

Review

Striving for Borehole Drilling Professionalism in Africa: A Review of a 16-Year Initiative through the Rural Water Supply Network from 2004 to 2020

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Abstract: Drilled boreholes are vital to achieving universal, safe drinking water and meeting Sustainable Development Goal (SDG) 6.1, particularly in Africa. Poor quality siting, borehole design, drilling and completion lead to premature failure of the water supply. From 2004 to 2020, a multi-stakeholder initiative through the Rural Water Supply Network (RWSN) has endeavored to raise the professionalism of borehole drilling and its management in Africa. The initiative comprised in-country and desk studies, training, and the development of guidelines, manuals, training materials, short animated films for advocacy as well as using blogs, webinars and online communities of practice to share experiences. The initiative was funded to approximately USD 750,000 in total. Funding was fragmented throughout, but the initial support by the World Bank Water and Sanitation Programme Africa (WSP-AF), consistent leadership and subsequent partnerships between Skat Foundation, United Nations Children’s Fund (UNICEF), WaterAid UK and others enabled progression on the topic, as well as innovation and opportunities to be harnessed. The initiative has raised the profile of drilling professionalism, provided a wealth of materials and inspired others to take action. Thousands of stakeholders have improved their knowledge. Academic research on the topic has also increased and capacity strengthening of groundwater management and professional drilling is now an action area for the African Ministers Council on Water (AMCOW). UNICEF and WaterAid are among the organizations that have made changes to procurement and project management as a result of the initiative. Despite a growing recognition of the importance of drilling professionalism, reliable, long-term investment in in-country training and professional development, and addressing challenges in the institutional environment remains inadequate. Despite the importance of water well drilling, and commitments to SDG 6.1’s, capacity strengthening in this area remains a marginal issue for national and international political leadership, and arguably for international funding agencies.

Keywords: drilling; boreholes; water supply; private sector; supervision; partnership; UNICEF; networking

1. Introduction

Drilled boreholes are vital to achieving universal, clean drinking water and meeting Sustainable Development Goal (SDG) 6.1, particularly in Africa. Reliance of the African population on groundwater is high, with over 75% of the population estimated to depend on it [1]. Water well drilling is extremely important to assure drinking water access in Africa, and professionalism is needed to ensure that boreholes are of high quality. Poor quality siting, borehole design, drilling and completion, inadequate supervision and inappropriate contracts can lead to premature failure of the water supply [2–6]. Despite its strategic importance, the practical realities of borehole drilling provision

in Africa, including the driller skills, siting, supervision, drilling standards, drilling procurement and contract management, drilling professionalism and drilling regulation have been neglected by academic research, although there is recent research on the underlying causes of borehole failure, as noted above.

The subject has also remained marginal to key global organizations with groundwater mandates. A case in point is the United Nations Educational, Scientific and Cultural Organisation (UNESCO)-International Hydrological Programme (IHP) Groundwater Portal [7], supported by the International Groundwater Resources Assessment Centre (IGRAC) in which a search for the term ‘transboundary’ provides 70 results and ‘climate’ provides 38, whereas the terms ‘drilling’ and ‘borehole’ each provide two results. The term ‘drilling’ is only mentioned once and ‘training’ or ‘skill’ is not mentioned at all in the ‘Shared global vision for Groundwater Governance 2030 and A call-for-action’ [8] published by the Food and Agriculture Organisation (FAO) in 2016.

Between 2004 and 2020, a multi-stakeholder initiative through the Rural Water Supply Network (RWSN) has endeavored to raise the professionalism of borehole drilling and its management, with a focus on Africa, and to document manual drilling experiences. The term professionalism has been defined by RWSN as “the skill, good judgment, and behavior expected from a person or organization who can undertake a job well” [9]. This review is the first systematic collation and analysis of the initiative activities, outputs, methods, outcomes, impact and learning. It is important to note that the applied, rather than academic nature of the initiative has generated considerable knowledge in the form of reports (grey literature) rather than academic manuscripts.

Given the lack of academic research on drilling professionalism in Africa, and relative lack of attention by global agencies with a groundwater mandate, this review provides an important comprehensive overview of the applied work that has been undertaken. The RWSN initiative has generated over 50 (grey) publications including guidance documents and country studies, hosted more than 20 webinars and 25 blogs, produced four animated films alongside in-country engagement and exchange at three international conferences. While the RWSN initiative has reached hundreds of professionals in over 50 countries in the process, it has not been published in the academic sphere. This review thus brings this practical experience of the initiative and information generated to academia.

The review covers the period from 2004 to 2020. Its scope is limited to the process, key milestones of the initiative and core areas, rather than a content analysis of publications. The review sets out how the initiative evolved over time, and compiles the publications, partnerships and funding mechanisms, as well as linkages to related efforts. It also provides an overview of how the initiative contributed to wider outcomes and impact in relation to drilling professionalism. The review examines how the understanding of the topic and the partnerships changed and adapted over time. It provides insights into the under-researched topic of drilling professionalism and the challenges faced today.

The study design comprised a desk review of all relevant RWSN and partner publications on the subject as well as relevant evaluations, internal reports, published annual reports, websites, webinar recordings, and related academic and grey literature. The review is enriched by insider knowledge of the initiative by the authors.

2. Initiative Chronology

2.1. Initiative Launch

A global network of handpump experts, entitled the Handpump Technology Network (HTN), was formed in 1992 [10]. Under the leadership of the Water and Sanitation Programme (WSP) of the World Bank, HTN was transformed into the Rural Water Supply Network (RWSN) in 2004 [10]. The remit of the network was broadened to include three new ‘flagships’, one of which set out to address the perceived problem of high borehole costs compared to the low cost of pumps, an issue that has been raised at the United Nations Development Programme (UNDP)-World Bank International Handpump Workshop in 1992 [11].

2.2. From Flagship, to Theme to Topic

Initially named ‘low-cost drilling’, the flagship was supported by WSP which, in 2003, had financed a study on how to reduce drilling costs [12] and, in 2005, contracted a then Ugandan-based consultant to lead the new flagship. The young professional brought in the topic of manual drilling; in other words, technologies that drill boreholes relying primarily on human energy, rather than fuel operated rigs and compressors. Recognizing that ‘low-cost drilling’ could be conflated with manual drilling, yet the flagship was broader in scope, and recognizing that ‘low-cost’ could be misunderstood as cheap and even low quality, the flagship was renamed ‘cost-effective boreholes’ in 2005.

With the launch of a new RWSN strategy in 2012, the borehole drilling work became part of the theme entitled ‘Sustainable Groundwater Development for Rural Water Supplies’ [13]. In 2018, it was renamed ‘Professional Water Well Drilling’, which is one of a broadened scope of topics covered by RWSN.

2.3. Phases of Activity, Core Partners and Leadership

Retrospectively, the initiative comprised a foundation phase (2004–2006), followed by five phases: (I) Cost-effective Boreholes (2007–2008); (II) Code of Practice for Cost-Effective Boreholes (2009–2014); (III) Professional Manual Drilling (2013–2014); (IV) Professional Drilling; (2015–2017) and (V) Strengthening UNICEF and Partner Capacity to Raise Professionalism of Drilling and Drilling Management (2017–2020). Table 1 provides a timeline of these six phases, noting key milestones that were undertaken within RWSN and those that were undertaken by others, but were influenced by, or influenced the RWSN initiative.

Table 1. Timeline of Rural Water Supply Network (RWSN) professional drilling/manual drilling initiative with key activities and milestones.

Phase	RWSN Professional Drilling/Manual Drilling Activity or Milestone	Year	Related Activity, Milestone or Outcome
n/a		2003	<ul style="list-style-type: none"> UNDP-World Bank study on drilling costs in Kenya [11].
Foundation	<ul style="list-style-type: none"> Flagship: ‘Low Cost Drilling’ launched Publication: <i>Solutions for Reducing Borehole Drilling Costs in Africa</i> [12] 	2004	
	<ul style="list-style-type: none"> Flagship named ‘Cost-effective boreholes’ Study & Publication: <i>A brief history of hand drilled wells in Niger: Only the Beginning</i> [14] Study: <i>Review of Borehole Drilling in Tanzania</i> [15] 	2005	
	<ul style="list-style-type: none"> Study: <i>Cost-effective boreholes-Ethiopia</i> [16] Publication: <i>Who is going to drill the African Boreholes</i> [17] Publication: <i>Ten-step guide towards cost-effective boreholes</i> [18] Dissemination & sharing: 4th RWSN Forum in Ghana including face-to-face exchange between drillers (of mechanized and manual equipment) 	2006	<ul style="list-style-type: none"> WSP Assessment of drilling sector capacity in Mozambique [19]

Table 1. Cont.

Phase	RWSN Professional Drilling/Manual Drilling Activity or Milestone	Year	Related Activity, Milestone or Outcome
I—Cost-effective boreholes	<ul style="list-style-type: none"> Dissemination & sharing: Online hand drilling cluster group & newsletter [20] Study: <i>Nigerian drilling environment and establishing a drillers association</i> [21] 	2007	
		2008	<ul style="list-style-type: none"> Establishment of Nigerian Drillers Association [22] Establishment of drillers association in Mozambique [23] UNICEF reflection on its drilling practices [24]
II—Code of practice for cost-effective boreholes	<ul style="list-style-type: none"> Publication: <i>Hand Drilling—Nigeria</i> [25] Study: <i>Cost-effective boreholes in Burkina Faso</i> [26] Study: <i>Cost-effective boreholes—Ghana</i> [27] Study: <i>Cost-effective boreholes—Zambia</i> [28] Study of public and private drilling in Nigeria [29] Publication: <i>Hand Drilling Directory</i> [30] 	2009	<ul style="list-style-type: none"> Cranfield University develops borehole drilling costing model and tool [31] First maps of manual drilling feasibility published for Benin, Central African Republic, Chad, Cote d'Ivoire, Mali, Mauritania, Niger, Liberia, Madagascar, Senegal and Togo [32] - UNICEF-funded.
	<ul style="list-style-type: none"> Publication: <i>Code of Practice for Cost-Effective Boreholes</i> [33] 	2010	<ul style="list-style-type: none"> Standards Organization of Nigeria publishes Code of Practice for Water Well Drilling in Nigeria [34] UNICEF/Government of Uganda assessment of Groundwater and Capacity in Uganda [35] Publication RWSN <i>Myths of the Rural Water Supply Sector</i> [36] UNICEF launches <i>Toolkit for the Professionalisation of Manual Drilling</i> [37] Manual drilling included as a Millennium Development Goal (MDG) Good Practice by the United Nations Development Group (UNDG) [38]
II—Code of practice for cost-effective boreholes	<ul style="list-style-type: none"> Dissemination & sharing: 6th RWSN Forum in Kampala with sessions and papers on drilling professionalism [39,40] Publication: <i>Siting Water Wells</i> [41] 	2011	<ul style="list-style-type: none"> UNICEF study of drilling cost-effectiveness in Mozambique [42]
	<ul style="list-style-type: none"> Dissemination & sharing: RWSN Online Community on Sustainable Groundwater development launched [43] Dissemination & sharing: First RWSN E-Discussion on Groundwater [44] Dissemination & sharing: First webinar on the application of the Code of Practice for Cost-Effective Boreholes (see Section 4.6) 	2012	<ul style="list-style-type: none"> UNICEF study of drilling sector in Sudan [45] Publication of study on corruption in Ethiopia [46] National Water Resources Institute, Nigeria conducted trainings on Cost Effective Boreholes

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Phase	RWSN Professional Drilling/Manual Drilling Activity or Milestone	Year	Related Activity, Milestone or Outcome
II—Code of practice for cost-effective boreholes	<ul style="list-style-type: none"> Publication: <i>Synthesis—Online Discussions from RWSN Groundwater Community</i> [47] Study, Workshop & Training: <i>Cost-effective boreholes in Sierra Leone</i> [48–51] Publication: <i>Costing and Pricing</i> [52] Publication: <i>Procurement & Contract Management</i> [53] Publication: <i>Drilling Supervision</i> [54] Publication: <i>Sustainable Groundwater Development</i> [55] 	2013 & 2014	<ul style="list-style-type: none"> Schneider publishes Water Supply Well Guidelines for developing countries [56] Sierra Leone government publishes principles for borehole construction and rehabilitation [57] & Technical Guidelines for Hand Dug Wells [58] WaterAid funds training two courses in drilling supervision in Uganda [59]
III—Professional manual drilling	<ul style="list-style-type: none"> Study: Survey of Manual Drilling Experiences [60] Learning: UNICEF internal webinars on manual drilling [61] Dissemination & sharing: public webinar series on manual drilling from 12 countries [62–67] Study: <i>Manual drilling in Chad</i> [68,69] Study: <i>Manual drilling in Nigeria</i> [70,71] 	2013 & 2014	<ul style="list-style-type: none"> Open University incorporates case study on manual drilling into one of its (MSc) courses. World Vision engages with drillers association in Chad [61].
	<ul style="list-style-type: none"> Publication: <i>Manual Drilling Compendium 2015</i> [72] 	2015	<ul style="list-style-type: none"> British Geological Survey launches research into the cause of borehole failures [73] Publication of new research on water point functionality [74]
IV—Professional drilling	<ul style="list-style-type: none"> Animated films on: <i>siting</i> [75] and <i>supervision</i> [76] Drilling professionalism promoted at the World Water Week in Stockholm 2015 Keynote on Groundwater in Africa at Oklahoma WaTER conference; presentation at Emory and Mercer Universities (USA) Dissemination & sharing: <i>Webinars on professional drilling (2015–2017)</i> [77] 	2015	<ul style="list-style-type: none"> World Bank documents drilling sector strengthening in Mozambique [78] Efforts to improve groundwater governance by Kenya Water Industry Association [79]
	<ul style="list-style-type: none"> Animated films on <i>drilling procurement and contract management</i> [80] and <i>drilling</i> [81] Training: <i>drilling procurement and contract management in Zambia</i> [82] E-discussion <i>groundwater regulations</i> [83] Study: <i>Borehole drilling practices in Burkina Faso</i> [84] UNICEF/Skat publishes <i>guidance note on professional water well drilling</i> [85] Dissemination & sharing: 7th RWSN Forum in Abidjan: four sessions on drilling professionalism ¹ [86] 	2016	<ul style="list-style-type: none"> <i>Developing Groundwater</i> made available freely online [87] Government of Uganda starts registering groundwater consultants [88] Uganda Drilling Contractors Organisation is established [89] Cardiff University initiates research on private boreholes & resilience [90] Oxfam GB conducts training on Drilling Supervision in Nigeria [91] Government of Malawi issues technical guidelines and standard operational procedures for groundwater [92]

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Phase	RWSN Professional Drilling/Manual Drilling Activity or Milestone	Year	Related Activity, Milestone or Outcome
(VI and V)	<ul style="list-style-type: none"> Training: <i>procurement and contract management in Angola</i> [93] 	2017	<ul style="list-style-type: none"> UNICEF study on the drilling sector in Angola [94] RWSN Evaluation [95] WaterAid funds training courses on drilling supervision and drilling quality in Burkina Faso [96]
	<ul style="list-style-type: none"> Training: <i>short course on drilling supervision in Zambia</i> [97,98] Training: <i>first online course on professional drilling management</i> [99] Publication: <i>UNICEF Borehole Drilling Toolkit</i> [100] 	2018	<ul style="list-style-type: none"> SADC-GMI and Africa Groundwater Network run drilling supervision course in South Africa [101] Climate Justice Fund runs drilling supervision course in Malawi [102] Water Resources Institute, Uganda runs training courses on drilling & borehole construction (2018/19) [103] UNICEF Madagascar trains on drilling professionalism [104] Government of Zambia publishes statutory instruments for groundwater [105]
V—Strengthening UNICEF & Partner Capacity to Raise Professionalism of Drilling and Drilling Management	<ul style="list-style-type: none"> Training: <i>second online course on professional drilling management</i> [106] Study: <i>drilling associations</i> [107] Study: <i>Handpump corrosion in Burkina Faso and beyond</i> [108] 	2019	<ul style="list-style-type: none"> AMCOW Pan African Groundwater Programme (APAGroP) launch [109] Burkina Faso government launches road map for water construction [110] German Cooperation (GIZ) Nigeria conducts training on professional drilling [111–113] Further research on causes of borehole failure published [6,114,115]
	<ul style="list-style-type: none"> Publication: <i>Manual drilling in the Democratic Republic of Congo</i> [116] Dissemination & sharing: Overhaul of RWSN Professional Drilling [116] & Manual Drilling [32] webpages Publication: <i>Groundwater and drilling insights from over 50 countries</i> [117,118] Dissemination & sharing 2018–2020: webinars [77] and blogs [119–121] 	2020	<ul style="list-style-type: none"> APAGroP establishes action group on Capacity Strengthening for Groundwater Management and Professional Drilling WaterAid starts to review its drilling contract procedures and contract documents

¹ The forum sessions were called: Drilling and Hand-dug wells; Groundwater Resources: finding common ground; Progress in Sustainable Groundwater Development; Rock Café.

In terms of financial support (detailed in Section 3), WSP was the major international partner from 2004 to 2008. UNICEF came joined in 2008 with a study of its own drilling history and practices [24], and subsequently joined hands with the Skat Foundation in the form of five Project Collaboration Agreements (PCAs) from 2009 to 2020. The core funding of the PCAs came from UNICEF, with the Skat Foundation providing a financial contribution. Phases II to V in Table 1 are named according to the titles of the respective UNICEF-Skat PCAs. USAID provided financial support to phase II, and WaterAid provided financial support towards the phases IV and V.

2.4. The Foundation Phase

In 1998, UNICEF estimated that the cost of drilling a borehole in India was about US \$1000, whereas comparable costs in sub-Saharan Africa were US \$6000 to US \$20,000 [122]. Concerns by Handpump Technology Network (HTN) partners about this disparity, as well as the high cost of boreholes compared to the low cost of handpumps in Africa [11], alongside reflections on what privatization would mean for water well drilling [15], and questions about who would be drilling boreholes in Africa to meet the Millennium Development Goals [17] triggered the launch of the flagship on borehole drilling.

Studies of the drilling sector in Ethiopia [16] and Mozambique [19] showed that high drilling costs in Africa were not the only issue, but that drilling enterprises also faced challenges in developing their technical skills, managing their businesses and dealing with corruption. It was recognized that improving borehole drilling cost-effectiveness required consideration of technical, political, institutional

and socio-economic aspects. The Tanzania study provided insights into the difficulty and challenges involved in transiting from public to private sector drilling [15].

The Ethiopia study led to the publication of RWSN's ten-step guide to cost-effective boreholes, which defined the scope of the flagship. A study to document the history of manual drilling in Niger shed light on a successful, and growing industry, providing water for agriculture as well as domestic use. The twin tracks of unpacking what cost-effective boreholes (for mechanized drilling) means and documenting manual drilling were thus established within RWSN.

The 2006 RWSN Forum in Ghana included a focus on drilling, and with the support of WSP, brought manual and mechanized drillers from all over Africa together for a 'drillers' exchange'. The emphasis was on face-to-face sharing and building of informal networks between the drillers. The Niger delegation travelled as a group, and so the Ghana forum enabled manual drillers to interact directly with senior government officials as part of the trip—something that would otherwise not readily happen in country.

It is worth noting that, from the outset, this new RWSN flagship was conceived as a multi-year, multi-partnership initiative, rather than a one-off project although no medium, or long-term funding for this had been secured.

2.5. Phase I—Cost-Effective Boreholes (2007–2008)

WSP remained the main driving force and financier of the flagship during phase I, which was part of their support for the private sector. A study of the drilling sector in Nigeria [21] was carried out. Within this phase, WSP supported the establishment of drilling associations in Mozambique [23] and Nigeria [22]. An online hand drilling cluster group (in the form of a mailing list) was established, bringing together experts working on this topic from different countries, and a newsletter was launched to share information in an accessible manner. In 2008, WSP stopped financing the flagship leader but remained involved in country work on drilling and RWSN for some time. In 2008, Piers Cross (WSP-Africa) handed over the RWSN chair to Clarissa Brocklehurst (UNICEF Global Chief of Water, Sanitation and Hygiene).

In 2007, UNICEF Programme Division (New York) started to develop an interest in the RWSN drilling topic, with a particular question as to whether it should continue to purchase, own and manage drilling fleets/purchase for government in its country programmes, or whether it should no longer buy equipment, but rather engage the private sector more. The study of UNICEF's history of borehole drilling [24] triggered the idea of establishing clear principles for borehole drilling for its country programmes. It was decided to move UNICEF towards contracting drilling out to the private sector rather than running its own drilling fleets or supporting those of government.

2.6. Phase II—Cost-Effective Boreholes (2009–2014)

This phase witnessed a period of studies and core publications followed by a period of sharing and dissemination, followed by the publication of guidance documents and the start of face-to-face training. This phase also saw the transformation of RWSN from a hub with a central mailing list to an online network with exchange between members.

The focus of the first part of phase II was to further establish what cost-effective boreholes meant in practice [123]. Building on the 'Ten-step guide' [18] and UNICEF drilling history [24], Skat Foundation, in partnership with UNICEF and USAID undertook a series of studies on drilling cost-effectiveness in Nigeria [29], Zambia [28], Ghana [27] and Burkina Faso [26]. The studies set out to understand cost-effectiveness and fed into a global code of practice for cost-effective boreholes [33], but were also intended to establish national codes of practice in the respective countries. With the exception of Nigeria [34], where other processes were also underway, the second objective proved to be too ambitious for short, two to three-week consultancy assignments with a stakeholder workshop at the end. However, RWSN's drilling and groundwater work would return both to Zambia and Burkina

Faso in the future. Meanwhile, Uganda reviewed its drilling sector [35] and a code of practice for water well construction in Nigeria was published [34].

Beyond the initiative, Cranfield University developed a borehole drilling costing model and tool [31], which would be subsequently used and promoted by RWSN. Having promoted manual drilling in Chad, UNICEF drew on the learning from this experience, and through a collaboration (PCA) with Enterprise Works/Vita and Practica Foundation, developed a 'Toolkit for the Professionalization of Manual Drilling' [37] covering technical, business and quality assurance aspects of manual drilling.

In parallel, and independently, RWSN published a 'Hand Drilling Directory' [30] outlining drilling technologies and experiences by a number of organizations in several countries. With no more funding available to lead the theme, the hand drilling newsletter ceased in 2009 after five editions.

In 2010, RWSN issued the Myths of the Rural Water Supply Sector [36], which would become one of its the most cited publications. Of particular relevance for the drilling initiative was the inclusion of data on the proportion of non-functional handpumps for 20 selected countries. This would propel further studies, one of which, Reference [74], became central to the advocacy by the initiative for improving drilling professionalism.

RWSN's 'Code of Practice for Cost-effective boreholes' [33] consolidated the issues affecting drilling professionalisms into a set of nine principles (Table 2). The Code was launched in 2010, and paved the way for a set of guidance documents that would detail the principles set out. Over the next five years, depending on the availability of funds, guidance documents on siting [41], costing and pricing [52] supervision [54], procurement and contract management [53] and groundwater resources [55] were published. The costing and pricing publication drew extensively on Cranfield University's drilling tool [31]. Table 2 shows that, of the nine principles, seven have been detailed in subsequent guidance. Principle 3—'Construction method' was covered to some extent by the 2005 publication on reducing drilling costs [12] and manual drilling technologies provides alternatives for shallow aquifers with relatively soft formations [72]. Principle 8 has not been covered as written guidance, but the topic was covered in a webinar. Guidance on post construction monitoring of boreholes has not been published by RWSN. However, recent research by the British Geological Survey examines how to assess functionality or rural community water supplies [124].

The RWSN Forum in Kampala (2011) provided an opportunity to take stock of progress in the RWSN theme (former flagship). A competition was launched to encourage potential delegates from around the world to write about their drilling sector. Uptake was limited, but it did draw out experiences from Nigeria [39], Sri Lanka [40] and Burkina Faso [125]. The step-change that did come out of the RWSN forum was that the World Bank attended, and decided that it wanted to share some of the most interesting presentations from the forum through online webinars. Thus, in 2012, a new era of RWSN webinars began.

Meanwhile, in-house, UNICEF continued to try to better understand the drilling sector, investing in studies of drilling cost-effectiveness in Mozambique [42] and Sudan [45]. A completely independent study of corruption in Ethiopia [46] further highlighted this aspect of the cost-effective boreholes' reality.

RWSN's other change in 2012 was shifting its entire membership from a mailing list onto the DGroups platform. This transformed a dozen core members and dissemination to about 2000 people on a mailing list to becoming a network of members who could now communicate with each other and has grown to over 10,000 members. While functionality for online exchange was embedded within the RWSN website, it was hardly used. Alongside the first webinar series, managed and funded by the World Bank, RWSN came into a new age of online discussion. The online community 'Sustainable Groundwater Development' [43] was launched, and grew to a membership of over 1500 people between 2012 and 2020.

The year 2012 witnessed the first e-discussion on groundwater [44], enabling exchange, alongside a webinar on the application of the Code of Practice for Cost-Effective Boreholes (Table 4). The new era of online dissemination and sharing was born. This groundwater discussion group has remained vibrant, with many questions posted and considerable debate around hot topics. However, due to

limited resources, the most recent synthesis of the informal discussions on the group relating to borehole drilling was published in 2013 [47].

Table 2. Principles for Cost-Effective Boreholes and Subsequent Guidance through the RWSN Initiative.

No	Topic	Principle	Guidance
1	Professional Drilling Enterprises and Consultants	Construction of drilled water wells and supervision is undertaken by professional and competent organisations which adhere to national standards and are regulated by the public sector.	Partly [54]
2	Siting	Appropriate siting practices are utilized and competently and scientifically carried out.	Yes [41]
3	Construction Method	The construction method chosen for the borehole is the most economical, considering the design and available techniques in-country. Drilling technology needs to match borehole designs.	Partly [12,72]
4	Procurement	Procurement procedures ensure that contracts are awarded to experienced and qualified consultants and drilling contractors.	Yes [52,53,100]
5	Design and Construction	The borehole design is cost-effective, designed to last for a lifespan of 20 to 50 years, and based on the minimum specification to provide a borehole which is fit for its intended purpose.	Yes [100]
6	Contract Management, Supervision and Payment	Adequate arrangements are in place to ensure proper contract management, supervision and timely payment of the drilling contractor.	Yes [52,53]
7	Data and Information	High quality hydrogeological and borehole construction data for each well is collected in a standard format and submitted to the relevant government authority.	Yes [100]
8	Database and Record Keeping	Storage of hydrogeological data is undertaken by a central Government institution with records updated and information made freely available and used in preparing subsequent drilling specifications.	
9	Monitoring	Regular visits to water users with completed boreholes are made to monitor functionality in the medium as well as long term with the findings published.	

Inspired during the 2011 RWSN Forum in Kampala, RWSN was approached by a Department for International Development (DFID)-funded programme to bring the Code of Practice work into efforts to strengthen the rural water supply sector in Sierra Leone. The subsequent work (2012 to 2014) in Sierra Leone was the most concentrated effort by RWSN on the topic of borehole drilling within one country. In addition to stakeholder consultation and a study of the drilling sector [50], three one-week face-to-face training courses were developed and run (siting, procurement/contract management and supervision [48,49,51]).

The training courses were developed from the RWSN guidance documents (Table 2). As a direct result of RWSN's work in Sierra Leone, in 2014, the government published Principles for Borehole Construction and Rehabilitation in Sierra Leone [57].

Sierra Leone arguably became the second sub-Saharan country, after Nigeria in which the government published how boreholes in the country should be drilled. Parallel to this development, WSP supported the publication of Technical Guidelines for the Construction and Maintenance of Hand Dug Wells in Sierra Leone [58].

2.7. Phase III—Professional Manual Drilling (2013–2014)

Phase III overlaps with phase II because, while DFID supported the work in Sierra Leone, UNICEF re-focused its interest in RWSN to manual drilling. Almost four years after the launch of UNICEF's manual drilling toolkit [37] and subsequent promotion of manual drilling in more than

25 countries [126], UNICEF was keen to learn from its experiences and reach out further. Manual drilling had remained a topic of interest for RWSN (although essentially dormant due to lack of funding). The PCA between UNICEF and Skat Foundation brought about more on-line exchange, and improved the methods for working with UNICEF country offices, influencing subsequent work.

Phase III focused on learning about manual drilling in various countries and sharing experiences. A series of five webinars, the second RWSN webinar series (in English and French) drew out experiences of manual drilling from 12 countries by those involved [62–67]. The webinars, combined with an online survey [60], and contact with stakeholders through a snowball effect, provided the information for the 2015 ‘Manual Drilling Compendium’ [72].

This publication, which was the first of its kind, collated experiences of manual drilling from over 36 countries. It provides an overview for those wishing to further examine the impacts and challenges of manual drilling, and improve practices. It was hoped that the document would spur others to undertake studies and research, as well as document stories and analyze the promotion, uptake and use of manually drilled boreholes. In-country case studies in written and visual forms in Chad [68,69] and Nigeria [70,71] provided a more nuanced understanding with respect to innovation and realities faced by the drillers themselves, and the way that the industry was evolving both within the two countries and between them.

It became clear that, in the right conditions, determination, and various levels of support, manual drilling industries are growing in some contexts, but the technology has not been taken up everywhere—a topic that is beyond the scope of this review.

Inspired by the visual story, the topic of manual drilling in Nigeria was subsequently pulled into a course in the Open University. Further, inspired by the work, and observing linkages between private boreholes and resilience, in 2016, Cardiff University initiated research on private boreholes and resilience [90].

2.8. Phase IV—Professional Drilling (2015–2017)

The guidance materials developed by the initiative up to this point provided information on what should be done in terms of principles, siting, supervision, procurement and contract management, as well as costing and pricing. However, the materials did not help agencies already active in drilling as to how to make changes to their planning and programmes to improve them. This was the emphasis of Phase IV, which saw a tripartite collaboration between Skat, UNICEF and WaterAid, with the US Groundwater Association providing additional support. It was entitled ‘Professional Drilling’.

New research on water point functionality [74] went further than previous estimates [36] and showed that not only does water point functionality decline with age, but that it drops to 70%–85% within the first one or two years of construction. This research strengthened the case being made by others that boreholes were failing due to poor siting, borehole design, construction and supervision [2–5]. These were all areas of concern that the previous phases were trying to address by raising drilling professionalism.

In order to inform stakeholders about the importance of good siting, supervision, contract management and good borehole design and construction in an easy-to-understand format, a series of four short animated films were developed [75,76,80,81] and launched online. As hoped, the films have provided entry points to very technical topics. Over the years, the films have been incorporated into professional training courses developed by others (e.g., Malawi [102], Madagascar [104] and Nigeria [91,92]) as well as in university degree programmes (e.g., Trinity College Dublin, and Mercer University).

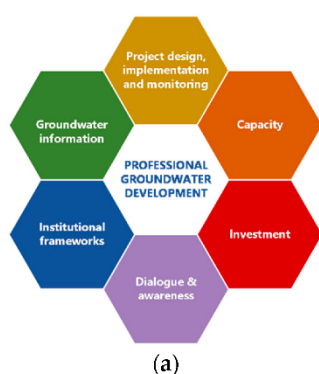
This phase witnessed a period of outreach by RWSN more broadly, in the form of an exhibition stand at the World Water Week in Stockholm and lectures at the University of Oklahoma WaTER Conference [127], Mercer University and Emory University [128] in 2015.

Following a careful process by UNICEF to ascertain in-country interest in drilling professionalism, three countries for in-country work were selected: Burkina Faso, the Democratic Republic of Congo

(DRC) and Zambia. Engagement with Zambia was triggered by a series of short meetings that took place between RWSN and a delegation from the Water Resources Management Authority (WARMA) at the RWSN exhibition stand in Stockholm in 2015 where two of the films were shown, triggering discussion on the situation in Zambia.

Unlike in the initial in-country work in 2009, which had comprised short, fairly uniform studies to define and understand cost-effective boreholes in Burkina Faso, Kenya and Zambia [26–28], the work in phase IV was more nuanced. The scope and type of engagement was more clearly defined by the country in question from the outset. The Burkina Faso study in 2016 [84], provided the opportunity to re-engage there, but unlike the 2009 study [26], which remained on the shelf, the 2016 work fed into the development of a road map on water supply construction by the Government of Burkina Faso [110]. The focus in the Democratic Republic of Congo was on manual drilling, with the work leading to a change in staffing within UNICEF DRC (i.e., taking on a consultant hydrogeologist) and an RWSN publication documenting over a decade of efforts on manual drilling in the country [116]. In the case of Zambia, the emphasis was on training—initially on procurement and contract management [82], and in Phase V (below) on drilling supervision [97,98].

This phase also set down how to improve drilling professionalism in the form of a Guidance Note published in 2016 [85] covering six areas of engagement (Figure 1). It was recognized that, due to the complex nature of the problem, there is no simple formula to raise the professionalism of borehole drilling and rehabilitation. The six areas of engagement are thus not a sequence of ordered steps, but rather a set of entry points and options. While not explicitly referred to as ‘systems thinking’ at the time, by recognizing the interconnected nature of these areas, the ‘*how*’ of professional drilling is arguably a ‘systems thinking’ approach. The note was published under the branding of UNICEF and Skat Foundation rather than RWSN as the primary target audience was the UNICEF programme staff.



(a)

The **institutional framework** matters – promote initiatives to improve national (or state) policies, regulation, standards and procedures of borehole drilling, including the clarification of roles and responsibilities.

Groundwater information is essential – value groundwater data and ensure that drilling records are collected, quality assured and collated. This data, together with information generated from it, should be made readily available to help inform future borehole siting and design, as well as groundwater resources management.

Capacity is fundamental – raise the skills and knowledge of groundwater development and encourage the availability of suitable equipment in the country.

Project design, implementation and monitoring needs to be thorough – improve the design, implementation and monitoring of specific borehole drilling or rehabilitation projects, and ensure that documentation of the process and results is readily available.

Dialogue & awareness is crucial – foster dialogue between government agencies (including regulators), drilling contractors and consultants, NGOs, development partners and civil society. Encourage and support efforts that raise awareness of decision-makers and the public about groundwater potential, management and its exploitation.

Investment is indispensable – invest adequate financial resources to improve and sustain professional groundwater development.

(b)

Figure 1. Areas for engagement in professional drilling: (a) Visual overview; (b) Summary.

Phase IV also included remote engagement and support (through Skype/telephone and email) to 16 UNICEF country offices. Semi-structured interviews enabled drilling professionalism within each particular context to be explored, followed with advice in the form of materials or linkages to other organizations. The interviews enriched the development of the Guidance Note, keeping it practical, ensuring the relevance, and provided insights as to capacities of UNICEF country offices. The interviews were undertaken jointly by UNICEF Programme Division and Skat. These conversations

also helped with the selection of countries for in-country engagement (discussed above), as well as more in-depth work with Angola, starting with a study of the drilling sector [94].

In-country work in Zambia, where a process to develop regulations for groundwater was ongoing, triggered RWSN to launch a formal e-discussion on groundwater regulations, enabling in-country stakeholders to learn from each other and also to provide inputs to the on-going process in Zambia [129].

The 2016 RWSN Forum in Abidjan provided several platforms for groundwater and drilling. A one-day seminar on groundwater management strengthened linkages between RWSN, the African Groundwater Network and BGR. Six groundwater sessions enabled 35 contributions in the form of papers, posters and films to be shared among the 470 participants.

In summary, phase IV witnessed the documentation of how drilling professionalism could be improved, alongside wide outreach online through the animated films, webinars, online discussions (formal and informal), face-to-face events and short face-to-face training courses. In-country engagement on the topic was tailored to the particular interests of specific UNICEF country offices and partners.

2.9. Phase V—Strengthening UNICEF and Partner Capacity to Raise Professionalism of Drilling and Drilling Management Professional Drilling (2017–2020)

Having set out how to raise professionalism in the 2016 Guidance Note [85], in phase IV, the emphasis of phase V was on finding ways to engage professionals with it, and catalyze action. Simply having the Note available online was not considered sufficient to bring about the desired change.

Further raising drilling professionalism through UNICEF country offices was a key emphasis of phase V and included the development and running of an online course entitled ‘Professional Management of Water Well Drilling Programmes and Projects’. With the 2016 guidance note as the course core textbook, the online course was structured around five modules (Figure 2). The overall objective was to offer participants an introduction to the management of boreholes drilling projects and programmes and provides an overview of what is required to improve professionalism within the organizations and the countries in which they operate. The course drew heavily on the resources produced by the initiative prior to 2018 (Table 1), complemented by materials published by others (e.g., films explaining groundwater and information on groundwater management). The online course ran for two consecutive years, in 2018 [99] and 2019 [106], for 181 participants in total. The 2018 course was part of the UNICEF-Skat PCA, and the 2019 course was made possible by a financial guarantee by Skat Foundation. The courses were developed and managed in partnership with the United Nations Development Programme Capacity Network (UNDP Cap-Net) and ran on their virtual campus. Participants were from UNICEF, WaterAid, UNHCR, Oxfam and numerous other organizations.

Module 1	• Introduction, Groundwater Information and Siting
Module 2	• Costing and Pricing and the Procurement and Contract Management of Borehole Drilling
Module 3	• Borehole Drilling and Supervision
Module 4	• Institutional Frameworks for Borehole Drilling Professionalism
Module 5	• Dialogue and Actions to Raise Drilling Professionalism
Closure	• Participants feedback and course closure

Figure 2. Modules of the online course on drilling professionalism.

UNICEF had already commenced on developing a Toolkit for Borehole Drilling Planning and Construction. It was not originally part of the UNICEF-Skat PCA, but was brought into Phase V in order to improve the structure and content, quality assure the document and finalize the layout. Like the 2016 Guidance Note, the Toolkit was branded a UNICEF document rather than RWSN, as UNICEF staff and partners were the prime audience, and the toolkit was structured around UNICEF internal processes and contracting language. In 2018, some ten years after UNICEF started to reflect on its borehole drilling practices, it had published a toolkit—this illustrates how long such processes can take and highlights the importance of longevity.

In terms of country work, interest in the initiative remained high in Angola, and a face-to-face short training course on procurement, contract management and costing and pricing was run in 2017 [93]. A second face-to-face training course on drilling supervision took place in Zambia, which was not only documented in the form of a report [97], but also as a documentary film [98] for subsequent use for advocacy purposes. Unfortunately, the security situation meant that it was not possible to travel to Burkina Faso. However, the issues with respect to the early corrosion of pump components raised in the previous study were examined in more detail, including the testing of components, and verifying that material standards were not being consistently met [108]. In some respects, this report was a return to the roots of RWSN, as the Handpump Technology Network (HTN).

3. Initiative Funding Mechanisms and Cost

Funding for the RWSN Professional Drilling initiative has come from several partners, particularly UNICEF, Skat Foundation/Skat Consulting AG, WaterAid and WSP. Other organisations that have contributed in cash or in kind are the National Ground Water Association, the Swiss Agency for Development Cooperation (by supporting the RWSN secretariat), Aqua for All, USAID, Oxfam UK, UNDP Cap-Net, United Nations High Commission for Refugees (UNHCR), the African Groundwater Network, the British Geological Survey, St. Gallen Lotteriefonds and the Water Integrity Network (WIN).

Funding was not secure for the 16 years from when the flagship was launched in 2004. From 2009, the five PCAs between UNICEF and Skat Foundation provided the backbone of funding for the work. While each PCA was only two to three years in duration, and there was no assurance that a new PCA would follow, the duration, size and flexibility meant that progress could be made, and there was substantial flexibility for innovation and learning. Without these PCAs, this initiative would have not been able to progress as it did.

RWSN networking activities (which cover other themes as well as drilling) have other funding sources. The Swiss Agency for Development and Cooperation (SDC) provide core funding that requires co-funding to be secured. Finance for RWSN networking, as well as the drilling initiative have, to date, never had funding horizons of more than three years, with many contributions for projects of shorter duration.

Estimates of the cost of the initial two phases, coupled with the analysis of the Skat Foundation accounts shows that, over its 16-year duration, the initiative cost approximately USD 750,000 at today's value (Table 3).

Table 3. Estimated cost of the RWSN initiative, by phase.

Phase	Expenditure (CHF) ¹	Expenditure (USD) ²	Notes/Source	Funders
Foundation (2004–2006)	≈ 50,000	50,000	Estimate—based on outputs	Water & Sanitation Programme (WSP)
Phase I (2007–2008)	≈ 65,000	50,000	Estimate—based on outputs	Water & Sanitation Programme (WSP), UNICEF
Phase II (2009–2014)	327,000	50,000	Skat Foundation accounts	UNICEF Programme Division (New York), USAID, Aqua for all, Skat Foundation/Skat Consulting AG, DFID/WASH Facility Sierra Leone
Phase III (2013–2014)	90,000	100,000	Skat Foundation accounts	UNICEF and Skat Foundation/Skat Consulting AG
Phase IV (2015–2017)	200,000	220,000	Skat Foundation accounts	UNICEF and Skat Foundation/Skat Consulting AG
Phase V (2017–2020)	270,000	280,000	Skat Foundation accounts	UNICEF and Skat Foundation/Skat Consulting AG
Total	≈ 1,000,000	≈ 750,000		

¹ Figure has been rounded to the nearest 10,000. ² Using average exchange rate for each phase (i.e., 0.8026, 0.8801, 1.0425, 1.0862, 1.0237, 1.0977) from <https://fxtop.com/> and adjusted for inflation from midpoint year, or midpoint year −1 from <https://www.officialdata.org/---USD> figures have been rounded to the nearest 10,000.

While the amount covers most of the cost of achieving the activities in the left-hand column of Table 1, it is important to acknowledge that additional in-kind and financial support that did not flow through Skat foundation is not included. In particular, additional support was provided through the RWSN secretariat, which managed and hosted the webinars and hosts the RWSN website, and manages the review process and layout of RWSN publications. Some RWSN professional drilling webinars were sponsored by the UPGro Programme. WSP provided staff time in the foundation phase. There was also volunteer time in subsequent phase (e.g., drilling associations publication) and in-kind support (e.g., Cap-Net online course hosting, support and facilitation; and some technical facilitation of the online courses). Not accounted for is funding for drilling, venues, and participant travel and subsistence for the face-to-face courses in Zambia, Sierra Leone, and Angola, which have not been monetized. Assuming the average of in-kind support of USD 20,000 per year over the 16-year duration, would add another USD 320,000 to the cost of the initiative.

4. Methods

4.1. A Mix of Methods

The initiative used a mix of face-to-face and online methods to document and understand the issues, provide guidance and deliver training and informing a wide audience to raise their awareness and inspire action. These different methods are discussed briefly below.

4.2. Documenting and Understanding

The country studies on the drilling sector and its wider operating environment were undertaken in order to understand in-country realities, draw out good practices and trigger changes where appropriate. Given that all of the in-country studies were not confined to one particular project or institution, the emphasis was on documentation and reflection, rather than evaluation. The principles in the code of practice (Table 2) provided the scope and basis for the structure of these studies, and has evolved over the years, with the most recent example being Angola [94].

Notably, the system-wide nature of the recommendations, the short duration of the studies and the fragmentation of the sector in terms of partners and funding, meant that it was difficult to embed actions for change with one particular country. For example, the Burkina Faso, Ghana and Zambia studies of 2009, generated learning for the initiative, but did not bring about change in the country at the time. The Sierra Leone work, which was longer in duration, conceived and resourced as more than a study from the outset, involving training, as well as the development of national principles, achieved considerably more (i.e., national guidelines and face-to-face training).

The country studies, data drawn from the interviews with UNICEF country staff, webinars, e-discussions, face-to-face and online courses generated a wealth of information on the issues that affect drilling professionalism, as well as measures being undertaken to improve it. Rigorous internal reporting was undertaken for the PCAs. However, resource limitations meant that has not been possible to fully synthesize the data generated or, for example, undertake comparisons between different contexts. Publications were limited to the specific studies or other events. However, by compiling the information generated by the initiative, this review should ease further academic engagement with the topic of drilling professionalism.

On the one hand, the initiative was limited by being undertaken in the form of a series of projects, with a consultancy-type speed of delivery, rather than as a research programme with more opportunity for in-depth analysis. On the other hand, this approach has meant that, throughout the initiative, there was a need to remain responsive to field realities. Further, specific learning from one country, or context could be rapidly applied to another if the opportunity arose.

The initiative did not get bogged down in extensive analysis of a particular issue, but was instead dynamic, trying to find ways to address the issues raised. The development of guidance on how to improve drilling professionalism, and the adaptation and transfer of face-to-face training courses from one country to another provide examples of this dynamism.

4.3. Engagement and Partnership

UNICEF, which invests in borehole drilling programmes all over the world, and WaterAid are the two main organizations that have taken on board the recommendations emerging from the initiative, of which both were part of.

UNICEF engaged in the initiative early on. The UNICEF 2008 Water, Sanitation and Hygiene annual report [130] notes the high cost of boreholes—especially in sub-Saharan Africa as a key constraint to achieving water targets, with “UNICEF redoubling efforts to address this including ongoing to develop a Code of Practice for Cost Effective Boreholes”. UNICEF engagement on manual drilling extends well beyond Phase III of the RWSN initiative, and includes documenting practices, assessing sector capacities, mapping the hydrogeological areas suitable, exchange visits, introducing techniques, training and funding manual drilling campaigns, developing national norms, standards and advocacy to support mainstreaming in national policies [32].

4.4. Engagement with UNICEF Country Offices and Responding to In-Country Needs

Building on lessons learnt about stakeholder engagement in phases I to III, phase IV involved engagement with UNICEF country offices through a series of short remote interviews. These allowed country offices to understand the nature and type of support that could be provided by the initiative, and enabled key issues and opportunities from within countries to be ascertained [131]. The content of all interviews was written up and sent to the interviewees immediately afterwards. The interviews were exploratory, with the emphasis on listening to descriptions of ongoing activities related to professional drilling and manual drilling and problems faced. With probing, practical ideas for practical support, as well as important issues for inclusion in the Guidance Note [85] were generated. As well as influencing the selection of countries for in-country work, the interviews enabled a number of remote support activities to be prioritized. This approach led to different types of support being provided to the countries (Tables 1 and 4).

On occasions, competing priorities within UNICEF country offices affected timely engagement with the initiative over the multi-year collaboration, leading to extensions in the time to complete the PCAs [61]. For example, cholera outbreaks in Angola meant that the planning, and subsequent execution of a face-to-face training course had to be delayed. The flexible arrangements within the PCA or new PCA's enables most delays to be accommodated.

Table 4. RWSN Public Webinars on Professional Drilling and Manual Drilling [61].

Topic ¹	Year	Webinar Title	Countries Included	Language ²	Link
PD	2012	Cost-effective boreholes	n/a	E	Not available
MD	2014	Introduction to Manual Drilling and its Potential to Improve Rural Water Supplies	n/a	E/F	https://vimeo.com/86508528
MD	2014	Manual Drilling at Scale	Senegal, India & Bolivia	E/F	https://vimeo.com/87084964
MD	2014	Good practices in Manual Drilling Construction and Design	Nigeria, Madagascar & Kenya	E/F	https://vimeo.com/87747145
MD	2014	What do governments love and hate about manual drilling?	Guinea, Niger & Ethiopia	E/F	https://vimeo.com/88240563
MD	2014	Private Sector and NGO Experiences of Introducing and Developing Markets for Manual Drilling	Malawi, Sierra Leone & Zambia	E/F	https://vimeo.com/88864336
PD	2014	Groundwater Matters: Drinking Water for Rural People	Botswana	E	https://vimeo.com/87851165
MD	2015	Manual Drilling—a global perspective of local realities	See manual drilling compendium	E & F	https://vimeo.com/119421543 https://vimeo.com/119535178
PD	2015	Groundwater Governance (Kenya)	Kenya	E	https://vimeo.com/121992412
PD	2015	Effective Procurement & Contract Management of Borehole Construction		E & F	https://vimeo.com/123310467 https://vimeo.com/123322678
PD	2015	Drilling supervision is no longer in fashion—the funders save, the users pay		E & F	https://vimeo.com/123839791 https://vimeo.com/123918873
PD	2015	Boreholes that last for a lifetime	Mali	E & F	https://vimeo.com/142475788 https://vimeo.com/142373715
PD	2015	Overcoming the rural water supply scandal of handpump corrosion		E & F	https://vimeo.com/145485267 https://vimeo.com/145494726
PD	2015	The magic and mystery of groundwater data	Uganda	E & F	https://vimeo.com/147584885 https://vimeo.com/147596997
PD	2017	Professional Water Well Drilling: Guidance for Ensuring Quality	Burkina Faso	E & F	https://vimeo.com/215145287 https://vimeo.com/215154161
PD	2017	Using groundwater in urban and slum areas: experiences from Africa	Nigeria & Uganda	E & F	https://vimeo.com/219979369 https://vimeo.com/219985403
PD	2018	Yes we can! Capacity Strengthening for Professional Drilling—Sharing Experiences from Southern Africa	Angola, Zambia Madagascar & Zimbabwe	E & P	https://vimeo.com/273842040 https://vimeo.com/273847798
PD	2018	A conversation about borehole drilling by private enterprises	Uganda	E	https://vimeo.com/336568174

¹ MD = Manual Drilling, PD = Professional Drilling/Cost-Effective Boreholes. ² E/F = English and French on the same webinar; E = English only; F = French only; E & F = English and French as two separate webinars; E & P = English and Portuguese as two separate webinars.

The RWSN evaluation identified the drilling professionalization courses in Sierra Leone (2013) and Zambia (2016) as valuable examples of addressing practitioners' needs and improving their professionalism [95]. The response to requests from Zimbabwe for guidance on raising capacity, also improved professionalization of drilling, leading to an acknowledgement that a multi-stakeholder platform to draft appropriate, enforceable regulations based on best practices from its pool of knowledge was needed [95].

4.5. Provision of Guidance and Training

The initiative commenced by providing guidance in written form—starting with the Code of Practice, and subsequent guidance documents (Table 2). These documents provided the basis for the face-to-face short training courses in Sierra Leone, Zambia and Angola, with about 20 to 35 participants per course. The training courses for siting and supervision comprised one to two days of classroom work, alongside practical work actually siting and supervising borehole drilling. The procurement/contract management course was classroom based, but used a variety of participative methods including drama, fishbowl discussions and group work to not only cover the materials, but enable the participants to reflect on difficult, and contentious areas. All courses benefitted from having a mix of participants with different technical backgrounds and from different organizations. The exchange, on aspects such as paying for dry boreholes, or roles and responsibilities was key, particularly given that in most of the contexts, groundwater regulations were not in place, and donor agencies have tremendous influence over practices, even when they may be problematic.

All the materials from the three training courses are available online through the RWSN website with a view that others may copy, and adapt the courses. This is known to have taken place in seven countries—Burkina Faso, Nigeria, South Africa (for Zambia), Uganda and Malawi (Table 1) and Mozambique [132]. However, face-to-face training on drilling professionalism has not taken off on a large scale.

The training materials have also been extensively used in short courses in Nigeria. The Japan International Development Agency (JICA) supported the Rural Water and Sanitation Center at the National Water Resources Institute (NWRI), Kaduna between 2010 and 2014. Several short courses were conducted to improve the capacity of the drilling supervision and management personnel. RWSN materials were used and disseminated. Additionally, Oxfam GB, Creative Associates International Inc., and GIZ working on humanitarian relief work in the crisis-torn north eastern part of Nigeria have funded training courses for their drilling supervision personnel, with the RWSN materials at the core of the training.

The animated films on siting [75], supervision [76], drilling procurement and contract management [80], and drilling [81] provided lighter, humorous entry points to the somewhat dry, and highly technical topics of siting, contract management, supervision and drilling quality. These films also proved to be very useful in triggering discussions within the face-to-face, and online training courses.

The Guidance Note on drilling professionalism (Figure 1) took the initiative a step further, by providing information on how a UNICEF country office could embark on the journey of trying to improve drilling professionalism, given the many issues that could be tackled, as exemplified by the Code of Practice (Table 1) and subsequent guidance.

The online courses provided the opportunity for participants to learn about and discuss drilling professionalism and how it could be tackled. The course modules (Figure 2) culminated in setting out actions for raising professionalism. The emphasis of the last module was on action and engagement with other stakeholders. Despite the success of the two online courses (discussed in Section 6), at the time of writing this paper, funding had not been obtained for two courses. The lead author of this publication, together with WaterAid, and others is trying to source funding courses to be run annually in the future.

4.6. Knowledge Management—Informing, Sharing, Inspiring and Exchange

The information generated by the initiative and related publications have been shared widely through the RWSN website, newsletter, online community on groundwater, a dedicated webinar series, within the RWSN bi-annual webinar series (Table 4) and through blogs (Table 5).

Table 5. RWSN Blogs on Drilling Professionalism and Manual Drilling.

Topic ¹	Year	Blog Title	Countries Included	Lang. ²	Author ³
PD	2020	The need for professional associations for water well drillers	Angola, Burkina Faso, Mozambique, Nigeria, USA	E	RM
PD	2020	Ugandan drillers receive training at the Water Resources Institute	Uganda	E	TL
PD	2020	Handpump corrosion and material quality: A challenge for Burkina Faso and globally	Burkina Faso	E & F	TL
PD	2019	Just how much do countries rely on groundwater point sources for their drinking water?	Global	E	TL
PD	2019	Understanding the invisible: Uganda's efforts to increase access to detailed groundwater data	Uganda	E&F	RS
MD	2019	An opportunity to reflect on manual drilling—UNESCO Seminar in Madrid, 2019	n/a	E	TL
PD/MD	2019	Integrity risks in professional borehole drilling: preventing corruption paves the way to sustainable infrastructure	n/a	E	RM
PD	2019	Regulating the private sector	Uganda	E & F	R
PD	2019	Attracting the best: Why some experienced consultants and drilling contractors are no longer willing to work for district local government	Uganda	E & F	R
PD	2019	Turnkey contracts for borehole siting and drilling	Uganda	E & F	R
PD	2019	Favouring Progress: Yemen's Water Scarcity Dilemma of the 21st Century	Yemen	E	RM
PD	2018	Borehole drilling supervision in Malawi: why it is essential, not optional	Malawi	E	RM
PD	2018	Professional Water Wells Drilling: Country Assessments of the Sector	Angola, Burkina Faso, Chad, Ethiopia, Ghana, Kenya, Mozambique, Niger, Nigeria, Sierra Leone, Sri Lanka, Sudan, Tanzania, Uganda, USA, Zambia	E	Theme leader
PD	2018	Achieving Professional and Sustainable Drilling in Madagascar? Yes we can!	Madagascar	E	RM
PD	2018	Voyage of groundwater discovery	n/a	E	TL
PD	2017	Getting groundwater off the ground	n/a	E	TL
PD	2015	A borehole that lasts for a lifetime	n/a	E	RS
MD	2015	What is the big deal about manual drilling anyway?	several countries (see [72])	E	TL
PD/MD	2015	"Your challenges are out challenges", reflections from Oklahoma, USA	n/a	E	TL

Table 5. Cont.

Topic ¹	Year	Blog Title	Countries Included	Lang. ²	Author ³
PD	2014	Addressing failure in rural water supply in Africa—how can we all do better	n/a	E	RM
MD	2014	Water Supply in Lagos and Nigeria—the importance of manual drilling	Nigeria	E	TL
MD	2014	Manually Drilled Wells: Providing water in Nigeria’s Megacity of Lagos and beyond	Nigeria	E	TL
MD	2013	Self-Supply at Scale: Lessons from rural Bangladesh	Bangladesh	E	RM
PD	2012	Realities of water well drilling in Africa: e-discussion highlights so far	Ethiopia, Kenya, Sudan, Nigeria, Uganda, Zambia	E	RM
PD	2012	Boreholes and trees—why drilling supervision matters	n/a	E	RM

¹ MD = Manual Drilling, PD = Professional Drilling/Cost-Effective Boreholes. ² E & F = English and French; E = English only; F = French only. ³ RM = RWSN member; TL = Initiative leader; RW = RWSN Secretariat; R = Researcher.

However, the initiative has also enabled the collection, collation and sharing of otherwise diffuse information. For example: over 100 individuals from numerous organizations around the world contributed to the compendium on manual drilling [61]; RWSN disseminated the groundwater statutory instruments for Zambia and the groundwater manuals and standard operating procedure for Malawi through its website; a participant of the 2018 online course shared her reflections on groundwater on Yemen through a professional magazine and blog (Table 5).

The initiative has thus not just disseminated its own materials, but shared relevant information from others where possible. Notably most of this sharing took place when the theme leader, or a close partner became aware of the materials and actively sought to share. Additional possibilities for sharing, such as more blogs, webinars and website postings were constrained by resource limitations.

The online group on hand drilling is relatively small with 191 members in 51 countries. Between 2012 and 2017, 153 online contributions came from 49 contributors in the group. The Sustainable Groundwater Development group is significantly larger, currently with 1549 members, from 108 countries. Between 2012 and 202, 4616 contributions were shared from 698 contributors. The breadth of topics discussed by the latter is much greater, and is not limited to professional drilling.

An extensive repository of information has been made available to a large audience through the RWSN website library and dedicated RWSN pages on professional drilling [117] and manual drilling [32] webpages.

Documents and films have also been shared by other organisations (e.g., websites of UNICEF, IRCWASH, ResearchGate, pseau, aquadoc, WaterChannel) and so comprehensive tracking of downloads or viewings are no longer feasible. However, in terms of scale, the RWSN and UNICEF guidance documents and the toolkit have been downloaded thousands of times; the films have been viewed thousands of times; while country studies have been downloaded dozens, or hundreds of times.

The webinars, online discussion platforms, as well as face-to-face and online training have been particularly important to enable exchange and sharing between professionals. Some topics were also picked up in webinars of other organizations (e.g., in 2015, Engineering for Change hosted a webinar on Manual drilling [133]).

The initiative was not only top down in terms of information sharing (i.e., the guidelines and guidance from RWSN), but also enabled peer-to-peer learning (i.e., discussion between RWSN members online and at events and writing blogs). However, limited resources or capacity to manage volunteers and lack of uptake by others has meant that the vast dialogue on the online group, comprising regular exchange (and at times arguments) between members has not been synthesized since 2014.

The online exchange has, however, been used for dedicated research, including a study on drilling associations [107].

4.7. Outreach and Engagement

The outreach of the initiative, and engagement of stakeholders extended to over 40 countries, with most, but not all in sub-Saharan Africa, as summarized in Table 6. As indicated by the Table footnotes, the type of engagement varied, from in-depth studies, training and national guidance in Sierra Leone as the most intensive, to response to a survey as the least.

Table 6. Overview of Initiative Country Outreach [61,131].

Country	Manual Drilling	Professional Drilling
Angola	yes ²	yes ^{6,7,8}
Bangladesh	yes ^{1,3}	
Benin	yes ²	
Bolivia	yes ^{1,3,5}	
Burkina Faso		yes ^{6,7,(8)}
Cameroon	yes ²	yes ⁶
Central African Republic	yes ²	yes ⁶
Chad	yes ^{3,4}	
Côte d'Ivoire	yes ²	
Democratic Republic of Congo	yes ^{1,4}	yes ⁶
Ethiopia	yes ^{1,3,5}	yes ⁷
Gambia	yes ¹	
Ghana	yes ²	yes ⁷
Guinea	yes ^{3,5}	
Guinea Bissau	yes ^{1,5}	
India	yes ^{3,5}	
Kenya	yes ^{3,5}	yes ⁵
Liberia	yes ^{1,2}	
Lao PDR	yes ¹	
Madagascar	yes ^{1,3,4,5}	yes ^{6,(8)}
Malawi	yes ^{1,3}	yes ^{6,(8)}
Mali		yes ^{5,6}
Mauritania	yes ²	
Mozambique	yes ²	yes ^{6,(7)}
Nicaragua	yes ²	
Niger	yes ^{1,3,4,5}	yes ⁶
Nigeria	Yes ^{4,5}	yes ^{6,(8)}
Nepal	yes ^{1,2}	

Table 6. Cont.

Country	Manual Drilling	Professional Drilling
Pakistan	yes ¹	
Republic of Congo	yes ²	
Rwanda	yes ^{1,2}	
Senegal	yes ^{1,3,5}	
Sierra Leone	yes ^{3,4,5}	yes ^{6,7,8}
South Africa		yes ⁽⁸⁾
South Sudan	yes ²	yes ^{6,}
Sudan	yes ¹	yes ^{6,(7)}
Tanzania	yes ^{1,2}	yes ⁷
Togo	yes ^{1,2}	
Uganda	yes ^{1,3}	yes ⁽⁸⁾
Vietnam	yes ²	
Zambia	yes ^{1,3,5}	yes ^{6,7}
Zimbabwe	yes ^{3,5}	yes ⁽⁸⁾

¹ Manual drilling survey [60]; ² Manual drilling compendium—summary information on status only [72]. ³ Manual drilling compendium—narrative [72]; ⁴ Manual drilling country study or RWSN publication (Table 1); ⁵ RWSN webinar (Table 4); ⁶ Remote support to UNICEF Country Programme (Phase IV); Professional drilling in-country study; ⁷ by RWSN initiative; ⁽⁷⁾ by other; Professional drilling face-to-face training; ⁸ by RWSN initiative; ⁽⁸⁾ by other.

Table 6 includes activities that were part of the initiative, as well as those that were done by others, but which built upon the initiative, used resources generated by it, and have been reported on. Obtaining reports from other organizations undertaking work to raise professional drilling has proven to be time consuming but was considered worthwhile in order to try to provide a comprehensive picture as possible of efforts in this regard [117]. The online courses on drilling professionalism in 2018 and 2019 were attended by participants from over 50 countries [118], reaching beyond the countries listed in Table 6.

4.8. Languages

The main language of the initiative was English, but in-country studies were also undertaken in Francophone and Lusophone countries. Training was undertaken in English-speaking and Lusophone countries. This reflects the main official languages used in sub-Saharan Africa, the geographic focus of RWSN, and the initiative. Webinars were undertaken in English, as well as one other language (usually French but on occasion Portuguese) where resources were available.

Of the guidelines, most are also available in French, and some are available in Portuguese. To avoid duplication, these are not included in the list of references. Translation of written materials was undertaken on an ad-hoc and opportunistic basis. Thus, training courses in Mozambique and Angola were able to generate resources for translation, as were the RWSN Forums.

4.9. Innovations

The initiative to innovate in terms of its approach, for example:

- Public webinars were still fairly new at the time of the manual drilling webinar series in 2014 (Table 4), which set a benchmark for RWSN.
- The photo documentaries of manual drilling in Chad [69] and Nigeria [71] were experimental formats.

- The manual drilling compendium [72] was the first document on the subject that pulled data together from so many diverse sources.
- Inspired by a film on sustainability produced by WaterAid, the animated films communicated rather dry, technical subjects in a short, concise and humorous manner.
- The online courses not only enabled professionals to be taught, but also enabled discussions and assignments by the participants to be mined to provide an overview of (otherwise undocumented) groundwater issues from over 50 countries [118].

4.10. Contention

One of the most contentious issues within the initiative has been whether drillers should or should not receive reimbursement for work undertaken to drill boreholes that are not productive, even if this may not be the fault of the driller (e.g., in difficult hydrogeological environments).

The RWSN initiative has emphasized that there is a need to separate the borehole siting from the drilling, and invest in professional drilling supervision, and pay drillers for the work done according to a bill of quantities. In other words, pay according to a bill of quantities. This is echoed in the Code of Practice and other RWSN publications. In contrast, prior to the publication of the UNICEF Toolkit on Procurement and Contract Management in 2018, UNICEF guidance was not in line with this.

In fact, the UNICEF evaluation section on efficiency recommended use of output-based contracts: establishing fixed-price contracts for drilling a successful borehole in a community. In more than three quarters of the case study countries and others evaluated/documentated, including Burkina Faso, Ethiopia, Guinea, Madagascar, Mali, Mozambique, Rwanda, the Sudan and Zimbabwe, contracts were paid based on the desired result (i.e., a functional water point of satisfactory quality). Failed boreholes were considered as the driller's responsibility and cost, at least within a cost limit fixed in the procurement and contract documents. "Transferring the responsibility, risk analysis and cost related to the dry boreholes to the contractor from the outset helps UNICEF better budget and control expenditure and better plan and deliver results within the timeframe agreed with donors" [126].

This contention between UNICEF and RWSN messaging was resolved with the publication of the UNICEF Toolkit on Procurement and Contract Management [45] in 2018, which states that with the exception of contracts of less than five boreholes in easy-to drill environments, that contracts for siting and drilling should be separate, with the driller paid according to the work done and supervision undertaken.

5. Perspectives and ISSUES

The two online courses [99,106] provide insights to the current status and challenges of drilling professionalism for over 50 countries from the perspective of 181 course participants. An analysis of all of the assignments and discussion, with information grouped into categories emerging from the data [118], provides insights into the following topics of interest.

- Groundwater use data: there are concerns in some countries that available data does not provide a full picture of the status quo of groundwater reliance. For example, participants from Somalia and Yemen believed that the actual groundwater dependency in their respective countries is much higher than data provided by the Joint Monitoring Programme. Alternative figures and data sources were shared from participants in Jamaica and Trinidad and Tobago.
- Self-supply refers to households taking care of their own water needs. Populations in Afghanistan, Nepal, Sri Lanka, Timor Leste, Zambia and Zimbabwe were mentioned as being particularly reliant on self-supply. Participants noted that the lack of knowledge of what "constitutes a good quality borehole by individuals that invest, as well as a lack of understanding of what this costs [has] long- term implications for the service and groundwater resources".
- Drilling data: Information from maps and records of previous drilling is often very difficult to obtain. Out of 42 countries, only 14 (33%) were believed (by participants) to have national

groundwater databases. In some cases, databases are old and not comprehensive, but, in some countries, there are initiatives underway to upgrade, or establish groundwater databases.

- Difficult hydrogeological settings and the challenges of drilling in hard-to-reach communities: include examples in Bangladesh, Ethiopia, Sierra Leone, South Sudan, Sudan, Sri Lanka, Syria and Timor Leste.
- Siting: Borehole siting practices vary, with some clients contracting it separately to consultants and others relying on the drilling company itself to undertake siting. A lack of skills and knowledge, professionalism, and equipment as well as particular challenges of working in insecure contexts are challenges for siting. Roles and responsibilities are not always apparent. Participants discussed who should be responsible for siting, and when it should ideally take place at length. The importance of addressing land issues when siting was noted.
- Skills: According to participants, there are weaknesses in the skills, knowledge and experience of staff responsible for siting, drilling, supervision, data collection (especially by drilling contractors) and project management in many countries. People tend to enter the drilling industry without any formal practical training and thus learn on the job.
- Procurement and contracting management: Among the participants, there was recognition of the importance of pre-qualification, pre-bid meetings, site visits, good communication between the client and contractors throughout the procurement and contracting process, as well as the minimizing distance between boreholes drilled under one contract. However, many organizations struggle with insufficient or inexperienced staff and unrealistic deadlines.
- Corruption is a major impediment to drilling professionalism. Ideas to prevent or reduce corruption include improving transparency, undertaking pre-qualification (with due diligence), registration and licensing, supporting drillers associations, undertaking inspection, use of penalties, paying proper salaries and raising skills. From the four steps listed above, experiences of post-construction monitoring was the most limited.
- Payment (or not) for dry boreholes or poor water quality is a contentious issue, as evidenced by lively online discussions and considerable reflections within the assignments. Some participants held on to their belief that dry boreholes should never be explicitly paid for by clients, while others took a different approach, recognizing the risks to the drilling contractor, particularly in difficult hydrogeological environments, and citing examples of inadvertent problems caused by non-payment—particularly with respect to reductions in construction quality.
- Drilling supervision was discussed widely, with reflections on who should supervise, noting that in some cases there may be more than one person/institution involved, with overlapping responsibilities, while in other cases drilling supervision is being neglected. Stories of supervision shared from several countries highlight staffing shortages vis-à-vis need, a lack of skilled supervisors, the practical difficulties of undertaking supervision in remote areas, inadequate logistics, a lack of budgeting for proper planning and supervision, travel restrictions due to security concerns and corruption. While full time supervision was recognized as desirable, funding realities and attitudes of management, political leadership or donors mean that part-time supervision is more common. There was recognition that communities can support drilling supervision, but that this needs to be handled with care, and while they can record what is taking place if given enough information, that communities cannot replace professional supervisors. Good practices of drilling supervision do exist, including oversight of junior staff by experienced supervisors, clearly defined milestones for part time supervision and making good use of checklists. There were several calls for more training on supervision to take place.
- Borehole cameras are rare or not available at all in several countries.
- Institutional (and legal) framework: Many countries have set up protocols, policies and regulations that are in line with the principles of cost-effective boreholes that the Rural Water Supply Network (RWSN) published in 2010. However, with few exceptions, the level of implementation and compliance with regulations was considered by participants to be low. Zambia, Uganda,

Malawi and Kenya demonstrated efforts and progress, while Trinidad and Tobago stood out in terms of licensing and training. As a federal country, particular states in Nigeria, including Lagos and Kaduna have set up regulatory commissions. In sharp contrast, Somalia, a country facing ongoing conflict is being left behind from the perspective of course participants. Zimbabwe and Bangladesh are examples of countries with regulations in place, but challenges in getting them widely known and enforced. In many countries, the situation was considered as mixed.

- Finance: private drilling companies face challenges with respect to finance (estimating costs and determining prices, cash flow, bank guarantees and payment delays), staffing, management, equipment maintenance, competition, time delays in project implementation, as well as challenges entering the market. However, there are experiences of businesses being supported with loans, tax relief, accessing equipment and quality materials.
- Drilling associations are considered a potential way of improving professionalism, and participants noted that they have been established in Chad, DRC (manual drilling only), Kenya, Mozambique, Nigeria, Thailand and Uganda, whereas in many countries there are none.
- Conflict, emergency and humanitarian settings face particular challenges with respect to including planning, getting to the field, risks of losing equipment, fluctuating funding and conflicts between host and displaced persons. In countries that have faced protracted crisis, human and equipment capacity can be very low.

Not all of these above issues are covered by the Code of Practice (Table 2), the current RWSN guidance, or the UNICEF Guidance Note or Toolkit. Updates of the code and further guidance should consider including: corruption, borehole cameras, drilling associations, finance and managing drilling in emergency settings. Given the breadth of the topics of institutional and legal frameworks, as well as groundwater data, these arguably deserve more attention in their own right.

6. Initiative Outcomes

The outcomes of the initiative have come about through an interplay of the activities and outputs of the initiative itself, with those of core partners (Skat Foundation, UNICEF and WaterAid) and those of others. “Outcomes of RWSN in reality relate to the influence members can have on policies and practice in the countries where they work, particularly if members are able to put to practice what they have learned through being part of RWSN” [95]. While it is difficult to attribute all outcomes directly to RWSN’s drilling initiative, it has contributed to the following outcomes in the following five different categories:

- Through and within UNICEF
 - The Code of Practice [33] provided much-needed guidance to country offices and became a reference document for the sector, inspiring a number of nationally endorsed standards and codes of practice/ conduct, guiding the creation/revitalization of national drilling associations and providing an analytical framework and benchmark for country assessments (e.g., Reference [45]) and the UNICEF Evaluation [126].
 - At least half of 63+ UNICEF country offices “strengthened the spare part supply chain and supported the professionalization and innovation in the drilling sector” [126].
 - UNICEF played a major role in either introducing or supporting the scaling up of manual drilling, and in sub-Saharan Africa, manual drilling techniques and the manual drilling sector are now well established [126].
 - UNICEF has encouraged new approaches and produced additional resources and guidance to support country offices to carry out efficient procurement and contract management and professionalize the national drilling sector [126].

- A few UNICEF country offices have introduced more professional, independent and closer/full-time supervision through third-party engineering companies (e.g., in the Democratic Republic of the Congo, Mali, Madagascar, Pakistan and Rwanda) [126].
- Professionalization of the drilling sector has been supported in nearly 20% of UNICEF's Rural Water Supplies programme countries, mainly in sub-Saharan Africa [126].
- Other organisations:
 - World Vision engagement with the association of low-cost drillers in Chad in 2014 [61].
 - Raised awareness of the importance of manual drilling by the Lagos State Water Regulatory Commission [61].
- Within the sector more broadly
 - Effective expansion of the body of knowledge and strengthening capacities in manual drilling and the professionalization of the drilling sector [126].
 - Application of skills and knowledge obtained from RWSN by network members [95]:
 - "I have initiated fabrication of Manual & Low powered water well Drilling Rigs in my establishment".
 - "I have used the manual drilling resources to promote percussion drilling with small manual drilling teams. This approach will hopefully lead to improved rural groundwater development in some remote, low-lying limestone islands in Solomon Islands".
 - Increased research to understand the linkages between borehole failure and drilling professionalism (e.g., [6,114,115]).
 - Capacity building in professional drilling is an action area for the African Ministers Council on Water (AMCOW) Pana African Groundwater Programme (APAGroP) [109].
- Country-specific
 - RWSN has played a role in pushing down the cost of drilling in Kenya through facilitating discussions and providing guidelines amongst practitioners. "Previously, major drillers with large scale rotary drilling rigs were recognized as having the capacity to deliver significant water supply. Through RWSN's continuous debate on cost of services and sharing knowledge around applicable technologies (for instance on manual drilling), and study visits have helped to stimulate individual entrepreneurs to take up less costly options. Eventually these entrepreneurs have formed an association that is now recognised by the government. An interviewee has stated that the cost of drilling in some instances has fallen from \$15,000 to \$3000 for shallow boreholes when low cost options are promoted. While there were likely other influencing factors to reduce drilling costs, RWSN's support in hosting the debate on the cost of services has in some way contributed to this outcome" [95].
 - Establishment of drillers associations in Mozambique [23] and Nigeria [22]
 - Development of guidance for Sierra Leone on hand dug wells supported by WSP [58].
- Online course participants [132]:
 - 84% of post-course survey respondents shared or spread knowledge gained, e.g., by sharing materials/resources and training
 - Human resources: "The organization has hired a dedicated engineer to undertake supervision of water facilities construction"; "A professional consultant is hired to supervise water well drilling work implemented with UNICEF support"; "The organization has hired a dedicated engineer to undertake supervision of water facilities construction"

- Bid documents/bosting and pricing: “Learning to write more rigorous contracts and development of Scope of Works, Engineers Estimates etc which helped the stemming of cash flow from the organization that would have been lost due to variations in the contract”. “methodology analysis method calculation tables” have been changed; “The preparations of bid document and requirements How to write the items of pricing in contract in case of wrong sitting” have been changed.
- “There was a meeting organised by JICA for the government, district water officers, WASH partners and drillers to discuss the effectiveness and implementation and use of the Technical Manual, what gaps are observed by the implementors of drilling projects as well as drillers. It was very good.”

7. Initiative Impact

The RWSN Evaluation in 2017 [95] and the 2018 Global Evaluation of UNICEF’s Rural Water Supplies and Small Towns Water Supplies [126] are the only two known sources that independently evaluate impact. The RWSN evaluation states that “It is crucial to emphasise that RWSN will not in itself achieve impact, but it can indirectly contribute to impacts, by enhancing the skills and knowledge of the key actors in the sector, so that they can improve sector performance and thereby impact on people’s lives” [95].

Weaknesses in the monitoring by other sector players mean that measuring the impact is constrained. The UNICEF evaluation notes that “the absence of a comprehensive oversight and tracking system also means that it is not possible to assess the impact of knowledge management, technical assistance, capacity building and other organizational and individual learning activities on the quality of UNICEF’s RWS programming. This is also a concern for organizations other than UNICEF”. Notwithstanding, documented contributions to impact by the RWSN drilling initiative are:

- “The Code of Practice led to—or reinforced—at least one major evolution in UNICEF’s RWS-related procurement activities: the more systematic application of the principle of subsidiarity for procurement. During the evaluation period (2006–2016), countries such as the Democratic Republic of the Congo, Mali and Mozambique followed this decentralized trend ... In the Democratic Republic of the Congo, purchasing locally led to a significant reduction in inland transport costs, which can be very high in such a large and infrastructure-poor country” [126].
- Efficiency gains have been documented in several countries, e.g., drilling costs have declined by one third in Ethiopia, Mozambique and Zambia [134]. However, the lack of systematic monitoring and reporting means that it is not clear whether these reductions have come at a cost of quality.

8. Discussion

At a cost of about USD 750 million, over a 16-year period, RWSN’s dual-track initiative on Drilling Professionalism and Manual Drilling has: developed an extensive suite of materials, had a considerable outreach, directly engaged with hundreds and indirectly reached thousands of professionals in the water supply sector. The initiative comprised committed partnerships, consistent leadership, and innovated throughout. The initiative contributed towards a number of outcomes and as some independently verified impacts.

Despite these achievements, Section 5 illustrates that there is still a considerable way to go to improve drilling professionalism. Drawing primarily on the UNICEF evaluation, and the online courses, problem areas are:

- Procurement: The UNICEF evaluation [126] found that the sector good practice on procurement as per the 2010 Code of Practice’s (Table 1), was to be rarely applied in case study countries. “Some staff noted that UNICEF’s standard proposals assessment system disproportionately favours tenders offering the cheapest price among those technically qualified” even if these are significantly

below the estimated cost price [126]. Given the longstanding contention between efficiency and quality noted in Section 4.10, this is not surprising.

- Contract management: “A minimum acceptable yield was not always established in contracts with drilling companies” in UNICEF Programmes [126].
- Supervision: Within UNICEF programming many countries have not met the requirement for professional, independent and rigorous field supervision and quality assurance arrangements [126] despite the Code of Practice (Table 1).
- Training: A lack of training of private contractors by UNICEF (broader than drilling only) [126]. Training with respect to drilling professionalism seems to be extremely limited.
- Monitoring: UNICEF staff were involved in field monitoring, on a sample, spot-check basis, in half of the case study countries [126], which is not in line with the Code of Practice (Table 1).
- Breakdown: alarming breakdown rates of hand pumps installed in sub-Saharan Africa [126,135].
- Skills: Concerns about a lack of skills, coupled with lack of training on borehole drilling and its management [118].

The 2017 RWSN Evaluation found convincing evidence that would suggest that RWSN has played a significant role in connecting members to knowledge, which has then allowed members to either influence within their own organization or to influence better practice amongst partners and colleagues [95]. However, it added that bringing about improvements at a national level needs more systematic thought. The experience of the initiative echo that bringing about change at national level requires commitment from within the country, and if RWSN is to play a role, a deep level of engagement is needed, such as has been the case in Sierra Leone and Zambia.

The UNICEF evaluation [126] notes UNICEF’s “progressive evolution from engineer-oriented topics of interest ([including], cost-effective boreholes and manual drilling) to broader programmatic issues related to [rural water supplies] sustainability (including risk and climate change resilient programming and accountability), broadly in line with the sector agenda globally”. This indicates a perception that cost-effective boreholes and manual drilling are engineering oriented, despite the fact that starting with first country studies, and code of practice, that good-quality drilling requires is significantly broader than engineering.

When the initiative started in 2004, the buzzword of the time was ‘private sector’, and WSP supported the then flagship, as part of ongoing efforts to support the private sector. Arguably, when UNICEF came on board in 2008, up to to 2020, the initiative has managed to continue to operate without paying too much concern to the development buzzwords of the day. Looking ahead, in order to maintain attention on the important, and arguably neglected topic borehole drilling professionalism while remaining relevant for global development trends, there may be a need for current development language, namely:

- Human rights—including accountability in procurement, contract management and the provision of high-quality services for provision of high-quality services.
- Leaving no one behind—including reaching remote-difficult-to-serve areas with manual drilling technologies and ensuring accountability.
- Systems thinking and systems strengthening—to consider the legal and institutional issues that impact on drilling professionalism.
- Youth—including training, skills development and professionalism of the drilling industry.
- Climate resilience—emphasizing the importance of groundwater data and its management (Principles 8 and 9 of the Code of Practice—Table 1). Further, recognizing sustainable groundwater development’s potential as an adaptation measure to cope with increasing incidence of droughts and water scarcity.

While the above may be a change of language, they do not change the reality that has been recognized by the initiative from its early days—that ensuring high quality services from drilled boreholes requires consideration of technical, political, institutional and socio-economic aspects.

9. Conclusions

While there has been extensive outreach and some impact from RWSN's drilling initiative, problems of poor-quality borehole construction remain. Accountability mechanisms for quality construction are inadequate. Despite the huge importance of boreholes for the achievement of the SDGs, investment to train and equip the next generation of drillers, programme managers, and those siting and supervising boreholes with the skills that they require is negligible. While this initiative has reached thousands of professionals working in hundreds of organizations in several dozen countries, there is currently no significant coordinated and funded global action in this area. Another investment of about USD 750,000 over the coming 16 years cannot achieve what is required. If the SDGs are to be met, raising drilling professionalism needs to be taken to another scale—it requires several tenfold in investments and national, regional and global organizations that give it the attention that it deserves.

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