Good practice for borehole drilling in Burkina Faso

2017 Mission Report

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Context

This document presents the field study undertaken in february/march 2017 on the drilling sector in Burkina Faso. This work has been conducted as part of the Project Cooperation Agreement (PCA) 2015-2017 established between UNICEF and the Skat Foundation called: Striving for Professionalism in Cost-Effective Boreholes (SPICE) – Phase IV.

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Summary

In Burkina Faso, concerns have been raised regarding the high number of handpump boreholes that have failed, or need to be rehabilitated within a relatively short time of their initial construction. If Burkina Faso is to reach its drinking water supply targets it cannot afford poor quality works. This document reports on a mission by Skat Foundation, UNICEF and the Government of Burkina Faso to document and explore ways of addressing the problems faced.

Physical audits of handpump boreholes in 2013 and 2014 in Burkina Faso raise concerns over water quality, inappropriate handpump for deep water and non-conformant pumps. In more than one third of cases, the handpump boreholes will function poorly, or cease to function completely within a few years. It is estimated that investments of between FCFA 0.6 billion (€0.9 million) and FCFA 2.9 billion (€4.5 million) per year are lost due to the installation of poor quality handpumps and other aspects of the construction. In one year, over 130,000 people were provided a water supply service that is likely to break down within a few years.

Despite knowledge of handpump corrosion for over 30 years, corrosion remains a problem in Burkina Faso, as governments and aid agencies have continued to install pumps manufactured with unsuitable materials, leading to high maintenance costs, pump failure and rejection of water sources due to poor water quality. Handpump corrosion is a major global problem which the WASH sector has so far, systemically failed to address, and which will impede the realisation of Sustainable Development Goal 6, not only in Burkina Faso.

The poor construction quality of boreholes in Burkina Faso has several underlying causes, i.e. the short drilling season, particularly in programmes which have to adhere to the annual cycle of the government financial year; lack of regulation of who is permitted to drill; lack of up-to-date reference prices; lack of sufficient skilled and experienced personnel in the public and private sector; turnkey contracts, poor quality handpump components (particularly the "stainless steel" India Mark II rising main) and a lack of sanctions for regional governments, or private enterprises that do not perform. Further issues include the lack of data available for previous drilling.

The last training courses with respect to borehole drilling were undertaken in 2006-2008, now over 10 years ago. Some drilling enterprises, consultancies and regional directorates are fortunate to have staff who were trained previously in the public sector and who can mentor others. However, as people move on or retire, trained technicians and managers are decreasing in number. There will soon be a generation of staff in Burkina Faso who have received no formal training, or any form of mentoring from those trained in borehole drilling or supervision. However, until the bottleneck of a very short drilling season is overcome, even trained staff will remain constrained to undertake a professional job as there is too much to oversee in an extremely short period of time.

The mission concluded with recommendations to strengthen the borehole drilling sector in Burkina Faso, i.e.: dialogue between the government and private sector, a study into capacity for contract award and drilling, efforts to address the very short drilling season, studies to examine the quality of pump components, improving data from borehole drilling, capacity strengthening and the development of a national code of conduct for borehole drilling.

Résumé

Au Burkina Faso, le nombre de forages équipés de pompes à motricité humaine (PMH) inutilisables ou qui nécessitent des réparations quelques mois seulement après leur réception est préoccupant. S'il souhaite atteindre ses objectifs en matière d'approvisionnement en eau potable, le Burkina Faso ne peut pas se permettre de construire des infrastructures de mauvaise qualité. Ce document présente les résultats de la mission menée par Skat Foundation, l'UNICEF et le gouvernement du Burkina Faso afin d'objectiver ces enjeux et d'explorer les solutions qui peuvent y être apportées.

Les audits physiques des forages équipés de PMH conduits en 2013 et 2014 au Burkina Faso ont révélé des dysfonctionnements au niveau de la qualité de l'eau, du choix de pompes inadaptées aux profondeurs des forages, et de l'installation de pompes non-conformes. Dans plus d'un tiers des cas, en quelques années à peine les forages équipés de PMH commencent à connaitre des avaries, ou cessent parfois même complètement de fonctionner. Le choix de PMH de piètre qualité et les malfaçons dans l'exécution des ouvrages génèrent des pertes estimées entre 0.6 milliards de FCFA (€0.9 million) et 2.9 milliards de FCFA (€4.5 million). En un an, plus de 130 000 personnes ont bénéficié d'un service d'approvisionnement en eau potable qui tombera probablement en panne d'ici quelques années.

Bien que la corrosion des PMH soit un problème identifié depuis plus de 30 ans, cette corrosion demeure un sujet d'actualité au Burkina Faso. Les gouvernements et les agences d'aide au développement ont continué d'installer des pompes fabriquées à partir de matériaux inadaptés, générant ainsi des coûts d'entretien élevés, de multiples avaries et de nombreux cas de rejet des points d'eau par les communautés déçues de la mauvaise qualité de l'eau obtenue. La corrosion des PMH est un problème majeur d'ampleur internationale, auquel le secteur EAH n'a toujours pas réussi à trouver de solutions systémiques et qui risque d'enrayer la réalisation de l'Objectif de Développement Durable n°6 au Burkina Faso comme dans d'autres pays.

La mauvaise qualité d'exécution des ouvrages au Burkina Faso résulte d'un écheveau de causes sous-jacentes : la brièveté de la saison de forage, surtout pour les programmes alignés sur le cycle financier de l'année administrative ; le manque de réglementation des opérations de forages ; le manque d'actualisation des prix de référence; le manque de personnel suffisamment qualifié et expérimenté, dans le secteur public comme dans le secteur privé ; les contrats clés-en-main et l'absence de sanctions vis-à-vis des autorités régionales ou des entreprises privées qui n'accomplissent pas leurs missions. Le manque de données sur les campagnes de forages et d'installation de PMH précédentes, ainsi que la qualité médiocre des pièces composantes des PMH (notamment « l'acier inoxydable » des colonnes d'exhaure India Mark II) s'avèrent tout aussi problématiques.

Les dernières formations sur le forage ont été organisées en 2006-2008, il y a plus de dix ans maintenant. Certaines entreprises de forage, bureaux d'études et directions régionales ont la chance qu'une partie de leur personnel ait été formé précédemment dans le secteur public et puisse désormais jouer le rôle de mentor auprès de leurs collègues. Toutefois, le nombre de techniciens et de responsables formés dans les règles de l'art diminue chaque fois que ces

personnes partent en retraite ou changent d’emploi. Il y aura bientôt toute une génération d’employés au Burkina Faso qui n’aura reçu aucune formation formelle ni aucun mentorat de ceux qui avaient déjà été formés au forage et à la supervision. Dans tous les cas, tant que la durée de la saison de forage ne sera pas davantage étendue, même les employés formés auront du mal à accomplir l’ensemble de leurs missions de façon optimale et professionnelle car ils doivent piloter un trop grand nombre d’opérations dans un laps de temps extrêmement limité.

En conclusion, la mission recommande de consolider le secteur du forage au Burkina Faso, notamment par : l’instauration d’un dialogue régulier entre le gouvernement et le secteur privé, l’étude et le renforcement des capacités pour à la fois la réalisation des forages et la gestion des contrats, des efforts pour allonger la durée très courte de la saison de forage, des études sur la qualité des pièces composantes des PMH, l’amélioration de la collecte et du traitement des données des campagnes de forage, et l’élaboration d’un code national de bonnes pratiques pour les opérations de forage.

Abbreviations

2IE	:	Institut International pour l'Eau et l'Environnement
ABNORM	:	Agence Burkinabé de la Normalisation
ABS	:	Appui Budgétaire Sectoriel/Sector Budget Support
AGETEER	:	Agence d'Exécution des Travaux d'Eau et d'Equipement Rural
ANP-SEBAP	:	Association Nationale des Professionnels du Secteur de l'Assainissement et de l'Eau Potable du Burkina
CGAB-CSLP	:	Cadre Global d'organisation des Appui Budgétaire du Cadre Stratégique de Lutte Contre la Pauvreté
CNIEau	:	Centre National de documentation de l'Information d'Eau
CNSS	:	Caisse Nationale de Sécurité Sociale
DANIDA	:	Danish International Development Agency
DFID	:	Department for International development (UK)
DGAEUE	:	Direction Générale de l'Assainissement des Eaux Usées et Excrétas
DGRE	:	Direction Générale des Ressources en Eau
DHS	:	Demograhic and Health Survey
DREAHA	:	Direction Régionale de l'Eau, des Aménagements Hydrauliques et de l'Assainissement
EU	:	European Union
FEER	:	Fonds de l'Eau et de l'Equipement Rural
IFU	:	Identifiant Fiscal Unique
HP	:	Handpump
IOTA	:	Instillations, Ouvrages, Travaux et Activités
MAH	:	Ministère de l'Agriculture et de l'Hydraulique
MAHRH	:	Ministère de l'Agriculture, de l'Hydraulique et des Ressources Halieutiques
MARHASA	:	Ministère de l'Agriculture, des Ressources Hydrauliques, de l'Assainissement et de la Sécurité Alimentaire
MATD	:	Ministère de l'Administration Territoriale de la Décentralisation
MC	:	Ministère du Commerce
MDG	:	Millenium Development Goal

MEA	:	Ministère de l’Eau et de l’Assainissement
MECV	:	Ministère de l’Environnement et du Cadre de vie
MEF	:	Ministère de l’Economie et des Finances
MFB	:	Ministère des Finances et du Budget
NTU	:	Norme Technique Universelle
PAGIRE	:	Plan d’Action pour la Gestion Intégrée des ressources en Eau
PN-AEPA	:	Programme National d’Approvisionnement en Eau Potable et d’Assainissement
RWSN	:	Rural Water Supply Network
SDG	:	Sustainable Development Goal
SONATER	:	Société Nationale des Travaux de l’Equipement Rural
UNICEF	:	United Nation Children’s Fund
USA	:	United States of America
WASH	:	Water, Sanitation and Hygiene

1 Introduction

On 14 December 2006 the Government of Burkina Faso endorsed a National Programme for Drinking Water Supply and Sanitation[1] (PN-AEPA) looking forward to 2015. The PN-AEPA embodies the programming approach adopted by the Government to reach the Millennium Development Goals (MDGs) in the WASH sector. The implementation of the Sector Budget Support[2] to the WASH sector means that three development partners, namely the European Union, Sweden and Denmark, all members of the "CGAB-CSLP"[3], provided financial support over the 2010-2015 period for a cumulated amount of 61,230 billion FCFA.

The PN-AEPA is implemented by the Ministry of Agriculture, Water Resources, Sanitation and Food Security[4] (MARHASA), the 13 Regional Directorates of Water, Hydraulic Installations and Sanitation[5] (DREAHA) (Centre, Nord, Centre-Nord, Sahel, Est, Centre-Est, Plateau Central, Boucle du Mouhoun, Hauts Bassins, Cascades, Sud-Ouest, Centre-Ouest, Centre-Sud), the General Directorate of Water Resources[6] (DGRE), the General Directorate for Wastewater and Excreta Sanitation[7] (DGAEUE), the delegated project management agencies (AGETEER, FEER, devenu SONATER), the Service Providers and the Municipalities.

The 2013[8] and 2014[9] technical and financial audits (Cabinet NTU international A/S, 2013 and 2014), both undertaken between December 2015 and February 2016, reveal a number of weaknesses with respect to the quality of water and sanitation infrastructure constructed and rehabilitated, including boreholes fitted with handpumps. Concerns have also being raised regarding the high number of boreholes that have failed, or need to be rehabilitated within a relatively short time of their initial construction. If Burkina Faso is to reach its drinking water supply targets it cannot afford to construct poor quality works.

UNICEF Programme Division (New York, USA) is working with Skat Foundation (Switzerland) to support in-country processes that raise the professional standards of borehole drilling across a number of countries in Africa. In 2016 this collaboration led to the publication of a Guidance Note on Water Well Drilling Professionalism (UNICEF/Skat Foundation, 2016), four short animated films and included in-country support to three countries. Following a request from UNICEF Burkina Faso, it was agreed that Skat Foundation would undertake a short

[1] Programme National d'Approvisionnement en Eau Potable et d'Assainissement, PN-AEPA
[2] In French - Appui Budgétaire Sectoriel - ABS
[3] Global Framework for the Organization of Budget Support of the Strategic Framework for Poverty Reduction
[4] Ministère de l'Agriculture, des Ressources Hydrauliques, de l'Assainissement et de la Sécurité Alimentaire
[5] Directions Régionales de l'Eau, des Aménagements Hydrauliques et de l'Assainissement
[6] Direction Générale des Ressources en Eau
[7] Direction Générale de l'Assainissement des Eaux Usées et Excrétas
[8] The samples were established on a sufficient statistical basis, whilst reflecting the diversity of construction companies and the geographical repartition of the works.
[9] 38 % of HPs have been inspected, 14% of HPs underwent a detailed check. HPs: samples have been taken from all regions but the Boucle du Mouhoun. In this region the contract execution has been delayed. The boreholes have not yet been equipped with HPs

mission to Burkina Faso to support the government and partners to develop a roadmap to develop a code of good practice and to improve the quality of borehole construction.

A team comprising Jean Paul Ouedraogo (UNICEF), Adama Zombre (DRGE) and Kerstin Danert (Skat Foundation) reviewed documentation, and discussed the experiences of the entire process from project planning to commissioning with various stakeholders (through one to one semi-structured interviews and group discussions) over a two week period from 20th Feb to 3rd March 2017, concluding with a multi-stakeholder workshop on the 6th March. This report was presented at the workshop for discussion.

This report presents the key findings of the mission, including a summary of the status of borehole drilling which has primarily drawn on the 2013 and 2014 audit reports and other select documentation. In order to bring together the diverse problems and ideas to improve the quality of drilled boreholes fitted with handpumps, the report sets out six issues for consideration. Annex 1 and 2 respectively provide a draft roadmap and preliminary list of topics that should be considered for inclusion in a code of conduct for borehole drilling.

2 Context of Burkina Faso

2.1 Geology and groundwater

The geology of Burkina Faso primarily comprises ancient (Precambrian) crystalline rocks, which are generally capped by a layer of weathered clayey rock (overburden), commonly 20 to 100m thick. This is in turn typically capped by a layer of weathered laterite soil (i.e. iron-rich and hardened). There are also intercalcations of younger (Birimian) crystalline rocks. Groen et al (1998) noted groundwater levels in basement rocks from north-western Burkina Faso of 10-60m below the surface, with a seasonal variation of 1-2m. The western border area and parts of the north are underlain by sedimentary rocks. Hand dug wells and seasonal ponds are the traditional water sources of the country. There are gold reserves in Burkina Faso, generally occurring along with quartz and occasionally sulphide minerals in veins in a number of areas in the crystalline basement (mainly the younger Birimian age rocks).

Increasingly, groundwater is tapped from boreholes/tubewells, typically equipped with handpumps. According to BGS and WaterAid (2002) the boreholes generally source groundwater from fractures in the basement rock whereas hand dug wells tap groundwater in the weathered overburden. The small piped water supplies, which are still relatively few in number in rural areas, also rely on groundwater. Despite the fact that more than 45,000 boreholes have already been drilled in Burkina Faso (MAH, 2011 plus an extra 7,000 estimated), there is no regional hydrogeological maps.

Annex 1 summarises groundwater quality issues in Burkina Faso. Of particular note is the extent of aggressive water (i.e. with a $pH < 6.5$) in the country which can cause handpump corrosion (Box 1).

Box 1 Handpump corrosion

Handpump corrosion can cause significant changes in water quality if the pump is not used for several hours. The result is red water, typically in the morning after the handpump has not been used for several hours (i.e. during the night).

Corrosion is one aspect of a poor quality water supply from a borehole. Despite knowledge of handpump corrosion for over 30 years, corrosion remains a problem, as governments and aid agencies have continued to install pumps manufactured with unsuitable materials, leading to high maintenance costs, pump failure and rejection of water sources due to poor water quality (Nekesa et al, 2016). This is a problem that globally, the WASH sector has so far, systemically failed to address, and which will impede the realisation of SDG 6. See annex 2 for a short introduction to corrosion.

MAHRH (2009a) has noted that certain water points which were deemed unsuitable for consumption (due to high arsenic and nitrate concentration) had still been equiped with a handpump.

However, given that this brief review only drew on studies collated in 1994 and 2002, further work is recommended to synthesise more recent information from published papers, grey literature, in national database and from drilling records. Groundwater pollution is a subject which deserves more attention.

2.2 Status of borehole drilling and rehabilitation

Groundwater, and boreholes fitted with handpumps in particular is central to providing safe and affordable drinking water supplies to the population of Burkina Faso. According to the 2010 Demographic Health Survey (DHS) data, groundwater provided 86% and 21% of the main drinking water supplies of the rural and urban population respectively. The proportion of the population benefiting from a borehole in 2010 was estimated to be 54% and 11% in rural and urban areas, up from 41% and 8% in 1999.

The number of boreholes in the country continues to grow, with PN-AEPA and other partners installing over 1,600 boreholes (equipped with a handpump) in 2016 (Table 2). Table 3 provides a breakdown of the boreholes drilled for each of the 13 regions in 2016 by the PN-AEPA and partners. It is noted that nationally between 24% and 34% of borehole works between 2014 and 2016 were rehabilitation. In 2016, rehabilitation comprised over one third of the drilling works.

Table 2 Status of WASH work completion (MEA, 2017b)

Types of works	2014	2015	2016	2014 to 2016
New boreholes constructed (a)	1350	1387	1089	**3826**
Rehabilitated boreholes (b)	708	404	339	**1451**
Proportion of works that are rehabilitation (b)/(a+b)	34%	23%	24%	**27%**

Table 3 Completion of newly constructed and rehabilitated boreholes in 2016 (PN-AEPA and partners)

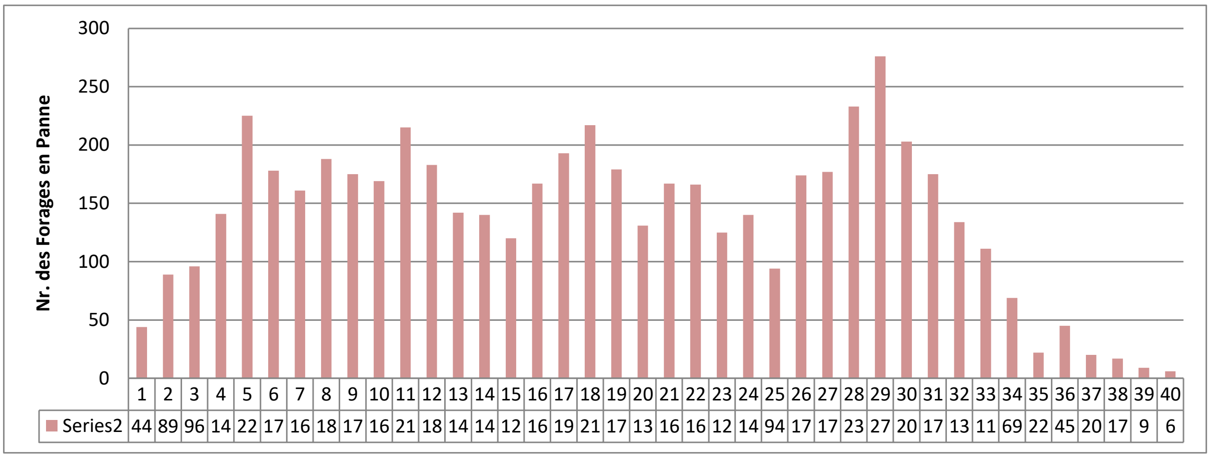
Regions	New boreholes constructed			Rehabilitated boreholes (y)	Proportion of works that are rehabilitation (y)/(x+y)
	Programmed	Extra	Total (x)		
Boucle du Mouhoun	61	34	95	55	**37%**
Cascades	53	36	89	54	**38%**
Centre	24	26	50	54	**52%**
Centre-Est	158	74	232	37	14%
Centre-Nord	126	15	141	22	13%
Centre-Ouest	62	58	120	141	**54%**
Centre-Sud	143	70	213	19	8%
Est	128	58	186	55	23%
Hauts-Bassins	48	16	64	1	2%
Nord	93	34	127	8	6%
Plateau Central	53	48	101	36	26%
Sahel	74	12	86	54	**39%**
Sud-Ouest	66	49	115	13	10%
National	**1089**	**530**	**1619**	**549**	**25%**

Source: Rapports 20ème CRP ; INO 2016 (MEA, 2017a)

A detailed analysis of the age and causes of borehole rehabilitation was beyond the scope of this study. However, Figure 1 shows the distrubution of age of over 5,682 non-functioning boreholes in DGEP's list. It should be noted that 133 boreholes were constructed in the previous two years. Assuming that they were constructed in 2014 or 2015 would mean that almost 5% of boreholes are not functioning within the first two years[10]. The 2013 and 2014 audits found that functionality had dropped by 6.5% within two years of service and by 4% within one year (Tableau 4 and 5).

Literature suggests in cases where pumps breakdown so early it is likely that this is caused by poor borehole construction or pump installation rather than innadequate community management. This issue is discussed further in chapter 3.

Figure 1 Number of broken down boreholes with respect to their construction year



2.3 Summaries of the 2013 and 2014 audits

Tables 4 and 5 summarise the key findings and recommendations of the 2013 and 2014 audit for handpumps fitted with boreholes. In addition to the alarming drop in functionality after such a short time (discussed above), the audit raises concerns over water quality (10% of sources in 2013), use of inappropriate handpump for deep water (in the Région du Nord); non-conformant superstructure (57% in 2013; 59%% in 2014) and non-conformant infrastructure, i.e. pump (32% in 2013 ; 34% in 2014). Thus, in more than one third of cases, the handpump boreholes will function poorly, or cease to function completely within a few years.

Taking the 2014 average cost of 6,603,000 FCFA for 2014 (Tableau 6), and noting that 1350 handpump boreholes were realised by the programme in 2014, this extrapolates to an estimated loss of investment of between FCFA 2.9 billion (€4.5 million) and FCFA 0.6 billion (€0.9 million) in one year[11]. Assuming 300 people per handpump borehole, in one year, an estimated 133,650 people were provided a water supply service that is likely to break down

[10] i.e. no of broken down pumps divided by no of new boreholes constructed in 2014 and 2015 (Tableau 2) =133 / (1350 +1387) = 4.9%

[11] 33% of 1350 = 447.5 facilities are likely to fall out of service. 447.5 x 6,603,000 = 2.94 billion. Divide by five if assuming that only the pump needs to be replaced. i.e. 2.92/5 = 0.59 billion.

within a few years. Even if they establish a management committee, are trained, can access spares, and can raise funds for maintenance, these people have been provided with a source that is sub-standard.

Table 4 Handpump Boreholes - Summary of 2013 audit observations and recommendations

Summary of observations :

1. 6% of the sampled boreholes **have not been inspected**[12]**.**
2. The **ID plates** were found in 43% of cases.
3. In half of the cases **the drilling logs** have been filled in (49.1%).
4. 10% of Handpumps (HPs) provide water whose **quality** is deemed dubious by the users due to its **color and smell**. No bacteriological nor physico-chemical analysis has been conducted to confirm this status. Some boreholes have been commissioned and put into use whilst results of the analysis, incuding physico-chemical ones, were not conclusive. The regions affected are the Hauts-Bassins, the Nord and the Sud-Ouest
5. Construction companies choose the **India Mark II pump** to equip the vast majority of the boreholes. This type of pump suffers from early wear and tear when **borehole depth is >40 m**, especially in the Nord region where the static level is very deep and so borehole depths are very high.
6. 57% of the HPs have **overground installations that are non-compliant** (cracks, spoiled platform, cracked trough, and poor quality of the sump pump slab).
7. 32% of the HPs have **underground installations that are non-compliant**. These are major defaults that threaten long term viability of the pump: quality of the cylinder, pipes, rods and external pumping systems ;
8. In terms of maintenance, 48% of HPs already show visible signs of **degradation** of both above-ground and below-ground installations. The functionality rate of HPs drops to 93.5% within two years of service.

Recommendations :

- 10% of HPs must be shut down immediately due to poor water quality: 1 HP in each of both Boucle du Mouhoun and Nord regions, 3 HPs in the Hauts-Bassins region et 4 HPs in the Sud-Ouest region;
- The underground installations of 32% of HPs must be rehabilitated in the short run to avoid the risk of losing the whole equipment in the long run;
- The overground installations of 57% of HPs must be rebuilt (fencing wall, apron, trough, slump) in order to ensure adequate hygiene and sanitation around the water points.

[12] The auditor could not check their actual localisation because of changes in the allocation of inspection sites or other reasons.

Table 5 Handpump boreholes - Summary of the 2014 audit observations and recommendations

Summary of observations :
1. 96% of the works constructed **were found** by the Consultant[13]. 2. Compliant identification plates were found in 22% of cases only. 3. 63.44% **drilling logs** were filled in. 4. The **water quality** of seven (7) HPs, so 4.7% of the sample, was non-compliant but they had been put into operation nevertheless. 5. 87% of the boreholes had been equipped with an **India Mark II pump**. In several cases this model makes the pumping very arduous and suffers from early wear and tear when installation depth are >40m. 6. More than 59% of boreholes have **non-compliant above-ground installations**. Defects are due to poor execution of the construction and engineering works: weak foundations, poor concrete pouring, insufficient gradients and dimensions. 7. 34% of HPs' **underground equipment have issues**: main defects are the poor quality of the pump, the pipes and the rods that made of galvanised, and the lack of guiding rod. Two boreholes had verticality issues, and the development of several other boreholes (flushing, equipment) had not been executed properly, with dire consequences for water quality. 8. 90.5% of the audited HPs **function** well and 5.5% provide a satisfying level of service, whilst 4% are below standard.
Recommendations :
• 5% of HPs must be shut down immediately due to poor water quality: 1 borehole in each of the three Centre-Est, Centre-Nord, and plateau Central regions, 3 in the Sahel region and 1 in the Sud-Ouest region that needs a re-development; • The underground installations of 34% of HPs must be rehabilitated in the short run so as to avoid the need for a large scale rehabilitation programme in the coming years ; • The overground installations of 59% of HPs must be rebuilt (fencing wall, apron, trough, slump) in order to ensure adequate hygiene and sanitation around the water points. • The DR must be vigilant in requesting repairs/replacement of all non-compliant elements before the final acceptance of the works and installations

The physical examination of work completion between 2013 and 2014 included a qualitative description of the whole above-ground installation and some observations regarding the pump. Although these descriptions provide some useful information, most of the borehole drilling work is actually undertaken underground. The 2015 audit should consider an inspection of the sub-surface with the use of a borehole camera to verify the casing, screen and well development. This, together with measurements of depth, static water level and verticality should be compared with data in the technical data sheet.

[13] The fact that some HPs were not found by the consultants is due to a change of sites allocation. These HPs were mentioned after the Consultant had finished her fieldwork with no possibility to come back for site checking given the mission's time constraints.

Figure 3 Select pictures from the 2014 audit

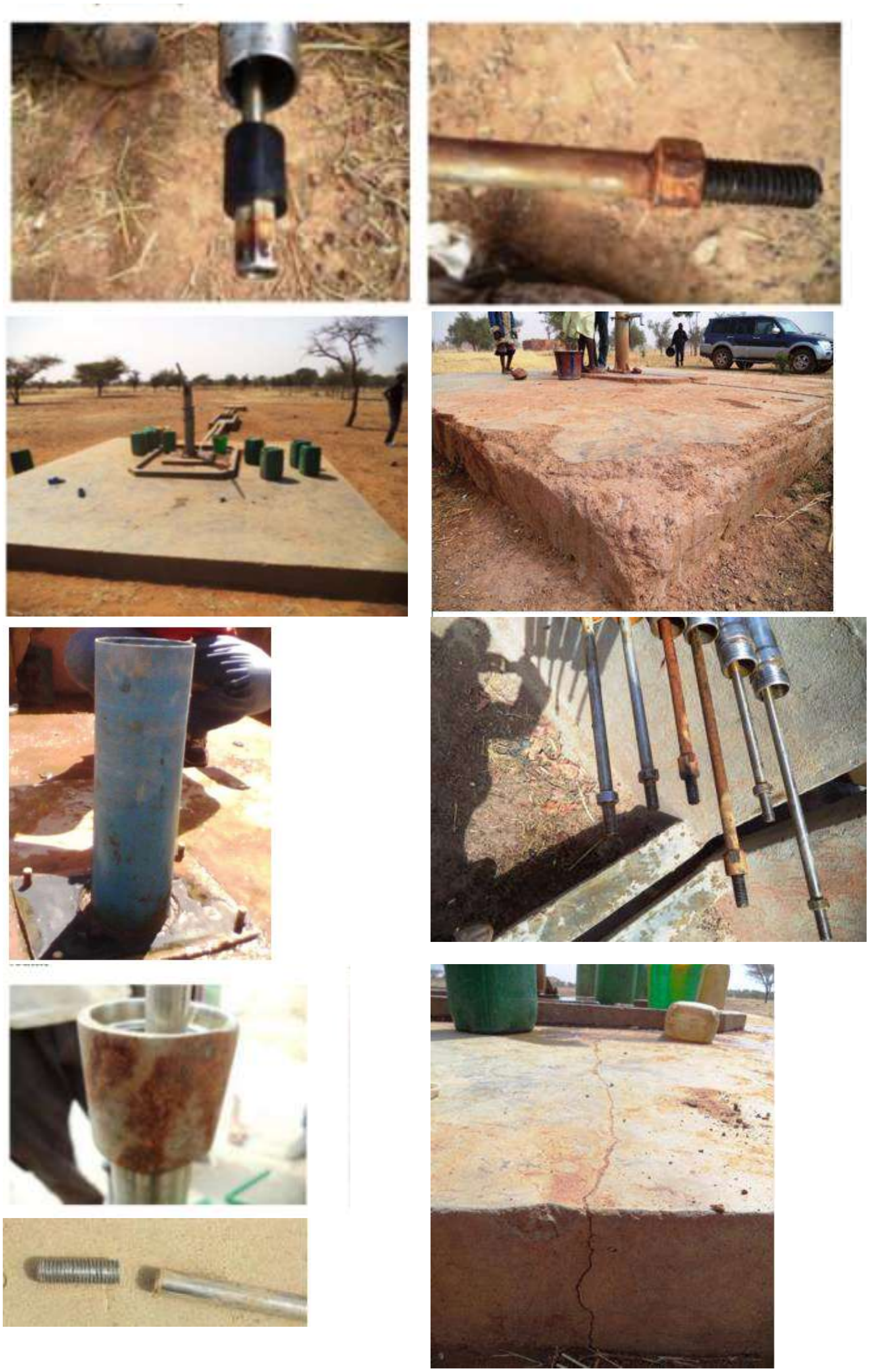


Figure 2 Borehole inspection camera

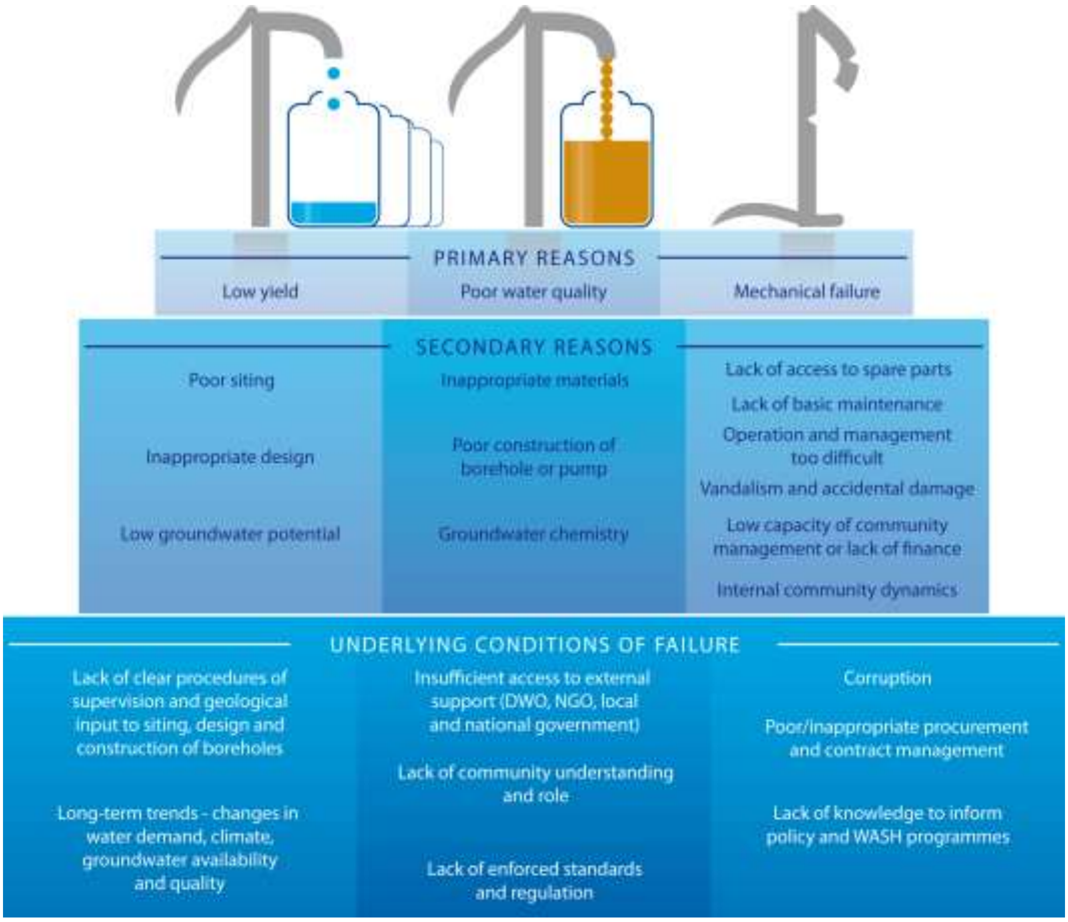
3 Underlying causes of poor quality borehole construction

The problem of poor quality borehole construction is not confined to Burkina Faso, as evidenced by findings in the UNICEF/Skat (2016) guidance note on professional water well drilling. A number of studies have documented concerns.

"*Hidden Crisis*" is an ongoing research project, funded by DFID within the UPGro Programme that is trying to understand the underlying causes of borehole failure. Figure 4 illustrates that the primary reason for a pump failure may be low yield, poor water quality, or mechanical failure. These are underlain by secondary reasons, including poor siting or inappropriate design. In turn, these have underlying causes, which can include a lack or procedures or insufficient qualified personnel. In order to improve quality, it is essential that the underlying reasons are identified and addressed. It is also important to note that a community may not be willing to pay for repairs to a facility if it was poorly constructed in the first place.

Stakeholders are aware that the poor construction quality of boreholes in Burkina Faso has several underlying causes. Key informant interviews and group discussions shed light on several key issues; the short drilling season, particularly in programmes which have to adhere to the annual cycle of the government financial year; lack of regulation of who is permitted to drill; lack of up-to-date reference prices; lack of sufficient skilled and experienced personnel in the public and private sector; "turn-key contracts", poor quality handpump components and a lack of sanctions for regional governments, or private enterprises that do not perform. Further issues include the lack of data available for previous drilling, and concerns over poor quality pump components (particularly the "stainless steel" India Mark II rising main). Each of these is discussed briefly below.

Figure 4 Primary Reasons, Secondary Reasons an Underlying Causes of Failure of Handpumps and Boreholes (Bonsor et al, 2015)

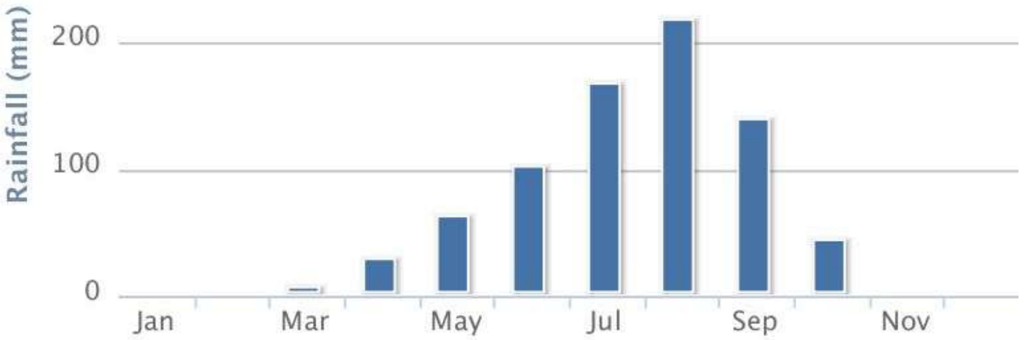


3.1 Short drilling season

"The results of our review pointed out recurring difficulties regarding the execution of contracts, namely the need to amend the Programme activities' implementation calendar to enable an optimal use of resources and the need to respect statutory consultation periods within the tendering process." (Cabinet NTU international A/S, 2013:8). The 2013 audit also mentions the need to redesign the construction works planning and financing process because its current design leads to a very short drilling and installation period which puts the drilling companies, supervisors and controllers under an unreasonable amount of pressure to complete and check works within severely limiting time constraints.

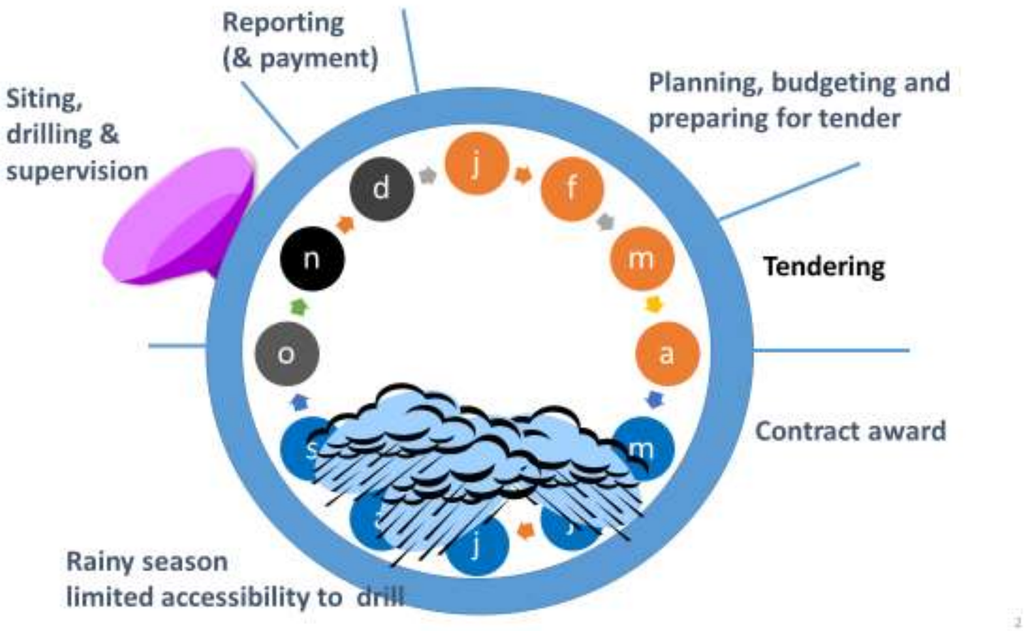
The Burkina Faso financial year runs from January to December. The planning period for the government is the first quarter of the year, once the budget has been approved. Tendering of works gets underway in March/April with contracts signed in April/June. However, this coincides with the onset of the rainy season (Figure 4).

Figure 5: Average Monthly Rainfall for Burkina from 1990-2012 (World Bank, 2017)



The inaccessibility of many (if not most) rural drilling sites in this season means that the commencement of drilling works is thus delayed late September, if not October. As reports need to be submitted by the end of the financial year (in December), the drilling season for government works is very short, perhaps six to ten weeks as illustrated in Figure 5b.

Figure 5b Burkina Faso weather and financial year and implications for the drilling season[14]

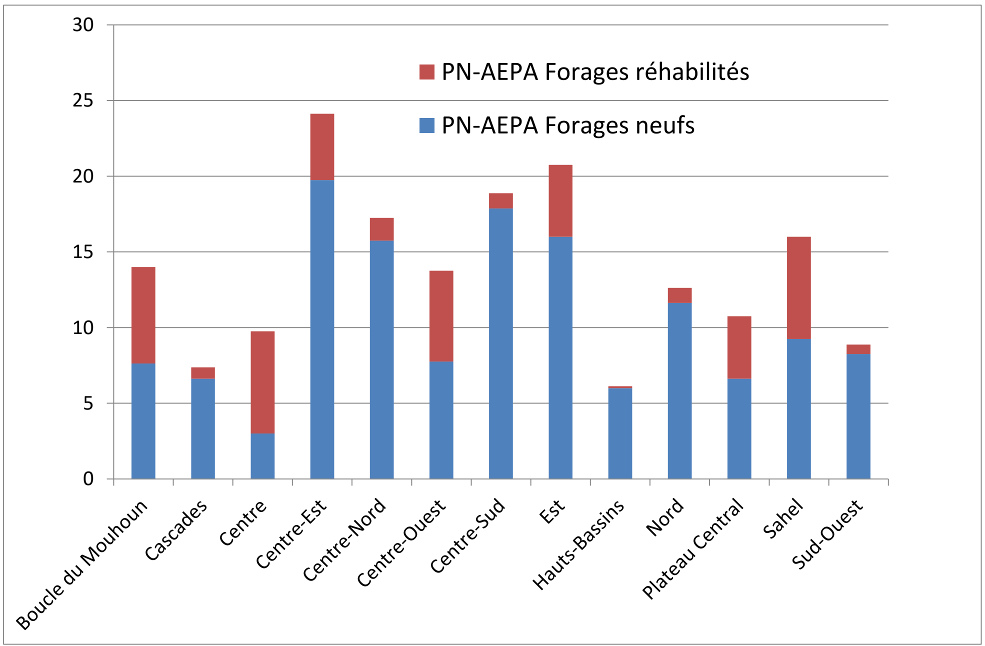


In an attempt to illustrate what this means for the regional office, Figure 6 shows the average number drilling works to be supervised per week. It assumes that all of the works in Figure 3 are undertaken within an eight week period. The sheer number of works to be supervised, coupled with low staffing levels (the regional offices in Est and Hauts-Bassins have three people responsible for water supplies) make quality assurance extremely difficult to undertake.

[14] Note that this diagram is not included in the French version of the report that was published in 2018. However, it was presented and discussed at the end of mission workshop.

The possibility of deferring drilling contracts from one year to another to extend the drilling season should be examined.

Figure 6: Average drilling works in AN-AEPA per week in 2016 assuming 8 weeks available (in Oct – Dec)



3.2 Drilling companies

It is estimated that there are more than 60 water well drillers operating in Burkina Faso. To get their license, companies must meet the conditions set by the decree: *N°2008 -0040 /MAHRH/MEF on the conditions for the granting of Technical Approval to Companies for works in the field of drinking water supply*[15]. There are three groups of companies depending on their activities:

- Groupe F: Drilling companies
- Groupe P: Modern well construction companies
- Groupe U: Water supply and utilities companies

This decree describes the content of the license application file (application form, statutory stamps, IFU[16] and CNSS[17] registration certificate, list of technical staff, list of tools and equipment, human and material resources needed for each category). The licenses are delivered by the Ministry of Water and Sanitation[18] of Burkina Faso through its Committee for Approval of Technical Allocation[19] (Box 2). This committee must provide an answer to all applicants within forty five (45) days following reception of their application. It is also meant

[15] *"ARRETE CONJOINT N°2008 -0040 /MAHRH/MEF Portant conditions d'Attribution d'Agrément Technique aux Entreprises des travaux exerçant dans le domaine de l'Approvisionnement en Eau Potable".*
[16] Unique fiscal identification number.
[17] National Social Security Fund
[18] Ministère de l'Eau et de l'Assainissement
[19] Commission d'Attribution des Agréments Technique

both to examine the application file and to investigate on site before taking its decision on the applications.

Box 2: Members of the Committee for Approval of Technical Allocation[19]

- Two delegates from the General Directorate in charge of Water and Sanitation[20], one being the Commission President and the other its rapporteur
- One delegate from the Department of Research and Planning of the Ministry in charge of Hydraulics[21]
- One delegate from the General Directorate in charge of dams and hydro-agricultural developments[22]
- One delegate from the National Office of Water and Sanitation (ONEA)[23]
- One delegate from the General Directorate of Public Works [24]
- Two delegates from the WASH private sector companies
- One delegate from the Association of Civil Engineers and Technicians[25]
- One delegate from the union of WASH private sector companies

Despite this licensing system, problems still arise as certain contracts are awarded to companies that lack the necessary equipment or human capacity to provide quality work. The people interviewed explained that the drilling works tendering process' limitations are amongst the weakest points of the system. "*Some companies have been doing mediocre work for 10 years*" (Anonymous, 2017). There does not seem to be any mechanism to ensure feedback from the contracting authorities/project managers at regional level to the commission.

Discussions with members of the committee revealed that it is a voluntary body, with no resources available to verify the documents provided by the enterprises seeking an agreement. There does not seem to be a clear mechanism to withdraw agreements, and there was no connection, for example between the results of the audit and sanctions by the committee. There is need for a review of the function of the committee.

The National Association of Drinking Water and Sanitation Professionals[26] (ANP-SEBAP) was initiated in 2005, and established in 2010, with support from DANIDA. Apart from donor or government-funded projects (including recent training in plumbing), the association remains largely dormant. There is thus no strong body representing the concerns and interests of the private sector involved in borehole drilling. According to the ANP-SEPAB president, there has been no formal exchange between government and the drillers since 2012. There are 56 drilling enterprises who are members of ANP-SEPAB, up from 40 back in 2009 (MAHRH 2009b).

[20] Direction Générale en charge de l'Eau et de l'Assainissement
[21] Direction des Etudes et de Ia Planification de la ministère en charge de l'hydraulique
[22] Direction Générale en charge des barrages et des aménagements hydro- agricoles
[23] Office National de I 'Eau et de l'Assainissement National Office of Water and Sanitation
[24] Direction Générale des Marches Publics
[25] Association des Ingénieurs et Techniciens en Génie Civil of Burkina
[26] Nationale des Professionnels du Secteur de l'Assainissement et de l'Eau Potable du Burkina

Despite widespread acknowledgment of the problem of poor construction quality, there is no regular forum at national level that meets regularly to discuss the issues, solutions and progress in addressing the problem. The government is in the process of preparing a decree to establish a dialogue framework: six-monthly meeting between DGRE and drilling representatives.

3.3 Drilling costs and prices

Duffau and Ouedraogo (2009) state that drilling prices ranges from FCFA 6,500,000 to FCFA 9,000,000 for a successful borehole (Tableau 6). Notably, the average price paid in 2014 by PN-AEPA (Table 7) includes negative boreholes. Costs have fallen over an eight year period.

Table 6: Cost structure of Drilled Water Wells in Burkina Faso (MAHRH, 2009b)

Stage	Price range (FCFA)	
Senstitisation	720	990
Siting	180	495
Control of works/Supervision	90	315
Drilling	3'015	5'985
Pump	990	1'620
Platform	405	585
Total	4'500	9'000

Table 7: Average drilling costs, 2014 (2014)

	Région	Coût moyen (KFCFA)
1	Boucle du Mouhoun	N/A
2	Cascades	7 164
3	Centre	6 336
4	Centre-Est	4 709
5	Centre-Nord	7 555
6	Centre-Ouest	8 361
7	Centre-Sud	6 289
8	Est	6 646
9	Hauts – Bassins	4 197
10	Nord	7 098
11	Plateau Central	5 619
12	Sahel	9 202
13	Sud-Ouest	6 104
	Moyenne nationale	**6 603**

The lack of realistic costs estimates provided by engineers to inform and guide the clients is a recurring challenge. Some prices set in the tendering process are too low for companies to be able to provide a good quality borehole and push them to cut costs and downgrade service levels.

3.4 Expertise and experience

Although the engineering consultants undertake full-time supervision, there is lack of trust that they are really overseeing the drilling properly by both the DREAHA and DGEP. It can be extremely difficult, if not impossible for a DREAHA supervisor to stop drilling, even if the quality of execution is very poor. The incentives in the system, from the donors, right through to national and regional government, are for the numbers of boreholes drilled, rather than quality.

Since the privatisation process, there has been practically no systematic training of technical or managerial staff in relation to borehole drilling, installation and contract management. MAH (2011) mentions training sessions on several themes including construction works management, tax regimes, tendering and water works pricing, and also funded the training of 70 engineers at the *Ecole Nationale d'Ingénierie* in Bamako and at 2IE.

According to several interviewees, the last training courses were undertaken in the years 2006-2008, close to 10 years ago. Some drilling enterprises, bureau d'etudes and DGREAH have been fortunate to have staff who were trained previously in the public sector and who could thus mentor others. It appears that not all have been so fortunate, and as people move on or retire, the cadre of trained technicians and managers is decreasing. There will soon be a generation of staff in Burkina Faso who have received no formal training, or any form of mentoring from those trained. "*PN-AEPA stakeholders do not have the skills required to drill and rehabilitate boreholes as such… in rural area*" (Cabinet NTU international A/S, 2013:7). "*an awareness raising campaign targeting the relevant entrepreneurs to improve the situation for the next projects*" (Cabinet NTU international A/S, 2013:17)

Stakeholders should develop and pilot a training and mentoring scheme for the sector's private and public sector staff in the coming years covering:

- Siting
- Supervision and control
- Testing and analysing water quality
- Borehole drilling and development and pump testing
- Apron building and pump installation

The above units should be integrated to ongoing-training courses given by national training institutes.

However, it should be noted that even with training, the number of staff responsible for water supply at regional level is limited (comprising a team of three in Hauts-Bassins and Est). Thus, even with training, there are limitations as to what can be expected of them in terms of supervision, technical support to the communes and oversight of partner projects. The sector should try to balance the human, logistical and financial requirements at regional level with the number of contracts to be overseen. Until the bottleneck of a very short drilling season is overcome, this will remain quite limited.

Communes also contract out drilling works, but, given that the contract size is very limited (can even be one borehole in a year), they are unlikely to attract the more professional companies. The ability of the communes to manage contracts and supervise the construction, as well as control or works is limited by their technical expertise. Plans are being made to strengthen technical capacity in WASH at commune level, with funding from the EU.

The supervision of drilling works is done by national engineering consultants. Apparently these consultancy firms hire employees with no formal training and who can claim some years of practical experience in the sector at best.

3.5 Tendering and contracting

Companies which do not have a technical licence cannot bid in the tendering processes. The tendering processes are based on competitive bidding. Before April 2008, the contract was awarded to the cheapest bid that had passed the preliminary technical conformity screening. This process did not give much weight to the technical quality of bids. The Decree No 2008-0173/RES/PM/MEF brought about change: now, within the pool of bids deemed technically compliant, the contract must be awarded to the most favourable one. The way DREA implement this decree however is not very clear yet.

The PN-AEPA uses turn-key contracts which combine the (i) siting, (ii) drilling, (iii) construction of the superstructure and (iv) pump supply and installation into one contract, and enterprises are paid for successful boreholes only. While this was introduced to overcome budgetary contraints (MAH, 2011), there are side-effects. There are concerns that what happens in practice is that the company which wins the tender may not actually have the expertise all of in the above four components. By not paying the driller for dry boreholes, all the risk is passed onto them, and they must estimate the losses when they tender. Given that in many cases, the communities where the work will take place may not be identified when the driller tenders, the enterprise has to take considerable risk. Non-payment for dry boreholes means that there are no incentives for submitting drilling records.

A further unintended consequence of non-payment for dry boreholes is that the drilling enterprise has no incentive to drill deeper in case of a borehole which has potential to be highly productive, and could later be upgraded to a small piped water supply system. As long as the minimum yield can be realised, the driller will stop.

While some borehole siting is professionally done, others use divining (sorcerie). Past drilling records are difficult to obtain. Some companies have good equipment, but poor technical know-how; some lack a compressor to do proper well development. Due processes are not always followed, but there are currently no effective sanctions for the drillers or DREAHA for poor performance nor are there rewards when they perform particularly well.

The drilling market appears to be quite fragmented, particularly with small contracts at the commune level. Further work could be undertaken to study the way in which boreholes are bundled into lots, and how the variation of drilling conditions and geographic areas affects drilling costs.

3.6 Handpumps

UNICEF used to import handpumps directly from certified factories in India. This is no longer the case, and there are a number of suppliers, mainly in Ouagadougou, who sell on to the drilling enterprises. Six types (India Mark II, Vergnet, Diacfa, Volanta et Cardia) are used in Burkina Faso, but apparently the current preference is for India Mark II and Vergnet. India Mark II is not protected by a production license and there are all levels of quality on the market.

There are major concerns of poor quality, and counterfeit pump components on the market in Burkina Faso. Government has started to take steps to address this issue but is seeking advice on how to ensure the quality of stainless steel pump rods and rising mains.

The country should develop quality insurance mechanisms regarding the quality of India Mark II handpump materials, and condition license delivery for the producer to such mechanisms.

3.7 Consolidating knowledge

The *Centre National de documentation de l'Information d'Eau* (CNIEau)[27] gather together all drilling data.

Regarding hydrogeological data, the PAGIRE[28] is planning a series of studies to improve the monitoring and to consolidate the knowledge of groundwater resources. There is a database compiling boreholes technical data (drilling date, type of pumps installed, depth of the borehole, static level, flow, gradient, maintenance schedule). But this database only contains data for 17,850 boreholes (Nikiema, 2016), which is fairly low compared to the 45,000 boreholes currently identified in Burkina Faso. There is room to improve data consolidation.

There are also concerns that of a lack of technical competency to properly classify the drilling samples when preparing the technical data sheets.

There are no regional hydrogeological maps.

Supposedly four copies of the technical data sheets (box 2) should be prepared: one remains with the drilling enterprise, and the other three should be submitted to the DREAHA, and other agencies. The audits found that only 49% and 63% of the drilling records were available for 2013 and 2014 respectively. The extent to which NGOs conform to the requirements is not clear.

[27] National Centre for Documentation of Information on Water

[28] Management Plan for Integrated Water Resources Management

Box 2 The IOTA data sheet : Installations, Equipment, Construction Works and Activities

Décret No 2005-187/PRES/PM/MAHRH/MC

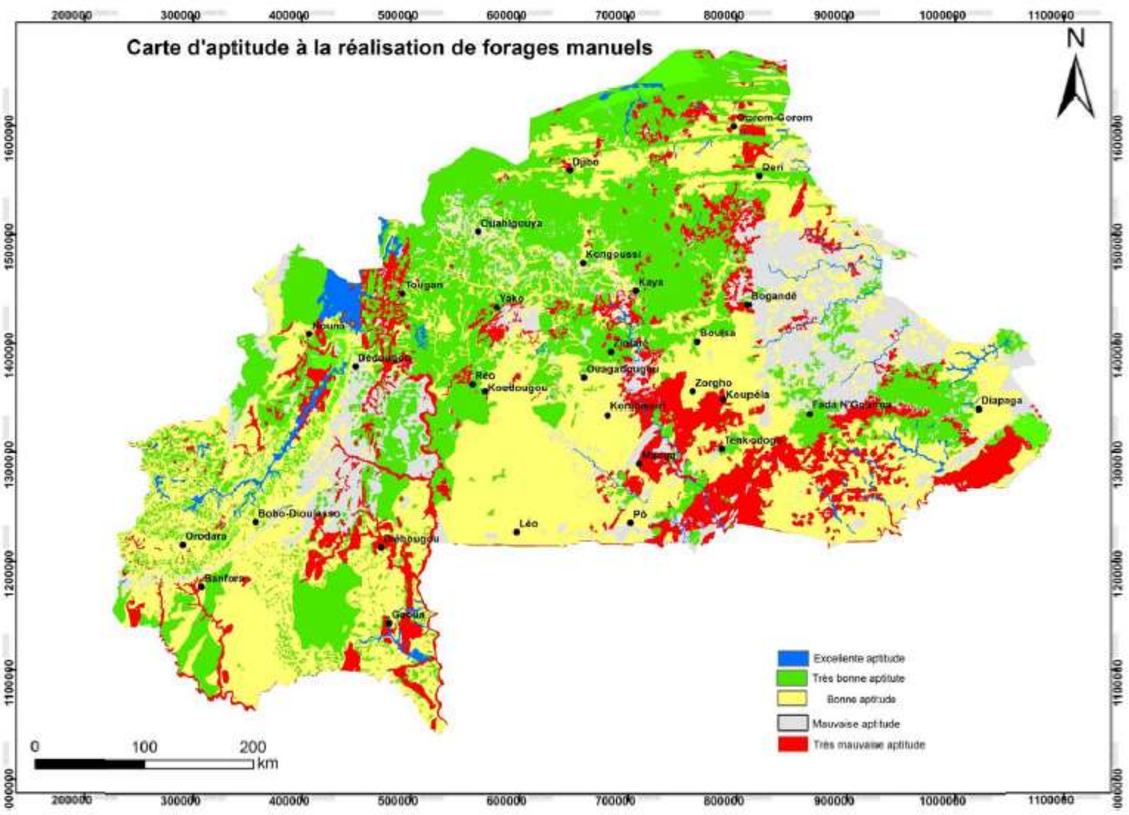
The data sheets provide information on the type of work, its construction date, the ID of the construction team, funding, sketch, localisation, water source. Similarly so for rehabilitation. These IOTA data sheets are centralised and processed by the database section for analysis and diffusion.

3.8 Manual drilling

The subject of manual drilling was beyond the scope of the study. In some parts of the country, manual drilling can provide a more cost-effective alternative than mecanical drilling. The recent study by Nikeima (2016) indicates that there are considerable parts of the country with excellent, or very good potential for manually drilled wells.

Manual drilling has the potential to considerably reduce the costs of domestic water supply in the country, provide services in areas that cannot easily be reached with mechanised drilling and even be affordable for some users themselves. Uptake of manual drilling technology can also provide work for small and micro-enterprises, to boost the local economy. However, without considerable support to ensure that drillers are trained, and efforts are taken ensure that quality standards are maintained, there are no guarantees that quality standards will be maintained.

Figure 7 : Carte d'aptitude aux forages manuels



Government is interested in lower cost options, and in new technology, but has concerns about water quality of manual drilled wells. UNICEF plans to undertake a study which compares the quality of boreholes installed with rope pumps with that of standard handpumps to improve the understanding in the sector.

4 Code of Good Practice for Drilling

The MEA recognises the need for document which sets out the norms and standards, procedures, as well as roles and responsibilities required in order to ensure the provision of quality handpump boreholes. In 2009 UNICEF and Skat Foundation supported an assignment by a two-person consultancy team to develop a code of conduct. A report, including a draft code of conduct was prepared but the work was not followed up and the draft code of conduct was never finalised, nor applied. Although the findings of the study were appreciated by the ministry at the time, it was noted by the consultants themselves the mission was too short, and too one-off to have a real chance of making a significant impact.

In contrast, this time there is much more interest in the issue, as evidenced by the actions that the ministry is already undertaking. Secondly, the consultation process comprising interviews and group discussions has been undertaken by a team comprising DGEP, UNICEF and a consultant.

An outline table of contents for a Code of Conduct is set out below. A key issue that needs to be considered is the extent to which it should include social, as well as technical aspects. The code of practice also needs to be in line with several decrees including, but not limited to:

- Decree N°2005-187/PRES/PM/MAHRH/MC – The IOTA data sheets
- Decree N°2008-0173/RES/PM/MEF – Most favourable bid
- Decree N°2007-0243/PRES/PM/MEF – The right to appeal to the Public Tendering Regulatory Authority
- Decree N°2000-514/PRES/PM/MEE – The management of water infrastructures
- Decree N°2008/00001/PRES/PH/MAHRH – Construction standards
- Decree N°2007-484/PRES/PM/MAHRH/MATD/MECV/MFB – Rehabilitation standards

Box 4 Good Practice Code for Drilling and Rehabilitation – Table of contents

Introduction (with a programme cycle)

Descriptions of roles and responsibilities of

1. Community
2. Regulatory authority
3. Contracting authority/client (DREA, Municipality or NGO)
4. Siting manager
5. Controller
6. Supervisor
7. Companies (or agencies) in charge of drilling, apron and overground construction, and pump installation works

8. Agency in charge of water quality testing and analysis
9. Regional technical support
10. Monitoring agencies
11. Funding partners
12. Agency in charge of the hydrogeological database

Finance, logistics and human resources

- National
- Regional
- Local

Types of contracts and their implications

- Read-to-use
- Non-payment of negative boreholes
- Ready-to-use and non-payment of negative boreholes
- Payment – billing according to actual quantities

Article 1 : Planning and Coordination

- Regional
- Local

Article 2 : Companies and professional agents

- incl. drilling companies' licenses, engineering consultants, pump manufacturer
- Process to appeal in case of poor quality

Article 3 : Selection and animation of the communities

Article 4 : Diagnostic for rehabilitation and the selection of the appropriate technology

Article 5 : Tendering

- Pre-qualification
- Tender for drilling, apron, above-ground installations, pump installation and control

Article 6 : Contract management

- Norms and standards
- Technical data sheets

Article 7 : Execution, Supervision and Control

- Deliver the gravel pack and pumping materials on site prior to the works
- Control
- Supervision
- Design adjustments, for instance take into account the depth of the borehole when choosing the HPs (or solar pumps) in order to facilitate their installation

Article 8 : Water quality check for consumption

- Water quality control
- Official decision to start operating the water supply system

Article 9 : Hand-over

- Technical data sheets : allowing for adequate work control by filling and sending in the technical data sheets and the completion reports
- Correct non-compliances before the final hand-over of drinking water supply systems

Article 10 : Reporting and transparency

- Numbering system for the works
- Technical data sheet
- Completion report
- Regional reports
- National report

Article 11 : Hydrogeological database

- Technical data sheet quality control

Article 12 : Monitoring

Annexes

1. SITING REPORT
2. BOREHOLE – NORMS AND STANDARDS
3. APRON AND OVERGROUND WORKS - STANDARDS
4. PUMP – STANDARDS
5. EXEMPLAR DRILLING CONTRACT
6. EXEMPLAR APRON AND OVERGROUND WORK CONTRACT
7. EXEMPLAR PUMP INSTALLATION CONTRACT
8. FORMAT OF TECHNICAL DATA SHEET
9. FORMAT OF COMPLETION REPORT
10. WATER QUALITY PARAMETERS
11. FORMAT OF PRE-HAND-OVER FORM
12. FORMAT OF HAND OVER FORM
13. COMPLETION CHECKLIST
14. CONTROL CHECKLIST
15. SUPERVISION CHEKLIST

5 Recommendations – Provisional Road Map

1. **Dialogue:** establish a regular exchange between the private sector and government, and NGOs and Government – in progress.

2. **Private companies – study of technical agreements and capacities:** undertake an inventory of the technical, human and financial capacity of all water well drilling companies, NGOs that drill directly and consultancies operating in the country and study the effectiveness of existing processes and finances to regulate the water well drilling industry.

3. **Public sector capacity:** undertake a detailed capacity analysis of national, regional and communal capacity with respect to the management and supervision of water well drilling as required by the AN-AEPA, to support the communes and for other projects.

4. **Benchmark prices:** prepare a set of benchmark prices for siting, borehole drilling, the superstructure and pump installation that consider variations in location, hydrogeology, drilling and installation depth, pump type and size of contract package and share this with the PTF and relevant government entities.

5. **Calendar:** initiate high-level political dialogue in government and with donors to discuss the effect of the annual financial cycle on the short drilling season and construction quality and seek ways to improve this.

6. **Types of contracts:** review options for water well drilling contracts appropriate for different scenarios (including turn-key contracts) and funding conditionality's (including fixed annual targets).

7. **Handpump quality:** undertake a detailed study of the quality of handpump components in the country in collaboration with the *Agence Burkinabé de Normalisation*[29](ABNORM).

8. **Use of drilling and hydrogeological data**: Establish and popularise the chain of reporting for drilling records so that they are collated centrally and can be accessed easily and free of charge.

9. **Code of practice (I):** develop and popularise a national code of conduct for effective water well drilling and rehabilitation which includes roles and responsibilities, checks and balances and implementable sanctions.

10. **Code of practice (II):** disseminate the national code of conduct through popular versions and using TV, radio, newspapers and online media.

11. **Capacity strengthening (I):** develop the outline content and shape of a set of training and mentoring programmes for technical and managerial staff in the public and private sector involved in siting, drilling, control and supervision as well as procurement and contract management.

12. **Capacity strengthening (II):** raise funds to develop and run the above training and mentoring programme on an annual basis for at least three to five years.

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Annex 1 Groundwater quality in Burkina Faso

Parameter	Issues	Source of information
pH	pH is a useful indicator of corrosion. < 6.5 will lead to the corrosion of galvanised pump parts. *Can be measured in the field.*	• 72.8% of the Burkina Faso lies on acidic rocks, and 10.5% is on intermediate rocks. Thus 83.3% of the country is on rocks that produce aggressive groundwater, with a pH < 7 (Langenegger, 1994).
Turbidity	Turbidity reduces the effectiveness of disinfection and turbid water is less acceptable to consumers from an aesthetic viewpoint *Can be measured in the field.*	• Turbidity values are usually below 1 NTU (nephelometric turbidity unit) but groundwater pumped from handpumped equipped wells can have higher turbidity than the original groundwater due to the presence of suspended corrosion products, mud entering the well due to defective aprons, improperly designed pumps (Langenegger, 1994) or poorly developed wells
Iron	Stains clothes and food, water may have a metallic, or bloody taste. Iron-rich water is often rejected by users. *Tests for iron must be performed immediately after sampling, or the sample may be acidified for testing later.*	• Iron is generally in very low concentrations in aquifers (Langenegger, 1994) • A high iron concentration is quite common in pumped groundwater because of handpump corrosion (Langenegger, 1994) • Some groundwater from shallow lateritic sources is noted to have high concentrations of iron (UN, 1998) and kigh iron (and manganese) may occur round areas of sulphide mining and mineralisation. (BGS and WaterAid, 2002)
Salinity[30]	Salinity is an important factor in taste, which affects user acceptance[31]. High electrical conductivity (>500µS/cm) leads to higher rates of bimetallic corrosion.	• Generally low mineral content, but variable salinity in samples from the north-west (Groen, 1998) • Salinity variations of sedimentary formations along north-west and northern border not known (BGS and WaterAid, 2002)
Fluoride		• Results from similar formations in granites and some meta-igneous horizons in the Birimian basement in Ghana suggest that areas of granite and other basement areas could have high fluoride concentrations, which would be tapped by tubewells (BGS and WaterAid, 2002)

[30] Electrical conductivity (EC) is measured to indicate the ions dissolved in water, which are about proportional to the amount of dissolved matter. EC is not a good indicator of water quality with regard to health hazards, but it is an indicator of salinity.

[31] The WHO guideline value for Total Dissolved Solids (TDS) in drinking water is 1000mg/l (EC of about 1,400µS/cm), which is close to the acceptance threshold for inhabitants of the Sahel areas of the West African sub-region, but is far above the acceptance levels of the forest zones.

Parameter	Issues	Source of information
Arsenic	High arsenic concentration in drinking water causes chronic arsenicosos, known as blackfoot disease.	• One case of high arsenic concentration close to Mogtedo in central Burkina Faso[32] (Jong and Kikeitta, 1981); high concentrations found in three boreholes (Appelo and Postma, 1993: 248) • High concentrations can occur in the Birimian rocks and are likely to be concentrated in and around the gold mineralised areas (BGS and WaterAid, 2002).
Iodine	Inadequate iodine from water leads to iodine-deficiency is dietary iodine supplements are not used (BGS and WaterAid, 2002)	• As the country is arid, and remote from maritime rainfall, iodine inputs from the atmosphere are likely to be low. This, combined with the hard rock geology of the region means that iodine concentrations in groundwater, soils and crops are likely to be low.
Nitrogen species (Nitrate, nitrite and ammonium)	Nitrate, nitrite and ammonium are classic indicators of organic pollution[33]. Iron bacteria (biofilm) can produce ammonium and nitrite and so under corrosive conditions, ammonium and nitrate cannot be considered classic pollution indicators. Excessive levels of nitrate can cause methemoglobobinemia in bottle-fed infants (blue babies) and certain forms of cancer may result from very high levels of nitrate concentrations.	• Ammonium and nitrite concentrations in groundwater are generally less than 0.1 mg/l and 0.01 mg/l, but excessively high concentrations can occur in groundwater pumped from wells equipped with corrosion affected handpumps. Here the presence ammonia and nitrite is an indication of the microbiological process of iron bacteria in connection with corrosion. • Groen *et al* (1998) found high nitrate concentrations greater than 10mg/l in 15% of 168 tubewell samples and 36% of 123 water wells. Nitrate concentrations were highest in areas with increased housing density elevated in areas in groundwater downgradient. High nitrate concentrations are likely to be a feature of shallow groundwaters in many areas of the country.

[32] Mogtedo is situated 60km east of Ouagadougou.
[33] Notably in the case of non-corrosion resistant hand pumps, nitrate may be decomposed though denitrification and thus not be a valid indicator of organic pollution.

Parameter	Issues	Source of information
Bacteria	Faecal contamination is a serious problem as it means that there is potential to contract diseases from pathogens[34].	• Well location, construction and condition, as well as the type and condition of the handpump and hydrogeological conditions can affect bacteriological quality Langenegger (1994) • According to the large scale study by De Lorenzi and Volta (1984), quoted in Langenegger (1994) the bacteriological quality of drilled wells with handpumps in Burkina Faos is better than that of concrete-lined large-diameter dug wells, which is better than that of traditional dug wells without lining. • Even if water is unpolluted at source, inappropriate transport and storage can lead to its contamination by the time it is consumed. Providing hygiene education to ensure a safe water chain is extremely important.

[34] Total coliforms include bacteria that are found in the soil and human or animal waste; faecal coliforms are considered to be present in the gut and faces of warm-blooded animals and so is considered a more accurate indication of animal or human waste than total coliforms.
Escherichia coli (E. coli) is considered to be the species of coliform bacteria that is the best indicator of fecal pollution and the possible presence of pathogens.

Annex 2 A Short introduction to corrosion

Background

Corrosion is the attack of the surface of materials by chemicals. Ferrous materials such as mild steel and galvanised iron can corrode, but concrete, glass, plastic and other materials can also corrode (Langenegger, 1994). Corrosion is the process of oxidation of metals, whereby they are returned to their natural state. There are three types of corrosion, all of which are oxidation-reduction (redox) processes as follows:

- Chemical corrosion – metal is in contact with oxidising constituents (e.g. oxygen, hydrogen, carbon dioxide).
- Electrochemical corrosion – the classic example is bimetallic, or galvanic corrosion, which occurs when two different metals are electorally connected and in contact with an electrolyte-
- Physico-chemical corrosion is caused by a combination of physical and chemical effects.

Corrosion can be greatly influenced by biological processes, especially the microbiological activity of iron bacteria.

"…it is evident that the complex phenomenon of corrosion is governed by such a variety of chemical, physical, biological and metallurgical factors that a universal approach and solution is not possible. Equally evident is the well-recognised fact that no universal index exists for predicting corrosion in all types of water systems and for all water quality conditions" (AWWA-DVGW, 1985)

Langenegger (1994) describes the most common forms of electrochemical corrosion which correspond to a galvanic element comprising an anode, a cathode, and electrical connection between them, and an electrolyte. In summary:

- Uniform corrosion is a relatively even attack on the metal surface. It mainly occurs on rising mains of handpumps, often combined with pitting.
- Pitting, or local attack is the local concentration of corrosion, either in very little spots or over relatively large areas. It occurs when anoidic areas as stationary, and can be caused by imperfections of the materials, high oxgen or chloride concentrations, stray currents and damaged protective surface layers. Pitting can develop rapidly, and can result in perforation.
- Galvanic of bimetallic corrosion occurs where two dissimilar metals are electrically connected and in contact with an electrolyte, such as a galvanised iron pump rod with a brass pump cylinder. The corrosion rate is very much lighter than that of electrochemical corrosion.

- Crevice and concentration cell corrosion develops easily in crevices and under rivets and bolts.
- Intergranualar or Intercrystalline corrosion only occurs at the interfaces of crystals, and is observed in stainless steel.
- Stress-Corrosion Cracking can develop in any metal under tensile[35] stress in a corrosive environment. It can lead to intercrystaline cracking (along the interface of the crystals) and transcrystalline cracking (through the crystals). Stress corrosion cracking may affect pump rods, particularly those under high tensile stress in deep pump installations. It characteristically result in shapeless cracking, which is typical of rod breakages.

Handpumps

In galvanised rising mains exposed to corrosive groundwater, three different zones can usually be distinguished (a) no corrosion on the part of the pipe that it above the water level; (b) slight corrosion in the part occasionally submerged in water and (c) heavy corrosion in the part always covered by water, covered by a red-brown biofilm.

Galvanization of iron is undertaken to protect it from corrosion. The quality of the galvanisation is very important, and this has led to specifications for the galvanisation of pipes. The standard for galvanized coating on rising mains and pump rods is a layer of zinc 60-70µm thick.

Field observations indicate that under moderately to highly corrosive groundwater conditions (pH<6.5), that the quality of galvanisation does not have a significant impact on the resistance of the handpumps and rising mains to corrosion. Langenneger (1994) found that the galvanisation of rising mains exposed to groundwater with a pH~6 was eaten away within approximately three to six months.

Pump rods are particularly vulnerable to corrosion. This is typically caused by galvanic corrosion, which occurs if the pump rods are made of galvanised iron and the pistons are made of brass.

Determining the source of iron in groundwater through testing

In order to determine the source of iron (i.e. is it due to corrosion or does it occur naturally) pump the well continuously and measure the change in iron concentration over time. If the iron concentration decreases rapidly within a few minutes of pumping, the main source is corrosion. In order to obtain reliable results, samples must be tested immediately after sampling the well site, or be preserved by acidification.

Corrosion effect on other parameters

[35] i.e. being pulled

Handpump corrosion affects not only iron, but also manganese, zinc, ammomuim, nitrite, pH, free carbpn dioxide, dissolved oxygen, alkalinity, and possibly other factors that affect water quality. The extent of effects depends on the corrosiveness and the natural composition of the groundwater.

Corrosion Products

Langenegger (1994) found that then rising mains and pump rods are in contact with water, they are generally covered with red-brown mud, known as a biofilm. This corrosion product is made up of iron, zinc, calcium, magnesium, potassium, sodium and aluminium as well as silica and organic matter from iron bacteria. The corrosion products range from very soft crusts (sometimes with a powdery texture) to hard crusts with a wide range of mixtures between the two. Whereas a very soft crust can be considered a typical biofilm, the hard crust is a protective coating. External surfaces of galvanised rising mains tend to be covered with biofilm which has a powdery structure when dried. In cases where the ph>6.5 and the conductivity was greater than 300µs/cm, the internal rising mains had a protective coating.

Annex 3 Agenda

DATE	ACTIVITIES	LOCATIONS	WITH WHO ?
Monday 20	Meetings at the UNICEF office	Ouaga	WASH Section
Tuesday 21	Meetings with the DGEP	Ouaga 2000	DGEP Team
Wednesday 22	9H-10H: Attending the PTF meeting 10h-13h : Interview with AN-SEPAB 13H : Departure to Fada for fieldwork	Ouaga	PTF DGEP UNICEF
Thursday 23	Interview of the DREA of Fada N'Gourma Site meeting on a drilling construction site Visit to a drilling site (Bougoui Village, Fada Community)	Fada	DGEP UNICEF DREA
Friday 24	Travel back to Ouaga	Ouaga	
Saturday 25	Office work		
Monday 27	Meeting at the UNICEF office Departure to Bobo-Dioulasso	Bobo-Dioulasso	
Tuesday 28	Interviews of Bobo-Dioulasso stakeholders (DREA) Peni townhall	Bobo-Dioulasso Peni	DGEP UNICEF DREA Municipalities
Wednesday 1st of March	Return to Ouaga	Ouaga	DGEP UNICEF DREA Municipalities
Thursday 02	Interviews of stakeholders	Ouaga	
Friday 03	Interviews of stakeholders	Ouaga	
Saturday 04	Office work		
Monday 06	Debrief meeting - UNICEF	UNICEF	DGEP, DNMP, DESS, PTFs
Tuesday 07	Office work		
Wednesday 08			
Thursday 09	Interview of 2IE Debrief meeting		
Friday 10	End of the country mission		

Annex 4 Contacts

	Surname & first name	Organisation	Function
1	Ye Dofihouyum	DGEP	DG
2	Bonkoungo Stanislas	DGEP	AT
3	Balima Amadou	DAEP	Agent
4	Somda V.H. Romaric	DGEP	DAEP
5	Zombre Adama	DGEP/DAEP	Geologist
6	Compaore Maurice	DGEP	Agent
7	Traore Alassane	DGEP	Agent
8	Rouamba Faizatou	DGEP/DAEP	Agent
9	Coulibaly Korotoumou	DGEP/DAEP	Agent
10	Jean Paul Ouedraogo	UNICEF	Adm. Programme
11	Daniel Spalthoff	UNICEF	Head of WASH
12	Boureima Compaore	AN-SEPAB	President
13	Aboubacar Zougouri	DANIDA	WASH officer
14	Yamba Ouibiga	GIZ	
15	Justine Denis	Agence Français de Development (AFD)	
16	Ouedraogo/Tapsoba Christine	Directrice	DREA (East)
17	Lassana Traore	SIDEV	Hydrogeologist DG
18	Ahmed Traore	Hydrass-Burkina	DG
19	Ouedraogo Boureima	DREA	
20	Nonguirma Edmond Paligende		Civil engineer/GETIA
21	Karambiri Alassane	Karal International Sarl	Director
22	Zanne Mamatou	Mairie de Peni	SG
23	Coulibaly Bakali	Mairie de Peni	Water adviser
24	Sawadodo Lucien	DREA/HBS	
25	Tiendrebeogo Colette/Nakelse	DREA/HBS	
26	Bonkoungou Ousmane	DREA/HBS	Director
27	Bourahima Ouedrago	DGESS/ MEA	CEO
28	Rouamba Marou	DMP/MEA	
29	Sisibe Abdilaziz Landry	DAF/MEA	
30	Suhas Cuncham	Saira International	Administrator
31	Issah Ouedrago	WaterAid	
32	Ouedraogo Bourima	Temfor	
33	Moulaye Coulibaly	*[Enterprise de forage]*	
34	Koita Mahamadou	2iE	Researcher
35	Prof. Dr. Ir. Hamma Yacouba	2iE Génie Rural/ Hydraulique Agricole	Head of Research