Report

Climate and environmental risk screening for rural water supply in Ethiopia

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Novermber 2015

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ISSN: 2052-7209

Cover photo: Farmers, district water experts and scientists discuss reasons why a hand-dug has failed. Photo: Eva Ludi, 2013

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Acknowledgements

The authors would like to thank the Ministry of Water, Irrigation and Energy for its strong support for this project, and in particular the steer provided by Ato Yohannes Ghebremedhen, former Director of the Rural Water Supply and Sanitation Directorate.

Particular thanks are also due to the staff from the Community-Led Accelerated Water, Sanitation and Hygiene project (COWASH) in Addis Ababa and Amhara Region who engaged so enthusiastically throughout in the planning and implementation of research, and provided vital support for the fieldwork in February 2013. In particular, Mr. Arto Suominen, Chief Technical Adviser for COWASH, played a key role throughout, and Ato Minilik Wube and many others from the COWASH Amhara office, South Gondar Zone and Farta Woreda, provided invaluable support in fieldwork.

The authors would also like to thank Ato Leulseged Yirgu from RiPPLE who conducted interviews with WASH implementing agencies in Addis Ababa. The project team would also like to thank local government staff and communities in Farta Woreda, Amhara, who gave their time so generously during fieldwork.

The work presented in this report was funded by DFID-Ethiopia under Accountable Grant 103022 and the Government of Finland, with fieldwork co-funded by COWASH. The strong support of Arto Suominen (COWASH) and Morag Baird (formerly of DFID-Ethiopia) is gratefully acknowledged.

This report was peer-reviewed by Dr John Butterworth from IRC. His reflections and comments are gratefully acknowledged.

Abbreviations

COWASH	Community-led Accelerated Water, Sanitation and Hygiene programme
CRGE	Climate-Resilient Green Economy
DFID	Department for International Development
GCM	Global circulation model
GoE	Government of Ethiopia
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
JMP	Joint Monitoring Programme (WHO/UNICEF)
lcd	Litres per capita per day
MDG	Millennium Development Goal
MoWIE	Ministry of Water, Irrigation and Energy (Ethiopia)
MUS	Multiple-use water services
NGO	Non-governmental organisation
ODI	Overseas Development Institute
SSA	Sub-Saharan Africa
WASH	Water, sanitation and hygiene
WASHCO	Water, sanitation and hygiene committee
WELS	Water economy for livelihoods
WHO	World Health Organization

Glossary

Adaptation - Adjustment in natural or human systems to a new or changing environment; adaptation can be anticipatory or reactive, private or public, autonomous or planned, incremental or transformative.

Adaptive capacity - The ability of a system (e.g. community or household) to anticipate, deal with and respond to change.

Climate change - A statistically significant change in either the mean state of the climate or in its variability, persisting for an extended period (decades or longer).

Climate model - A quantitative approach to representing the interactions of the atmosphere, oceans, land surface and ice (see also Global Circulation Models).

Climate risk - Likelihood of a natural or human system suffering harm or loss due to climate variability or change.

Climate variability - The departure of climate from long-term average values, or changing characteristics of extremes, e.g. extended rainfall deficits that cause droughts or greater than average rainfall over a season.

Community management - An approach to service provision in which communities take responsibility for operating and maintaining their own water supply systems.

Coverage - Level of access to a minimum standard of service, usually defined by government.

Domestic water - Water used by households for drinking, washing and cooking.

Functionality (of water systems and services) - A measure of whether systems and services are 'fir for purpose' and functioning as intended; typically used to distinguish between systems that work and provide services, and systems that do not because they have fallen into disrepair.

Global Circulation Models (GCMs) - Global climate models used to project future climates using various scenarios to see how the climate would evolve under certain parameters.

Green economy - An economy with significantly reduced environmental risks and ecological scarcities, resulting in improved human well-being and social equity.

Household water economy - The sum of the ways in which a household accesses and uses water to support its livelihood(s).

Improved water supply/source - A source that is likely to be protected from outside contamination, particularly from faecal matter. The WHO/UNICEF Joint Monitoring Programme (JMP) includes within this category piped water, public taps, boreholes, protected dug wells, protected springs and rainwater.

Integrated Water Resources Management (IWRM) - A process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

Millennium Development Goals - A set of eight international development goals that UN member states and international organisations agreed to achieve by 2015.

Multiple Use Services (MUS) - Water supply systems that incorporate both domestic and productive uses of water in their design and delivery. Multiple services can be provided from a single source or from different sources.

Potable water - Water that is safe for humans to drink.

Productive water - Water used for economic activities, including livestock watering, small-scale irrigation, brick-making, brewing etc.

Resilience - The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a shock or stress in a timely and efficient manner.

Robust decision-making - Those decisions made with consideration of uncertainty, such as climate uncertainty. A robust decision will deliver desired benefits under a range of possible scenarios but will not necessarily be the optimal decision for any one single (e.g. climate) scenario.

Self-supply (facilitated) - Approach to service provision in which the initiative and investment to build or improve water or sanitation sources comes from individual households, usually with some support from external agents.

Unimproved water supply/source - A source that is considered to be at risk from contamination. The WHO/UNICEF Joint Monitoring Programme (JMP) includes within this category unprotected dug wells or springs, vendor-provided water, surface water, tanker-truck supply and bottled water.

Vulnerability - The exposure and sensitivity of a system (or population) to external shocks and stresses, such as climate impacts, mitigated by the ability of that system to adapt.

Water and Sanitation Committee (WASHCo) - A committee nominated by a community to operate local water systems and carry out minor repairs.

Water security - The availability of an adequate quantity and quality of water for health, livelihoods, ecosystems and production, and the capacity to access it, coupled with an acceptable level of water-related risks to people and environments, and the capacity to manage those risks.

Water service - The quantity, quality, reliability and cost of water accessible to users over time.

Woreda – Administrative area equivalent to a district.

Zone – Intermediary administrative unit composed of several woredas, usually without financial autonomy.

Executive Summary

This report presents the findings of research into the risks to rural water supply posed by climate change and environmental degradation in Ethiopia, and what can be done about them. The focus is on low cost, groundwater-dependent hand dug wells and springs that are potentially vulnerable to climate-related risks, and which form a key component of Ethiopia's One WASH[1] National Programme. The research was commissioned by the UK Department for International Development (DFID) and the Government of Finland.

While Ethiopia has made enormous progress in extending access to safe water over the last two decades, sustaining systems and services remains a huge challenge. There are many pressures and problems, and it would be wrong to single out climate change as the major threat. Indeed climate change, measured in decades, is arguably much less significant than existing variability, especially given the design life of most rural water supply systems. So while climate change may be the practical hook for framing problems, the most pressing issues remain variability and vulnerability.

What do we know about the impact of climate on the sustainability of systems and services? Disentangling the climate signal from the many other factors affecting the sustainability of services is difficult, and data are scarce. What we can say is that while groundwater provides a valuable buffer against rainfall variability because of the storage groundwater aquifers provide, the shallower aquifers on which springs and wells depend generally have less storage. This makes these resources and the sources that tap them more vulnerable – to reductions in recharge from rainfall, increases in demand, and contamination.

While we have few robust data on climate-related supply problems, the risks are well rehearsed. First, runoff from floods can damage infrastructure and contaminate water supplies. Major flood events in recent years have caused significant social and economic disruption, affecting tens of thousands of people. Localised flooding in rural areas, exacerbated by land degradation, is less likely to hit the headlines but undoubtedly affects access to safe water. Second, dry season and drought-related decreases in groundwater recharge can reduce water availability and trigger mechanical problems. Drawing on the few audits that have looked at seasonal water access, we know that households can struggle to meet even minimum (emergency) drinking water needs in the dry season because water points dry up, or their yield declines. In each case we are dealing with known risks. And while climate projections remain uncertain for Ethiopia – at least in terms of rainfall – we know climate change will amplify such risks.

The Government of Ethiopia has responded to one part of the sustainability challenge by putting more emphasis on lower cost technologies, and by asking households, communities and the private sector to do more in terms of articulating demand, planning and implementing projects, procuring goods and services and managing funds. By giving households and communities a stronger voice in service choices and implementation, so the argument goes, services are more likely to meet real needs, harness local capabilities and be sustained over time. However, the OWNP makes only passing reference to the sustainability challenge posed by climate and environmental degradation, and the steps needed to address it. Our own review of WASH implementation guidelines used by different organisations reveals a similar gap: stakeholders know there's a problem, but practical guidance on how to mitigate risks is missing. The recent Climate Resilience Strategy for Water and Energy[2] provides an excellent summary of climate risk, but does not meet this need.

What needs to be done? Based on field work facilitated through Ethiopia's COWASH project and previous work on WASH and climate change, we argue for a much stronger focus on the reliability and protection of sources. This does not mean replacing dug wells with deep boreholes, or abandoning delivery approaches that put communities and households centre-stage. Rather, we think the risks to rural water services posed by climate change, environmental degradation and growing demand can be addressed via three key steps: (1) improving local understanding of water resources, (2) ensuring that siting decisions are informed by an understanding of water availability and demand, and (3) by addressing environmental hazards in the wider catchment.

How can this be achieved? Working with the COWASH project, a series of practical tools have been developed for each step. These address the technical and environmental determinants of sustainability that are most relevant to climate resilience, and which receive little or no attention in existing guidelines. In this report we describe why the guidance is important, what the evidence base is for the recommendations being made, how the guidance can be used by programme staff, and the institutional and capacity-building implications for application in the field.

The guidance sheets themselves are presented in a separate report.[3] They can be applied by woreda staff without prior geological or hydrogeological expertise, and used by zonal and regional planners to inform

1 WASH - water, sanitation and hygiene

2 FDRE (2015).

3 Calow et al (2015).

programme design. With modest adaptation, they can also be used to assess the vulnerability of existing water points to climate and environmental hazards. As this report makes clear, however, the tools are appropriate to some – but not all - siting environments and technical choices. The focus to date is on increasing the resilience of hand dug wells and protected springs in the relatively dissected and mountainous topography of the Ethiopian Highlands. Further work is needed to extend them to other areas, albeit based on the same underlying principles and approach.

1. Introduction

The debate about climate change in Ethiopia has evolved rapidly over the last five years. Much of the current discussion is focussed on the ambitious plan to transform to a carbon-neutral, middle income country by 2025, presented as a Climate Resilient Green Economy (CRGE) 'Vision' (EPA, 2011).[4] Among academics, donor agencies and government ministries, conversations revolve around how emission reductions, adaptation and poverty reduction can be achieved through 'low carbon climate resilient development' and 'triple wins'. While these are fine ideals, there is a danger that instead of getting on with the urgent tasks of reducing vulnerability and poverty - the linchpins of effective adaptation - government and its development partners become increasingly embroiled in debates about green growth and how to measure it. Focussing on rural water supply, this report seeks to move the discussion back towards the practical substance of adaptation by asking: what does 'good adaptation' and 'building resilience' actually mean in the context of delivering sustainable water services for rural people, and what steps can be taken to make services sustainable in the face of multiple pressures? These are important questions: access to secure water underpins poverty reduction, and eliminating poverty is central to both development and adaptation (World Bank, 2010).

Despite near double-digit economic growth over the last decade, Ethiopia remains a poor country, and poverty remains overwhelmingly rural. More than three quarters of the population live in rural areas, relying on a fragile natural resource base for livelihood security. Climate variability and change already threaten these livelihoods. At a national level, the CRGE states that climate change will reduce Ethiopia's GDP growth by between 0.5 and 2.5% per year unless effective steps are taken to build resilience (FDRE, 2011). At a local level, climate change threatens the resource base on which most rural people still depend, and the infrastructure they use. This is not to suggest that climate change is the only – or even the principal – pressure affecting rural livelihoods, however. Population growth, land degradation and fragmentation, and the rising costs of goods and services all have a major influence on the ability of rural households to build assets and break out of poverty.

Against this background, extending access to more resilient water services is a key priority. While Ethiopia has made significant progress, sustaining services and ensuring hard-won public health and poverty alleviation gains are not lost remains a huge challenge. Climate change will make this challenge harder still. Yet it remains difficult to predict, with confidence, the impact of climate on water resources and water-dependent services. This is because of the problems associated with climate modelling and the downscaling of rainfall projections to local scales and impacts. Uncertainty increases as attempts are made to translate rainfall scenarios into impacts on surface runoff, groundwater recharge and water-dependent services, while changes in land cover and water demand add to the complexity (see Section 2.3 below).

In Ethiopia rainfall projections are uncertain, although most models suggest a gradual increase in rainfall over the coming decades, at least in the south of the country (McSweeney, New, & Lizcano, 2010). What is clearer is that Ethiopia will experience a more unpredictable and variable climate, exacerbating a number of existing risks: Floods can damage WASH infrastructure, increase the risk of contamination of water sources and cause land degradation that can indirectly threaten water resources. Droughts, or periodic decreases in runoff and recharge, can reduce water availability, precipitate mechanical breakdowns and lead to system and/or source failure. These risks are already apparent, with a growing body of evidence indicating that existing climate variability (rather than longer term change), coupled with rising demand for water, is already stressing systems and services (Calow, Ludi, & Tucker, 2013). Floods have also caused major economic and social disruption over recent decades, displacing people and damaging infrastructure. In rural areas, the impact of floods on access to safe water is almost certainly under-reported (Conway & Schipper, 2011; Calow, Ludi, & Tucker, 2013).

Given the uncertainties with climate change, but also the known risks associated with existing climate variability, we argue that WASH planning needs to be 'robust to uncertainty', i.e. appropriate to a range of different rainfall and runoff conditions. This implies a greater focus on ensuring the reliability and protection of

4 The original CRGE Vision was set out by Ethiopia's former Prime Minister Meles Zenawi, soon followed by a more detailed CRGE 'Strategy' presenting a framework for promoting the country as an early adopter of low-carbon growth. The Strategy has three over-arching objectives: (1) fostering economic development and growth; (2) ensuring abatement and avoidance of future emissions; and (3) improving resilience to climate change. For a detailed critique of the CRGE, see Jones and Carabine (2013).

sources under existing pressures, bringing benefits that are desirable regardless of climate change (so-called 'no or low regrets' measures). How can this be achieved, and what needs to change in terms of WASH policy, planning and implementation? More specifically, how can we help those working at the sharp end of service delivery – woreda water officers and zonal and regional planners – mitigate the risks of climate variability and change?

This report, the product of an intensive six month project supported by the Government of Ethiopia (GoE) and funded by the UK Department for International Development (DFID) and the Embassy of Finland, sets out to answer these questions. Working with the Embassy of Finland supported Community WASH (COWASH) project, and drawing on field work in Amhara Region, Section 2 describes the rural water supply situation in Ethiopia, focussing particularly on service sustainability. This provides broad context, framing the risks posed by climate change against the many other factors that affect the sustainability of services.

Section 2 then looks at the links between climate change and rural water supply, presenting the evidence on what is happening, and what the uncertainties are. The focus is on groundwater resources and groundwater-dependent rural water supplies, as groundwater is the principal source of water supply for most rural people, particularly in the dry season (Calow, Ludi, & Tucker, 2013). Moreover, the importance of groundwater is set to increase because of its relative ubiquity, storage and development potential (ibid).

In Section 3, the steps that can be taken to increase the resilience of water sources to climate change and other pressures are described, focussing on geological assessment, catchment screening and the management of environmental risks to both sources and resources. The tools developed for local application are presented in a compendium report.[5] These are based on our understanding of both climate hazards, the existing vulnerabilities of systems and services, and approaches to water point siting and construction.

Finally, conclusions and recommendations are discussed in Section 4.

A number of qualifications should be highlighted. First, the guidance presented is based on short field investigations in one woreda in Amhara (Farta Woreda) and focussed on 'low end' technologies – hand dug wells and protected springs – rather than shallow wells or deep boreholes. However, Farta Woreda is representative of the moist highland volcanic geology and environmental conditions that dominate the more populous parts of Ethiopia, so the guidelines are applicable elsewhere with minor modification. Second, an emphasis on simple technologies is a key element of the Government of Ethiopia's new One WASH National Programme – OWNP (FDRE, 2013). That said, different guidelines are needed to deal with (for example) hand dug wells in lowland alluvium, shallow drilled wells or deep boreholes. Third, research has examined risks to water services, not sanitation, and this remains a significant gap. However, the guidance does examine links between the two in terms of the risk of contamination to water supplies from on-site sanitation during floods. Hand dug wells and springs are both potentially vulnerable to flood-related contamination and damage.

Finally, we should emphasise that although this study has focussed on the resilience of systems and sources, building resilience is also about the other factors that help ensure services are sustainable, from effective management by communities to the back-stopping of services provided by local government. However, much more is known about these determinants of sustainability, and on the institutional arrangements required in community-managed projects. Hence the emphasis in this report is more on the technical elements of programme design that receive little or no attention in existing guidelines – such as appropriate assessment of demand, siting of wells and environmental protection.

5 Climate and environmental risk screening for rural water supply in Ethiopia: A guidance note for programme staff (Calow et al, 2015).

Box 1: Project objectives

The overall goal of the project Climate risk screening for rural water supply in Ethiopia was to enhance the capacity of individuals and institutions in Ethiopia to plan and implement secure rural water supplies that are robust to existing climate variability and longer term change.

The specific objective of the project was to develop a risk screening approach that could be used to assess climate-related risks to rural water supply, and to identify steps that could be taken to reduce such risks. The focus was on community managed projects prioritised under Phase 1 of the One WASH National Programme (OWNP - see below) using hand dug wells and spring development/protection to extend coverage under the oversight of woreda WASH teams. These 'low end' technologies are potentially the least resilient to climate-related stresses.

The project was commissioned by the Ethiopia desk of the UK Department for International Development (DFID), and funded by DFID and the Government of Finland. The project was supported by the Rural Water Supply and Sanitation Directorate of the Ministry of Water, Irrigation and Energy (MoWIE) and the COWASH Project. Research was carried out by the Overseas Development Institute (ODI), the British Geological Survey (BGS) and Addis Ababa University between December 2012 and July 2013.

The research outlined in this report draws on a growing body of ODI work on managing the impacts of climate change on water resources and WASH, including:

- Climate Change, Water Resources and WASH: A Scoping Study (Calow et al, 2011).
- Adaptation to Climate Change in Water, Sanitation and Hygiene: Assessing risks, appraising options in Africa (Oates et al, 2014).
- The economics of climate change adaptation in Africa's water sector: A review and way forward (Doczi & Ross, 2014).
- Building adaptive water resources management in Ethiopia (Mosello et al, 2015).

2. WASH ambitions and outcomes

2.1 Ethiopia's WASH challenge

The Government of Ethiopia (GoE) has enacted ambitious plans to extend access to safe water. The Universal Access Plan (UAP), launched in 2005 and revised in 2011, was key in galvanising political and financial support for water supply and sanitation as a means of alleviating poverty. The UAP came under the umbrella of the GoE's Growth and Transformation Plan (GTP) – the country's economic development and poverty reduction strategy, covering the period 2010 to 2015.

More recently, the OWNP (FDRE, 2013) has reiterated the GoE's commitment to achieving near universal access to safe water in rural and urban areas (98% and 100%, respectively) and extending access to basic sanitation, with responsibilities for achieving targets split between the Ministry of Water, Irrigation and Energy (MoWIE), the Ministry of Health (MoH), the Ministry of Education (MoE) and the Ministry of Finance and Economic Development (MoFED). The OWNP is significant in that it proposes a 'single window' approach to the financing, planning, procurement and implementation of services, with all key stakeholders working through government systems at federal, regional, zonal and woreda levels.

Box 2: Ethiopia's One WASH National Programme

The OWNP is the GoE's main instrument for achieving its ambitious WASH goals.

The main objective the OWNP is to extend and sustain access to water supply and sanitation services in rural and urban areas. The aim is to move away from discrete WASH projects towards a programmatic, sector-wide approach: a single, government managed WASH programme with a single consolidated WASH account based on four key principles:

- Integration of water, health, education and finance sectors.
- Alignment of partner activities (donors, NGOs, private sector agents) with those of the GoE.
- Harmonisation of partner approaches and activities.
- Strengthened partnerships between WASH stakeholders at all levels, from federal to Woreda.

In order to meet its targets, the programme will address existing disparities in WASH services within and between regions, and between rural and urban areas. The OWNP also has a strong emphasis on capacity development, particularly for lower levels of government, and the strengthening of community-based and household involvement in WASH planning and implementation, particularly in Phase 1 (July 2013 – June 2015) and Phase 2 (July 2015 – June 2020).

It is anticipated that achieving the WASH targets will require a total investment of some USD 2.65 billion (53% from the GoE), with the largest proportion (45%) earmarked for rural water supply. This will fund the construction of over 55,000 new water points and water supply schemes, and the rehabilitation of over 20,000 existing schemes to bring non-functionality levels down to 10%. In addition, roughly 19,000 household dug wells and 24,000 community dug wells are expected to be constructed by households and communities through support for facilitated self-supply.

Four different 'implementation modalities' are identified for rural water supply: (1) Woreda Managed Projects (WMP), in which the Woreda WASH Team takes the lead role in project management and implementation; (2) Community Managed Projects (CMP) where communities are supported to initiate, plan, implement and manage their projects through financial intermediaries with technical back-stopping from the Woreda WASH Team; (3) NGO-supported projects in which NGOs lead and fund, but follow national protocols; and (4) Self-supply, where individual households or groups of households are supported to construct their own wells.

Source: FDRE (2013).

At the time of writing, the second Growth and Transformation Plan (GTP II; July 2015 to June 2020) is under preparation. It is expected that the GTP II will focus on service level improvements and the sustainability of WASH services, with more ambitious targets for both rural areas (a service level increase from 15 to 25 lcd) and urban localities (from 20 to 40-100 lcd), as well as new targets for wastewater collection. Phase 2 of the OWNP will facilitate these improvements.

Starting from a very low base, progress in extending WASH services to a poor and predominantly rural population has been significant (WSP, 2011; Calow, Ludi, & Tucker, 2013). In the late 1990s, access to safe water and sanitation stood at roughly 19% and 5%, respectively. By 2015, government estimates – albeit contested - put the figures close to 80% and 70%, respectively. Figures for 2015 released by the WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation put access to safe water and sanitation at 57% and 28%, respectively (UNICEF/WHO, 2015).

Progress has gone hand-in-hand with a vigorous decentralisation process, with responsibilities for delivering services progressively devolved to lower levels of government and, more recently, including additional service delivery models with an emphasis on community contracting and facilitated self-supply at household level.

2.2 Sustaining services

Despite these gains, the number of people lacking access to safe water and sanitation remains amongst the highest of any African country (FDRE 2013; Calow et al 2013). A major factor is population growth: in 1980, Ethiopia's population was roughly 35 million; by 2000 the figure stood at 66 million, and by 2020 the population is expected to reach 112 million (UN-DESA, 2012). In addition, sustaining existing services remains a key challenge: many systems fail to provide safe water on a continuous basis – for security of supply – or fail completely after construction. This has been termed a 'hidden crisis' because sector stakeholders have tended to focus on new

Box 3: Access to rural water supply: findings from the National WASH Inventory

Historically, coverage data in Ethiopia (and elsewhere in SSA) have been based on inventories of built infrastructure and assumed levels of service, rather than outcomes monitored post-construction. Hence MoWIE figures have been estimated by multiplying the number of water schemes – shallow wells, boreholes, protected springs - by their design capacity. Yet many sector professionals have highlighted problems of scheme functionality, albeit with patchy evidence. Studies conducted by the RiPPLE programme in two woredas in SNNPR, for example, indicated that 43-65% of water points or schemes were non-functional. A recent high-level review of service delivery in Ethiopia highlighted 'increased sustainability of infrastructure' as a key priority if hard-won public health and poverty alleviation gains were not to be lost (WSP, 2011).

The National WASH Inventory (NWI), completed in 2011 at a cost of roughly USD 12 million, collected both user (access) and provider (infrastructure/scheme) data through a sector-specific household and water point census. The census covered 92,000 rural water supply systems, over 1600 small town systems and 50,000 schools and health institutions. Some 12 million households were interviewed about their water and sanitation facilities (Butterworth et al, 2013). One outcome is a revision downwards of WASH coverage figures from the MoWIE's 2010 estimate, and renewed attention on system and service sustainability in the OWNP, with a target of reducing 'non-functionality' levels to 10%.

Table 1: Access to safe water

	JMP 2010	JMP 2011	JMP 2015	MoWIE 2010	MoWIE 2011
Rural (%)	34	39		66	49
Urban (%)	97	97		92	75
Total (%)	44	49	57	69	52

Note: definitions vary. JMP data are based on use of improved water facilities. MoWIE data are based on assumed levels of service provided by all water systems.

While NWI data provide a much better understanding of the types of water supply systems that exist across the country and their functional status, they do not provide insights into the causes of failure, the existence and functioning of WASH committees, or details of their financial management. Hence while the ambition of improving the sustainability of services under the OWNP is laudable, the risks that need to be addressed remain unclear (Calow, Ludi, & Tucker, 2013; Butterworth et al, 2013).

infrastructure and assumed sustainability, with coverage data based on systems installed rather than the services people actually receive (Calow, Ludi, & Tucker, 2013).

The situation is now changing, with comprehensive data on the functionality of systems emerging from the country's first comprehensive audit of water supply and sanitation systems – the National WASH Inventory (NWI) – and a target under OWNP of increasing system functionality rates to 90% (see box below). As a result of the NWI, WASH coverage figures were revised downwards significantly. Combined urban and rural coverage was reported in 2013 (based on the 2010/11 NWI data) as 52%, compared with 69% by the MoWIE in 2010, and the figure for rural water supply coverage was revised downwards from 66% to 49% (Butterworth et al, 2013). While these figures were clearly disappointing, they highlighted a problem most sector stakeholders were aware of, and provide a robust baseline against which sector performance can now be measured. Subsequently both JMP and national sector coverage estimates have climbed upwards, with the JMP declaring 57% coverage (the MDG target level) had been reached in 2015.

The GoE has responded to one element of the sustainability challenge by putting more emphasis on lower cost technologies, including facilitated self-supply, and by asking households, communities and the private sector to do more in terms of articulating demand, planning and implementing projects, procuring goods and services and managing funds. By giving households and communities a stronger voice in service choices and implementation, so the argument goes, services are more likely to meet real needs, harness local capabilities and be sustained over time. The COWASH Community Managed Project (CMP) approach, now included as one of four service modalities in the OWNP, provides an excellent example (see box below).

While empowering households and communities is clearly important for sustainability, the aspiration of universal coverage will not be realised unless investments are resilient to a range of threats, including both current levels of climate variability and future change. Failure to ensure that services are resilient will have major public health consequences if water quality deteriorates and/or water availability becomes less certain (Howard & Bartram, 2010; Calow et al., 2011). A study by Hunter, Zmirou-Navier, & Hartemann (2009) indicated that even occasional short-term failures in water supply (or water treatment) could seriously undermine many of the public health benefits associated with an improved supply. Clearly not taking climate variability and change into account, alongside other pressures on services, could result in a reversal of progress against future targets and the loss of hard-won public health and poverty alleviation gains.

While much has been written about resilience and adaptation in general terms, relatively little has been written about its practical substance (Fankhauser & Burton, 2011). In short, what 'adaptation' and 'resilience building' actually mean in the context of delivering sustainable water and sanitation services in the face of multiple pressures remains ambiguous. In part, this is because of the uncertainty regarding the translation of large-scale climate scenarios into local adaptation solutions on the ground (Ranger, 2013), and the difficulties associated with untangling the climate signal from the many other factors affecting the sustainability of services (Calow, 2009; Conway, 2011; OECD, 2013). This has not stopped a simplistic crisis narrative emerging around climate change and WASH, in which climate change is held principally responsible for perceived increases in water scarcity and system failure (Calow et al, 2011; Conway, 2011) The evidence, such as it is, does not support such claims. Rather, an understanding of the known risks posed by existing climate variability reinforces the need for responses that are robust to both existing variability and future uncertainty, alongside other pressures on resources, systems and services.

Box 4: Decentralisation and moves towards community procurement of services

In an effort to improve the sustainability of rural water supply and harness demand for improved services, the GoE is promoting household self-supply and community procurement alongside more traditional, government-led approaches to service delivery. In particular, the Community Development Fund (CDF - now known as CMP for Community Managed Projects) is an approach that transfers funds and all planning, financial management, implementation and maintenance responsibilities to communities, including responsibility for procuring goods and services (FDRE, 2013).

Under the CMP, funds for the development of water-supply infrastructure are transferred via a Regional Credit and Savings Institution – a financial intermediary – to trained Water and Sanitation Committees (WASHCOs). The WASHCO leads the process of planning and developing a new water point, with significant in-kind contributions from community members that relate to effective demand for a specific service level, and the local contracting of artisans and suppliers. Cash contributions for operation and maintenance are collected in a separate savings account held with the same financial intermediary.

An evaluation in 2010 concluded that the CMP offered an efficient, cost-effective and sustainable approach to extending services compared with other modalities.

2.3 Climate change and WASH: risks and uncertainties

2.3.1 Climate variability and change in Ethiopia

Ethiopia has a complex and varied climate, with high levels of spatial and temporal variability linked to topography, seasonal weather cycles, and responses to regional and more remote influences (McSweeney, New, & Lizcano, 2010) (Conway & Schipper, 2011). Broadly though, Ethiopia can be divided into three main topographic-climatic regions: (1) western, (2) central and eastern and (3) south and south-eastern, each with one or two rainy periods. Total annual rainfall ranges from less than 600 mm per annum in the eastern corner of Ethiopia to over 1400 mm per annum in the highlands. Inter-annual variability is significant, particularly in the south and south-east, with annual rainfall varying between +36% and -25% of the mean (Figure 1).

High temporal and spatial variability in climate and the poor state of the country's climate observing system makes it difficult to detect long term trends (Conway & Schipper, 2011) [6]. However, the available evidence suggests an increase in mean annual temperature of 1.3°C between 1960 and 2006. Regional level analysis shows a similar trend in all regions, although with different absolute average temperatures.

The overall national trend for rainfall is more or less constant, with no statistically significant changes for any season since 1960 (McSweeney et al, 2010). In addition, no clear trends in rainfall intensity and the frequency of extreme events are apparent, although there is a general perception amongst rural communities that the characteristics of rainfall are changing, including the timing and duration of the wet season(s) (Kaur et al, 2010; Di Falco et al, 2011).

What about future change? Drawing on a major review of global circulation model (GCM) results for Ethiopia in McSweeney et al (2010)[7], some key patterns emerge. Firstly, results from all 15 GCMs (an 'ensemble') show continued warming throughout Ethiopia, with the mean annual temperature projected to increase by 1.1° to 3.1° C by the 2060s, and by 1.5° to 5.1° C by the 2090s. This warming is likely to be associated with a greater frequency of heat waves, higher rates of evaporation and, potentially, higher soil moisture deficits.

Box 5: Why do rural water supplies fail?

Achieving long-term, enduring increases in coverage that reach the poorest people continues to present a huge challenge for governments in Africa, not least because of the largely hidden crisis of functionality: many systems fail to provide safe water on a continuous basis because they deteriorate or break down completely (Hayson, 2006; Reitveld, Haarhoff, & Jagals, 2009; Calow et al, 2011; WHO/UNICEF, 2012; Calow, Ludi, & Tucker, 2013). Ethiopia is one of the few countries in SSA to have collected comprehensive data on the functionality of water systems through a National WASH Inventory (NWI - see above). Frustratingly, however, NWI data shed little light on the causes of failure.

In reality, the causes can be difficult to untangle, with environmental, financial, institutional, technical and social factors at play (Calow, Ludi, & Tucker, 2013). What is clear, at least from local water audits, is that existing levels of climate variability affect the services people receive, to the extent that even in 'covered' communities with functioning infrastructure and robust institutions, households can struggle to meet even minimum (emergency) drinking water needs.

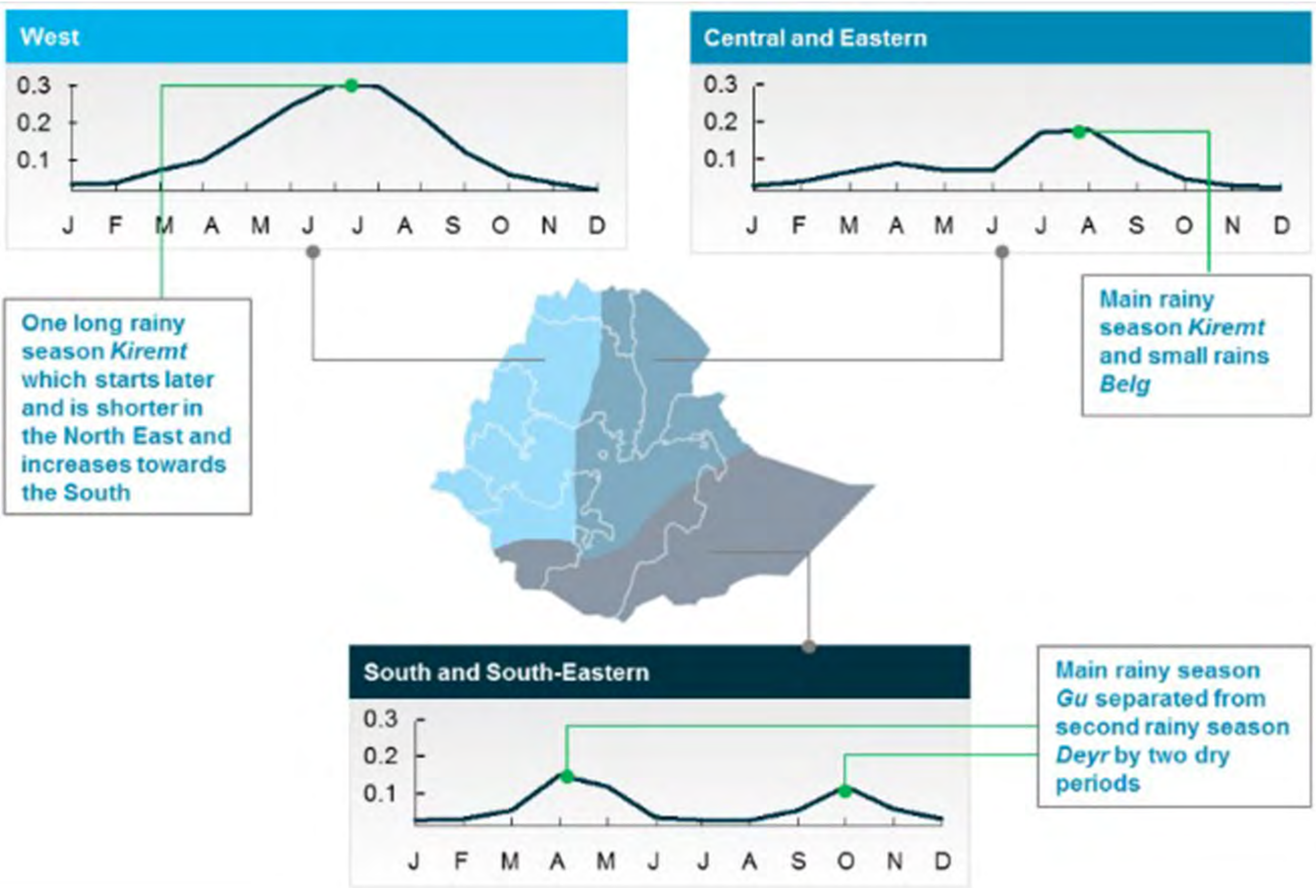
Water audits conducted along a highland-lowland transect in the Oromia Region of eastern Ethiopia (Coulter, Kebede, & Zeleke, 2010; Tucker et al, 2014) showed that very few households in any livelihood zone exceeded the domestic (drinking, cooking, personal hygiene, laundry) water requirements recommended by the Sphere project (Sphere, 2011) for humanitarian emergency situations (7.5 – 15 lcd), let alone reached the levels recommended for non-emergency situations. The majority of households used 8-12 lcd - levels which present a high level of health concern (Howard & Bartram, 2003). Moreover, poorer households were consistently using less water than their better-off counterparts, particularly for hygiene, and especially in the dry season.

Increasing collection times affected the poorest households most severely, as they had the least labour to release, the fewest assets to collect and store water, and the least cash to pay for it. They were also more likely to forego vital income generating activities in favour of water collection, and more likely to see the condition of their livestock deteriorate as a result of constrained water access.

Not all problems revolve around water access and availability, however. Water quality is a key issue, even for protected sources, with strong links to climate. Floods, for example, can contaminate sources, damage water supply infrastructure and prevent access to safe sources. Major floods in 1997, 2006, 2007 and 2014 displaced tens of thousands of people and damaged infrastructure (OFDA/CRED), though impacts on water supply in rural areas go largely unreported.

6 There is also no coordinated programme of research on climate and climate change in Ethiopia, despite the attention climate change is now receiving in terms of economic policy and poverty reduction (Conway et al, 2011).

Figure 1: Historic month-to-month rainfall variability



Source: National Meteorological Agency (NMA) cited in FDRE (2015).

Climate models show different projections in annual rainfall, with some models predicting more rain and others less, but with a tendency for slightly wetter conditions. Over the shorter term, all models indicate modest changes in mean annual rainfall for the 2020s (+0.4%) and 2050s (+1%). Seasonal changes are slightly larger but still modest (Conway, 2007). However, there are some marked regional differences in the size and direction of rainfall change, with much of the average increase in rainfall accounted for by higher rainfall during the Belg season in southern Ethiopia (McSweeney et al 2010). Models also suggest a tendency for more frequent and intense extreme events – for both temperature and rainfall.

Before looking at what these changes might mean for water resources and water services, the uncertainty surrounding future changes in rainfall should be emphasised. While multi-model averages suggest wetter conditions over Ethiopia in general, the climate model range for wettest and driest changes is very large (+/-20%), with some models producing extremely large increases and decreases in rainfall according to region and season.

2.3.2 Risks to WASH: untangling the web

The impacts of climate change on people, ecosystems and economies will be transmitted mainly through water (Cisneros et al, 2014). However, predicting impacts on the availability, reliability and quality of freshwater resources, and on the downstream services they support, is very difficult. While there is a high level of confidence in the processes linking emissions to warming, much less is known about how warming will affect patterns of rainfall, runoff, stream flow and groundwater recharge at local levels (OECD, 2013; Cisneros et al, 2014). This is partly because of the difficulties of downscaling global and regional models to the local level, but also about attribution. Untangling the climate signal from what the IPCC call 'confounding' factors – things like land use change and water withdrawals – is hampered by the shortage of observational data needed to establish baselines and project impacts (Neumann et al, 2007; Batisani, 2011; Conway, 2011; Hall et al, 2014).

So what do we know? Precipitation and potential evapotranspiration are the main climatic drivers controlling freshwater resources (Cisneros et al, 2014).

7 Although the McSweeney review was published in 2010, findings remain valid. The IPCC's 5th Assessment confirms the warming trend for East Africa (and the rest of SSA), and modest increases in projected rainfall, despite recent drying caused by remote influences originating in the western Pacific Ocean (Cisneros, et al., 2014).

Where rainfall decreases over the longer term, we might expect to see a reduction in renewable freshwater resources and vice versa. While this is likely, it is by no means certain. Much depends on local conditions and, specifically, the relationship between evapotranspiration, soil moisture and land use change. The local water balance[8] is very sensitive, not only to changes in climate, but to changes in soil properties and vegetation cover (see box below).

In terms of the timing and intensity of rainfall, climate models are broadly consistent in projecting increases in the proportion of total rainfall that falls in heavy events (Allan & Soden, 2008; Cisneros et al, 2014). Ethiopia is no exception. This will likely increase flood hazards and, as exposure to floods goes up, socio-economic losses will increase, especially in smaller, 'flashier' catchments with high population densities (ibid). The flip side is an increase in the frequency and/or duration of droughts, at least in those areas where rainfall is already low.

The combination of changes in streamflow and rising temperatures is also expected to have broadly negative impacts on freshwater ecosystems and water quality (Cisneros et al, 2014). Higher water temperatures encourage algal blooms and increase risks from cyanotoxins and natural organic matter in water sources. Increased runoff results in greater loads of fertilisers, animal wastes and particulates. Low flows, meanwhile, reduce the capacity of rivers to dilute, attenuate and remove pollution and sediment. Reductions in raw water quality pose risks to drinking water quality, even with conventional treatment, though the extent and nature of changes remain uncertain and very dependent on the seasonality of rainfall, land cover and soil management practices (ibid).

Box 6: Summary of climate change projections for Ethiopia

Temperature

- The mean annual temperature is expected to increase by 1.1° to 3.1° C by the 2060s, and by 1.5° to 5.1° C by the 2090s. Considerable uncertainty in the magnitude of change exists: under a single emissions scenario, the projected changes from different models span a range of up to 2.1° C
- All projections indicate an increase in the frequency of days and nights that are considered 'hot' in the current climate.

Rainfall

- Projections are consistent in indicating an increase in annual rainfall, mainly because of increasing rainfall in the October – December period in southern Ethiopia.
- October – December rainfall is expected to change by +10% to 70% on average over the whole of Ethiopia.
- Proportional increases in October – December rainfall in the driest, most eastern parts of Ethiopia are large.
- Projections of change in the rainy seasons (April – June; July – September) which affect the largest area of Ethiopia are more mixed, though with a tendency towards a slight increase in the south-west and a decrease in the north-east.

Extremes

- Projections from different models in the ensemble are broadly consistent in indicating an increase in the proportion of rainfall that falls in heavy events, with annual changes ranging from -1 to +18%.
- The largest increases are seen in July - August and October – December rainfall.

Source: McSweeney et al (2010). Note: all projections relative to a 1970-99 baseline

8 How rain falling at a particular place becomes divided between surface runoff and infiltration, and then between evapotranspiration and groundwater recharge

To conclude, the range of climate-related impacts on freshwater resources and services is potentially very wide. Most studies linking climate modelling to impacts have focussed on long term changes - generally beyond the 2050s - (Conway, 2011). The Vision 2030[9] work on the resilience of water supply and sanitation in the face of climate change (Howard & Bartram, 2010; Howard et al, 2010; Charles, Pond, & Pedley, 2010), ODI's work on climate change and WASH (Calow et al, 2011; Oates et al, 2014) and IRC's Thematic Overview (Batchelor, Smits, & James, 2011) remain exceptions.

2.3.3 Summary

Despite the uncertainty and knowledge gaps, there is a growing body of evidence documenting the range of possible impacts on water systems and services that could be expected in a changing climate. These are summarised below in relation to the spring and hand dug well technologies prioritised under Phase 1 of the OWNP, and in terms of the risks arising from climate extremes - specifically intense rainfall events (Table 2) and prolonged dry periods (Table 3). The tables also summarise the kinds of measures that can be employed to reduce or mitigate risks at the planning and design stage, and later on.

The key point here is not about climate prediction, but rather vulnerability reduction. The risks to public health outlined below already affect access to safe water because of existing climate variability and, in the case of reduced water availability, because of rising demand. Climate change will exacerbate these risks, not change their nature

Box 7: Understanding the impacts of climate change on groundwater

Despite rapid urbanisation in SSA, the majority of people still live in rural areas and poverty remains an overwhelmingly rural phenomenon. The development of groundwater for rural water supply offers significant advantages (compared to surface water sources) in terms of climate resilience because of the storage groundwater aquifers offer; specifically, large storage volume per unit of inflow makes groundwater less sensitive to annual and inter-annual rainfall variation and longer-term climate change (MacDonald et al, 2009; Calow et al, 2011). The relative ubiquity of groundwater, its generally higher quality and (typically) lower development costs for meeting dispersed demand provide additional benefits.

Nonetheless, uncertainty remains about the impacts of climate change on groundwater resources as a result of both the major uncertainty in GCM projections of rainfall, but also that associated with the downscaling of GCM projections, the hydrological models used, and intervening factors such as land cover and land use change (Taylor et al, 2013). Climate variability and change can also affect groundwater indirectly through changes in groundwater use – for example increasing demand for irrigation water to help buffer the effects of more erratic rainfall (ibid).

Recharge to groundwater is highly dependent on prevailing climate as well as land cover and underlying geology. Climate and land cover largely determine rainfall and evapotranspiration, whereas the underlying soil and geology dictate whether a water surplus (precipitation minus evapotranspiration) can be transmitted and stored in the subsurface. Recharge is strongly influenced by climate extremes – droughts and floods – with recharge in semi-arid environments often restricted to heavy rainfall events (MacDonald et al, 2012; Taylor et al, 2013) The result can be a non-linear relationship between rainfall and recharge (ibid).

Land use change can exert an even greater effect and a much stronger influence than climate change. In the West African Sahel, for example, groundwater recharge and storage increased in the latter part of the 20th Century despite a multi-decadal drought because of a shift from deeper rooted savannah to crop land that increased surface runoff and focussed recharge (Taylor et al, 2013).

What are the implications for groundwater resources and groundwater dependent services in SSA? Much will depend on the distribution, timing and intensity of rainfall, underlying soil and geology, and future land use change. However, as climate models are broadly consistent in indicting increases in the proportion of total rainfall that falls in heavy events (Allan & Soden, 2008), impacts on recharge could potentially be positive. However, increased runoff and flooding could result in greater microbial contamination of water supplies and cause damage to infrastructure, highlighting the importance of source-catchment protection.

The conclusions of MacDonald et al. (2012) and Taylor et al. (2013) also demonstrate that modest yields of groundwater are quite widely available at accessible depths and sufficient to sustain small communities, but larger yields (>5 l/sec) suitable for urban development or major agricultural schemes are unlikely outside sedimentary basins. The availability and accessibility of groundwater over much of Africa is therefore favourable to rural domestic supply and minor productive use, rather than intensive development of the kind seen in south Asia (Calow & MacDonald, 2009; Edmunds, 2012).

9. A DFID and WHO study that looked at the projected impact of climate change on water and sanitation services by 2020 and 2030. See http://www.who.int/water_sanitation_health/publications/9789241598422/en/

Table 2: Intense rainfall events – risks and adaptations

Protected Springs	
Hazard	Seasonal or drought-related reductions in spring yield, or spring dries up completely. Seasonal or drought-related reduction in water quality – less dilution of pollutants.
Impact	Public health risk as water quality deteriorates. Maybe rapid but short term, or longer term if wider aquifer contaminated.
Adaption planning, design	Prepare hazard map with community; address direct threats, including risks from open defecation, or investigate alternative sites/sources. Construct bunds or cut-off drains to divert runoff away from collection area. Implement land management activities in wider catchment to reduce severity of floods e.g. terracing, drainage, retention basins, re-vegetation. Ensure water collection & storage infrastructure is properly designed and built from durable materials. Raise awareness of risks from water quality changes during and after flooding, and need for household water treatment/ use of safer alternatives. Develop communication plan: (1) when to avoid contaminated sources for drinking during and after floods until water quality is verified; (2) what are the safe alternatives (e.g. household treatment, different sources
Adaption - ongoing	Regularly check and repair infrastructure. Monitor & maintain bunds, drains & other catchment protection measures. Sanitary inspection. Implement communication protocol and advise on safety; provide support for household treatment if necessary.
Hand-dug wells	
Hazard	Increased contamination of groundwater and lateral flow in soil.
Impact	Water quality deteriorates – may be rapid but short term, or longer term if surrounding aquifer contaminated. Damage to infrastructure e.g. from landslips, gullies and flooding.
Adaption planning, design	Prepare hazard map with community; address direct threats, including risks resulting from open defecation, or investigate alternative sites/sources. Site well away from latrines and other sources of groundwater pollution. Address direct flood risk by building bunds or cut-off drains to divert runoff. Implement land management activities in wider catchment to reduce severity of floods e.g. terracing, drainage, retention basis, re-vegetation. Improve and/or extend well lining to prevent ingress of contaminated water; raise well head. Raise awareness of risks from water quality changes during and after flooding, and need for household water treatment/ use of safer alternatives. Develop communication plan: (1) when to avoid contaminated sources for drinking during and after floods until water quality is verified; (2) what are the safe alternatives (e.g. household treatment, different sources).
Adaption -ongoing	Seal any abandoned wells to protect groundwater quality. Regularly check and repair infrastructure. Monitor and maintain protection areas and wider catchment protection measures. Sanitary inspection. Implement communication protocol: advise on safety; provide support for household treatment if necessary. Shock-chlorinate well water after floods have subsided.

Table 3. Dry periods and droughts – risks and adaptations

Protected Springs	
Hazard	Seasonal or drought-related reductions in spring yield, or spring dries up completely. Seasonal or drought-related reduction in water quality – less dilution of pollutants.
Impact	Seasonal or drought-related shortages – insufficient water for demand. Public health risk from water rationing/cut-backs, or use of alternative (unsafe) sources. Public health risk from deteriorating water quality at end of dry season or drought.
Adaptation – planning, design	Collate secondary information on geological conditions to understand water availability and supplement with field observations. Discuss seasonal yields of alternative sites with community – select most reliable source(s). Estimate spring yield and catchment size needed to meet current and projected demand. Increase capacity of collection and storage facilities. Raise awareness of need to prioritise water use for drinking over other uses, and/or water rationing at times of peak demand and low flow. Investigate management practices that might increase infiltration and groundwater recharge – in vicinity of spring and in wider catchment. Develop supplementary sources if necessary to spread risk.
Adaptation - ongoing	Regularly check and repair infrastructure. Monitor and maintain protection areas and wider catchment protection measures. Excavate spring further if necessary. Collect data on seasonal changes in discharge. Monitor water quality during high risk periods at end of dry season or drought.

Hand-dug wells	
Hazard	Seasonal or drought-related reductions in well yield, or well dries up completely. Failure of handpump as demand increases and water levels fall. Seasonal or drought-related reduction in water quality – less dilution of pollutants.
Impact	Seasonal or drought-related shortages – insufficient water for demand. Public health risk from water rationing/cut-backs, or use of alternative (unsafe) sources. Public health risk from deteriorating water quality at end of dry season or drought.
Adaptation – planning, design	Collate secondary information on geological conditions to understand water availability and supplement with field observations. Discuss community experience of well performance past and present (water quality, availability) as guide to selecting best site. Estimate well yield and catchment size needed to meet current and projected demand. If marginal, investigate alternative sites and options. Test yield of well at peak of dry season to assess resilience. Raise community awareness of need to prioritise water use for drinking over other uses, and/or water rationing at times of peak demand and low flow. Investigate land management practices that might increase infiltration and groundwater recharge – in vicinity of well and in wider catchment. Develop supplementary sources if necessary to spread risk.
Adaptation - ongoing	Regularly check and repair infrastructure. Collect data systematically on seasonal changes in water levels. Focus handpump maintenance in dry seasons when mechanical failure is most likely. Regular desilting and cleaning of wells to maintain yield; consider deepening wells if feasible. Monitor water quality during high risk periods at end of dry season or drought.

2.4 Existing guidelines for rural water supply – a brief review

To develop a better understanding of the guidelines and protocols WASH implementing agencies are currently using, and whether (and how) climate variability and change are considered, the project commissioned a brief review.[10] The objective was to find out: (a) what guidance or technical standards/norms were being used in the field; (b) whether guidance considered climate variability, longer term change and increasing demand for water; and (c) whether agencies were integrating rural water supply with catchment protection and water resources management. Key findings are summarised below:

- *National protocols.* All agencies aim to implement national standards relating to the numbers of people served by different technologies (e.g. springs, hand dug wells, boreholes) and participatory approaches to planning and implementation, including the formation and training of WASHCOs. Service levels and specific implementation approaches are outlined in the OWNP (see box above).
- *Detailed technical guidance.* Water point design, siting, construction etc. Different agencies have developed their own technical guidance, but the focus is on technology choice and construction. The available 'how to' guidance on the selection of springs and the siting of hand dug wells is strongly focussed on social factors and sanitary protection[11], though some (e.g. WaterAid) recommend that baseline studies include a delineation of the source catchment. However, no guidance is provided on how this should be done, or how to estimate the minimum catchment size needed to ensure available water resources can meet current and projected demand.
- *Consideration of climate variability and change.* Climate change is regarded as a major pressure on sustainable water supply. A widely held view was that increasingly erratic rainfall and longer and more frequent dry spells were reducing water availability. In addition, it was thought that existing climate variability and resource degradation – and in particular deforestation – was leading to a fall in shallow groundwater levels and causing springs and wells to dry up. Flooding and the risk it poses to the contamination of water sources was also highlighted. However, only UNICEF guidelines on the Identification of climate-resilient water and sanitation technological options for schools in Ethiopia (UNICEF, 2012) consider specific, climate-related options for WASH, and the guidance does not cover water resource assessment, water point siting or links to watershed management (beyond general principles).
- *Catchment protection.* Integrated planning approaches linking rural water supply with wider catchment protection and water resources management were identified as important by all agencies. However, while interviewees stated that integrated water resources management (IWRM) should be carried out, they remarked on the lack of practical guidance. So while some NGOs (e.g. HCS) implement groundwater recharge and micro-watershed activities close to water points, there is no guidance on how rural water supply could be better coordinated with watershed rehabilitation activities carried out (for example) under the GoE's Productive Safety Net Programme (PSNP). Interviewees noted the sector 'silo' between WASH and IWRM, and the institutional siloes between WASH signatories and the Ministry of Agriculture (overseeing most watershed protection programmes).
- *Recommendations.* Overall, the WASH organisations interviewed identified a need for: (a) shared, practical guidance on how to address pressures on water systems and sources arising from climate and other drivers of change; and (b) practical guidance on how to link water supply with watershed protection to ensure the sustainability of water supply.

At the time of writing, a National Climate Resilient Water Safety Planning Strategic Framework is being developed under the leadership of MoWIE and with support from DFID. This framework builds on Water Safety Plan Guidelines for rural and urban areas and incorporates aspects of watershed management as part of the risk mitigation component of the Water Safety Plan.

10 The review was carried out by RiPPLE, an Ethiopian NGO engaged in WASH planning and implementation, and was based on interviews with WASH implementing agencies in Addis Ababa conducted in 2013. Interviews were held with: KHC, AFD, Amref, Plan Ethiopia, WaterAid Ethiopia, Water Action, HCS, IDE, World Vision, Care, WSP and UNICEF.

11 Borehole sitting is carried out by drilling contractors (private and public) using standard geophysical techniques

3. Risk screening and mitigation

3.1 Introduction

In this section we outline the steps that can be taken to increase the resilience of groundwater-dependent hand dug wells and springs to climate variability and change, focusing on specific interventions for ensuring source sustainability and protection.

We begin by discussing risk screening approaches in general, and their application in Water Safety Plans (WSPs) that focus on risks to water quality. We also summarise broader approaches developed recently by ODI (Oates et al, 2014) that consider risks to both water quality and availability from the perspective of programme design (Section 3.2).

In Section 3.2 we then describe the tools developed on the current project, focussing on the technical and environmental determinants of sustainability that are most relevant to climate resilience, and which receive little or no attention in existing guidelines (see Section 2.4). The tools deal with three key areas:

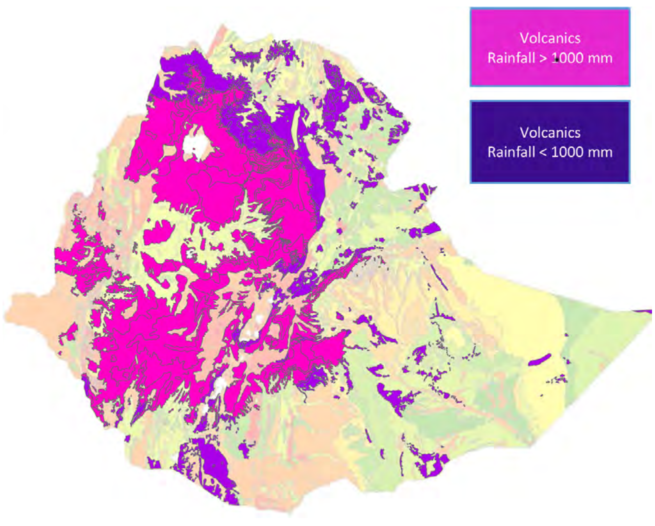
- Understanding water availability through simple geological assessment.
- Ensuring source sustainability through 'catchment screening' of demand and supply.
- Protecting sites and sources from direct and indirect environmental hazards.

In each case, we describe why guidance is important, what the evidence base is for the recommendations being made, how the guidance can be used by WASH programme staff, and the institutional and capacity-building implications for application in the field. The guidance sheets themselves are presented in separate report (Calow et al, 2015).

A number of qualifications should be highlighted. First, the guidance presented is based on short field investigations in one woreda in Amhara Region, not a comprehensive regional or national study. Farta Woreda is a hilly upland area and the elevation gives it a moist/humid climate. Combined with a volcanic geology, this means that groundwater is available from weathered or high permeability zones, accessible via springs or hand dug wells. Similar geological and hydrological conditions are found across large parts of rural Ethiopia, so the guidelines developed are widely applicable with minor modification (see Figure 2). However, further work would be needed to adapt the approach for very different environments, such as the lower lying rift, with different aquifer types, recharge regimes and water supply options (see box below).

Second, the tools developed address risks to the sustainability of water services, not sanitation or hygiene, or water quality specifically. This remains a significant gap, although one that is currently being addressed through the COWASH project (see Section 3.1 below). However, the tools that deal with the protection of sites and sources are relevant to water quality issues since hazards such as floods can directly or indirectly contaminate sources and damage the infrastructure needed to maintain safe supply.

Figure 2 Areas of Ethiopia with similar conditions to Farta Woreda



Source: Seifu Kebede, 2013

3.2 Risk screening approaches

Climate risk management describes the process of identifying climate-related risks and implementing measures to reduce such risks to acceptable levels (Olhoff & Schaer, 2010). Risk assessment has been defined as '…a methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend' (UN, 2004). Therefore, both the physical climate hazard, and the vulnerability of the system, is considered under 'risk'.

Box 8: Where can the guidelines be applied, and who are they for?

The guidelines summarised here and detailed in a supplementary report (Calow et al, 2015) focus on groundwater-dependent, low cost hand dug wells and springs. These technologies feature prominently in the OWNP.

Across Ethiopia there is a wide range of climatic conditions, varied geology and different livelihood patterns and needs. The current guidelines were developed in the context of the Amhara highlands – a relatively wet area of Ethiopia underlain by volcanic geology, with dispersed rural communities and water schemes that use springs or hand dug wells. Since similar volcanic terrain with moderate to high rainfall (above 1000 mm per annum) occurs across large parts of Ethiopia (see Figure 2), the guidelines could be applied to these areas with minor modification. Moreover, the environmental assessment and risk screening approach could be adapted to different geological and hydrological contexts with further work.

The kinds of adaptations needed would include the provision of locally appropriate examples for field identification of geological environments and identification of the major constraints and environmental stresses affecting groundwater availability and quality. In Farta Woreda these were primarily catchment area and the risk of gully development. In a lowland environment with shallow sedimentary deposits, for instance Fogera Woreda on the shores of Lake Tana, constraints are likely to be associated with the presence of clay and silt in shallow sediments, and flooding will be the major environmental risk.

In the lower lying rift, where demands are different and there are deeper, more extensive aquifers with lower rates of recharge, deeper boreholes are needed to withdraw water, and sophisticated geophysical techniques are needed to site them. However analysis of the constraints on borehole yield and environmental hazards would still be important, especially if recharge is low and the risks to infrastructure and services posed by flooding, for example, are still important.

This report is aimed at those organisations that fund, oversee and/or help implement Ethiopia's OWNP. These include the governmnet itself (MoWIE – federal and regional), Consolidated WASH Account partners such as the World Bank, the African Development Bank (AfDB), UNICEF and DFID, bilateral partners such as the Government of Finland, and international and national NGOs and CSOs. The accompanyting report, which offers much more detailed 'how to' guidance, is aimed at those designing and implementing WASH programmes on the ground. These include regional, zonal and (particularly) woreda WASH teams under MoWIE, and NGO practitioners. Increased coordination between WASH and environmental constituencies is also recommended, and so the tools should be useful for those engaged in natural resource management also.

Both reports can help shape national WASH implementation guidelines currently being prepared by the COWASH project. To achieve traction on the ground, we propose a series of 'training for trainer' events at national and regional level. The aim would be to translate project guidance into a 'hands-on' training course with both classroom and field-based components.

Climate risk screening typically avoids probabilistic calculations associated with traditional (more technical) conceptions of risk assessment. Rather, it involves systematically examining activities (or projects, programmes, policies, technologies) with the aim of:

- Identifying hazards which could potentially cause harm.
- Identifying inherent vulnerabilities in the system.
- Assessing whether these risks – the product of hazard and vulnerability - are being taken into account.
- Considering the extent to which risks can be reduced or mitigated.

Since the probability of the hazard occurring cannot be reduced, this implies exploring opportunities for reducing the vulnerability associated with physical hazards. The usefulness of a risk management approach lies in its emphasis on preventative rather than reactive measures. Whilst the complete elimination of risk is seldom possible[12], what is important is identifying the most significant risks and prioritising their mitigation.

One risk management framework gaining wide recognition is the Water Safety Plan (WSP). Conventional WSPs focus on risks to water quality along the water supply chain from source to consumer, and aim to identify and avert contamination risks before problems emerge (see box below).

12 The term 'climate-proofing' has been used to describe this desire to eliminate the vulnerability of physical infrastructure to climate variability and change. Good engineering practice (though not all aspects of WASH system design) has always taken account of climate variability, by designing to estimated return periods (statistical frequency) of extreme events. Even under relatively well-known variability, engineers have never designed structures to withstand every single extreme event. Under greater future variability it is economically unrealistic to design engineering structures to withstand all extremes.

Box 9: Water Safety Plans

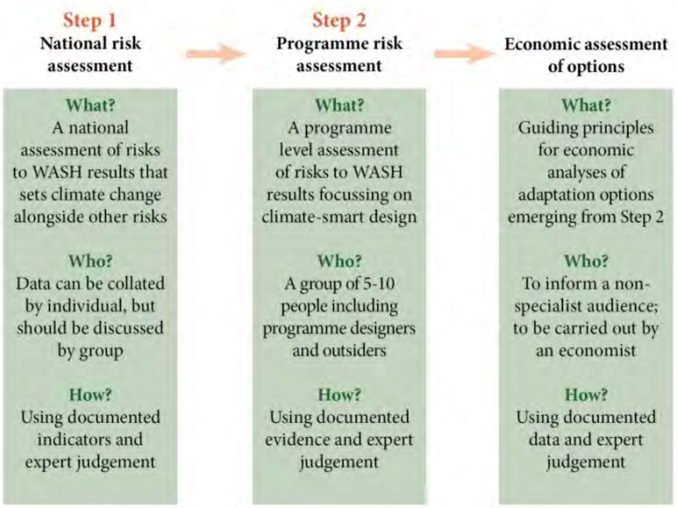
The World Health Organisation (Bartram et al, 2009) promotes WSPs as the most effective way of ensuring the safety and acceptability of a drinking water supply. The approach was designed to safeguard water quality for human health, and offers a comprehensive risk assessment and management methodology which considers all steps in the water supply chain from source to consumer. Crucially, this is a preventative approach which aims to avert contamination before it happens by identifying and mitigating risks in advance, rather than rely on end-of-pipe testing and ad-hoc measures. WSPs require identifying all potential hazards which could occur along the water supply chain and assessing the risk associated with the hazards, with the aim of distinguishing more significant risks from less significant risks (see box above).

Most experience in implementing WSPs has taken place for utilities within a developed country context, but there have been some reports of applying the methodology for small community-managed schemes in developing countries (e.g. (Mahmud et al, 2007; Greaves & Simmons, 2011; Rickert et al, 2014). Generic, technology-based WSPs are based on an understanding of the hazards which may pose a risk to each technology type. They provide a framework of typical hazards and risks, appropriate control measures, critical limits (which specify when action is needed), monitoring requirements (who does what and when), and required corrective action if critical limits are reached. These can be adapted as needed to the local circumstances.

Box 10: Adaptation to climate change in water, sanitation and hygiene: Assessing risks & appraising options

Research led by ODI and funded by DFID assessed the risks to delivery of WASH results posed by climate change in Africa, drawing on rapid case study reviews of WASH programming in Malawi, Sierra Leone and Tanzania. A three-step risk screening approach was developed, highlighted in the figure below.

First, a national-level assessment of risks to WASH posed by climate change and other pressures is set out as a scorecard. The aim is to shed light on whether climate change is a key risk in the context of other trends and hazards, such as demographic change and environmental degradation. Second, a further checklist is used to assess risks to specific projects and programmes, based on factors such as knowledge about climate change risks, the design and enforcement of technical standards, and integration with catchment management and protection. Finally, some simple economic tests are applied to adaptation options to see if they are cost-effective under different climate and planning scenarios.



Source: Oates et al, 2014.

A number of commentators have suggested that the approach could be usefully widened to include climate risks (Bartram et al, 2009) and concerns with water resources and environmental hazards – additional factors that could affect water availability, water quality and water infrastructure (Howard & Bartram, 2010; Calow et al, 2011). The obvious appeal is building on an existing framework that is already widely adapted by implementing agencies. The COWASH project in Ethiopia is taking this idea forwards, with the aim of developing a set of national WASH guidelines that address risks to both water quality and availability, informed by the recommendations set out in this report.

In addition, recent work led by ODI has set out the risks to WASH from climate change in a national and programme-level planning framework (Oates et al, 2014). One of the key concerns voiced by government ministries and development partners in Malawi, Tanzania and Sierra Leone was the lack of practical guidance on how to mainstream climate resilience into WASH planning, and the need to work across WASH-water resources management siloes to address growing and competing demands for water. In short, their concerns echoed those raised by the Ethiopian stakeholders interviewed for this project, summarised in Section 2.4.

3.3 Filling the gaps: Resource sustainability and environmental management

3.3.1 Introduction

In the sections below three approaches and associated tools are discussed for assessing and improving the technical and environmental sustainability of water supply schemes using hand dug wells and spring protection:

- Step 1: Understanding water availability – assessing geology and source behaviour
- Step 2: Ensuring source sustainability – catchment screening for demand and supply
- Step 3: Protecting sites and sources – dealing with environmental hazards

The approaches are designed to be mutually supportive, with, for instance, sites that are deemed to have catchments that are marginal in relation to projected demand selected for greater focus in environmental assessment and management.

Steps 2 and 3 can be applied to existing schemes as well as the planning and implementation of new ones. For example, the GIS-based approach to assessing source-catchment vulnerability (under Step 2) can be applied across a woreda or larger area to create maps showing which water sources are likely to have adequate catchment areas. Similarly, the tools outlined under Step 3 can be used at the planning stage or applied retrospectively to protect existing sources rated ‘at risk’ from one or more of thehazards identified.

3.3.2 Step 1 - Understanding water availability

Why is this step important?

Taking the time to collect existing information on the factors that are likely to affect the availability and sustainability (and quality) of water for a village or group of households is important. Investing time at this stage in understanding groundwater conditions can help the project team assess what water supply options are likely to be feasible and cost-effective, and the likely yield and sustainability of water sources. An understanding of local geology and the behaviour of existing water sources can also be used to inform water point construction and rehabilitation decisions.

What is the evidence base?

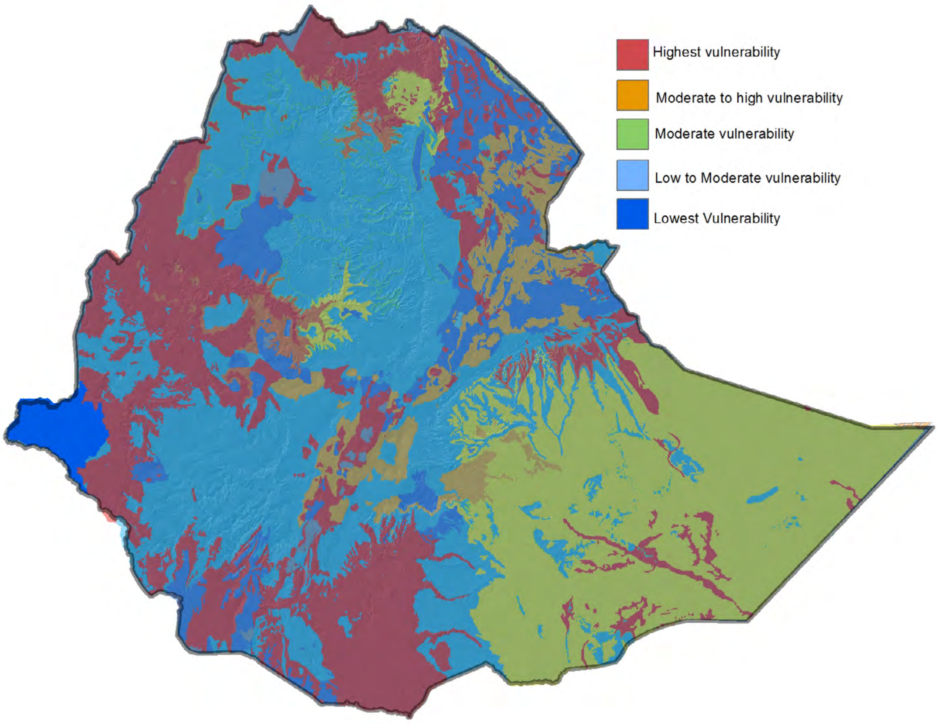
The underlying geology of an area will determine whether water is stored in underground formations, how much is stored, and the ease with which water can flow to a water point. This determines the yield of an individual source. Geology can also influence water point choice, construction, cost and periodic rehabilitation requirements.

Whether a hand dug or drilled well is appropriate depends on the characteristics of the rocks and the local topography. Once a source type is selected, geology influences the choice of digging or drilling technology, the stability of the well wall during construction, well design (e.g. lining requirement) and the need for periodic dredging and/or cleaning. For organisational and logistic reasons, implementation programmes often select a limited set of source technologies, but matching technology to hydrogeological setting remains important (MacDonald et al, 2009).

For a given target yield, storage is the key factor affecting the resilience of water supplies. Aquifer storage transforms highly variable natural recharge from rainfall into more stable natural discharge regimes. It also results in groundwater residence times that can sometimes be counted in decades or centuries ((MacDonald et al, 2009). The generally large storage volume of aquifers means that groundwater is less sensitive to annual and inter-annual rainfall variability – and therefore provides insurance against rainfall variability and longer term climate change.

Storage is a function of rock porosity. The most porous geologies (e.g. alluvial sediments, highly weathered hard rocks) can store large volumes of water, so that when

Figure 3: Groundwater resilience to drought



Note: The lowest vulnerability (highest resilience) corresponds to the highest storage potential of the loose sediment aquifers in the Rift Valley and Gambela. The highest vulnerability corresponds to shallow aquifers in the basement rocks. Source: (Kebede, 2012)

recharge from rainfall or discharge through pumping occurs, changes in water levels are relatively small. However, if the porosity of the rocks is small (e.g. with mudstones, shales, unweathered hard rocks), changes in recharge or discharge will have a bigger impact on water levels and a well or spring can dry up. However, even these rocks can store water from several years or decades' of rainfall and support climate-resilient domestic and minor irrigation uses if sources are sited appropriately (MacDonald et al, 2012).

The higher the storage of an aquifer, the less vulnerable it will be to periods of drought. In Ethiopia, basement rocks have the lowest specific storage are least resilient, while loose alluvial sediments with high storage capacity are the most resilient. Figure 2 below highlights the vulnerability of the four principal aquifer-geology types in Ethiopia.

In some aquifers, and specifically those with low yield, where water is in zones of shallow weathering or where aquifer storage is low, dug wells can provide more resilient supplies than drilled boreholes. This is because a large diameter dug well can both intercept more fractures than a narrow borehole and function as a cistern, storing water that seeps into the well overnight and allowing higher pumping rates during the day.

Ethiopia's geology is highly complex, with a range of different sub-environments and groundwater targets summarised in Table 4 below. Detailed assessment and monitoring of groundwater conditions in these sub-environments is largely absent in Ethiopia, and groundwater assessments that are underway are geared primarily towards irrigation development rather than rural water supply (Mosello et al, 2015).[13]

13 For example, the Household Irrigation Strategy developed by the Ethiopian Agricultural Transformation Agency (Ethiopian Agricultural Transformation Agency, 2013 (draft)) identifies poor information on groundwater conditions as a 'systemic bottleneck', but the national groundwater assessment and mapping currently underway to address this issue makes no reference to any wider application. The activities of the Groundwater Directorate of MoWIE are focussed overwhelmingly on irrigation development (Mosello et al, 2015).

How can the approach be applied?

There are very few hydrogeologists in Ethiopia, and even fewer plying their trade on rural water supply programmes (Mosello et al, 2015). Many regional-level hydrogeology posts are unfilled, and at zone and wordea level there is a chronic shortage of staff with the basic geological knowledge needed to support woreda or community managed water supply programmes. At the same time, the groundwater assessment and mapping activities underway in Ethiopia are geared more towards irrigation development than domestic water supply (see above), leaving woreda WASH teams with little to go on in terms of high resolution geological and hydrogeological information.

In this context, two priorities were identified by the project team: (1) providing simple guidance on 'understanding local geology' to help assess resource potential and inform technical choices; and (2) providing guidance on understanding the behaviour of existing water sources in terms of their yield and reliability over time as guide to selecting new sites and sources, and/or the rehabilitation of existing ones. The second priority, in particular, relies on tapping the knowledge of local people. The tools are aimed squarely at the non-specialist.

Under (1), guidance focusses on local observation – interpreting the terrain and any rock outcrops to 'know where you are' in terms of underlying geology. Field guidance sheets can be used by the non-specialist to identify rocks in the field and place a water scheme in a geological context. The sheets can be used at hand-specimen scale, at outcrop scale and at landscape scale. Photographs and block diagrams can be included as an aid (see Box below).

The checklists provided under (2) are designed to help members of the WASH Team learn from community experience of water supply. The aim is to develop a deeper understanding of which areas and source types provide the 'best' service, and why. Conversely, which locations and source types have failed to provide reliable, good quality water over time.

What are the institutional and training implications?

Basic geological interpretation is within the grasp of woreda staff, with the right kind of guidance. However, the preparation of the guidance sheets that reflect local conditions requires input from regional or national experts, e.g. regional water office geologists. A programme of field-based training is also recommended, covering:

- Identification of rocks.
- Implications of rock type in water point siting decisions.
- Implications for scheme design.

Tapping into community knowledge of source behaviour is less demanding, but does require patience and respect for local views. The information gained is also likely to be much richer if technical staff (mainly men) canvass the views of women – those most likely to know about water access, availability and quality over time.

Table 4: Groundwater potential of major hydrogeological environments in Ethiopia

	Hydrogeological sub-environment	GW potential & average yields	Groundwater targets and technologies
Crystalline basement rocks	Highly weathered and/or fractured basement	Moderate 0.1-1 l/s	Fractures at the base of the deep weathered zone. Sub -vertical fracture zones. *Dug wells can capture water from weathered zone.*
	Poorly weathered or sparsely fractured basement	Low 0.1 –1 /s	Widely spaced fractures and localised pockets of deep weathering. *Drilled boreholes, although failure rate can be high if not carefully sited.*
Consolidated sedimentary rocks	Sandstone	Moderate – High 1 – 20 l/s	Coarse porous or fractured sandstone. *Drilled boreholes.*
	Mudstone and shale	Low 0 – 0.5 l/s	Hard fractured mudstones Igneous intrusions or thin limestone / sandstone layers. *Dug wells.*
	Limestones	Moderate – high 1-100 l/s	Fractures and solution enhanced fractures (dry valleys). *Springs, drilled boreholes. Failure rate can be high if boreholes not carefully sited.*
Unconsolidated sediments	Major alluvial and coastal basins	High 1 – 40 l/s	Sand and gravel layers. *Dug wells, but may require support during digging.* *Drilled boreholes.*
	Small dispersed deposits, such as river valley alluvium and coastal dunes deposits	Moderate 1 – 20 l/s	Thicker, well-sorted sandy/gravel deposits. Coastal aquifers need to be managed to control saline intrusion. *Dug wells, but may require support during digging.* *Drilled boreholes.*
	Valley deposits in mountain areas	Moderate – High 1 – 10 l/s	Stable areas of sand and gravel; river-reworked volcanic rocks; blocky lava flows. *Dug wells, boreholes.*
Volcanic Rocks	Extensive volcanic terrains	Low - High Lavas 0.1 – 100 l/s Ashes and pyroclastic rocks 0.5-5 l/s	Generally little porosity or permeability within the lava flows, but the edges and flow tops/bottom can be rubbly and fractured; flow tubes can also be fractured. Ashes are generally poorly permeable but have high storage and can drain water into underlying layers. *Dug wells, springs, boreholes.*

Source: based on MacDonald et al, 2005.

Box 11: Using photographs to help identify geological environments

Photographs or diagrams can be used to help the non-specialist identify geological environments and inform groundwater development decisions.

The photographs below help identify areas of **volcanic ash** in terrain dominated by shield volcano, typical of the Ethiopian Highlands.

Morphology

Gently undulating slopes, with slope breaks where rocks are harder

Outcrop

Light-coloured, friable, sugary texture

Hand Specimen

Light weight porous

Source photos: Seifu Kebede, 2013

Implications for rural water supply:

- High groundwater storage but low permeability: dug wells preferred over drilled boreholes.
- Weathered rock may contain high levels of clay: wells may have very low yields.
- Modest water level fluctuations between wet and dry periods: yield, if adequate, should be sustainable through the dry season.
- Weathered zone may be unstable: well lining may be needed, at least in top part, and wells may need periodic cleaning.
- Springs generally diffuse discharge type: spring boxes may need to be widened to collect multiple outlets.
- Water quality generally good, though may contain high fluoride.

3.3.3 Step 2 – Catchment screening

Why is this step important?

For a system to be sustainable in the long term there must be balance between recharge to the aquifer, and discharge from the aquifer, whether natural or from pumped abstractions. Over short periods aquifer storage can even out seasonal variations and inter-annual variability. But where discharges and abstractions exceed recharge groundwater levels will inevitably fall, and this may lead to the drying of springs or the failure of wells. Building on Step 1, this makes it important to ensure that new sources are developed with a reasonable understanding of both groundwater availability – including likely replenishment from rainfall - and groundwater demand.

An assessment of the catchment water balance for an aquifer involves quantifying the sources of recharge, natural discharges and artificial abstractions. Detailed and quantitative studies of the water balance require major investment in data collection and long term observation, with mapping and data analysis that is generally only justified when analysing the sustainability of large scale investments in groundwater abstraction, such as major irrigation schemes or urban supplies.

For small scale rural water supply projects, detailed water balance data (apart from abstractions) are unlikely to be available at a scale and with sufficient detail to allow a detailed water balance to be prepared. However, simple methods can give reasonable estimates of the recharge area needed to meet demand from a source based on rainfall data, assumptions about how much rainfall recharges groundwater and can be captured by a source, and the required yield of or demand from the source.

What is the evidence base?

The input side of the water balance – recharge - is controlled by many factors. Rainfall is the dominant factor, but the rate and duration of rainfall, temperature, wind speed and relative humidity, vegetation, conditions in the upper soil layers, the depth of the water table, the soil type and underlying geology all play a role in determining how much water reaches an aquifer (Famiglietti, 2008). Factors such as topography and soil cover further influence how much of the rainfall is 'lost' as runoff and where, and how much, water can infiltrate and reach the water table, and be transmitted and stored in aquifers (see Section 2).

In the absence of site specific data, it is acceptable to use data derived from larger catchments, or to use empirical relationships between rainfall and recharge. Over a wider range of environments and based on evidence from numerous empirical studies from across Africa, especially where average annual rainfall is above 750mma year, an approximation of recharge as 10% of rainfall is reasonable. In areas with less rainfall, the linear relationship between rainfall and recharge breaks down and recharge is related more to extreme rainfall events than averages (Bonsor & MacDonald, 2010).

Getachew (2008) estimated the groundwater recharge contributing to the flow of the Upper Blue Nile basin, using several different techniques. These included a soil/water model, analysis of the direct contribution of groundwater to the flow of rivers and analysis of groundwater chemistry. The range of values calculated for different sub-catchments and for different methods ranged from 4% of rainfall to 20%, with most values around 6% - 8% of rainfall.

In reality recharge across a landscape will vary considerably depending on local soils, topography and vegetation. Rapid run off over parts of the catchment may be compensated by focussed recharge from streams and depressions that receive runoff. The slightly low value of groundwater recharge for the Blue Nile basin may partially reflect the high seasonality of Ethiopian rainfall, but is also an estimate of overall recharge to a very large system that may discount some local recharge and discharge at smaller scales. It is this local recharge that is important for sustaining rural water sources.

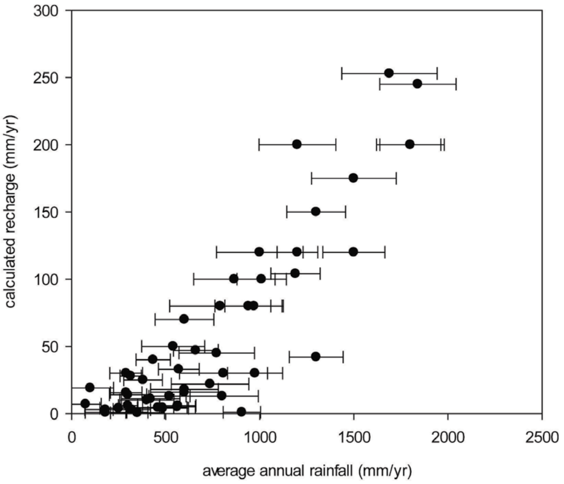
Only a proportion of aquifer recharge will be extractable using shallow wells. Much of the recharge will flow to deeper aquifers, and since a shallow well only imposes a small amount of drawdown, its ability to induce or 'pull in' flows that would otherwise be lost is limited.

If a well is sited without an adequate catchment area, this substantially increases the chance that the well will be dry or it introduces a greater probability that dry season yields may be inadequate for community requirements. For a spring source local knowledge is normally used to assess if dry season flows are adequate, and so springs will not generally be developed if the catchment area cannot provide the water. In both cases, however, if catchment areas are marginal in relation to required yield and demand, then any reduction in recharge - whether from climate variability or catchment degradation - is likely to put the source under strain.

Where communities are located on extensive aquifers and population densities are low, catchment size may not be a limiting factor. But where population densities are higher, or where the topography is dissected and mountainous (as it is in the Ethiopian Highlands), variable catchment sizes and groundwater drainage down slope present real problems, especially where communities live on higher ground. During the course of our study, we visited sources where the design yield exceeded 100% of infiltration within the source catchment.

Deeper drilled wells offer the possibility of capturing recharge and groundwater flow from areas outside the immediate surface water catchment of a spring or dug well. If most groundwater is found in zones of shallow weathering, however, a dug well may still be more productive than a borehole because of its ability to store water.

Figure 4 Calculated recharge rates and average annual rainfall across a range of African aquifers



Source: Bonsor and MacDonald, 2010, MacDonald et al, 2011

How can the approach be applied?

The required recharge area can be calculated by considering the following:

- Required yield of the source – dependent on the number of people that need to be served and their per capita requirements.
- Recharge to groundwater – dependent on rainfall and climate, as well as topography, land cover and the characteristics of the unsaturated soil and rock.
- Topography – opportunities for recharged water to flow towards the water point.
- Aquifer characteristics – storage, aquifer thickness and permeability.

To allow practical application of a recharge area calculation in the absence of detailed data it is necessary to make a number of simplifying assumptions:

- Yield and service level requirements within a programme are normally standardised.
- Recharge is empirically related to rainfall as discussed above.
- Topography can be derived from topographical maps, digital elevation models or simple field observation. Land cover and soil characteristics are assumed invariant over moderate scales.
- Aquifer characteristics may be largely unknown, but can be assumed to be invariant over moderate scales.

With these assumptions a nominal catchment area can be calculated for both planned and existing water points. If the catchment area is sufficiently large the water point should, other factors being equal, be resilient to climate variability and have some capacity to satisfy increases in demand. Conversely, if the catchment area is marginal with respect to required yield or demand, a water point will be more vulnerable to change, even if it normally provides an adequate supply.

To assess the catchment area required for typical water schemes, water demands can be calculated for different sizes of scheme based on the number of households to be served and a daily per capita water requirement. In many WASH programmes in SSA, a figure of 20 lcd for domestic use (drinking, food preparation, personal and domestic hygiene) is prescribed in national guidelines. In Ethiopia, the current (target) service level for rural water supply is 15 lcd, but may increase to 25 lcd under the new GTP (see Section 2). If sources are used for multiple uses, including garden irrigation, livestock watering and brewing, figures based on domestic use only may need to be increased.

Box 12: From rainfall to recharge to source: How much water can be captured?

Over much of the highland areas of Ethiopia rainfall is relatively high and strongly controlled by topography. Mean annual rainfall over Farta Woreda varies from 975 mm in the lowest parts of valleys to 1500 mm over the highest ground, with a mean value of 1300 mm.

Some rainfall will runoff overland to rivers, but much will soak into the soil. The largest proportion of this soil water is taken up by the roots of vegetation, and through evaporation and transpiration returned to the atmosphere. The remainder will infiltrate down to aquifers, and then flow through an aquifer to its eventual point of return to the surface: discharging to springs rives or lakes, pumped to the surface through a well or borehole, or taken up by vegetation from areas with a high water table. The percentage of rainfall that reaches an aquifer will depend on many local environmental factors, including climate, topography, vegetation and geology. In the Ethiopian highlands, about 10% of rainfall might become groundwater.

Even under ideal conditions, it follows that only a proportion of aquifer recharge will be extractable through a dug well. Some water will infiltrate deeper regional aquifers (which in Farta Woreda eventually sustain Lake Tana), find its way to local streams, or be taken up by deep-rooted vegetation. We have assumed that a maximum of 30% of groundwater recharge (3% of annual rainfall) could be extracted from shallow aquifers by dug wells, with 10% of recharge (1% of rainfall) more cautious.

Box 13: The influence of topography and drainage

Steep slopes pose a second challenge in that water within an aquifer will naturally drain to the lower parts of a catchment. In the worst case an aquifer may have adequate annual recharge, but be unable to sustain dry season yields because recharged water drains down slope.

The steep topography means many communities, often located on the higher ground on ridge lines and near hill tops, have relatively small catchment areas available, and this may mean that even the modest demands of a domestic water point exceed the practical limits of recharge.

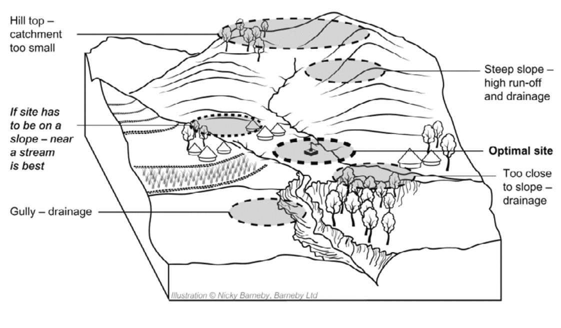


Illustration Nicky Barneby, Barneby Ltd

The influence of steep slopes on the resilience of water sources will generally be confined to hand dug wells rather than springs. The exact effect of slope will depend on the storage characteristics of the aquifer, and on how deep the well penetrates.

For a typical hand dug well, 10-20 m deep, we can assume that if the land falls away by more than the depth of the well within 100-150 m, the source is at risk of available water draining away and threatening sustainability, especially in the dry season. In these circumstances, additional options may need to be considered (e.g. rainwater capture and storage; the development of both spring sources and wells).

Estimated demands can then be used in conjunction with the assumed recharge to calculate the catchment area required for a reliable supply. Two methodologies are suggested:
GIS based approach best suited to assessing the catchment size of existing water sources for vulnerability classification
Field based methodology for use during water point site selection.

Both are described in further detail in the guideline report, with a particular focus on the field-based (manual) approach as this can be applied with no specialist expertise or equipment. Brief descriptions are provided in the boxes below.

For decision making around new sources, the advantages of a sufficiently large catchment and the risks of rapid drainage can be explained to the community. The discussion can then focus on the sites likely to meet sustainability criteria – those likely to 'pass' the risk screening process. For existing sources, an understanding of which sites are likely to provide reliable water can also help project staff identify which sites might fail to provide enough water during the dry season, or during drought. Marginal siteWs could be targeted for extra monitoring, or re-visited to develop additional supplies.

Although primarily designed to assess shallow dug well catchments, a similar approach can be used to assess the security of spring sources. If dry season flow measurements suggest a spring is marginally able to support the desired number of households, a catchment area calculation can suggest whether the spring is likely to be vulnerable to low flow in particularly dry years.

What are the institutional and training implications?

The GIS methodology is appropriate for offices and institutions with existing GIS expertise and capacity.

The simple field assessment of catchment size is designed to be used as part of normal water point siting by woreda staff. The main capacity building requirements will be training for woreda experts in topographic mapping and map interpretation. While the very simple techniques described can be used in the field without extensive training, their accuracy and effectiveness will be increased significantly if more use is made of topographic maps.

Maps at 1:50,000 scale, while available, are not commonly used by field staff. Training in map reading, catchment delineation, and transferring GPS coordinates onto maps will have major benefits for woreda staff involved in planning WASH interventions, but also for those involved in watershed protection activities.

While there are no institutional barriers to implementing assessments of catchment size, there is considerable scope for tension between experts and communities, as large catchments imply water sources at lower levels in valleys, and may rule out community favoured sites at higher elevation, and hence closer to households. This can only be addressed by building up a knowledge base of water point failure, so that the likelihood that sites with smaller catchments will fail can be clearly communicated to the community.

3.3.4 Identifying and mitigating environmental hazards

Why is this step important?

Environmental hazards such as floods and landslides can have an impact on water sources – directly or indirectly. In particular, gullies, floods and landslides can damage water infrastructure and affect water quality directly, for example through ingress or infiltration of contaminated water, or the collapse of unlined wells when soil becomes saturated. In addition, land degradation within the wider catchment can affect water resource conditions, indirectly compromising the sustainability of sources. For example, deep gullying can draw down the local water table beyond the depth of a well, and land degradation can affect runoff, infiltration and groundwater recharge.

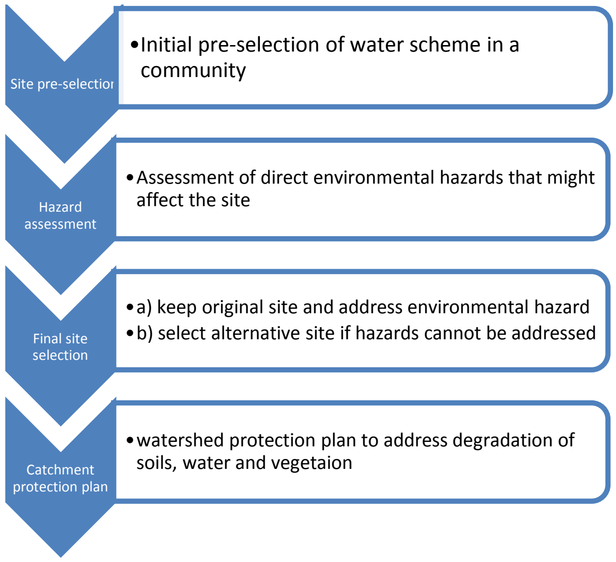
The hazards above will likely be exacerbated by climate change, not least because of the increasing frequency and magnitude of climate extremes. This makes it important to ensure that siting decisions are informed by an environmental risk assessment, and that water supply programmes more broadly are integrated with catchment protection plans.

What is the evidence base?

The benefits of protecting drinking water sources from contamination are well rehearsed, as are the design features that confer protection. For example, the design and construction of protected wells typically includes (1) a concrete apron to direct surface water away from the well; (2) a sanitary seal (typically clay, grout or concrete) that extends at least 1-3m below ground to prevent the infiltration of contaminants; and (3) a method to access water that enables it to be sealed following use. Handpumps can be fitted to most wells to improve convenience and decrease the likelihood of contamination (Elliot et al, 2011).

Location is another key risk factor, though typically considered only in terms of recommended distances

Figure 6: Integrating environmental risk assessment in water point siting



between water points and potential sources of contamination, such as latrines and animal waste. These risks can be identified through sanitary surveys using the forms found in Annex 2 of the WHO Guidelines for Drinking Water Quality (WHO, 1996).

The guidelines developed for this project also focus on the siting of water points, but deal with a broader set of watershed risks related to flooding, landslides and gully development – near water points, but also in the wider catchment. These risks are significant in Ethiopia because of widespread land degradation, and because existing climate variability already contributes to such risks. However, our review of existing guidelines on WASH implementation highlights a lack of practical guidance on how to identify and mitigate risks, beyond generic statements about the importance of catchment management and integrated natural resource management (see Section 2).

Box 14: Households served and average consumption

Although CMP projects potentially serve up to 50 households for dug wells, and up to 70 households for protected springs, much depends on local conditions.

In Farta Woreda, a dispersed rural population and the need to site water points within acceptable distances from households means that springs often serve only 20 households, with well schemes typically serving 30 – 40 households.

A well equipped with an Afridev pump would typically need to be pumped for six hours continuously to serve 50 households (50 x 5 x 15 l = 3,750 l). Because most pumps are used for less than six hours per day, it can be assumed that people do not access 15 lcd. Findings from COWASH and RiPPLE (Coulter, Kebede, & Zeleke, 2010) suggest that actual consumption is rather in the order of 10 lcd or less. This low level of use was typical of the schemes visited during this study.

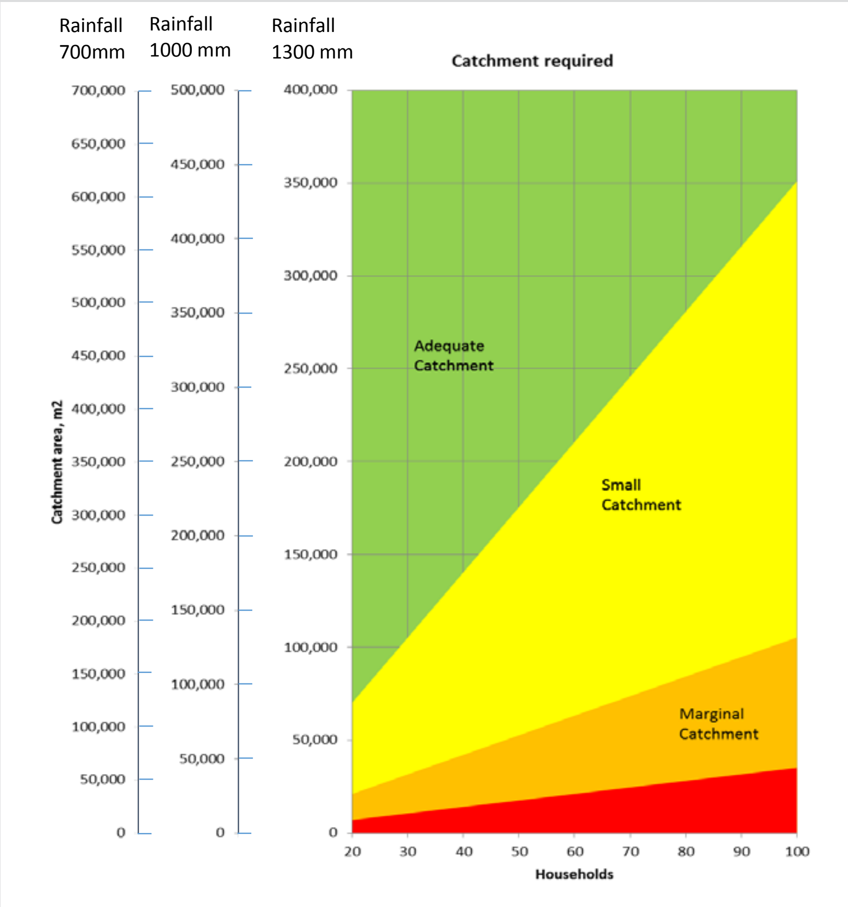
Box 15: Assessing catchment size – field approach

A number of tables and graphs have been developed to help non-specialist users 'look up' the catchment area needed to meet demand for different numbers of households under different rainfall-recharge scenarios.

For a manual estimation, take Farta Woreda as an example. The woreda receives roughly 1300 mm of rainfall per annum. We assume 130 mm of rainfall will infiltrate, and that between 13 mm and 39 mm of this recharged water will be recoverable from the shallow aquifer (see previous box). For a small community water supply, aiming to provide 25 lcd for 20 households (roughly 100 people), we would need to extract 912,500 litres per annum. Recharge of 13 mm equates to 13 litres of water per m2, so the needs of the community could be supplied from roughly 70,000 m2 of catchment.

In Figure 5 below, a catchment size of 70,000 m2 and above is classified as adequate, and should produce secure water points. Less cautious recharge scenarios are associated with small and marginal catchments sizes. Users can consult the graph for new projects to find the catchment area needed to serve a given number of households, or see if an existing community well has an adequate catchment.

Figure 5: Catchment sizes for different rainfall, recharge and demand scenarios



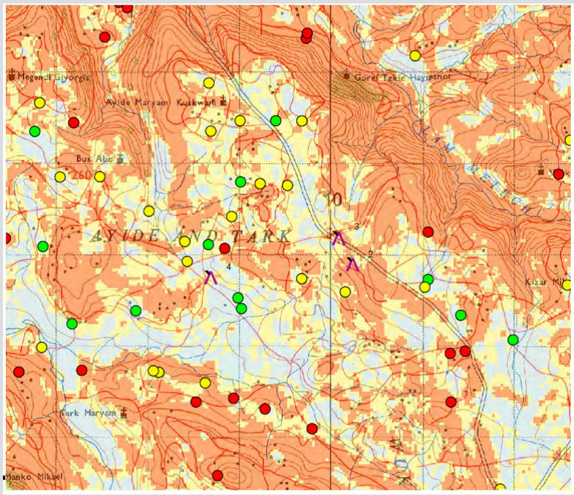
Note: assuming 5 people per household, and target service level of 25 lcd.

In terms of wider catchment protection, Ethiopia has a long history of programme-based interventions aimed at improving the productivity and sustainability of the natural resource base, enhancing food security and (ultimately) strengthening livelihoods. For example, the Productive Safety Net Programme (PSNP)[14], the MERET programme[15] and the Sustainable Land Management Programme – SLM (Ludi, 2015 forthcoming)[16] - all focus on food insecure areas characterised by serious land degradation, albeit with slightly different points of emphasis. A range of more regionally-oriented interventions also exist, such as the watershed protection component of the Tana Beles Integrated Water Resources Development Project.[17] Community mobilisation campaigns orchestrated by the government also contribute labour for soil and water conservation activities, such as terracing. However, none of these initiatives are coordinated with WASH programmes, and very few include specific water-related activities, although benefits to water resources are often inferred or claimed.

Box 16: Assessing catchment size – GIS approach

A GIS methodology has also been developed using data that are generally available in Ethiopia. The approach can be applied across a woreda or larger area (e.g. zone, region) to create maps that show which water points – existing or proposed - are likely to have adequate catchment areas. The methodology requires accurate water point locations, a Digital Elevation Model (DEM) and a map of rainfall or (if available) groundwater recharge data.

There are four steps: (1) The catchment area of an existing or potential site is estimated; (2) the risk of rapid groundwater drainage is assessed (for wells); (3) the amount of extractable groundwater is estimated based on rainfall data, recharge estimates and assumptions about the proportion of water that can be captured by a well or will flow to a spring; (4) the available water is compared with the design demands of the source.



The figure above is a GIS map of sources in an area of Farta Woreda, Amhara Region. Sources in red are considered highly vulnerable, yellow sites are vulnerable and green sites should have sustainable supplies.

14 The principal objective of the PSNP is to provide predictable, timely and well-targeted transfers to food insecure households. In return, households (except those deemed unable to contribute work because of age, health or disability as well as pregnant and lactating women) are required to contribute labour to PSNP public works. Activities supported through PSNP include the development of community assets such as economic and social infrastructure (e.g. markets, roads, schools, clinics, etc.) and a range of investments aimed at restoring natural resources (e.g. soils, water, or forests).

15 MERET aims at supporting households to increase their ability to manage shocks meet necessary food needs and diversify livelihoods through improved, sustainable land management and community-based approaches.

16 The objective of the SLM project is to reduce land degradation in agricultural landscapes and improve agricultural productivity of smallholder farmers. The first of three components of the project is watershed management. It is aimed at supporting scaling up of best management practices in sustainable land management practices and technologies for smallholder farmers in the high potential / food secure areas that are increasingly becoming vulnerable to land degradation and food insecurity.

17 http://tana-beleswme.org/

Box 17: Myth or reality? Links between watershed protection and groundwater availability

A watershed is an area from which all water drains to a common point, making it an attractive unit for efforts to manage water and soil resources for production and conservation. Watershed protection promises a 'triple-win' in which natural resource conservation, agricultural productivity and poverty reduction go hand-in-hand.

Ethiopia has a long history of implementing watershed protection programmes extending over 30 years. These have evolved from largely technical initiatives in the 1970s and 80s to more participatory ones in which local people help design and implement plans. More recently, their role in increasing resilience to climate change has received growing attention (Conway & Schipper, 2011). However, while claims are often made about their role in enhancing groundwater recharge, only a few (e.g. MERET, Tana Beles) include measures designed specifically to enhance water availability, and the target is water for production rather than domestic use. Groundwater recharge interventions are implemented in Ethiopia, but these are generally restricted to local NGO projects (e.g. HCS) and do not form part of government-sponsored watershed or rural water supply programmes.

Although much has been written on the impacts of watershed protection programmes, there have been very few attempts to systematically assess them – in Ethiopia or elsewhere (Ludi, 2015 forthcoming). Moreover, claims about their impact on water resource conditions and, by implication, on groundwater availability from springs and wells, should be treated with caution. This is because of the complex relationships between climate, land use change and groundwater recharge discussed in Section 2. Drawing on the few rigorous studies that have been carried out, we make the following observations, if only to challenge a few prevailing myths:

- Myth 1 – planting trees and restoring native vegetation increases groundwater recharge and availability. While much will depend on local conditions, recharge may decrease even if runoff declines. This is because in dry climates, trees and perennial native vegetation evaporate more water than field crops or grassland because of their greater rooting depth and a longer growing season.
- Myth 2 – non-vegetative measures to improve soil moisture retention will automatically lead to increases in groundwater recharge and availability. Not necessarily so in drier climates where evapotranspiration is much greater than rainfall, and recharge processes are dominated by rapid seasonal flows from rivers beds and wadis.
- Myth 3 – groundwater recharge from check dams and percolation ponds can impact groundwater conditions at scale. These interventions can have positive, localised effects (e.g. around individual wells), but are unlikely to make much difference to the overall water balance of an aquifer system.
- Myth 4 – water conserved is water that would otherwise be lost. There is often an assumption that upstream water conservation 'saves' water that would otherwise be lost. In practice, upstream conservation may deprive downstream users of 'their' water, so conservation is essentially about upstream-downstream reallocation, at least in those basins where water is intensively used.

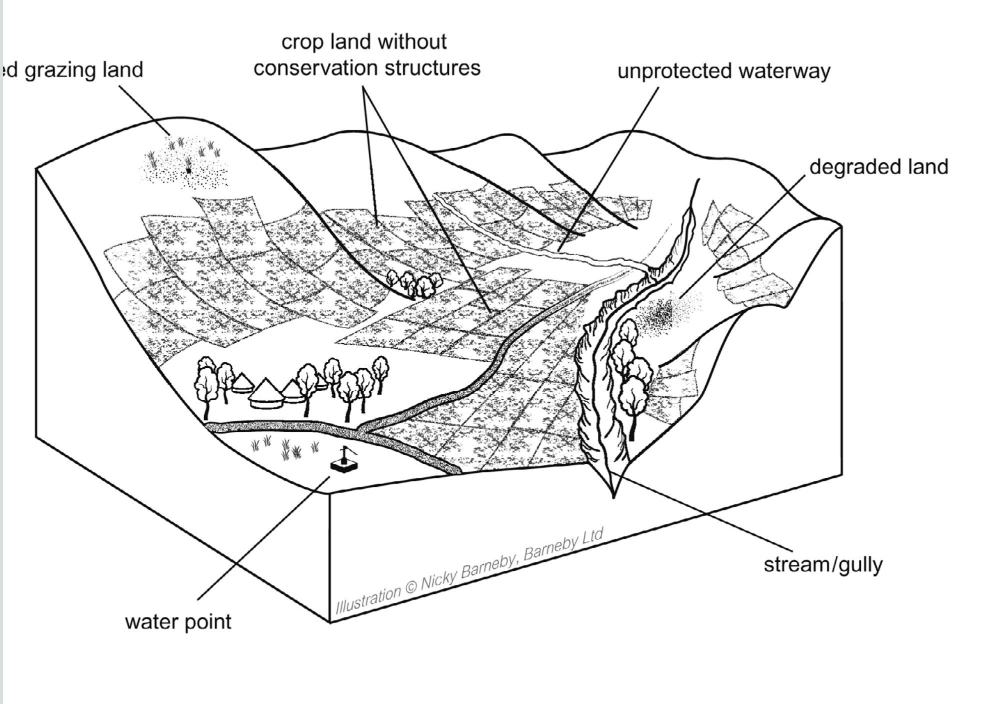
How have we considered this evidence in our guidelines? First, the guidelines that deal with environmental risks focus on catchment degradation processes that can draw down local water tables and damage infrastructure; we do not make claims about the impact of catchment protection more generally on groundwater conditions at scale. That said, in the upland catchments of the Amhara highlands, our judgement is that watershed protection measures of the kind prioritised in MERET-type programmes would be likely to have a positive influence on local groundwater availability, and therefore rural water supply.

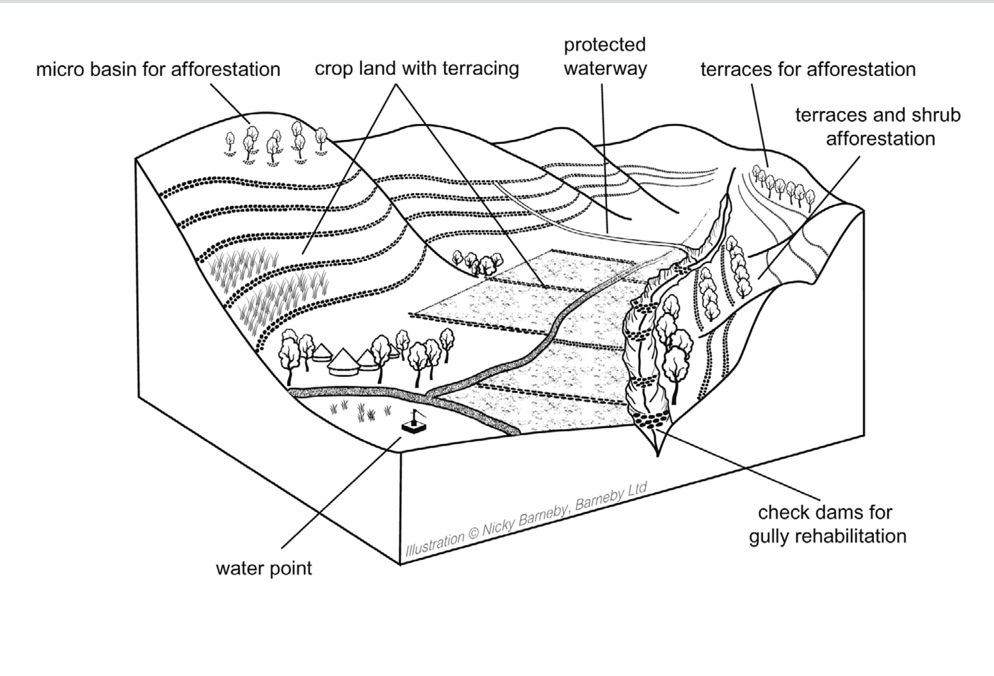
Second, the focus of the catchment screening guidelines is on areas receiving more than 1000 mm rainfall per annum, where recharge is more clearly linked to average rainfall. In these environments, we can justify the assumptions we make connecting rainfall, recharge and catchment sizing for water points serving different numbers of households.

Source: Calder, 2005 ; Gale, 2005 ; Kerr, Pangare, & Pangare, 2002 ; Taylor, et al., 2013.

Box 18: Identifying hazards and developing a catchment protection plan

The figure below shows some of the main degradation features that pose a direct or indirect risk to rural water supplies in a catchment. A simple 'traffic light' assessment, described further in the guidelines, can be used to determine the level of risk, and what actions might follow. The mapping of risks should be carried out with communities, and by team members drawn from different line departments – not just the Woreda Water Office.





Guidelines also summarise the kinds of corrective measures that can be used to address risks as part of a wider catchment protection plan. The figure below highlights some of the key interventions.

Illustration, Nicky Barneby, Barneby Ltd

Conclusions

Growing concern about the impacts of climate change in Ethiopia is feeding through into sector-specific analyses of impacts and guidance on adaptation. Despite the proliferation of toolkits and decision-support systems, however, remarkably little has been written on the practical substance of adaptation for WASH, particularly in terms of near-term impacts and the practical needs of decision makers This report, and the 'how to' sheets contained in its sister publication, help fill the gap. The focus is on low cost, groundwater-dependent dug wells and springs that are potentially vulnerable to climate-related and environmental risks, and which form a key component of Ethiopia's OWNP.

A key conclusion is that adaptation should start with the measures that tackle the weather risks that Ethiopia already faces, since climate change will exacerbate these risks. A key argument is that many of these measures, such as improved siting of water points, are relatively straightforward. A focus on vulnerability rather than prediction is also pragmatic given present uncertainties with climate projections, and the 5-10 year design life of springs and wells.

Field investigations in Farta Woreda in Amhara Region, and evidence collected from other sources, highlights three key requirements for increasing the resilience of rural water supplies:

- Understanding local water availability through simple geological assessment;
- Ensuring source sustainability through the 'catchment screening' of demand and supply; and
- Protecting sites and sources from direct and indirect environmental hazards.

In their simplest form, these have been developed as practical guidance sheets for woreda staff that can be applied without prior geological and hydrogeological expertise. Adaptations of these tools can be used to screen existing water points for climate and environment risks, and at regional and national level to inform programme planning and technology choices.

The tools developed are appropriate to some, but not all, siting environments and technical choices in Ethiopia. The focus to date is on increasing the resilience of 'low end' technologies (hand dug wells, protected springs) in highland areas with basalt geologies. While these areas and systems are significant in terms of people served, further work is needed to adapt principles to different areas and alternative technologies

In summary, the threats posed by climate variability and change to rural water supply have received relatively little attention in programme and project design, beyond the general rhetoric around adaptation and resilience-building. By developing practical tools that can be used in the field, and in programme design, the project addresses an important need. It is hoped that project findings can inform the new One WASH Implementation Guidelines, and that a further phase of work can address remaining training, piloting and coverage needs in Ethiopia.

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