts of the County.**

3. DATA USED

- Data of 60 boreholes constructed by ACF from 1999-2000 in Nimba county
- Data and borehole logs of 24 boreholes constructed by ACF in 2005-2006 in Tappita district (Nimba county)
- Data of 9 hand dug wells constructed by ACF in 2005-2006 in Tappita district (Nimba County)

  The above data gathered range from geological sequences, static water level, dynamic water level, depth to bed rocks, to yield.

  Other data used mainly to compute cost are:
- **Time frame required to complete a borehole/hand dug wells**
- **Material cost**
- **Labour cost**
- **Equipments maintenance cost**

4. METHODOLOGY

The methodology used to carry the study involved:

- Modelling the geological sequences according to the data available (average depth to bed rock, average static water level…)
- Needs analysis
- Modelling cost of one borehole and one hand dug well taking into account the data above-mentioned (section 3)
- Modelling cost of 12 months drilling/ hand dug well digging campaign.
- The details of the different modelling calculation and procedures are presented in annex 3.

5. RESULTS AND INTERPRETATION

The following results can be found in this report:

- **An investigation of the sub-geological context in Nimba County** is provided, based upon experience gathered during this first ECHO/OFDA phase, as well as during ACF intervention in the county from 1999 to 2000 using the borehole logs.
- **The requirements for both hand dug wells and boreholes** are investigated
- **A justification between cost and time** for hand dug wells and boreholes is developed. A cost per beneficiary analysis is also provided.
- Finally **a zoning crossed with need analysis** completes the report.

6. LITHOLOGICAL SEQUENCE IN NIMBA

During this first phase (2005-2006), 24 boreholes and 9 hand dug wells were completed. In addition ACF has implemented 60 successful boreholes in the 5 districts of Nimba County from 1999 to 2000.
Around 70% of the boreholes constructed in 1999-2000 did not reach the bed rock. In addition to these data, the data from the 24 boreholes completed this year (2006) have been used to have a better understanding of the geological context at the county level. The graph in Annexe 2 indicates the depth to the bed rock. The borehole logs and boreholes data have allowed the modelling of the type of aquifer encountered at the district level.

Mainly, four types of formations are encountered:

- The non permeable formation which main components are loam and laterite located from 0 to 5 meters below the ground level.
- **Quite permeable formations with sandy clay content formations. This type of formations have good water content but do not have a good transmissivity. The layer of these formations starts from 5 meters to around 9 meters.**
- **Very permeable formation which component is sand ranging from medium to coarse, located from 9 meters to 15 meters.**
- **The bed rock, mainly granitoïd rocks located below 15 meters depth.**

The graph in the Annexe 1 summarizes the various geological formations encountered in Tappita district when taken into account the boreholes log from the ECHO/OFDA first phase program.
. The graph in Annexe 2 indicates the depth to the bedrock as well as the static water level.

The results show that for Zoegeh Gbeley-Gay and Tappita districts, the bed rock is reached at shallow depth while in Saniquellie and Yarwein Mensonneh it is deeper, thereby the sedimentary formations are thicker in Seniquelle and Yarwein Mensonneh.

The boreholes drilled between 1999 and 2000 in Tappita, Saniquellie, Zoegeh and Yarwein Mensonneh did not reach bed rock. This is because the 201 drilling rig has limited investigation depth 60m in soft formations. As soon as the ground formations are becoming hard (consolidated sedimentary formation or weathered hard rocks, igneous rocks), the drilling depth decreases.
Thus the yield obtained with boreholes drilled with PAT 201 drilling rig is generally satisfactory but can be subjected to seasonal variation.

The table below gives an estimation of the specific yields of the water bearing formations exploited with boreholes in the districts of Tappita, Saniquelle, Zoegeh and Yarwein Mensonneh.
Tappita district has the greatest specific yields with 174 litres per hour per meter of aquifer. The average is around 110 litres per hour per meter of aquifer in the county level.

Table 1: Estimated[1] sedimentary formations specific yield per district

County	District	Average total depth (m)	Average water Static Level (m)	Average yields(l/h)	Estimated average specific yield(l/h/m)
Nimba	Gbeley-Gay	21,97	10,35	1006	**87**
	Sanniquellie	19,59	7,71	1 177	**99**
	Tappita	12,64	10,00	460	**174**
	Yarwein Mensonneh	17,90	6,55	1 044	**92**
	Zoegeh	19,34	8,01	1 195	**105**

[1] This estimation was done by using the boreholes where only the sedimentary formations were reached. For Gbeley-Gay district 55% of drilled boreholes results were used while in Tappita district 4 hand dug wells yield test results were used. 100% of others boreholes results were used since the so call boreholes did not reach the bed rock

7. REQUIREMENTS FOR SUITABLE HAND DUG WELLS CONSTRUCTION

According to one of the quantitative guiding indicators in emergency situation (SPHERE Standards), *average water use for drinking, cooking and personal hygiene in any household is at least 15 litres per person per day*. When considering a maximum of 500 persons per water point equipped with HP (it can be borehole or hand dug well) as mentioned in the ECHO/OFDA proposal, a water point should be able to supply 7500 liters per day, with 8 hours of pumping time a day, as it is the case in Nimba (in general people in Nimba county areas are pumping from 6Am to 10 Am then from 3 pm to 7 pm).

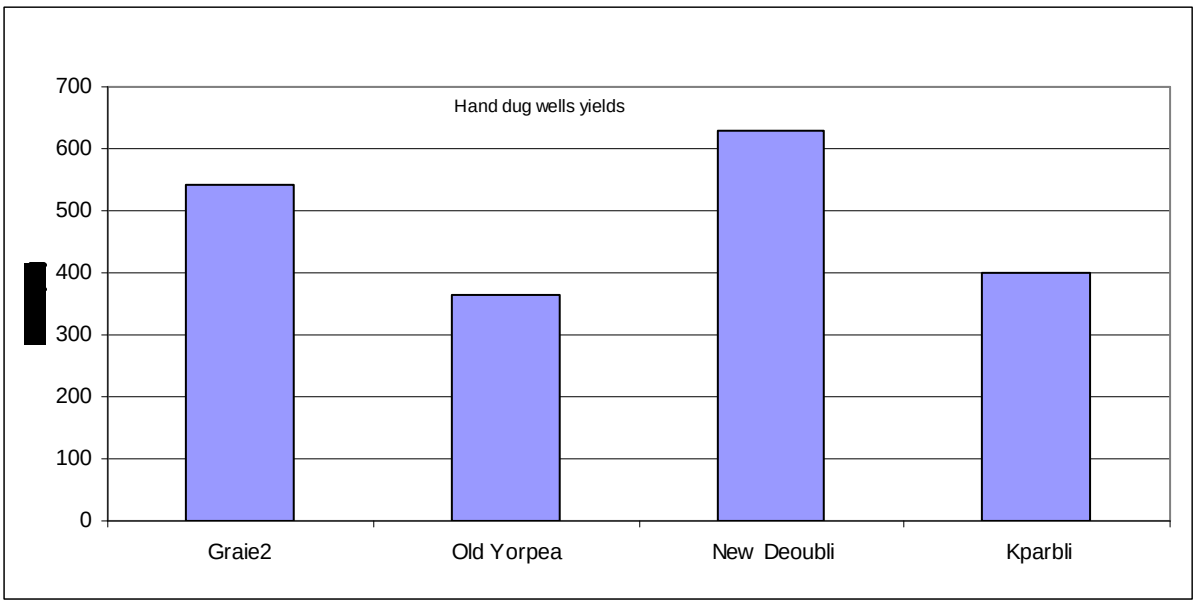
To meet the quantitative requirements following assumptions have been taken into account:

- The dry season is considered, as it is the critical period. The lowest water table occurred during this period.
- Water point use is from 6 Am to 10 Am with a high consumption between 6-10 Am while in the afternoon the pump is used from 3 pm to 7 pm. In between, people in this area use to be on the farm.
- The average specific yields per district from the table above are used as recharge. The storage effect plays a key role based upon the water use habit in the area (enough time for the well to recharge from 7 Pm the day before to 06 Am the next day).
- A maximum pumping rate of 1, 3 m3 /h is considered as the water point is equipped with an Afridev hand pump.

The success of a hand dug well implementation lies on factors such as the surface and subsurface geology, topography as well as position in relation to geo hydrological features like valley, swamp, and syncline but also to the digging standard applied by the implementer.

- For a well construction, the best site should be located on sedimentary/weathered formation near accumulation areas such as valley or depression with a gentle slop. A good recharge and a water table not too deep are expected. The possibility to undermine deeper is likely provided the geological formations encountered are stable (difficulties faced mainly when crossing sandy clay).
  The well number 2 in Graie town is an example about the advantage of implementing well near the valley with a gentle slop. The water table was reached at 7 meters and the undermining was possible up to 10,5 meters with a water column of 3,5 meters. Nevertheless, due to the presence of sandy clay the undermining process was very difficult and stopped at this stage.
- Similar to well# 2, well number 1 (still in Graie town) is located near a valley (found in the opposite direction). However the slope toward the valley is steeper. As a result, water table was reached at a greater depth of 12m. Undermining process is therefore very difficult even if the formations encountered were stable. To be able to undermine deeper and to avoid an overload of the culverts below, a telescoping process option was applied.
- In villages where there is outcropping hard rocks, as observed in Bonglay, a hand dug well is not possible with the actual tools used in the area due to the nature of the rock. In such type of situation, the hand dug well option should be avoided as there is no possibility to have well with good sufficient water column, hard rock boulders or shallow bed rock may stop the digging operations

For sites located in hilly places and far from valleys the water table is likely to be deep and the possibility to undermine when the water table is reached is very difficult. In such type of area, the hand dug well option should be avoided.



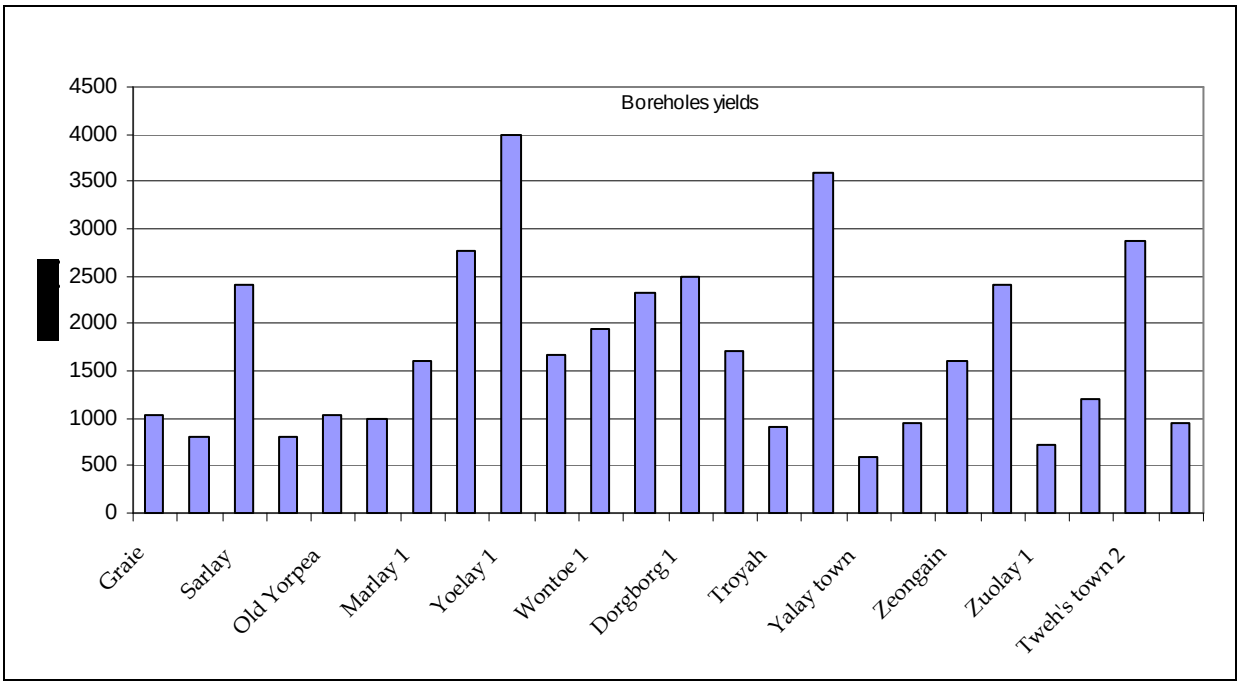
Graph 1: Tappita district hand dug wells yields

The maximum yield from the five hand dug wells yield tested is around 640 litres per hour with a average of 460 litres per hour. As compared to the borehole average yield, this yield represents around ¼ of the boreholes yield (see graph below).

8. REQUIREMENTS FOR BOREHOLES

The boreholes are drilled mainly to reach deeper aquifers than the hand dug wells. Thus the reached aquifers are most of time less vulnerable to seasonal water fluctuation. Due to its low storage capacity, borehole key parameter is the recharge while for a hand dug well it is the storage capacity.

The average discharge from 24 boreholes in Tappita district is around 1725 litres per hour with a lowest value of 600 litres per hour and a highest value of 4000 litres per hour. The monitoring done in the boreholes with discharge close to 600 litres per hour had shown a quite good respond to the pressure from the users.



Graph 2: Borehole yields in Tappita districts

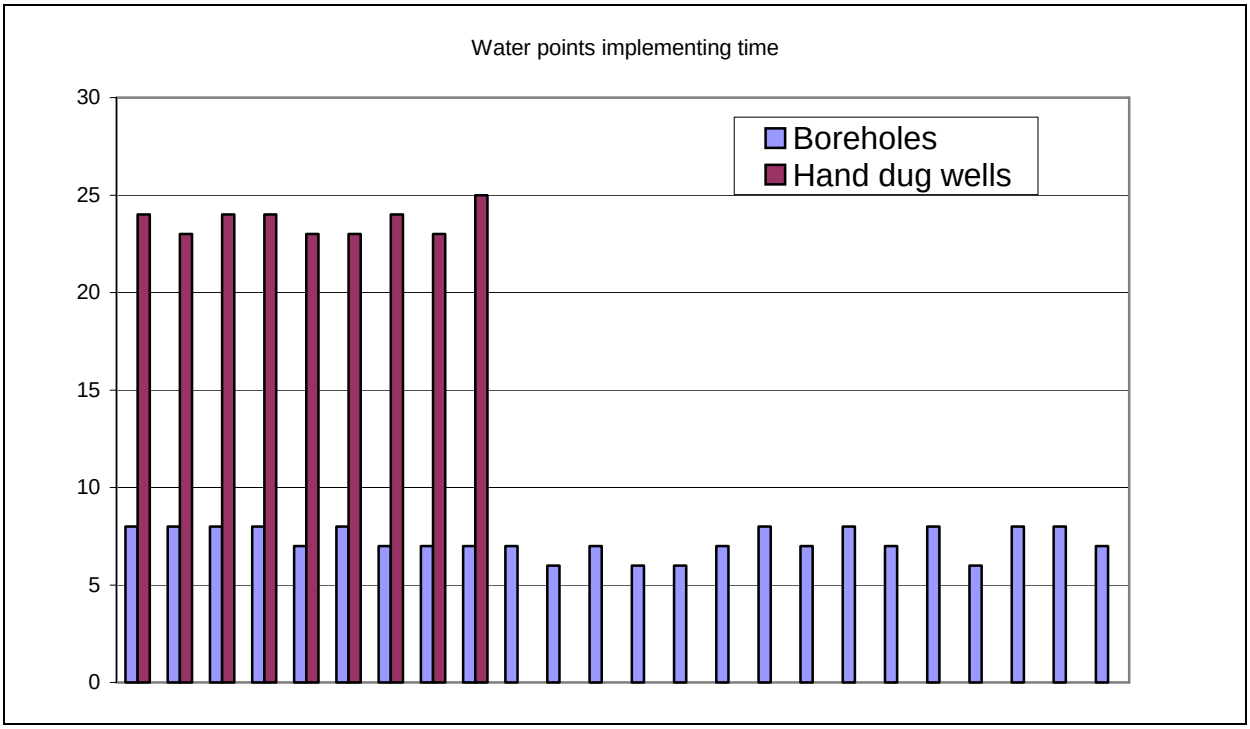
In term of quality, great attention is taken while doing the grouting to abstract surface water from laterite formations which are one of the reasons of the red colour observed in some boreholes (Freeman town borehole which has been rehabilitated during this phase).

The other main reason of having reddish water is the battery effect resulting from connecting stainless steel rods with galvanized rod when installing Afridev pumps.

9. JUSTIFICATION BETWEEN COST AND TIME

- The implementing time

Based on 24 boreholes and 9 hand dug wells duration of implementation, **the average duration for a borehole is 7,3 days including days for apron construction while for a hand dug well the duration is 23,6.** As a Result, a well construction needs 3 times borehole implementation duration.



Graph: Implementing time

- **The cost**

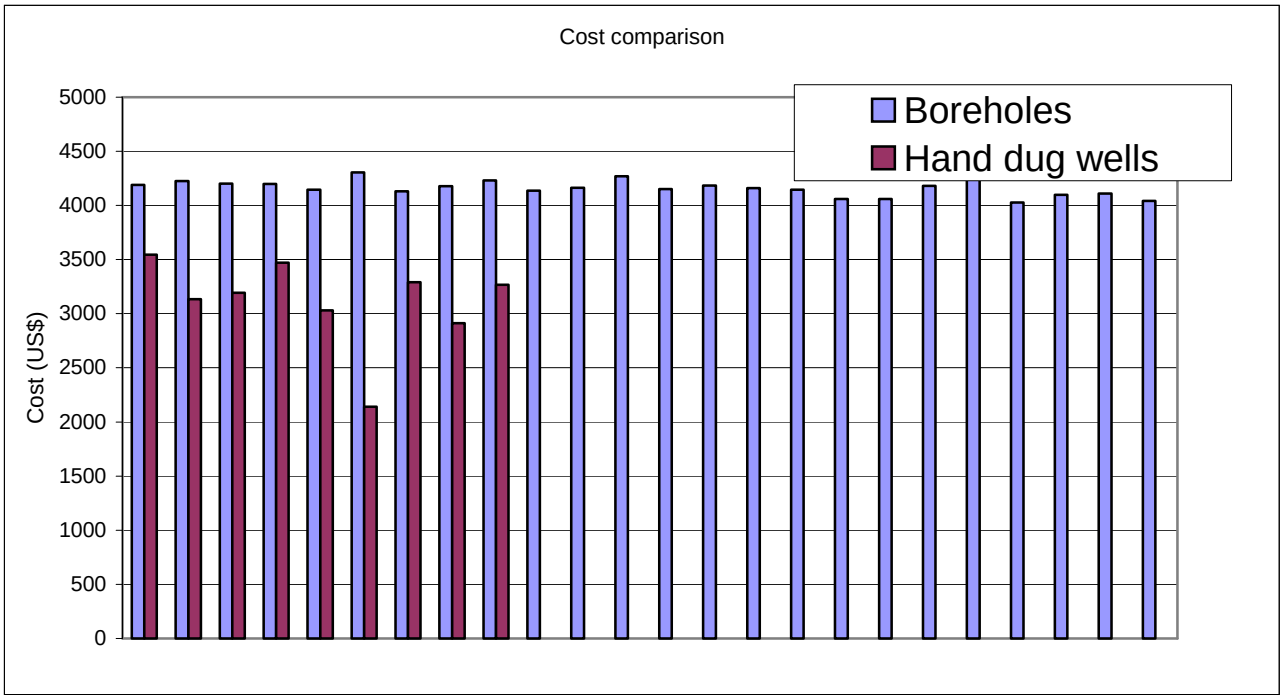
This cost comparison considers the well size of 1,2m inner diameter with a height of 0,8m (see below for the efficiency of this well size) average depth of 12 m.
For the borehole the average depth considered is 26 m drilled with 6" bit and equipped with 4.5" PVC casing.

The remaining main parameters taken into account in the cost calculation are as follow:

- **Boreholes**
- The truck, the pick up and the compressor fuel consumptions
- The boreholes equipments tools such as PVC plain and perforated.
- The drilling equipments service and spare parts cost.
- The negative borehole cost effect.
- The drilling rig depreciation cost
- The human resources cost (staff salary)
- The apron cost (car, cement, steel rod)
- Hand dug wells
- The non durable material cost such as cement, steel rod.

- The well durable material depreciation cost (such as the culverts moulds, Apron moulds, digging tools)
- The dewatering pump fuel consumption.
- The human resources cost (staff salary)
- Surface works (apron, well head, cover slab) cost (car, cement, steel rod..)

The graph below shows a highest cost when it comes to implement a borehole instead of a hand dug well. **The average cost for a borehole of 26 meters depth is around 4150 US$ which represents 20% more expensive than a hand dug well cost. The difference lies on the spare part cost and the depreciation of the drilling rig which is more expensive than the hand dug well depreciation cost.**



Graph 4: *Cost comparison*

10. DEPTH TO WHICH A HAND DUG WELL IS SUITABLE

ACF has build boreholes in Nimba county from 1999 to 2000.
During this ECHO/OFDA first phase, 24 boreholes were completed successfully. The analysis of the borehole led to the modelling of the lithological sequence in Tappita district as mentioned above.
Given the average static water level of 8,9 [2]meters in Tappita district, based upon this lithological sequence and the well diameter sizes mentioned above, **the well with 12 meters depth (3 meters below water table) will be able to supply 7500 litres per day to 500 persons (15 litres per person per day)**. Since in Tappita, the average bed rock depth is around 15 meters, this depth of 12 meters can be reached.

To compute the required depth for hand dug wells, the estimated average specific yields were used and the water use habit in the area[3].

[2] Average static water level in 24 boreholes. 60% of these boreholes were drilled during the dry season so that one can consider this static water level a dry season one.
[3] As mentioned above, the pumps are used in the morning from 6 -10 Am and from 4 hours Pm to 7 hours Pm, in between the great majority of the community members spend the time in the farms.

The table below gives the various required depth in each district based upon the above assumptions for 2 well size.

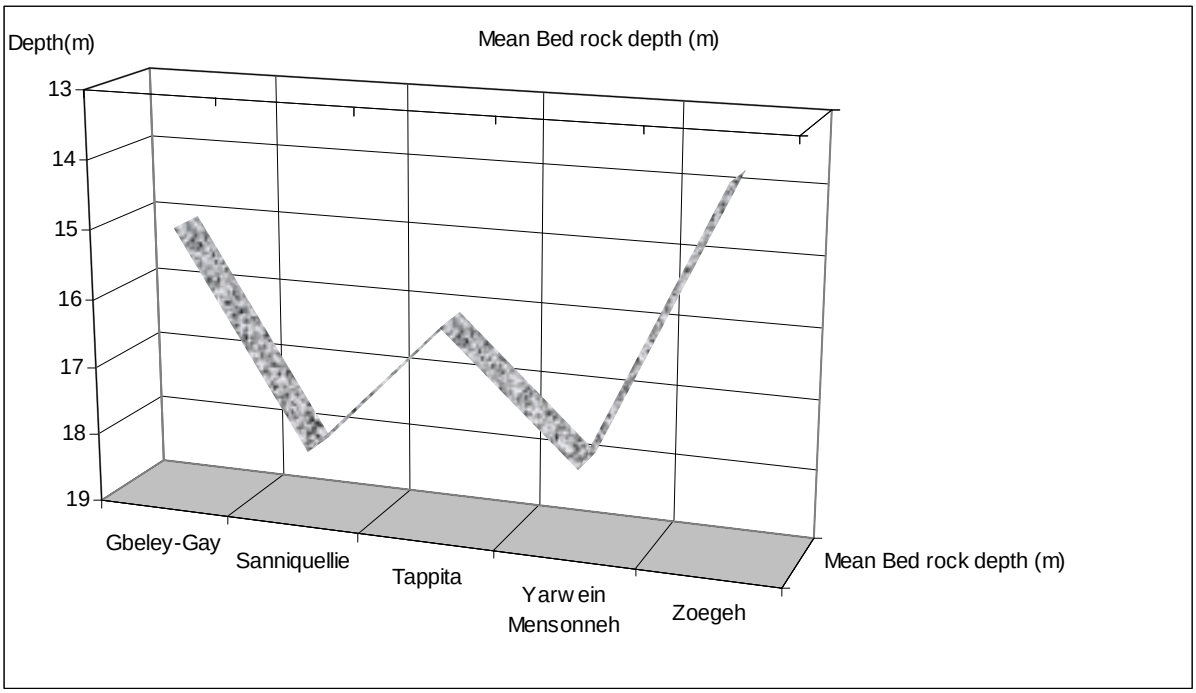
District	Average water Static Level (m)	Estimated average specific yield(l/h/m)	Required depth(m) below water table for 1,2 inner diameter	Required depth(m) below water table for 0,9 inner diameter
Gbeley-Gay	10,35	87	3,35	4,74
Sanniquellie	7,71	99	3,27	4,57
Tappita(considering only the wells)	10	174	2,82	3,68
Yarwein Mensonneh	6,55	92	3,32	4,67
Zoegeh	8,01	105	3,22	4,48

Table 2: required depth below water table for hand dug well in dry season.

Data source: ACF (1999-2000 and 2005-2006)

From these above results, it's clearly indicated that **the average depth under water table in the county level is around 3 meters for 1.2 meters well inner diameter and around 4.5 meters for 0.9 well inner diameter.**
In sum, the more the inner diameter of the well is small, the more the height of the water column should be increased so as to have a good volume of water storage.
The maximum required depth is found in Gbeley-Gay and Yarwein Mensonneh due to their low specific yields.

The graph below indicates the depth to the bed rock, thereby the limit to hand dug well digging. These results were obtained based on the data's from boreholes drilled by ACF from 1999-2000 and 2005-2006. As regard to the depth of the bed rock per district and following the above results in the table, the hand dug wells can't be dug all over the county.



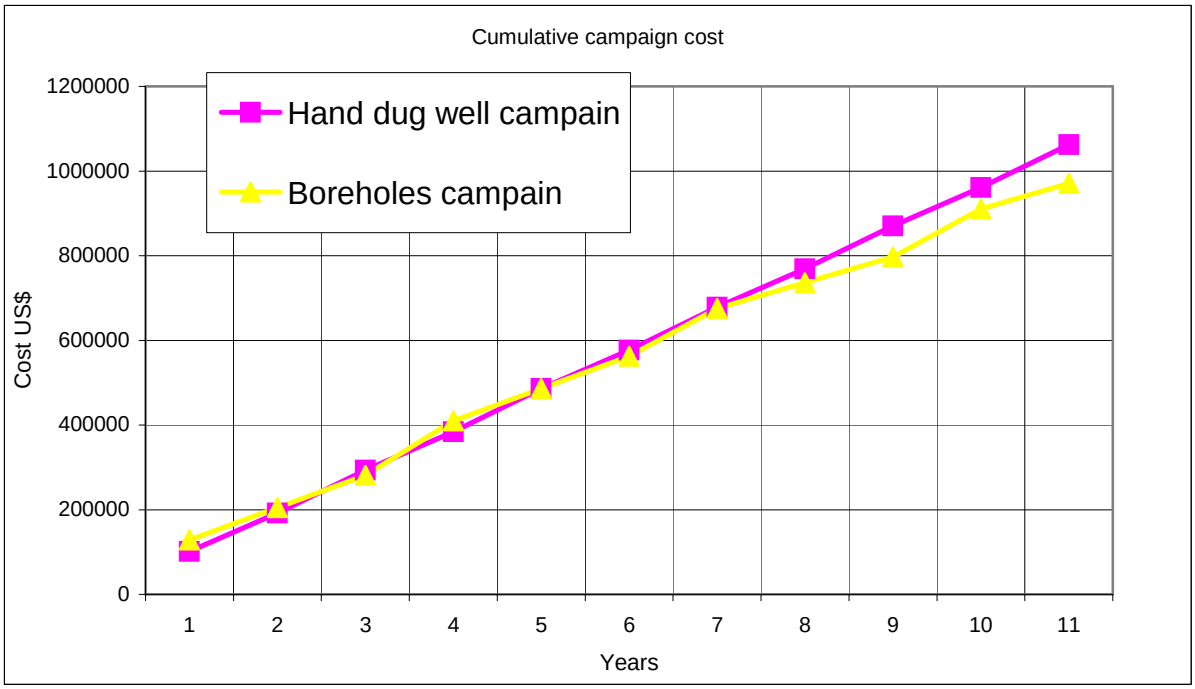
***Graph 5**: Average bed rock depth*

11. BOREHOLE AND HAND DUG WELL COST

This cost computation was done based on the cost of the 24 boreholes drilled during ECHO/OFDA first phase from September 2005 to May 2006.
The cost per beneficiary was done by estimating the realistic number of water points per year for both borehole and hand dug wells campaigns taking into account annual leaves for the staff, service time and the negative water point effect for the borehole (for hand dug well it's assumed that there is no negative well).
Thus **31 boreholes can be constructed within a year while for hand dug well campaign only 10 wells can be completed with one team. To get the same number of beneficiary coverage a hand dug well campaign needs 3 teams**. The details of the computation are attached in the Annexe 1.

The cost per beneficiary for a borehole campaign is <u>1.3 times</u> the hand dug well campaign cost per beneficiary for the first year. This is due to the cost of the drilling rig and the spare part cost. In order to take the depreciation cost into account, the following assumption have been made based on ACF field experience: the spare part for the drilling machine has a depreciation time of 3 years while the hand dug well material depreciation duration is 2 years

The cumulative cost for boreholes campaign is more than for a hand dug well for mainly the first six year due to the depreciation of the drilling rig. After 6 years the cumulative cost for a hand dug well becomes greater than the one for a borehole campaign. The graph below shows the cumulative cost for both hand dug wells and borehole campaign.



<u>Graph 6</u>: *Cumulative cost campaigns*

12. **ZONING CROSSED WITH NEED ANALYSIS**

The aim of this chapter is to come out with recommendations regarding the suitable area for boreholes and or hand dug wells in line with the water needs.
First an estimation of needs in the whole county is performed by using various data's from stakeholders.
Finally, the geological conditions from boreholes drilled in the county are coupled with this need analysis results.

12.1 Need analysis

The population figures considered are the one released by UNHCR through the Community Based Recovery and Restoration (CBR) of Social Services on February 2006. In this report the water gaps were indicated too. The initial released data's were corrected due to its incoherence when it comes to the non functioning pumps figures. According to the CBR report 100% of existing pumps are functioning well up to the reporting period which is to far from the reality on the field.

The last program evaluation has served as a baseline to quantify rate of non functioning hand pumps in the county level. The average non functioning rate was used to compute the gap throughout the county. A ratio of 500[4] person /pump was considered.

Table 3: Non functioning pump rate in Nimba County

Organisation	Date	Total pumps	Non functioning pumps	Percentage of non functioning pump (%)
ACF assessment	May 2005	50	32	64
ACF reassessment	October 2005	38	17	45
ACF assessment	June 2006	12	8	66
ADRA ECHO 2 report	2005-06	40	28	70
ADRA ECHO update	Dec 2006	39	24	61
IRC evaluation activity	June 2006	40	27	67
Average %				62

Following the above table, the average rate of non functional pump was estimated to 62%. This is before the inception of ACF/ECHO 2005-2006 Water and sanitation program.
When applying the rate of 62% to the existing pumps, number of functional/non-functional pump is then obtained. Knowing, the standard requirement to reach 500 persons/pump, the existing functional pump, the total number of pumps needed to cover the County with a rate of 500 persons /pump is calculated: this represent the gap. **Thus, there is need of 1046 hand pumps in Nimba County to reach the standard of 500 persons/water point.**
The different figures per district are summarized in the table below:

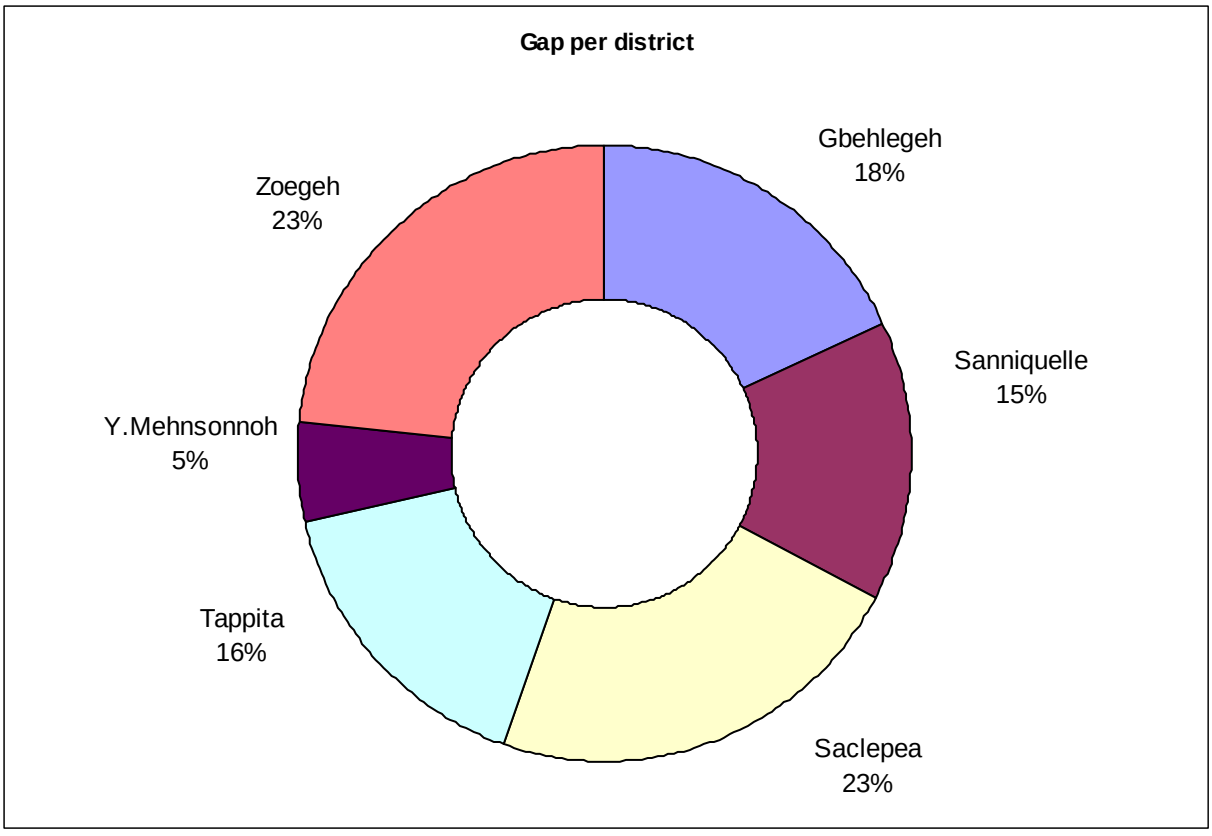
[4] The Community Based Recovery Service (CBR) had reported the figures based on a ratio of 291 persons per hand pump

Water (Handpump)									
District	Estimated Popln	Standard/ [5]Requirement	Pre-war Pumps	Hand pumps				Gaps[6]	%
				Existing		Functioning	Non functionning		
Gbehlegeh	110 321	221	79	86		33	53	188	12
Sanniquelle	107 675	215	113	163		62	101	153	10
Saclepea	134 189	268	123	84		32	52	236	15
Tappita	93 596	187	76	48		18	30	169	11
Y.Mehnsonnoh	35 501	71	28	41		16	25	55	3
Zoegeh	145 858	292	164	127		48	79	243	15
Total	627 140	1254	583	549		209	340	1046	65

Table 4: Water need in Nimba county

Data source: Community base recovery sectoral gap analysis, February 2006

The Graphic below gives a visual breakdown of the distribution of the estimated gap among the different districts of Nimba County.



Graph 7: ACF Revised Community Based Recovery figures (Data source: community base recovery report :February 2006, ACF, ADRA,IRC 2006 assessments reports)

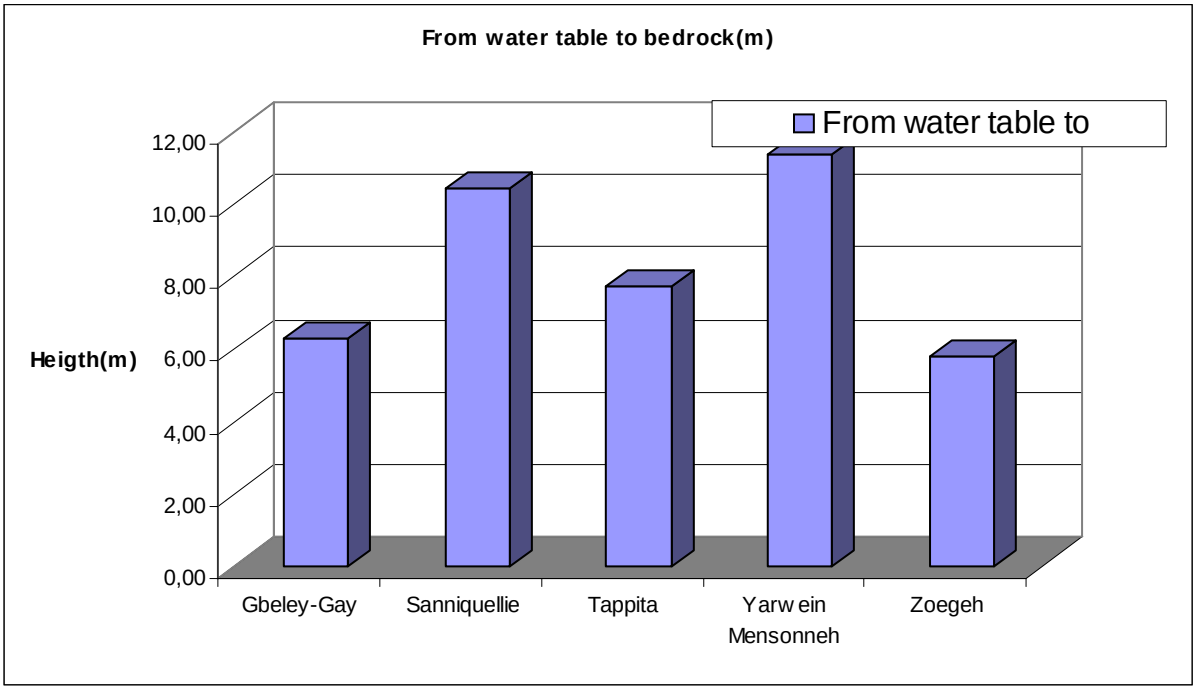
[5] Standard requirement=number of pump required to reach a coverage of 500 persons/pump
[6] Gap= number of pump needed to each the standard requirement

In the light of the above figures, the great part of the needs concerns the following districts: Zoegeh, Saclepea, Gbeley-Gay and Tappita.

12.2 Geological context

The geology of Nimba county is predominantly made of Gneiss and granite gneiss (Ref: republic of Liberia planning and Development Atlas, 1983).

In such a geological context, to carry out hand dug well digging and even drilling, there is a need to locate and assess thickness of weathered formation. This was performed using the data and log of ACF boreholes constructed in Nimba county from 1999-2000 and from 2005-2006. The table below gives per district an average depth to the bed rock.



Data source: ACF (1999-2000 and 2005-2006)

The geological context for each district was described /studied using 97 boreholes data's from 1999 to May 2006. For each district the average static water level was computed as well as the average depth of the bed rock. Two districts Yarwein Menshonneh and Sanniquellie have thicker sedimentary formation layers with respectively 11,35 and 10,40 meters below water table. Since the sedimentary formation layers are the targeted formations while digging a hand dug well, thus, digging wells is more suitable and reasonable in these two districts. Nevertheless even if the sedimentary layers are not as thick as Yarwein Mensonneh and Saniquellie ones, good hand dug wells are also realizable in Tappita and Zoegeh where the specific yields obtained (respectively 174 and 105 l/h/m) are good compared to the one in Gbeley-Gay (87 l/h/m).

12.3 Crossing analysis

In the light of the above results, there is a real need to intervene quickly in Zoegeh, Saclepea, Gbely-Gay and Tappita where the needs are high so as to close the gap. The key factor is therefore the time. Given the required time for boreholes construction compared to hand dug wells construction, the specific yields and the geological context, following recommendations can be done:

- **For Zoegeh** both boreholes and hand dug wells are recommended since the needs are high and also because of the good specific yield. Due to the needs, more weight should be given to borehole campaign.

- **Saclepea:** Due the great gap to be field, the borehole campaign due to its small time consumption will be the best response. However, in Saclepea, lack of suitable data did not allow to carry the geo hydrological study as performed in the other districts.

- **Gbeley-Gay:** sedimentary formation layer has an average thickness of 6 meters and the specific yield is low (87 l/h/m) hand dug wells option is therefore not recommended. Additionally the gap to be covered is also high in this district. A borehole campaign is thus recommended[7]

- **Tappita:** the needs are not too high (refer to graph 7 p.11), and, as the sedimentary formations are thick enough and coupled with a big specific yield in the district, hand dug wells can be successfully implemented.

- **Saniquellie and Yarwein Mensonneh:** hand dug wells campaign option is recommended due to the low need and the thickness of sedimentary formations is suitable for hand dug well. However there is need to increase the storage by digging deep because the specific yield is not very important as compared to Tappita for example

The table below summarize the various recommendations:

District	Boreholes option	Hand dug wells	Boreholes and hand dug wells
Gbeley-Gay	X		
Saclepea			
Sanniquellie		X	
Tappita			X
Yarwein Mensohnneh		X	
Zoegeh			X

Table 5: recommendations for boreholes and or hand dug well campaigns

However, the above recommendation based on the geology should be coupled to the advantages/disadvantages tabulated in the table below to make suitable choice for sustainability.

	Hand dug well	Borehole
Advantages	Easy to maintain by the communities	Tap water from deep aquifer
	Low cost maintenance	Not subject to the effect of falling water table in dry season
	Big storage capacity	Not subjected to bacteriological contamination
	In case of broken pump, possibility to draw water with bucket and rope using the manhole	Can be constructed on any type of ground formation
		High yield
Disadvantages	Relatively shallow(12-15m) thereby prone to bacteriological contamination	Maintenance is costy and requires means not existing at community level (such as compressor for flushing or redevelopment)
	Tap water from uppermost formation thereby subjected to the effect falling water table in dry season.	In case of pump breakdown no way to draw water
	Can only be constructed efficiently on soft formation	Required high skilled staff for implementation

Table 6: Advantages /disadvantages of borehole & hand dug well

13. CONCLUSION

This study uses the experience gathered in the field from 1999 to 2000 and from 2005 to 2006 and leads to the following conclusions:

- **In term of quality, the borehole is suitable due its less vulnerability regarding surface water but also generally not subjected to seasonal water level fluctuation as may be the case of the hand dug wells**

- **The implementing time is 3 times less for a borehole than for a well. For example, within 1 month 4 boreholes can be completed (apron and pump installed) while only 1 well can be completed.**

- **2 zones were recommended for hand dug wells and or boreholes implementation: the first zone is composed by the districts located in the eastern part of the county, Tappita, Zoegeh, and Gbeley-Gay. This zone is suitable for borehole campaign based upon the geological conditions and the water needs. This campaign should be mixed with a hand dug well one.**

  The second zone is composed by Sanniquellie and Yarwein Mensonneh where based on the same reason the hand dug wells campaign is suitable

Finally, it is worth mentioning that this study is not an absolute hand book. It is based on ACF experiences gained over years of operation in Nimba County. However, it gives necessary information on the soil condition and the hydrogeology of the areas concerned by the study. It is therefore for users to take the information needed and adapt to their program and operating capacity.