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Global Water Partnership

WASH Climate Resilient Development

Technical Brief

Linking risk with response: options for climate resilient WASH

About UNICEF

UNICEF works in more than 100 countries around the world to improve water supplies and sanitation facilities in schools and communities, and to promote safe hygiene practices. We sponsor a wide range of activities and work with many partners, including families, communities, governments and like-minded organizations. In emergencies we provide urgent relief to communities and nations threatened by disrupted water supplies and disease. All UNICEF WASH programmes were designed to contribute to the Millennium Development Goal for water and sanitation.

About GWP

The Global Water Partnership is an intergovernmental organisation of 13 Regional Water Partnerships, 86 Country Water Partnerships and more than 3,000 Partner Organisations in 183 countries. Its vision is a water secure world. Its mission is to advance governance and management of water resources for sustainable and equitable development through integrated water resources management (IWRM). IWRM is a process that promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems and the environment.

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HR Wallingford
Working with water

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Supporting climate resilience in the WASH sector

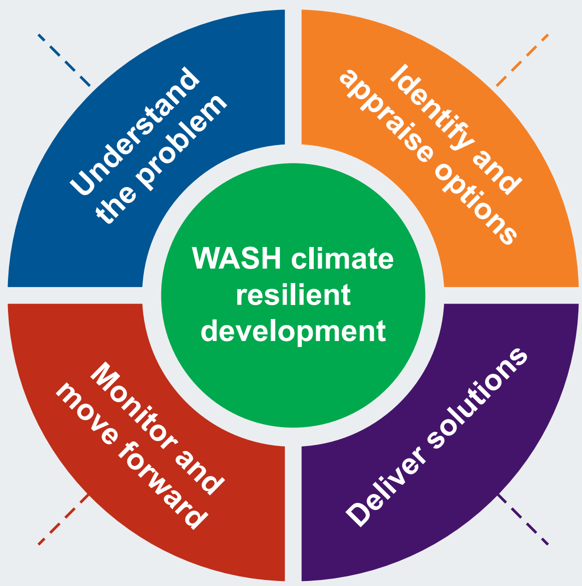
This Technical Brief forms part of the Strategic Framework for WASH Climate Resilient Development, produced under a collaboration between GWP and UNICEF.[1] The Framework advances sector thinking around WASH and climate change, cutting across both development and emergency preparedness programmatic spheres; climate resilience is addressed as a cross-cutting issue encompassing elements of both disaster risk reduction and climate change adaptation.[2] It serves to set out the rationale and concepts for WASH climate resilient development, as well as improve understanding of how to ensure that climate resilience is considered in WASH strategies, plans and approaches.

The objective of the Strategic Framework is to support WASH service delivery that is resilient to the climate, both now and in the future. The Strategic Framework is centred around four quadrants of activity; this Technical Brief sits within the 'Identify and appraise options' quadrant, shown in the figure below.

Strategic Framework for WASH climate resilient development

Guidance Note:
- Risk assessments for WASH

Technical Briefs:
- Linking risk with response: options for climate resilient WASH
- Appraising and prioritising options for climate resilient WASH



Technical Brief:
- Monitoring and evaluation for climate resilient WASH

Technical Briefs:
- Integrating climate resilience into national WASH strategies and plans
- Local participatory water supply and climate change risk assessment: modified water safety plans

Source: Adapted from GWP and UNICEF (2014)

This Brief builds on the Guidance Note on Risk assessments for WASH but drills down further into the specific threats to WASH from climate change, and responses at national, subnational/watershed and local/project levels that can limit those threat.

1. Introduction

In this Technical Brief, we look at how the water supply, sanitation and hygiene (WASH) sector could adapt to climate change. Action must be taken now if the Sustainable Development Goal (SDG) targets on WASH are to be achieved in the face of climate change. While there is uncertainty over how climate change will affect services, there is already an 'adaptation deficit' in relation to current climate variability, and challenges will intensify and evolve in many global regions as climate change progresses. If resilience to climate change matters for WASH, WASH also matters for climate change resilience. If delivered in the right way, WASH can improve people's resilience to climate change directly – for example, by enabling access to water at times of scarcity, or reducing risks of disease from faecal contamination of water during floods. WASH can also support resilience indirectly – for example, where it enables increased economic activity and investments in resilience-building activities, such as better housing or education.

This Brief recommends a pragmatic approach to improving resilience of WASH services to climate change. Decisions should be based on the best available information for the time period in question. For example, there may be limited value in scrutinising climate projections to the end of the century for rural WASH programmes that prioritise household or community-based systems with a design life of a few years (e.g. pit latrines) or decades (wells, boreholes). For major investments in storm drains, sewerage and other big infrastructure projects – particularly those that are long-lived and inflexible – the situation is clearly different.

Much of the adaptation literature on WASH – and on other sectors – focusses on project-based investments that prioritise new systems and standards. The preference is for structural and readily visible options that demonstrate 'additionality', over and above business as usual. This may be necessary, but insufficient if 'softer' adaptation options or paths focussing on changes in policy, planning and management are neglected; or alternatively, if the basic bottlenecks to providing public goods in the context of wider water resource challenges are overlooked in favour of new projects and/or narrow technical change. For this reason, this Brief looks at key elements of the whole results chain, from the enabling framework for WASH sector design and commissioning on the one hand, to local-level technologies, institutional reform and behaviour change on the other. This reflects the Results Framework for Climate Resilient WASH illustrated in Figure 1.1, which also locates WASH within a wider water resource and waste management context. So, while we explore adaptation options in terms of technical change, we also look at the broader institutional architecture that supports climate resilient programming. We therefore use the term 'option' in this Brief (as in 'options for climate resilient WASH') in a broad sense.

Users seeking rapid guidance on specific adaptation options can refer to the tables in Appendix A, which are organised for different service delivery approaches: from wells and boreholes to utility piped networks in the case of water supply, and from pit latrines to sewerage in the case of sanitation.

Finally, we note that building resilience to climate change may also provide incentives for the WASH sector to improve its response to a number of different pressures, particularly those arising from population growth and accelerating demand and competition for water. Indeed, the opportunity to re-focus attention on ensuring the reliability and protection of drinking water sources and the safe disposal of waste through a wider sustainable management lens, aligns with the broad aspirations of SDG 6.[1]

[1] To ensure availability and sustainable management of water and sanitation for all.

SIMPLIFIED RESULTS FRAMEWORK FOR WASH CLIMATE RESILIENCE

OUTCOME	**Rural WASH infrastructure and services are sustainable, safe and resilient to climate related risks; and WASH contributes to building community resilience to climate change**			
	NATIONAL	**SUB-NATIONAL LEVEL/ WATERSHED LEVEL**	**LOCAL AND PROJECT LEVEL**	
INTERMEDIATE OUTCOME	1. An ENABLING ENVIRONMENT conducive to climate resilient WASH services and communities	2. Water resources are MONITORED and MANAGED considering climate risks to WASH services and infrastructure	3. ACCESS to climate resilient WASH infrastructure and services	4. Climate resilient BEHAVIORAL CHANGE and GOVERNANCE at community and local level
OUTPUT	STRENGTHEN WASH SECTOR ENABLING ENVIRONMENT 1.1 Knowledge of climate risks generated and shared 1.2 Climate risk informed policies, strategies, plans and programmes 1.3 Adequate budget and resources allocated 1.4 Plans implemented and monitored 1.5 Inter-sectoral coordination strengthened with focus on health, food security and education sectors 1.6 Strengthened Early Warning Systems in place	BUILD WATER RESOURCE MONITORING AND MANAGEMENT CAPACITY 2.1 Water resource status and pressures understood 2.2 Long-term monitoring systems implemented and maintained 2.3 Guidelines/rules developed prioritising WASH services and accounting for hydrological change 2.4 Agreed rules implemented for resource development and adaptive management	SUPPORT CLIMATE SMART INFRASTRUCTURE AND TECHNOLOGIES 3.1 Project design and implementation of WASH standards strengthened 3.2 Water storage enhanced and protected 3.3 Water supplies diversified where possible 3.4 Climate smart technologies (low and no-regret options) for WASH investigated and implemented	SUPPORT INSTITUTIONAL REFORM AND BEHAVIOUR CHANGE 4.1 Capacities and resources of local government and local private sector to implement and monitor WASH resilient programming strengthened 4.2 Awareness and capacity of communities to respond to shocks and stresses is enhanced 4.3 Local markets and supply chains extended and deepened to increase availability of climate resilient WASH products and services 4.4 Early warning and response systems strengthened
ACTIVITY	1.1.1 Improving understanding of climate risks 1.1.2 Understanding resilience of technology types 1.1.3 Understanding WASH contribution to building community climate resilience 1.2.1 Reviewing and updating WASH policies and strategies to account for climate risks 1.2.2 Strengthening evidence based policy advocacy 1.3.1 Making budget allocations available to enhance resilience of existing WASH systems 1.3.2. Making budget allocations available to prioritize WASH interventions in identified risk areas 1.3.3 Ensuring adequate emergency budget allocations for WASH sector 1.4.1 Developing, implementing and monitoring plans 1.4.2 Mainstreaming bottleneck analysis and planning 1.5.1 Identifying and incorporating cross-sectoral considerations to manage climate risks 1.5.2 Increasing partnership and collaborative working 1.6.1 Ensuring Early Warning Systems predict and mitigate climate risks to WASH related outputs and outcomes	2.1.1 Assessing water resources – quantity and quality 2.1.2 Assessing risks to water resources from climate change and other pressures 2.2.1 Monitoring water availability and quality 2.2.2 Monitoring patterns of use and climate-linked (and other) threats 2.3.1 Developing agreed guidelines/rules across water sector informed by climate risks 2.3.2 Supporting basin planning initiatives that coordinate water-using and polluting sectors and that prioritise support for the most vulnerable areas 2.4.1 Developing new water sources in a resilient and sustainable manner 2.4.2 Prioritising WASH in the allocation of resources between sectors	3.1.1 Ensuring conformity with climate-informed standards 3.1.2 Supporting supervision and enforcement of standards 3.2.1 Developing decentralised storage systems 3.2.2 Strategically developing groundwater resources 3.3.1 Spreading risk between different water sources and systems 3.3.2 Targeting areas/communities affected by climate hazards and vulnerable sources by providing climate resilient WASH systems 3.4.1 Adapting technologies to account for climate risks 3.4.2 Exploring innovative, climate smart technologies (e.g. solar systems) 3.4.3 Exploring wastewater reuse/ recycling, nutrient recovery and energy production from waste 3.4.4 Improving sanitation and hygiene practices (e.g. ending open defecation) to reduce vulnerability	4.1.1 Strengthening capacity of WASH professionals and practitioners 4.1.2 Making sure sufficient resources are available for local WASH agencies in most vulnerable regions 4.2.1 Education and training of community groups for climate-responsive WASH management 4.2.2 Sharing knowledge on local WASH climate resilient options 4.3.1 Supporting local markets and supply chains for resilient WASH systems/technologies 4.4.1 Assessing status and functionality of early warning and response systems in relation to WASH needs 4.4.2 Contingency planning for WASH – esp. droughts and floods 4.4.3 Water Security and Water Safety Planning

Figure 1.1: Results Framework for Climate Resilient WASH

Note: the location of different outputs and supporting activities at national, subnational and local levels should not be interpreted too rigidly. In practice, for example, many of the changes sought at a local level will likely result from changes in policy and practice at national and subnational levels.

DRINKING WATER LADDER	SANITATION LADDER
Safely managed Drinking water from an improved water source which is located on premises, available when needed and free of faecal and priority contamination	**Safely managed** Use of an improved sanitation facility which is not shared with other households and where excreta are safely disposed in situ or transported and treated off-site
Basic Drinking water from an improved source provided collection time is not more than 30 minutes for a roundtrip including queuing	**Basic** Use of improved facilities which are not shared with other households
Limited Drinking water from an improved source where collection time exceeds over 30 minutes for a roudtrip to collect water, including queuing	**Limited** Use of improved facilities shared between two or more households
Unimproved Drinking water from an unprotected dug well or unprotected spring	**Unimproved** Use of pit latrines without a slab or platform, hanging latrines and bucket latrines
Surface water Drinking water directly from a river, dam, lake, pond, stream, canal or irrigation channel	**Open defecation** Disposal of human faeces in fields, forests, bushes, open bodies of water, beaches or other open spaces or with solid waste
Note: Improved sources include: piped water, boreholes or tubewells, protected dug wells, protected springs and packaged or delivered water.	Note: Improved facilities include: flush/ pour flush to piped sewer system, septic tank of pit latrine; ventilated improved pit latrine, composting toilet or pit latrine with slab

Figure 1.2: JMP 'ladders' for monitoring drinking water and sanitation in the 2030 agenda.

Source:UNICEF/WHO (2017).

Note: handwashing ladder (the indictor for improved hygiene) is not shown, but improved access is associated with handwashing facilities with soap and water at home.

The main focus of the Brief is on building more resilient rural water supply and sanitation services, because (i) the majority of the world's poor, and most of those without access to safe drinking water and sanitation, still live in rural areas; and (ii) WASH contributes to building community resilience to climate change.[2]

Although the key indicator selected by the UN's Joint Monitoring Programme (JMP) for assessing progress on the SDG drinking water target (6.1) is based on water access 'on premises', individual countries are still expected to adopt customised targets that incorporate more basic levels of service in a revised service ladder (Figure 1.2). A key challenge for governments and their development partners therefore lies in balancing support for *extending* access and *improving* service levels (Hutton and Varughese 2016; UNICEF 2016; WHO 2017). Since many unserved households will need to *step on* to the ladder before they can *step up*, this Brief considers a number of different source types and service levels – from protected springs offering limited or basic levels of service, to piped systems delivering household water connections.

For sanitation, similar arguments apply (Figure 1.2). The new 'safely managed' indicator goes beyond the hygienic separation of excreta from human contact to include the safe management of human waste along the sanitation chain – from containment and emptying to transport, treatment and reuse/disposal. Realistically, however, many households will first become open defecation free with an unimproved latrine, or a limited/ basic service (ibid.).[3]

All of the major WASH technologies can, to varying degrees, be adapted to account for climate risk.

In many cases the adaptations available and the governance arrangements in which they are embedded are 'no regrets' options – desirable regardless of climate change or a particular climate scenario. This is because they reduce the overall vulnerability of services, and help maintain access to safe water and sanitation, under a range of climate and non-climate hazards and pressures. Those wishing to understand the wider hazard and risk assessment context for WASH should refer to the Guidance Note on *Risk Assessments for WASH* – part of this GWP/UNICEF series.

[2] Globally, eight out of ten people without improved drinking water live in rural areas. Seven out of ten people without improved sanitation, and nine out of ten practising open defecation, live in rural areas (UNICEF/WHO 2017).

[3] See Technical Brief: Monitoring and evaluation for climate resilient WASH: http://www.gwp.org/globalassets/global/about-gwp/publications/unicef-gwp/gwp_unicef_monitoring-and-evaluation-brief.pdf

2. Strengthening the Enabling Environment

An effective sector-wide response to climate risk should aim to achieve each of the national level outputs highlighted in Figure 1.1. Combining some of the indicative (supporting) activities, we focus here on:

- Screening technology choices for climate resilience. This links to 'Improving understanding of climate risks' (Activity 1.1.1), and 'Understanding the resilience of technology types' (Activity 1.1.2).
- Strengthening standards and guidance for WASH programmes. This draws together elements of 'Reviewing and updating WASH policies and strategies' (Activity 1.2.1) and 'Strengthening evidence-based policy advocacy' (Activity 1.2.2).

2.1. Screening technologies for climate risk

Most national or regional level WASH programmes include recommendations on preferred technologies, approaches and service standards. Detailed 'how to' manuals – e.g. for developing boreholes or shallow wells, or constructing pit latrines and 'triggering' communities to achieve open defecation free status – are also available. Very few, however, apply a climate lens to thinking about (a) what technologies and approaches may be resilient – to either short-term variation (seasonal, inter-annual) or longer-term change (several decades) – or (b) what could be improved, or done differently to reduce or mitigate risks.

Here, we look at the former. Specifically, we ask: What scope is there to rationalise the range of WASH options that programmes offer to account for climate risk?

Perhaps the simplest way of addressing climate risk is to categorise different technologies according to their assumed or expected resilience, and then exclude those deemed to be high risk. There are strong advocates for this kind of policy prescription, not least because of its top-down simplicity and the scope it offers to "rationalise the choice of technologies used to deliver sustainable and effective services" (WHO, 2009).

Categorising technologies according to their technical *vulnerability* to climate hazards and their *adaptive potential* is one approach, illustrated in Box 1 below. This draws on the approach to risk assessment described in the Guidance Note: *Risk assessments for WASH*.[4] The Guidance Note considers a range of different hazards – climate and non-climate. Here, we focus on risks to different WASH technologies or systems posed by two principal climate hazards: (1) increasing rainfall and flooding; and (2) decreasing rainfall and drought. Appendix A provides more detail. Where technology selection is demand-driven, this implies that the menu of options provided on programmes, and offered to households or communities, has been pre-screened for climate resilience, as well as for concerns such as cost, affordability and acceptability.

Following this logic, some water supply technologies, such as dug wells, could be considered intrinsically less resilient because of their vulnerability to contamination, susceptibility to drought or long-term reductions in water availability, or the difficulty in preventing damage during flooding. Following a 'specified technology' approach would therefore imply excluding dug wells from the menu of technologies on offer, especially in more densely populated areas with high rates of open defecation, or in areas expected to face declining water availability.

In urban settings, the combined influence of climate change and growing water demand will likely undermine water-dependant sewerage systems; the (long-term) implication in drying and/or more drought-prone environments would be a shift to modified systems that use lower volumes of water in combination with other water conservation measures.[5]

Box 1 illustrates how this kind of screening approach can be applied to the main water and sanitation technologies as a guide to decision-making. Figures 2.1 and 2.2 show two different scenarios but, in practice, these often occur in combination.

[4] Available at: http://www.gwp.org/globalassets/global/toolbox/publications/technical-briefs/gwp_unicef_guidance-note-risk-assessments-for-wash.pdf
[5] These include simplified sewers (sometimes referred to as condominial sewers) commonly used in south America – which have proven effective in suspending solids at relatively low-flow velocities – and small-bore systems that include receptor tanks to remove solids at the household level, combining the features of on-site and off-site sanitation.

Box 1. Technology-based risk screening for WASH

Within the health sector, specified technology targets take the form of recommendations concerning technologies that are applicable in certain circumstances (e.g. filtration and disinfection of surface water). A similar approach can also be applied to the screening of water and sanitation technologies. In the figures below, the dominant water supply and sanitation technologies are screened according to their (a) vulnerability (a function of engineering and environment) and adaptability (ability to be adjusted or managed to cope with climate change) in two different scenarios. Note, however, that for some regions, climate change may increase the risk of having both too much and too little water, at different times – for example, where an overall decrease in rainfall leads to reduced soil infiltration, this may increase the risk of flooding when rainfall does occur. It may therefore be necessary to consider both scenarios in some locations.

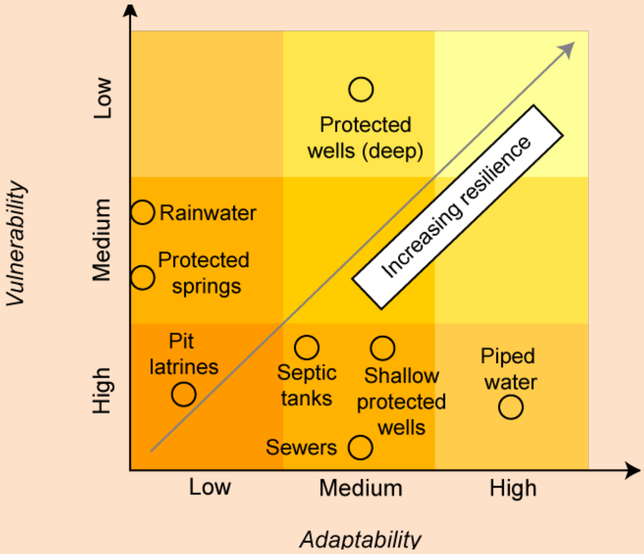


Figure 2.1. Resilience under increasing rainfall/floods

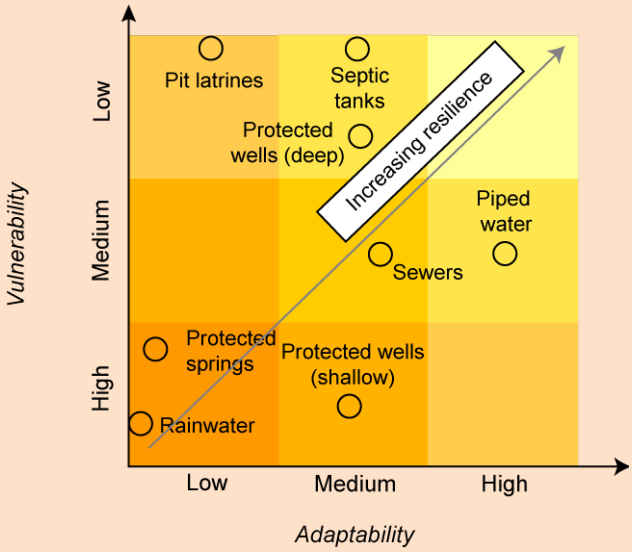


Figure 2.2. Resilience under decreasing rainfall/ droughts

In terms of **water supply**, smaller household or community-based supplies (springs, wells, rainwater harvesting from roofs) are classified as least resilient. This is because of their vulnerability to contamination (especially during flood events or with rising groundwater levels), susceptibility to drought (limited storage) and/or the difficulty in preventing damage during floods. Springs and rainwater harvesting also offer little flexibility in terms of location. From an adaptation angle, climate change may also overwhelm the ability of households and communities to deal with problems (e.g. flood damage) in situations where the quality and reliability of services is already poor. In contrast, although piped supplies may be exposed to multiple threats from source to sink, larger utilities have the potential to draw on significant human and financial capital to deal with problems and invest in more resilient infrastructure, including through decentralised management, oversight or contracting arrangements with local providers.

For **sanitation**, resilience is directly linked to whether water is part of the technology process (e.g. sewerage), or indirectly where the capacity of the environment to absorb or reduce the effect of wastes is affected. The resilience of simple on-site sanitation is closely linked to climate scenarios. In drying environments, the risk of pollution may decline as the distance between the base of pits and groundwater (and hence travel time for pathogens) increases. Nonetheless, on-site sanitation may still be vulnerable to damage from short-term flood events. Where rainfall and/or flooding increases, risks may be significant, especially if groundwater tables rise, with serious public health implications. In contrast, both declining water availability and increased flooding will pose major risks to sewerage and septic systems relying on water, although their potential adaptability is higher, at least with utility backstopping.

Source: WHO (2010); Howard et al (2016)

The classification above, and the programming discussion it can generate, provide a good starting point for thinking about technology choices. The underlying approach can also be usefully applied to map areas and people at risk, as elaborated further in this publication series.[6] For example, it can be used to determine rural areas exposed to a combination of:

- High climate risk – e.g. from droughts or floods
- Difficult hydrology and/or hydrogeology – e.g. low-yielding, low storage aquifers
- Less resilient technologies – e.g. rainwater harvesting, springs and shallow wells

Ideally, a programming discussion based on the above should draw on sector-wide consultations with actors familiar with the performance of WASH across seasons, and in both good and bad (drought/flood) years. The best available reported/recorded information on WASH coverage, functionality, water quality, hydrology and climate should also be reviewed. The identification of 'hotspots' can then inform programme responses – e.g. groundwater investigations to better characterise water supply potential; the development of additional sources and storage to spread risk and create a water buffer; and close monitoring and backstopping of potentially 'risky' areas by government agencies and development partners.

Box 2 describes how the impacts of the El Niño drought in Ethiopia played out in terms of water supply, and how evidence is being collected to help with future 'hotspot' prediction and WASH programming.

Box 2. From crisis management to crisis prevention: Learning lessons from the El Niño drought in Ethiopia

The El Niño-triggered the 2015-16 drought and precipitated one the worst humanitarian crises in east Africa for decades. By April 2016, the Government of Ethiopia reported that 10.2 million people across six regions needed humanitarian assistance, with around 9 million people affected by acute water shortages and water-related illness (WASH Cluster Bulletin, April 2016).

The response of the Government and its development partners in averting a likely catastrophe was widely commended. In particular, the focus on rural schools and clinics as well as communities, helped keep children in education and helped keep health care systems functioning. There was also a broad range of response measures: from the rehabilitation of water systems to the distribution of household water treatment kits, and help with water storage and transport.

Nonetheless, tough questions are now being asked about why the drought left millions of people water insecure, despite significant progress in extending access to safe water – and by implication in reducing dependence on more vulnerable, unprotected sources. More specifically, it raises questions about whether the country's success in getting people onto the first rungs of the water ladder masks an underlying problem with the resilience of more basic technologies and the water resources that support them.

To address these questions, UNICEF-Ethiopia is supporting a research study to better understand the pattern, evolution and causes of the water problems experienced in 2015-16. The study involves compiling different information sources and data sets on:

1. Baseline water coverage and functionality, by technology type, area and population dependence
2. Real-time monitoring of water point functionality, levels of household water consumption and time/distance for water collection in affected areas
3. The responsiveness of groundwater systems to variations in rainfall and recharge, drawing on conventional monitoring data and maps, and also novel methods to characterise variations in groundwater age and recharge processes
4. The institutional response in terms of the timeliness, appropriateness and targeting of different interventions – what worked or did not work, and why?

A key contention is that more could be done to protect and predict problem areas and vulnerable populations, and increase the resilience of water services as part of 'normal' WASH programming. In other words, a shift away from ex poste disaster relief to ex ante risk management. A key issue is whether the menu of source-service options needs to change, or at least be better tailored to different hydrological and hydrogeological environments.

[6] In particular, the *Strategic Framework for WASH Climate Resilient Development* and the Guidance Note on Risk Assessments for WASH.

One potential outcome from such an exercise could be a decision to aim directly for higher levels of service for those currently unserved, without passing through the 'basic' and 'limited' steps of communal service summarised in Figure 1.2. – in other words, jumping from the 'high-risk' options (top right) in Figures 2.1 and 2.2, straight to the technologies identified as lower risk (bottom left) that, in the case of water supply, meet the SDG aspiration of 'safely managed'. However, such decisions should be approached with caution, and certainly not without first gathering the kind of evidence described above. There are two main reasons:

- A focus on *individual* technologies or systems may be too narrow. Flexibility is needed, based on an understanding of local conditions and trends, and the potential to develop multiple systems/sources to spread risk (see Section 4 below).
- The temptation to jump to higher and *potentially* more resilient service levels/technologies implies a level of institutional capacity that may be lacking. For example, multi-village, piped water schemes will only provide reliable and safe services if the technical and institutional capacity exists to carry out more complex repairs, even if the water sources themselves are resilient.

Key messages

The kind of screening process outlined above provides an indication of risks to individual technologies considered as 'improved' by the JMP, and the potential envelope for adaptive design or management under different climate futures. Combined with evidence from the field on *existing* seasonal and drought/flood-induced changes in WASH performance, and the best available secondary information, results can be used to help rationalise technology choices and tailor them to different subnational environments.

2.2. Strengthening standards and guidance – water supply

Having looked at the resilience of individual technology types to climate change, we turn our attention to the potential for adaptation through changes in norms and standards, without 'screening-out' individual technologies at the outset. This is important because all drinking water and sanitation technologies are potentially vulnerable to climate change, and all have some adaptive potential.

Section 4 and Appendix A describe in detail the kinds of changes that should be considered as part of a climate resilient WASH programme. Here we look at the initial design and commissioning process that makes such changes possible, focussing on water point siting and construction in rural areas. We ask: What can be done by those commissioning WASH programmes to ensure that services and good practices are sustained, and are resilient to climate change?

For water supply, we look at groundwater-dependent services that rely on boreholes, since drilling programmes are typically commissioned at national or regional levels[7], and because these programmes often struggle to deliver safe, continuous supply (Box 3).

[7] This is because of the economies of scale that can be achieved at higher levels. Contracts are typically let to either government/parastatal entities or private companies. Some NGOs and donors may also retain their own drilling capacity

Box 3. Unravelling the causes of water point failure: what does the evidence tells us?

Sustainability in WASH is about whether WASH services and good hygiene practices continue to work and deliver benefits over time. In other words, permanent beneficial change. However, existing data sets collected by government agencies or reported by the JMP tell us very little about the quality, reliability and level of services people actually receive over the longer term, and how they respond to climate stresses. For water supply, a key concern is the failure or 'non-functionality' of services. Although data remain poor, studies in sub-Saharan Africa indicate that between 10 per cent and 65 per cent of boreholes are 'non-functional' at a given time. The consequences are serious in terms of lost investment, health and poverty. Even short interruptions in supply can jeopardise many of the health benefits associated with continuous access to safe water (Hunter et al, 2009).

Simple narratives have emerged to explain problems and indicate solutions. These often focus on maintenance challenges, financing and, more recently, climate change. In practice, problems can be difficult to diagnose and the climate signal may not be clear. However, a growing body of evidence from post-construction audits points to 'upstream' problems in the commissioning, design and oversight of programmes that make failure much more likely, particularly when water points are stressed by rising/peak demand and climate-related stresses. Specifically:

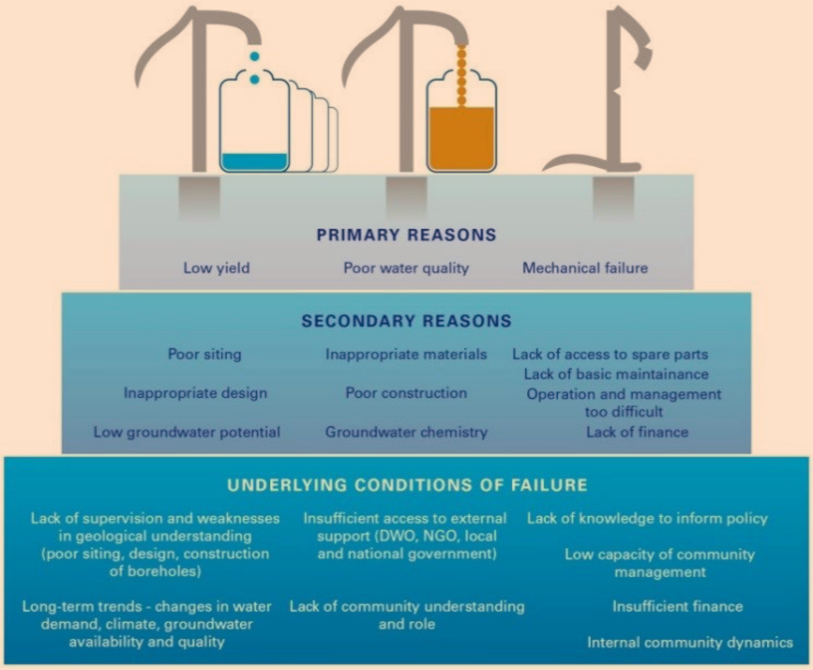


Figure 2.3. Unravelling the causes of water point failure

- Water points are often poorly sited, failing to tap the most productive (and therefore drought-resistant) parts of an aquifer. This is because siting is often carried out by drillers with no specific training or by inexperienced hydrogeologists. As a result, siting tends to be more random than scientific.
- The quality and fitting of materials (casings, screens, grouting, sanitary aprons) is often poor, compromising both continuity of supply and water quality – directly (e.g. because the screen corrodes) or indirectly (e.g. because upper, polluted parts of an aquifer are not adequately cased-off).
- Clients take the view that since they cannot adequately supervise drilling contractors, they should issue contracts of a 'no-water-no-pay' type. But without adequate supervision, this form of contracting can set up perverse incentives which encourage short-cuts and misreporting. As a result, low-yielding boreholes or boreholes with poor water quality are commissioned, with impacts on drought vulnerability, contamination risk during/after floods, and the ability of communities to manage and repair water points.

A key takeaway is not to lose sight of the 'bigger picture' when it comes to understanding why systems and services underperform, even when the reasons may seem obvious. For example, the reported failure of services during a drought may result from a combination of different factors including the vulnerability of more basic technologies such as springs and wells. But failure may also result from poor siting, design and construction, as well as long-standing problems with the maintenance and rehabilitation of systems – which are exacerbated by drought. Addressing these issues might go a long way to improving the overall resilience of programmes.

Sources: Calow et al (2010); Carter and Ross (2016); Howard et al (2016)

What steps should programmes take to ensure that the approaches and technologies they adopt are safe and sustainable in the face of climate threats and other pressures?

First, programmes should consider the importance of siting or site-specific groundwater investigation. Water sources should be located where groundwater resources can provide reliable and safe supply, and will do so in circumstances where climate extremes (and water demands) are increasing. In some areas, groundwater is widely available at relatively shallow depths and little or no hydrogeological investigation is needed to ensure water security. In environments that are more geologically heterogeneous, however, investigations ranging from simple field observation to more costly surveying and exploratory drilling may be required. Even modest investment in resource assessment and siting can pay dividends in terms of higher drilling success rates and in locating higher-yielding, more resilient sources (MacDonald et al, 2005).

Simple tests can also be carried out after drilling (but before completion) to assess the performance of a source, providing valuable information on how the source will behave during drought or at times of peak demand. If a single source cannot meet peak dry season or drought demand, further sources may need to be developed – a more cost-effective strategy than attempting to develop additional supplies during a crisis (Calow et al, 2010; MacDonald et al, 2010). In practice, test pumping and water quality testing are often skipped to save money.

Second, programmes need to consider the importance of good quality construction. A poorly constructed and engineered well or borehole is much more likely to fail during a drought or become contaminated during a flood than a well-constructed one.[8]

Key elements of sound construction – that take into account the climate resilience of sources – include:

- Drilling to an adequate diameter and depth, bearing in mind seasonal and inter-seasonal variations, and drilling straight. Both have a bearing on yield and pumping efficiency, and the longevity of pump components.
- Installation of appropriate materials – in particular, screens, casings and sanitary seals. Correct screen choice, for example, is needed to maintain yield. ‘Casing out' upper layers and an effective sanitary seal (and grout) are needed to prevent contamination from shallow groundwater or the ingress of contaminants from the surface, especially during floods.

Coming up with specific design adaptations that can improve the resilience of water points is relatively straightforward. Many of these are summarised in Section 4.1 and could be considered good practice for dealing with both climate risk and rising demand. However, much less attention is given to the incentives for contractors to actually deliver climate resilient water supplies and the ability (and interest) of clients to hold them to account.

Proper siting and construction will become increasingly important as programmes tackle more difficult areas and harder to reach populations – for example, hard rock environments where yields are highly variable and expertise is needed to site productive sources. Some countries (e.g. Kenya, Nigeria) are supporting the ‘professionalisation' of the drilling sector[9] by moving towards licensing systems in which a degree of vetting (of equipment and competence) is part of the licensing process (Adekile, 2014). This is step in the right direction, but does not address the need for independent siting and oversight. Training and retaining a professional cadre of hydrogeologists to undertake these tasks is a key priority.

Finally, those funding and commissioning water supply programmes should, as a matter of routine, conduct regular post-construction audits of infrastructure and services. Some of these audits should involve the complete dismantling and inspection of water points to check on materials and construction. The aim would be to learn lessons for future programmes in terms of performance (including performance under climate stress) and check standards against contracts and invoices to assess corruption risk (see Calow et al, 2012).

[8] Conversely, ‘over-engineering' will see costs spiral for little, if any, added benefit.
[9] See http://www.rural-water-supply.net/en/resources/details/775

Key messages
Many different factors affect the sustainability of services, from climate change/variability to the commissioning, design and oversight of programmes. Untangling the climate signal is difficult but a growing body of evidence suggests changes in programme execution could strengthen the overall resilience of services – to both climate risks and other pressures. In particular, ensuring that siting decisions are informed by an appropriate understanding of the resource base, and that best-practice design and construction standards are followed, would go a long way to improving the sustainability of services.

2.3. Strengthening standards and guidance – sanitation

The impacts of climate change on sanitation relate to both the ability to sustain and extend sanitation services, and the risk of inadequate sanitation to the quality of drinking water sources and the wider environment.

In terms of extending and sustaining services, risks are linked to water availability – where water provides the means to transport and dilute waste (e.g. conventional sewerage) – and to the damage that can be caused by flood events in particular. In rural areas where household-managed sanitation will remain the norm, floods can destroy latrines, spread faecal matter, undermining the demand for rebuilding and therefore the long-term commitment to the achievement of open defecation free status. Threats to groundwater quality and drinking water then become a serious concern. In areas of inadequate sanitation, health risks are amplified significantly because of the threat of widespread and enduring contamination of the surface environment, soils, water resources and water sources.

Section 4 provides more detail on the principal risks and adaptation options for different sanitation technologies, rural and urban. Here we look at the general programmatic guidance available for assessing and addressing risks in rural areas, focusing on two key issues:

- Minimising the risk of environmental and water source contamination through risk-based guidance, especially in flood-prone areas and/or where water tables/levels are rising.
- Financing options for maintaining and extending the use of hygienic latrines in high-risk areas, where poorer households in particular may need support.

Box 4. UNICEF Case Study: Context-specific sanitation programming responses

UNICEF aims to tailor its support for sanitation according to different contexts (UNICEF, 2016):

- In areas where open defecation is common, creating demand for sanitation is prioritised.
- Where the level of open defecation is low but there is a high proportion of unimproved latrines, the priority switches to supply.
- Where overall rates of basic sanitation coverage are high but still patchy, financing solutions are promoted for the unserved.
- Where communities face specific hazards or handicaps, further tailoring is recommended.

How could climate-related hazards and, in particular, risks to on-site sanitation infrastructure and water quality, be incorporated into this context-specific approach? In drying environments, impacts on simple on-site sanitation infrastructure may be positive and pollution risks may decrease. In wetter environments, however, and/or where flood risk will increase, programmes will need to implement robust water safety plans and adapt or replace some technologies. They will also need to support communities with the know-how and expertise to build flood-resilient latrines. Where latrines need to be rebuilt or replaced, poorer households may need targeted subsidies (e.g. toilet vouchers) to help communities regain open defecation free status.

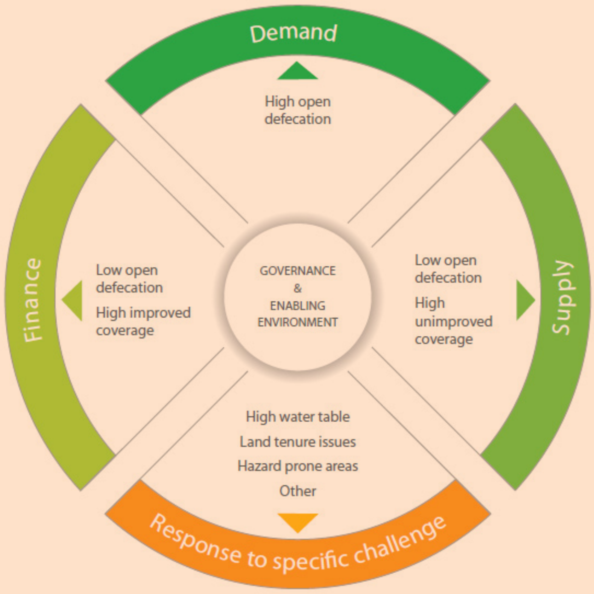


Figure 2.4. Context-specific sanitation options
Source: UNICEF (2016)

2.3.1. Minimising risk of contamination through risk-based guidance

Where technology selection is demand-led, there is a need to ensure that information on climate resilience, as well as on cost and other factors, informs programme design. This means tailoring the ‘menu’ of sanitation options or designs to areas with different hazard profiles and linking this with area-specific support for the supply of locally available and affordable materials and construction expertise. It also implies using risk-based assessments of the threat to water quality from latrines alongside household-community mobilisation and demand-creation – through Community-led Total Sanitation (CLTS) or Community Approaches to Total Sanitation (CATS).[10]

There is now a solid evidence base demonstrating that risk-based approaches to the siting of drinking water sources and latrines can prevent microbial contamination of water supplies (Howard et al, 2010 and 2016; WHO in press). These can be used to make locally appropriate estimations of separation distances between latrines and boreholes. Where these distances are difficult to achieve, or where the risks of diffuse pollution are significant, then vertical separation has been shown to be effective. This involves deepening the water intake and screening the contaminated shallower zones (see Box 5). Where shallow wells are prevalent, similar approaches can also be used, although adaptations may be more difficult to implement.

In each case, ensuring good quality construction is essential – for both water points and toilets. Poor siting, construction and materials are a significant factor in both the abandonment of toilets and reversion to open defecation (Cavill et al, 2015), and the poor performance of water points (Section 2.2 above).

With reference to the need for context-specific responses (Box 5, Figure 2.4), this implies:

- Identifying areas of high flood risk and high open defecation, where the development of water sources may need to combine both horizontal and vertical separation approaches, as well as tight oversight of construction quality. Where risks are particularly high – for example, where drinking water sources tap unconfined, fractured aquifers with little attenuation capacity – the use of dug wells and springs may need to be discontinued.
- Identifying areas of high flood risk where latrines are more common (and rates of open defecation lower), but where point source pollution from latrines still poses a risk to water quality. Here, co-development of latrines, boreholes, wells and protected springs may still be possible but only with appropriate water safety planning.
- Reviewing and, if necessary, changing the menu of water supply and sanitation options offered or available to communities and households in riskier areas, with complementary adjustments to (for example) supply chains, the training of local artisans and (if necessary) targeted subsidies for the poorest.
- Considering whether support for the construction of low-cost, temporary sanitation facilities that can be easily moved and re-built offers better long-term outcomes than support (and possibly subsidy for) more costly ‘climate-proof’ structures. The answer to this question will likely be context specific and influenced by the frequency and magnitude of hazard events, the sanitation status of communities and households, the willingness and ability of households to re-invest in sanitation, and subsidy/ financing arrangements (see below).

[10] A number of approaches to sanitation have emerged that focus on promotion rather than provision, with minimal or zero subsidies for hardware. Notable among these are CLTS and CATs. Although each ‘branded’ model has its own advocates, in practice, differences are often about points of emphasis. Both are aimed at creating demand for change and the supply chain needed to meet it (Cairncross et al, 2013).

Box 5. Risk assessment for climate resilient in sanitation planning – programme guidance

Assessing the risk of water point contamination from latrines is based on understanding the time it would take water, and the pathogens within it, to travel from the pit to the water point. The longer it takes, the greater the reduction in pathogens through natural die-off. The overall aim in siting either a latrine or water point is to ensure that pathogen die-off is sufficient to reduce the risk to a level where it ceases to become a major health concern. Where rainfall is expected to increase, or where the intensity of rainfall increases, the risk of contamination via the pathways highlighted in Figure 2.5 will also increase.

Water sources in **Sierra Leone** are highly vulnerable to contamination because of a combination of risk factors. These include: intense rainfall for six months of the year; shallow, fluctuating water tables and permeable soils; widespread sources of pollution arising from low sanitation coverage; and heavy reliance on shallow wells as drinking water sources. A British Geological Survey (BGS)-led study concluded that diffuse pollution of groundwater from surface-deposited waste was at least as significant as pollution from pit latrines and other point sources (Lapworth et al, 2015). Hence 'standard' risk-based approaches based on site investigation and lateral spacing between hazard sources and water points would not provide effective protection for domestic supply, even with support for implementation and enforcement. An alternative approach was recommended, focusing on vertical (depth) as well as horizontal separation or deeper water points and the appropriate design, siting and construction of both shallow wells and boreholes.

In **Pakistan**, UNICEF has developed its own approach to climate resilient CLTS in which climate risks (particularly from floods) are assessed in parallel with the 'normal' CLTS or CATS process. The assessment of flood risk makes use of digital terrain mapping, as well as community experience of flood events canvassed during transect walks and represented on community-generated maps.

The NGO Tearfund has published its own guidance on how CLTS can be combined with water safety planning to mitigate the risks of water contamination (Greaves, 2010). Drawing on case studies from **Afghanistan** and **South Sudan**, they highlight the advantages of correlating areas of open defecation with potential water contamination routes and flood-prone areas. However, Tearfund also suggest that a single, fully-combined CLTS-Water Safety Plans (WSP) process may not be desirable: a WSP tends to take longer than the pre-triggering and triggering phases of a typical CLTS campaign, potentially threatening its fluidity and spontaneity.)

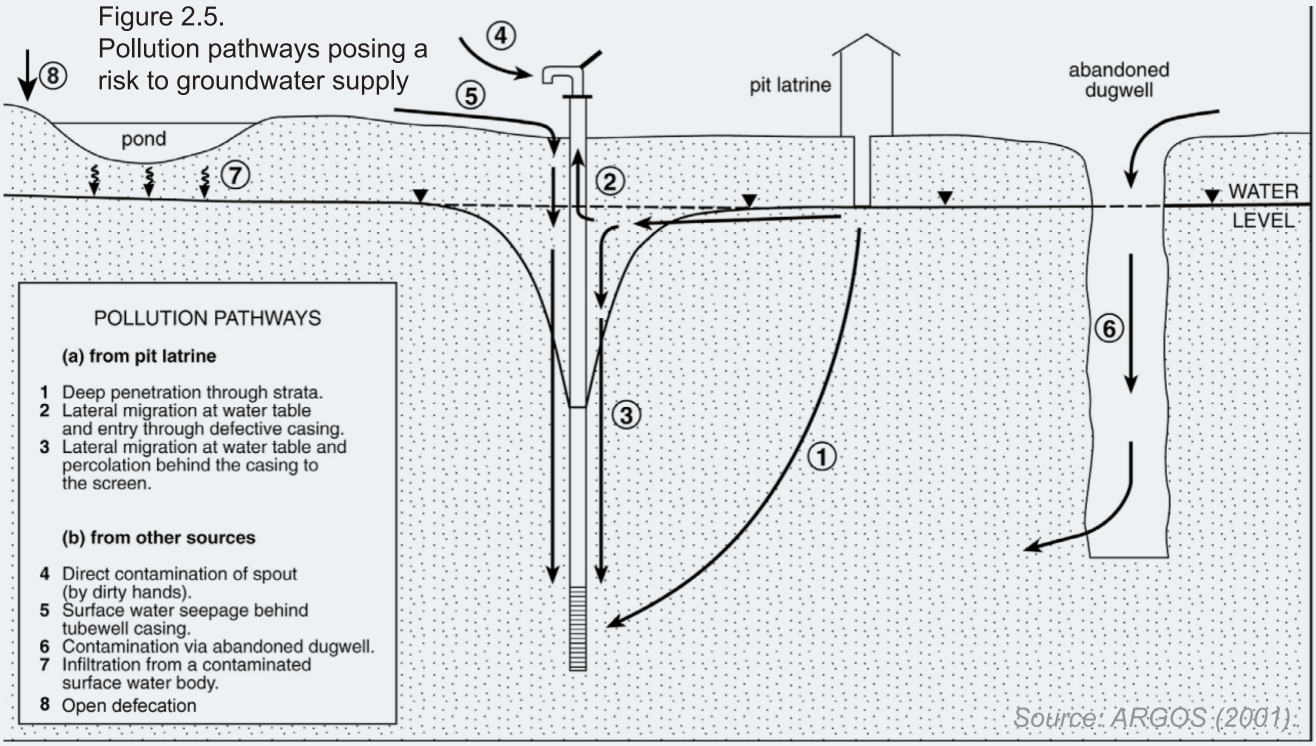


Figure 2.5.
Pollution pathways posing a risk to groundwater supply

2.3.2. Financing options to support use of hygienic sanitation by vulnerable households

While the success of CLTS/CATS has challenged conventional thinking on sanitation finance (in particular the use of “subsidy”), close examination of successful open defecation free achievement can reveal different forms of subsidy for the poorest and most vulnerable: from within the community, from a village government, or from a development partner (Chambers, 2016; Robinson and Gnilo, 2016). Given the fact that poorer households are often the first to revert to open defecation because their limited resources tend to result in less well-built latrines, sited in more vulnerable (e.g. flood-prone) locations, the need for targeted finance remains important, especially in areas of high flood risk (Robinson and Gnilo, 2016). So what are the options? More specifically, how can we best provide targeted finance to sustain sanitation practices without undermining CATS principles?

There is relatively limited experience of the use of micro-finance and micro-insurance in the WASH sector generally (Howard et al, 2016). Micro-finance has the potential to support the acquisition of hygienic latrines and move people up the sanitation ladder, but for poorer households in particular, the benefits of microfinance must be weighed against costs of families, already in debt, accruing debt. The challenge is likely to be greater in riskier environments where floods damage infrastructure and impact household income. A tentative conclusion is that microfinance could assist better-off households move up the sanitation ladder – perhaps to more resilient and costly designs – while other tools are used to help the poorest step onto the ladder. It is particularly important that programmes which aim to promote behaviour change (i.e end open defecation) and increase the demand for sanitation products and services come before the use of targeted subsidies, otherwise the use of such subsidies has the potential to undermine initial and sustained behaviour change.

The use of cash transfers to support WASH is growing, especially in emergencies; although in development contexts they remain more commonplace in other sectors such as health and education (Hagen-Zanker et al, 2016). One reason for their increasing popularity is because they allow some degree of household choice, and are becoming easier to administer and monitor – for example, with digital transfer and payment technologies. However, there is also concern that where markets are insufficiently strong or regulated, the supply of high-quality WASH products (such as climate resilient latrines) may be insufficient. This implies that additional market development support may be needed, alongside cash transfers or multipurpose cash grants (Global WASH Cluster, 2016). Another concern for WASH specialists is that households often may not choose to spend cash on sanitation, particularly if more immediate needs of food, water and healthcare are prominent. In such circumstances targeted voucher schemes may be preferred because they can be restricted to certain types of expenditure. Toilet vouchers that can be exchanged for sanitation goods or services are one example of this. Vouchers can provide households with some choice (of options, supplier and timing) and help strengthen local production and supply. Eligibility can be restricted to vulnerable households, to prevent the distortion of markets and maximise equity benefits, although careful targeting will increase the administrative costs.

In their review of cash transfer programming for emergency WASH and shelter, Julliard and Opu (2014) highlight examples where transfers have been used to allow households to purchase emergency health and hygiene kits, or to pay for the emptying of latrines (e.g. via Oxfam-supplied vouchers in Haiti, Jordan and Lebanon). Cash or voucher support is not restricted to sanitation and hygiene: there are applications in emergency water supply such as vouchers for water trucking (Global WASH Cluster, 2016). In Bangladesh, BRAC (an NGO) has provided toilet vouchers through its WASH programme to enable 6.6 million people to benefit from hygienic toilets. Loans for sanitation upgrading are provided to wealthier households (Bongartz et al, 2016).

In principle, cash transfers or vouchers could also be used to help households rebuild latrines and purchase basic hygiene items (e.g. soap, jerrycans, etc.) following a flood; though this would depend on the ability of markets to provide the affordable goods and services required. The aim would be to provide the financial means (provided as a toilet voucher or equivalent) to ensure the lowest acceptable level of service – in most cases, a simple hygienic toilet (Robinson and Grilo, 2016).

Micro-insurance could provide another source of support, especially in areas regularly affected by floods. However, extending basic house insurance (still rare) to cover the replacement or rehabilitation of water and/or sanitation facilities might be difficult or too costly for poorer households to consider (Howard et al, 2016).

A key conclusion from the discussion above on risk assessment and financing is the need to base sanitation interventions on a thorough situation analysis which will ensure needs of the poorest and most vulnerable households are met. This needs to cover the household level (the demand side), the supply side (small-scale and institutional providers), and environmental conditions and risks. Looking at the range of tools/approaches already employed in sanitation programmes, we identify the following priorities for a climate resilient sanitation situation analysis:

- Impact evaluations of previous sanitation projects and programmes that include analysis of how climate hazards have affected outcomes and impacts.
- Formative research that provides information on the drivers of demand for sanitation, including the influence of hazards on people's long-term willingness and ability to (re)invest in sanitation.
- Market surveys that provide information on the potential suppliers of sanitation goods and services (toilets, pit emptying services, etc.) in riskier environments, including existing local adaptations to toilet design that could be offered by approved suppliers.
- Institutional analysis that considers a range of financing options and intermediaries to support investment, including (for example) cash transfers to help with re-investment and rebuilding, particularly for poorer households.

Key messages

The overriding concern about the vulnerability of sanitation to climate change lies in its response to heavy rainfall, floods and storms, and the associated threats to infrastructure, water and wider environmental quality; which can, in turn, affect the underlying demand for safe sanitation in riskier settings. The use of risk-based approaches to the siting of drinking water sources and latrines is now well established, and should form an integral part of the CATS/CLTS process, along with climate-informed situation analyses, formative research, market surveys and institutional assessment. The latter may need to consider financing options for households living in vulnerable areas – for acquiring a latrine or for rebuilding one damaged by flood.

3. Building Water Resource Monitoring and Management Capacity

An effective national and subnational response to climate risk should also frame WASH within the broader water resources (and waste management) context articulated in SDG 6 (see Box 6). This means building capacity for water resource monitoring through the outputs highlighted in Figure 1.2 and the activities that support them. In this subsection, we look specifically at:

- Water resources assessment and monitoring. This draws together elements of 'Assessing water resources – quantity and quality' (Activity 2.1.1), 'Assessing risks to water resources from climate change and other pressures' (Activity 2.1.2), 'Monitoring water availability and quality' (Activity 2.2.1) and 'Monitoring patterns of use and climate-linked (and other) threats' (Activity 2.2.2).
- Water resources management. This links to 'Developing agreed guidelines/rules across the water sector informed by climate risk'(Activity 2.3.1), 'Supporting basin planning initiatives that coordinate water-using and polluting sectors and prioritise support for the most vulnerable areas' (Activity 2.3.2), and 'Prioritising WASH in the allocation of resources between sectors' (Activity 2.4.2).

Box 6. The post 2015 rationale for linking WASH with water resource monitoring and management

The SDGs set a high bar: 'safely managed' water and sanitation services. In particular, the indicator measuring progress towards the drinking water target specifies on-plot access to a safely managed water supply that is available when needed, and compliant with faecal and priority chemical water quality standards (Figure 1.2). Although the indicator does not specify the quantity of safe water that should be supplied, the implication is that households with on-plot access will use significantly more water than those with only 'limited' or 'basic' access.

Although the water requirement for domestic supply typically comprises a very minor component of total water withdrawals, the jump in water demand from limited or basic services to safely managed (on-plot) supply may still be difficult to achieve in areas where water is scare, where climate change will result in reduced water availability, and where competition for water is increasing. To date, however, the availability of sufficient (safe) water for domestic use has been assumed rather than planned for. In short, WASH has remained in its own silo, disconnected from wider water resource management debates about sustainability and climate change, allocation priorities and the rules/incentives for achieving them.

We draw two main conclusions. First, much better information on water resource conditions, trends and patterns of use will be needed to support the ambitions of SDG 6, especially for poorly characterised, climate-affected groundwater systems. Second, as pressure on water systems increases, and climate change affects both supply and demand for water, the WASH sector will need to play a much more active role in wider policy and planning debates on water resource management, allocation and protection (Howard et al, 2016; UNICEF, 2016). Otherwise, water which should be earmarked for high priority domestic use may be captured by other users and uses, particularly where investment in irrigation is increasing.

3.1. Water resources assessment and monitoring

Understanding the resource base and patterns of use is an essential prerequisite for risk-informed planning. Although much can be done on the back of individual programmes and projects (see above), more systematic approaches to water resources assessment and monitoring are urgently needed in many countries.[11]

Globally, monitoring records have been in decline for decades, with under-investment leading to the degradation of established networks and a reduction in the quantity and quality of data available for decision-making (Robins et al, 2006; Foster and MacDonald, 2016). Reversing the trend will be neither simple nor quick, not least because the value of hydrological, meteorological and hydrogeological records depends crucially on record length.

Good data can inform both site-specific investigations (e.g. where to drill) and the evidence base on how water resources will be impacted by changing climate and socioeconomic drivers. Data are also needed to support early warning and response systems (see below), to detect and prevent pollution and to ensure overall water withdrawals fall within sustainable limits.

Focussing specifically on groundwater resources (Box 7), where the knowledge base is weakest, monitoring efforts should include the following (after MacDonald and Foster, 2016):

Assessing water availability and reliability:

- Assessing aquifer characteristics using geological information on rocks, sediments and soils, and through scientific analysis of transmissivity and storage – the two key characteristics that determine how resilient groundwater supplies are to variations in rainfall and recharge.
- Developing a monitoring system for recording long-term groundwater level fluctuations that can be compared with the rainfall record.
- Preparing national or regional hydrogeological maps showing the location of main aquifers, together with national databases to systematically store aquifer and groundwater data. Once the basic data are in place, applied maps can be developed to show (for example) vulnerability to drought or long-term declines in rainfall.
- Compiling an inventory of major groundwater abstractions combined with estimates of smaller ones that can be used to develop basic water balances that compare natural recharge with discharge and abstraction. Ideally, dynamic numerical models should be developed to assess the implications of alternative scenarios – including future climate and its impact on water availability and quality.

Assessing water quality and pollution vulnerability:

- Characterising groundwater quality by implementing a systematic programme for sampling water sources, with a baseline established to enable the monitoring of changes against agreed water quality standards.
- Assessing the vulnerability of aquifers to pollution and developing vulnerability maps for use in land-use planning.

In each case, building and sharing knowledge on how aquifer characteristics, underlying geology and chemistry shape groundwater development potential, and condition vulnerability to climate change and other pressures, is key.

Although resource assessment and monitoring can be expensive, benefits will likely outweigh costs where resources are poorly characterised, climate change amplifies uncertainties and demands are increasing. Studies in sub-Saharan Africa, for example, have shown how the benefits of groundwater assessment outweigh costs where benefits are measured in terms of higher drilling success rates and drilling costs avoided for low-yielding or dry boreholes (MacDonald et al, 2006).

Looking beyond conventional developmental or programmatic applications, growing value will be attached to monitoring systems linked to disaster risk reduction (DRR) – such as drought or flood preparedness – and early warning and response. For example, data on how water resources respond to variations in rainfall, runoff and recharge, combined with data on water coverage, system type and functionality, can be used to predict where drought-related problems with drinking water access are likely to emerge (see Box 2). These data, in turn, can be used to target and tailor pre-drought WASH interventions to build resilience.

The relative costs and benefits of establishing early warning systems depend on the magnitude and frequency of hazards, and the vulnerability of exposed

11 For additional information, see Technical Brief: Monitoring and evaluation for climate resilient WASH: http://www.gwp.org/globalassets/global/about-gwp/publications/unicef-gwp/gwp_unicef_monitoring-and-evaluation-brief.pdf

communities. Reported cost-benefit ratios vary widely, but assessments of early warning for storms, floods and droughts undertaken throughout Asia indicate potential returns of up to US$ 599 for each dollar invested (Subbiah et al, 2008).

Across the data applications highlighted above, opportunities are emerging to tap into the large quantities of data collected through remote sensing (e.g. for water resources assessment), which are potentially transferable through mobile phones (e.g. data on water point failure transferred to pump mechanics).

Care is needed in interpreting the data, however, particularly when not 'ground-truthed' with basic field measurement. This is illustrated in northern India, where remote sensing studies using GRACE[12] data warned of widespread groundwater depletion across the Indo-Gangetic basin. However, careful analysis of water well measurements in the region shows a much more nuanced picture, with rapid groundwater depletion limited to smaller areas within the aquifer, and large areas of stable or rising groundwater levels. The same analysis indicates that deteriorating water quality, rather than widespread depletion or climate-induced change, is the principal concern for both WASH and irrigated agriculture in the basin (MacDonald et al, 2016).

Key messages

Achieving the aspiration of universal access to safe water on a sustainable basis will demand much better information on resource conditions, trends and pressures than currently exists in many countries. Climate change will increase the value of good information – particularly when linked with DRR and drought/flood early warning and response – because of the additional uncertainties that changes in rainfall, runoff and recharge introduce.

Box 7. The adaptive potential and limits of groundwater supply

Groundwater has major advantages over surface water in terms of climate resilience because of the storage groundwater aquifers offer. This 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. Widespread availability, higher water quality and lower development costs provide further benefits (Calow et al, 2010; MacDonald et al, 2010; MacDonald et al, 2012).

The implication is that national WASH strategies and sector programmes will become much more dependent on groundwater, particularly as water demand to meet higher service levels goes up. The development of groundwater as an adaptive strategy, however, is hampered by limited knowledge of resource conditions and trends, and uncertainty over the potential of groundwater to sustain higher levels of service, particularly as other demands increase.

Across both Asia and sub-Saharan Africa, the emerging evidence suggests that groundwater storage is substantial – in sub-Saharan Africa, as much as 20 times the water stored in the continents lakes (MacDonald et al, 2012). However, storage and yields are patchy. Modest yields of groundwater are widely available at accessible depths – sufficient to sustain handpump abstraction and with enough storage to sustain use through inter-annual variations in rainfall. However, the higher yields needed for multi-village schemes and urban development are more difficult to find beyond major sedimentary basins. Urban groundwater supplies may also require greater attention to, and management of, pollution risks – for example, through land-use planning

What are the implications for climate resilient WASH? While the availability and accessibility of groundwater over much of Africa is favourable to rural domestic supply and minor productive use, there are limits to the levels of service that can be provided. For example, multi-village schemes offering on-plot access to water would require the development of one or more high-yielding boreholes. Beyond the sedimentary terrain, locating them would require the kind of in-depth hydrogeological investigations that are currently lacking, with no guarantee of success.

[12] Gravity Recovery and Climate Experiment (GRACE) data are collected by two NASA satellites that have been flying in low-earth orbit since 2002.

3.2. Water resources management

Investment in water resources assessment and monitoring is also needed to support water resources management. Building robust institutions and frameworks for managing water remains a long-term goal in many countries, not always helped by a preoccupation with basin-scale, integrated water resources management (Calow and Mason, 2014). From a WASH perspective, the priority is to protect domestic supplies from both pollution and competing demands and, where water is part of the sanitation process, to ensure that systems remain effective in removing and treating waste. All of this has to be achieved in the face of accelerating climate change.

In Table 3.1 below, we identify a number of shared issues and actions based on the building blocks of climate-adaptive water resources management (WRM). These are found wherever water management is effective, and absent (in whole or in part) where it is not (Perry, 2013).

Table 3.1: Entry points for WASH engagement in adaptive water resources management

Key elements of a WRM strategy	Priorities for WASH sector engagement
A. Accounting – water resources and use Ensure clear and publicly available information on resource conditions in time and space, and systems for monitoring changes in water availability, quality, withdrawals and pollution.	■ Advocacy: make the WASH-specific case for better monitoring and assessment. ■ Partnership: work with government to strengthen technical capacity, including social and environmental impact assessments for new infrastructure projects. ■ Funding: co-investment in monitoring and assessment, focussing firstly on high-risk areas; work with government to secure climate finance for strengthening climate-hydrological observing systems.
B. Bargaining – priority setting Determine, through political processes, priorities among users for the available water.	■ Advocacy: highlight risks to WASH from unconstrained development of agriculture and industry, and risks posed by accelerating climate change. ■ Partnership: work with governments to ensure allocations for rural and urban WASH are ring-fenced in basin allocation plans and account for expected/projected impacts of climate change. ■ Funding: co-invest in basin allocation planning initiatives to safeguard WASH priorities.
C. Codification – rules and incentives Translate agreed priorities and allocations into rules, statutes and laws, so that the water service for each sector or user is clear under different hydrological conditions.	■ Advocacy: make the case for the human right to water and supporting legal provisions. ■ Partnership: work with government on national water law, sector strategies and basin plans, to ensure water rights have legal force, land rights are de-coupled from water rights, and regulations for waste disposal prioritise maintenance of safe water. ■ Funding: support government-led efforts to revise statutes and laws.

Key elements of a WRM strategy	Priorities for WASH sector engagement
D. Delegation – who does what Delegate implementation to institutions and agencies, with clearly defined roles and responsibilities for the provision of all water services – from resource monitoring to the enforcement of allocation licences and pollution control.	■ Advocacy: champion cross-sector working groups linking WASH with agriculture, energy, industry and environmental agencies/departments at different levels; ensure WASH has targeted objectives in national climate change policy. ■ Partnership: work with regulatory agencies to implement source-resource protection plans, or work with government to help establish such agencies; explore opportunities for local, community-based approaches to WASH–watershed management. ■ Funding: support technical capacity-building of regulatory bodies (national, regional and local) charged with protecting rights and controlling pollution.
E. Enforcement – agreed rules Enforce the rules, statutes and laws agreed above, with priority given to the protection of drinking water supplies in terms of both quality and quantity.	■ Advocacy: highlight cases of good and bad water stewardship impacting WASH. ■ Partnership: work with regulatory agencies to implement source-resource protection plans, or work with government to help establish such agencies and give them political ‘teeth’. ■ Funding: support oversight and enforcement capacity of regulatory bodies (national, regional and local) charged with protecting rights and controlling pollution.

Source: based on Perry (2013) and Mosello et al (2016)

Shared concerns over climate change present an opportunity for WASH actors to make the case for investment in water resources assessment, monitoring and management. There are few quick-wins though; the development of robust water accounting, user registration systems, allocation licensing, environmental impact assessments, stakeholder platforms and pollution control all take time, and results can be hard to measure.

Funding remains a problem, although new sources of finance for climate adaptation (e.g. from Green Climate and Adaptation Funds) present opportunities. To date, however, disbursements have fallen a long way short of pledges and most of the (very limited) adaptation finance earmarked for WASH has flowed to middle-income countries, and has been de-coupled from wider concerns about sustainable management (WaterAid, 2016). WASH actors have a role to play here, both in helping governments gain the accreditation they need to directly access funds, and in making the case for WASH for the most vulnerable countries, communities and households – as a key component of adaptive water resources management.

Making the case may mean thinking beyond the usual justifications for ‘better’ management. In Ethiopia, for example, a growing body of work on adaptive management conducted with the Ministry of Water, Irrigation and Energy only gained traction once the costs of inaction had been framed in economic terms and linked to the Government’s national development strategy. This included highlighting the costs of intensive industrial and irrigation development in upstream river basins in circumstances where downstream towns were already rationing supply and spending most of their utility budget on water treatment (Parker et al, 2016).

Key messages

Achieving universal access, and particularly higher levels of service associated with on-plot supply, will not be achieved with a business-as-usual approach to service delivery that assumes quantity and quality needs can be met in isolation from other demands. Shared concerns over climate change present an opportunity for WASH actors to work with others in making the case for co-investment in water resources management – to secure and safeguard domestic use and ensure equitable water allocations within environmental limits.

4. Supporting Climate Smart Infrastructure, Technologies and Governance

In this section we look in more detail at some specific options or outputs that could emerge from higher-level national planning and ask: what do they look like at the local/project level?

A comprehensive list of local and project-level outputs and supporting activities is provided in the Results Framework (Figure 1.1). Here, we look specifically at:

- Applying climate resilient standards and practices. This draws together a number of activities from the Results Framework, including 'Ensuring conformity with climate-informed standards' (Activity 3.1.1) and 'Adapting technologies to account for climate risks' (Activity 3.4.1).
- Diversifying and decentralising services, which links to 'Spreading risk between different water sources and systems' (Activity 3.3.1) and 'Exploring wastewater reuse/recycling, nutrient recovery and energy production from waste' (Activity 3.4.3).
- Developing and exploiting water storage, linked to 'Developing decentralised storage systems' (Activity 3.2.1).
- Climate smart solutions (e.g. solar-powered technologies). This links to 'Exploring innovative, climate smart technologies' (Activity 3.4.2).

First, we review a wide range of options covering both rural and urban WASH, elaborated further in Appendix A. In the sections that follow we focus in on some specific options or approaches in more detail.

4.1. Applying climate resilient standards and practices

All of the major WASH technologies can, to varying degrees, be adapted to account for climate risk. In many cases the adaptations available are 'no regrets' options – desirable regardless of climate change or a particular climate scenario – because they reduce the overall vulnerability of systems to different hazards and help maintain water availability, access and quality.

An extract of adaptive responses for water supply and sanitation is provided in Table 4.1 and 4.2, based on the more comprehensive summary provided in Appendix A.

4.1.1. Water supply

For water supply, large rural populations in sub-Saharan Africa and parts of Asia will continue to rely on community-managed systems based on simple technologies such as rainwater harvesting, springs, wells and boreholes (see Section 1).

Household-level rainwater harvesting and springs are relatively inflexible in that their location is essentially predetermined, they have limited adaptability in design and can be susceptible to changes in rainfall. Household rainwater harvesting, for example, rarely delivers year-round supply, and even in areas where rainfall is set to increase, limits on storage may still be a limiting factor, especially where rains fall in increasingly intense events (e.g. intensification of monsoonal rain). That said, rainwater harvesting and storage can provide vital backup or supplementary supply as part of the technology 'mix' and, when earmarked for non-potable uses, can help relieve pressure on drinking water sources (see Section 4.2 below).

Protected springs and dug wells are both vulnerable to microbial contamination (e.g. during/after flood events) and potentially vulnerable to seasonal or longer-term reductions in rainfall and recharge. However, catchment protection measures, when integrated with a WASH programme, have the potential to reduce flood damage to infrastructure, reduce the risk of contamination and enhance groundwater recharge.[13] As discussed in Section 4.3 below, impacts on recharge will be context specific and dependent on the local hydrological balance. For both technologies, the quality of construction and follow-up maintenance will also have a major bearing on overall resilience.

Drilled wells or boreholes typically have greater resilience to climate-related risks, particularly where they tap major groundwater storage, and adaptations exist to make them less vulnerable to physical damage, contamination and rainfall-recharge variation. For example, raising wellheads and extending the sanitary apron can both be effective in minimising the impacts of floods; and 'casing-off' and sealing upper layers can help minimise contamination from shallow aquifers and the land surface. As noted above, however, the

[13] Described in a further Technical Brief in this series – *WASH Climate Resilient Development. Local participatory water supply and climate change risk assessment: modified water safety plans.*

quality of siting and construction has a major impact on functionality and resilience. In some environments, dug wells may be more resilient to climate change than boreholes, at least in terms of their ability to provide continuous supply. For example, where groundwater is found in zones of shallow weathering, the ability of a dug well to store limited seepage is a significant advantage.

More complex **piped systems** may have multiple points of vulnerability, from the source through treatment systems (if used) and subsequent distribution. For example, the large spread of pipes and numerous joints mean that damage in one area can potentially affect water availability and quality for large numbers of people across a network, particularly where water and sewage networks intersect, or when pressure in the water network varies and contaminants are ‘sucked in’ from drainage channels and leaky sewers.

Securing and protecting the water source – or sources – is a critical first step. Source protection and treatment are clearly linked, since changing source water quality has a significant impact on treatment need and efficiency, and knock-on effects on plant design and process selection.

Given the greater complexity of piped systems, there are many possible adaptations and, in larger towns and cities at least, the resource potential (human, financial, technical) to implement them. Adaptations include the use of multiple sources to spread risk, innovations in treatment, more robust pipe materials and demand management measures such as leakage control (Danilienko et al, 2010; Tyler and Moench, 2012; Howard et al, 2016).

Many actions could again be viewed as low or no-regret. Leakage reduction, for example, can help meet higher levels of demand, ease pressure on sources and enhance cost recovery. Wastewater reuse and the recovery of wastewater energy and nutrients can lower energy bills, reduce water demand and decrease greenhouse gas emissions – see below (Larsen et al, 2016; Foster, 2017). Box 8 below summarises the city of Windhoek’s experience in implementing comprehensive demand management and drought response measures in an increasingly drought-prone environment. Important features include the progressive application of different strategies, from information campaigns to rationing, dependent on the severity of the drought; and background strategies including wastewater reuse and regulations for water efficient appliances.

In contrast, major infrastructure investment in water storage, treatment, drainage or wastewater reuse will be more climate-sensitive, requiring planners to weigh up long-term risks and make choices based on the best available climate science. That said, major network-based infrastructure projects built for fixed target populations and climate scenarios increasingly risk locking-in inappropriate design. Hence, the growing interest in decentralised systems that can be added in stages to meet demand, and that allow for greater design adaptation as climate risks and understanding evolve (Larsen et al, 2016; Foster, 2017).

Table 4.1 summarises adaptation options that may be relevant for water supply interventions in response to different types of climate risk. Greater detail is provided in Appendix A, including for different types of water supply interventions or schemes – from protected wells, boreholes and springs, to piped schemes.

Box 8. Balancing water supply and demand in the city of Windhoek (Namibia)

The city of Windhoek in Namibia, southern Africa, offers some important insights into what can be done to bring water demand in-line with water supply in a water-scarce and increasingly drought-prone area.

Windhoek has a long history of adaptive water management. Since the 1930s demand has outstripped groundwater supply and the city now combines groundwater with bulk water transfer from the so-called 'three dam system'. At the same time, the city has implemented comprehensive demand management measures, including wastewater reclamation and reuse.

<table>
<tr><th>Normal</th><th>Water scarcity</th><th>Drought</th><th>Severe Drought</th><th>Water Crises</th><th>Water availability</th></tr>
<tr><td>Do not Waste Water</td><td>Drought Watch</td><td>Water Savings Required</td><td>Com-pulsory Water Savings</td><td>Ration-ing</td><td>Months of available water supply</td></tr>
<tr><td rowspan="5">Baseline Con-sumption</td><td></td><td></td><td></td><td></td><td>30</td></tr>
<tr><td rowspan="4">Reduced Water Con-sumption</td><td></td><td></td><td></td><td>24</td></tr>
<tr><td rowspan="3">% Water Savings</td><td></td><td></td><td>18</td></tr>
<tr><td rowspan="2">Requires % Water Savings</td><td></td><td>12</td></tr>
<tr><td>Restric-tions</td><td></td></tr>
</table>

Figure 4.1. Windhoek's Drought Response Plan

Wastewater reclamation and reuse began in the 1960s, with the latest plant completed in 2002. The new plant treats wastewater from the city's domestic wastewater treatment works and currently supplies about 26 per cent of the city's total water supply, as well as providing non-potable water for irrigation.

A range of other measures are also used to balance demand and supply, including public awareness campaigns, leakage reduction, rising block tariffs to discourage high water use, regulations on the use of water efficient appliances, and managed aquifer recharge to store surplus seasonal water.

The city has also developed a flexible Drought Response Plan, summarised in Figure 4.1, that triggers different actions depending on the severity of the drought. Drought severity indictors are based on water availability in the city's supply reservoirs. Corresponding actions range from public awareness-raising, including school education and a 'hot line' for reporting wasteful use, to the imposition of water scarcity tariffs, use restrictions and rationing associated with more severe drought and declaration of a water crisis.

Source: City of Windhoek Drought Response Plan (2015)

Table 4.1: Extract of climate risks and responses – water supply

Major climate-related risks	Adaptations
Physical damage to water infrastructure from increased rainfall/floods.	■ Site water points away from areas of known flood risk. ■ Build bunds/drains to divert flow away from water point; implement wider catchment management measures to reduce flood risk. ■ Adopt robust construction standards and materials for water supply-distribution infrastructure. ■ Adapt design and construction of water point to reduce vulnerability. ■ Implement climate resilient water safety planning.[14]
Threats to water quality from increased rainfall/floods.	■ Site water points away from flood-prone areas and sources of pollution risk (e.g. latrines, sewers). ■ Implement catchment management measures to reduce flood risk. ■ Raise awareness of risks from water quality deterioration during and after flooding, and need for household water treatment/use of safe alternatives. ■ Improve design and construction of water points to prevent ingress of contaminants. ■ Elevate and extend radius of sanitary apron around well head. ■ Implement climate resilient water safety planning.
Threats to water availability and supply in drying conditions/droughts.	■ Use appropriate investigation techniques to target most productive parts of aquifer (and increase drilling success rate). ■ Position and use appropriate screen to maintain yield within unconsolidated material (boreholes). ■ Dig wells in dry season to ensure adequate depth. ■ Develop supplementary/backup sources and storage. ■ Implement demand management programme to conserve water and reduce losses (urban). ■ Adapt intake structures on rivers/reservoirs to accommodate low/intermittent flows. ■ Implement climate resilient water safety planning.

[14] See https://www.unicef.org/wash/files/GWP_UNICEF_Tech_A_WEB.PDF

4.1.2. Sanitation

Adaptation responses for sanitation systems[15] depend on whether water is a direct part of the technology process (e.g. sewerage), or whether they are indirectly affected by the capacity of the environment to absorb or reduce the effect of wastes (e.g. from pit latrines).

Globally, on-site sanitation is still the dominant form of sanitation. As a group of technologies, pit latrines are generally considered resilient because designs can be adapted relatively easily and cheaply, though much depends on the quality of construction. The impacts of drying environments, in fact, may be positive if groundwater levels drop, increasing the potential for the attenuation of pathogens. Pit stability may be affected but simple adaptations exist to mitigate risks –for example, by lining pits with local materials. If water scarcity becomes a major issue, then 'dry' toilets that operate without flush water can be used.

In environments where flooding is likely to increase, however, risks to infrastructure, water quality and health will likely grow, especially where flooding results in the widespread spillage of faecal matter in the environment. Changes in pit design (e.g. vault designs), the implementation of risk-based approaches to defining separation distances to water sources (see Section 2.3), and appropriate water point construction (e.g. sealing or casing-off shallower, polluted parts of the aquifer) can all help mitigate risks. Where future levels of climate variability or the direction of climate change impacts is unclear at the local level, there may be legitimate concerns about how far to invest in more expensive adaptations – as opposed to selecting less costly designs that are safe under current climate patterns but which can be replaced once trends become clear. Decisions will also depend on local context, including risk levels, population density, the willingness and ability of households to pay for replacements/alternatives, and levels of subsidy (if any) that are available (Section 2.3).

In urban and peri-urban areas, faecal sludge management (FSM) is gaining support as the need for low-cost toilets drives demand for on-site sanitation, and as utilities struggle to serve growing urban populations with conventional sewerage. Since pits cannot be easily replaced in densely populated areas with limited space, the FSM chain relies on the collection and transport of waste in vehicles, and disposal at a treatment facility. Floods pose an obvious risk: to latrines themselves, to the shallow groundwater used for 'self-supplied' domestic purposes, to the ability of vehicles to access flooded sites, and to the wider environment where sewage and floodwater mix. In many high density informal settlements, the result is widespread contamination of the environment and water supply, and frequent outbreaks of cholera, typhoid and other diseases that can spread across a town or city (Charles et al, 2012).

Since FSM remains largely unregulated, a key priority is to introduce some degree of systematic management or oversight, focussed on improving the quality and resilience of household containment, and safe transport and disposal at dedicated treatment facilities that do not pose a threat to the environment (WSP, 2014; Hawkins et al, 2013; Howard et al, 2016). Perhaps the biggest challenge, however, is political: how to galvanise political commitment to FSM in a context where mains sewerage remains the gold standard to which governments and utilities aspire (Hawkins et al, 2013; Reymond et al, 2016; Larsen et al, 2016).

Against this political backdrop, sewage systems remain the dominant form of utility-managed sanitation globally. These are vulnerable in both wetter and drier climates. Where rainfall declines, sewerage systems may become more difficult to operate and maintain – especially conventional sewerage with its higher water requirements. Treatment may also become more difficult and costly if, for example, standards have to be raised to account for the lower absorptive and dilution capacity of receiving water bodies. Modified systems such as small-bore and condominial sewerage typically use less water and are less vulnerable to blockage if flows decrease or are unreliable, but have yet to be widely adopted beyond South America (Hawkins et al, 2013).

Where rainfall increases or the intensity of rains increases, the separation of stormwater from sewage will become increasingly important for reducing the risk of overwhelming collection and treatment systems. Increases in suspended solid loads in rivers may also mean that treatment systems require significant upgrading or redesign.

Table 4.2 summarises adaptation options that may be relevant for sanitation interventions in response to different types of climate risk. Again, Appendix A provides greater detail for different types of sanitation technology, including pit latrines/septic tanks and sewers.

[15] For a comprehensive overview of sanitation systems and technologies (in several different languages), see Tilley et al (2014) and the many other web resources available from the Swiss Federal Institute of Aquatic Science and Technology (EAWAG).

Table 4.2: Extract of climate risks and responses - sanitation

Major climate-related risks	Adaptations
Physical damage to sanitation infrastructure from increased rainfall/floods.	■ Build bunds/drains to divert flow away from latrines; implement wider catchment management measures to reduce flood risk and protect infrastructure and treatment. ■ Site latrines, storage and treatment facilities away from areas of known flood risk. ■ Adopt robust design and construction standards for sanitation infrastructure in high-risk areas. ■ Implement climate resilient water safety planning.[16]
Flooding of sanitation infrastructure and threats to public health from water and wider environmental contamination.	■ Strengthen flood defences and upstream catchment management. ■ Regular pumping or emptying of latrines to prevent overflows, and clearing of drains and sewers to prevent blockages. ■ Adapt or design new systems – e.g. elevated latrines; non-return valves on septic tanks; separate sewage and stormwater removal (urban). ■ Public awareness and education around risks to public health and protection measures. ■ Implement climate resilient water safety planning.
Less water available for flushing and cleaning of systems in drying/drought conditions.	■ Adapt or design new systems – e.g. low/zero water-use latrines; modified and/or decentralised sewerage systems; treatment processes that can function effectively with reduced dilution. ■ Step up maintenance programmes to detect and clear blockages in sewers. ■ Implement climate resilient water safety planning.

Key messages

All of the conventional technologies and management approaches for delivering safe water and sanitation can, to varying degrees, be adapted to account for climate risk. Moreover, many of the adaptations outlined are strikingly similar to known practices of good management aimed at ensuring the reliability, protection and extension of services. Hence, securing and protecting water sources, and strengthening the faecal sludge management chain, are sensible programming investments that can benefit vulnerable populations exposed to a variety of climate and non-climate risks.

[16] See https://www.unicef.org/wash/files/GWP_UNICEF_Tech_A_WEB.PDF

4.2. Diversifying and decentralising services

Diversifying sources of drinking water supply, and decentralising water supply and sanitation services in urban areas to smaller cells or mini-networks, can help reduce the risk of single source or network-critical failures. For example, developing a number of different sources of supply, each with their own risk profile and (potentially) end use, can help spread risk. Similarly, developing mini water and sanitation networks that can be added incrementally in rapidly growing towns also spreads risk, and allows for more flexible (and adaptive) design.

4.2.1. Water supply

Spreading risk between different sources and separating domestic use from other needs, has the potential to maintain water services as climate risks increase. Depending on the context, the development of multiple, independent sources of supply might involve:

- Combining spring protection with the development of dug wells or boreholes in rural areas, or combining one or both with household rainwater harvesting and storage.
- Supporting the development of individual or grouped household sources as an alternative to multi-village piped schemes that depend on one or more network-critical source.
- Developing additional water sources in an area while a drilling contractor is on-site. For example, if a single source is unlikely to meet peak dry season or drought demand because of limited yield, further sources can be developed. As noted above, this is likely to be a more cost-effective strategy than attempting to develop alternative supplies during a crisis (MacDonald et al, 2010).
- Developing backup 'relief' boreholes in the most favourable hydrogeological areas – away from settlements if necessary – that could be uncapped and used in emergency situations. Relief sources could be used by households from different villages or could provide water for tankering operations if necessary (Calow et al, 2010; Elliot et al, 2011).
- Promoting clustered service networks in urban areas that can be added in stages to meet demand. This is particularly relevant for servicing peri-urban areas where such systems can be operated to minimise infrastructure costs, energy use and water losses, since they reduce the distance between household use and water abstraction/treatment (Foster, 2016). Note that while the infrastructure

Box 9. Multiple-use water services (MUS)

Multiple-use water services can be developed by upgrading single use systems – for example, by adding cattle troughs or small irrigation systems to a domestic system ('domestic-plus'),[17] or by adding a standpipe or washing basin to an irrigation system ('irrigation-plus'). Alternatively, an 'MUS-by-design' approach begins from scratch; matching design and provision to people's needs at the planning stage (van Koppen, 2014).

An MUS approach takes the reality of multiple uses of water as a starting point for the planning and design of new infrastructure, or the rehabilitation of older systems. The aim is to provide water for a range of uses, recognising that rural people rarely want and use water for domestic needs only. Minor productive uses may include backyard gardening, micro-irrigation, livestock keeping, the processing of agricultural products, brewing and brick-making.

While 'minor' in water withdrawal terms (e.g. compared with commercial irrigation), the impacts on health, wealth and livelihood resilience can be significant. Studies have reported large increases in total household income due to productive water-using activities, with women in particular benefiting from household-scale economic activities linked to water (Srinivasan et al, 2012; van Koppen et al, 2014). Mutually reinforcing livelihood benefits may also impact positively on the resilience of the domestic water service, since systems that meet people's multiple priorities are more likely to be valued by users, and more likely to provide the cash income needed to pay for repairs. Moreover, domestic systems may also come under less demand stress if productive use has been factored into design at the outset (Adank et al, 2013; van Koppen et al, 2014). Where men control productive uses of water and prioritise these at times of scarcity, MUS may offer benefits to women in terms of more secure access to water for other purposes including domestic uses.

[17] Essentially, the promotion of higher levels of service to allow for minor productive needs – doubling or tripling supply to 50-100 lcd.

may be decentralised, and to some degree locally managed, oversight by an appropriate government agency is generally required.

Recognizing domestic and productive uses of water as distinct categories, through multiple-use water services (MUS), may also involve the development of different sources; although there are other alternatives (Box 9). In each case, however, the idea is to cater for people's domestic and productive water needs, recognising that rural and peri-urban households need and use water for a variety of purposes. Allowing for small-scale productive uses of water can boost and 'smooth-out' household income and increase livelihood resilience. Moreover, there is a specific WASH dividend if users have a stronger incentive and financial capacity to sustain and maintain the 'domestic' water service and, potentially, finance sanitation.

Nonetheless, mainstreaming MUS into conventional WASH programmes has proved challenging, largely because health sector oversight of WASH has traditionally not considered the productive use of water as important for health, nutrition and poverty reduction. In short, the aim of meeting people's multiple needs is frustrated by the single purpose mandates of line ministries.

4.2.2. Sanitation

There is a growing interest in the FSM chain, particularly in fast-growing urban areas, because most of the urban poor rely on on-site sanitation – pit latrines, septic tanks and cesspits – where domestic wastewater accumulates as 'faecal sludge' or 'septage'. Without proper management, faecal sludge accumulates in poorly designed pits, is discharged directly into storm drains or open water, or is simply dumped wherever space allows (WSP, 2014). Households living in informal settlements are at particular risk because of the density of settlement, because they are often located on marginal, low-lying land, and because they lack secure tenure.[18]

With sewer-based systems out of reach for a large and growing part of the global population, there is an urgent need to develop more cost-effective systems that can deliver the services needed for public health in the face of growing demand and climate extremes (Reymond et al, 2016). Flooding, in particular, can cause widespread contamination in informal settlements characterised by inadequate drainage and lack of space to cover and safely abandon a full pit latrine or construct a new one elsewhere. In flood-prone Dhaka, Bangladesh, for example, floods regularly inundate the on-site sanitation systems most people (especially the urban poor) depend on, causing widespread contamination and disease – yet FSM services remain minimal (Box 10).

These circumstances create a need for a sanitation service chain in urban areas to hygienically remove, transport, treat, reuse or safely dispose of faecal material. To date, experience at scale has been limited, in part because of a government preference for sewerage as the only 'proper' form of urban sanitation, and uncertainties over what kinds of organisational and regulatory models to employ (Larsen et al, 2016). However, the experience of Lusaka in Zambia (Box 10) offers some important insights for climate resilient and (potentially) commercially viable FSM approaches, including the need for political prioritisation of on-site sanitation services.

Other municipalities, including Dakar in Senegal and Ouagadougou in Burkina Faso, have also begun to adopt FSM into their urban planning and explore business models that work commercially, and provide services that remain affordable to poorer urban households.

Alongside benefits to public health, decentralised FSM services also open up the potential for on-site or more localised approaches to separating, treating and reusing excreta, wastewater and other waste streams (such as food waste). This can help spread risks in the service chain – for example, between different operational 'cells' with their own storage/treatment facilities – and help with the recovery and reuse of valuable by-products, since energy and nutrients (and greywater) are more easily recovered from separated streams. Sale of recovered resources can, in turn, provide financial support to the service chain, reducing collection fees at the household level and increasing demand for sanitation services where it is price-sensitive (Strande et al, 2014).

Energy recovery can also be significant where biogas reactors are linked to the treatment of sewage from septic systems, as they frequently are in China – with the added benefit of lower overall greenhouse gas emissions (Tilley et al, 2014; Howard et al, 2016; Larsen et al, 2016).[19]

[18] Insecurity of tenure matters because it undermines incentives for private or public investments in infrastructure and FSM.
[19] Biogas is a mix of methane, carbon dioxide and other trace gases which can be converted to heat or electricity. Digested slurry, the second by-product, can be used as a fertiliser, though further treatment may be needed to make application safe.

Box 10. Faecal sludge management and flood risk: lessons from Lusaka and Dhaka

In Lusaka, only 16 per cent of the urban population are connected to sewers. The remaining population, and particularly those living in densely populated peri-urban areas, rely on on-site sanitation, mainly pit latrines. High rates of population growth, flat topography, frequent flooding and lack of drainage lead to regular outbreaks of cholera and other sanitation-related diseases.

An initiative led by the Lusaka Water and Sewerage Company (LWSC) and supported by the NGO, Water and Sanitation for the Urban Poor (WSUP), aims to introduce a complete FSM service in two areas where service provision is delegated to community-based Water Trusts under the oversight of LWSC. Work began with a market assessment of the demand for end products and household willingness-to-pay for pit emptying and sludge transport services. Technical aspects of the FSM chain were then explored, including a pit emptying service capable of dealing with elevated latrines, transport services for hard-to-reach areas, the development of local transfer and treatment stations, and construction of a semi-centralised treatment facility for producing safe and marketable biosolids. Marketing of the service then had to be prioritised to drive up sales, together with sustained behaviour change messaging to encourage uptake.

Although the FSM service is still at a formative stage, early results have been encouraging. In the first 23 months of service, roughly 900 pits serving nearly 25,000 people were emptied, with peak demand just before the rainy season. While the service has been subsidised to date, there is an expectation that the complete FSM service can become commercially viable for much wider scale-up, reducing the public health risk associated with flood-related environmental contamination.

The experience of Dhaka, Bangladesh, illustrates the urgency of implementing FSM but the obstacles to implementation. With a population of over 15 million people and growing at over 4 per cent a year, Dhaka is one of the largest and fastest-growing cities in Asia. It is also one of the most flood-prone. Major floods are a regular occurrence and the waste disposal system is largely ineffective: floodwaters in the city's slums mix with raw sewage; water supplies become contaminated; and outbreaks of typhoid, cholera and other flood-related diseases are common. Almost all (99.7 per cent) faecal sludge ends up in drains or the wider environment, yet demand for FSM remains low, and the supply of services (emptying, transport, treatment) minimal.

Providing a fully-functioning service chain to deal with the problem requires action on several fronts, including (1) formalised and operational transport, treatment and end use of biosolids, including the development of viable business models; (2) improvements to existing containment infrastructure, and the disconnection of latrine outlets to drains as upgrading proceeds; and (3) support for a range of affordable, emptying services, especially for the urban poor

Source: WSUP Topic Brief (2015); Ross et al (2016).

Key messages

Approaches to WASH delivery that spread risk between sources and systems, and limit the exposure of populations to source/network-critical failures, will grow in importance. In rural areas, simply developing an additional source of water or catering for people's multiple needs can build resilience. In urban areas, decentralised forms of water supply and sanitation may have significant benefits and present opportunities for private sector and civil society organisation involvement along the chain; although strong government oversight will remain important. Effective FSM is a particular priority in fast-growing towns and cities in view of the risks to public health posed by floods in areas dependent on on-site sanitation.

4.3. Developing and exploiting water storage

In many areas of the world, people experience periods of acute water scarcity even when annual rainfall and runoff is plentiful. By capturing and storing water in a 'buffer' – for example, a groundwater aquifer or storage vessel – water variability can be smoothed out. Similarly, water storage can also contribute to flood control.

It follows that water storage will be particularly important in areas where the intensity and/or frequency of droughts and floods is likely to increase, and in areas that will experience long-term declines in rainfall.

Many governments have responded to the storage challenge by investing in major infrastructure projects – reservoirs and dams. For the majority of dispersed rural users, however, more decentralised household and community-based investments are more relevant, particularly those that exploit the natural storage of groundwater aquifers. The storage capacity of aquifers includes not only groundwater already stored, but the potential of their void space (and elastic storage) to receive enhanced recharge.

There are many different options depending on (a) how water is intercepted and (b) where water is conveyed. Table 4.2 provides a summary of the main techniques. Those most relevant to WASH are highlighted in grey.

Table 4.3: The range of water storage options

Groundwater storage	Closed tank storage	Open reservoir storage
Riverbed infiltration	**Rainwater harvesting**	**In-stream storage**
■ Gully plugs ■ Subsurface dams ■ Retention weirs ■ Check dams	■ Rooftop tanks ■ Small tanks ■ Underground cisterns	■ Small storage reservoirs
Land surface infiltration	**Fog harvesting**	**Off-stream storage**
■ Infiltration ponds ■ Trenches, ditches, drains ■ Floodwater spreading/spate irrigation	■ Fog shield and tank	■ Off-stream storage reservoirs ■ Road water harvesting ■ Trapezoidal bunds ■ Rock outcrops / hillside storage
■ Direct infiltration		
■ Infiltration wells/tube recharge ■ Injection wells ■ Riverbank infiltration		

Source: based on IGRAc Acacia Water (2003) and Foster et al (2009). Options most relevant to enhancing the resilience of domestic supplies are highlighted.

Aquifer recharge enhancement and the manipulation of subsurface storage can be used to increase long-term average rates of groundwater abstraction and protect individual water points. A range of structures can be used, roughly grouped into (a) riverbed interception via in-channel structures; (b) infiltration from the land surface (off-channel techniques); and (c) direct infiltration through wells. Water sources can be rainwater, river water, stormwater runoff or treated wastewater. In each case the aim is to increase the recharge of groundwater where it can be safely stored for reuse later.

Before action is taken, however, it is important that storage objectives are clear (to protect individual drinking water sources or enhance subsurface storage more widely?) and choices are informed by an understanding of hydrogeological site conditions (is the objective realistic and achievable?). In addition, the following should be considered:

- The potential 'downstream' impacts of water retention and recharge. In closed basins where water does not reach the sea, upstream recharge enhancement will reduce downstream water availability for existing users. Good water accounting, or at least a basic understanding of upstream–downstream use/users, is needed to ensure that downstream users do not lose out from upstream 'conservation'.

- The quality of water for recharge. If poor quality water is introduced directly into aquifers – for example, via wells with no prior filtration – groundwater quality may be affected. Promoting recharge enhancement in densely populated and/or polluted areas may therefore pose a serious contamination risk.
- Institutional issues in terms of raising investment (who pays?), use priorities (who benefits?) and management arrangements (who controls?).

Box 11 below summarises experience with some of the simpler approaches employed in rural areas to strengthen the drought resilience of drinking water sources, and to enhance aquifer recharge more widely.

Rainwater harvesting has been practiced in arid and semi-arid areas of the world for centuries using a variety of techniques. Storing rainwater can be a convenient and inexpensive way of supplementing domestic and non-potable supply, especially where hard roofs (metal, tile) are replacing traditional materials, and the cost of metal and plastic parts needed for conveyance and storage is decreasing. Water quality can be an issue, but can be protected with filtration/screening, chemical disinfection, or a 'first-flush' process whereby the first flush of water from a rainfall event is discarded.

As noted above, however, household-scale capture and storage rarely deliver year-round supply, and even in areas where rainfall is set to increase, limits on storage may be a limiting factor, especially where rains fall in increasingly intense events.

Options for rainwater harvesting vary widely, but in drying environments at least, should be viewed as 'backup' or supplementary sources of domestic water rather than mainstays. The most basic systems involve collection, management and use by individual households. For poorer households, storage containers may then become a major expense, especially if greater storage volumes are needed to capture more intense rainfall and bridge dry periods (Elliot et al, 2011). Groups of households can benefit by directing rainfall to one or more (larger) shared containers if supply chains exist (or can be promoted) to provide them.

Box 11. Enhancing recharge: examples from the field

Riverbed infiltration techniques are widely practiced in sub-Saharan Africa and south Asia, to capture and store runoff in the subsurface. Sand dams, for example, have been developed in the beds of seasonal rivers in Ethiopia, Burkina Faso, Kenya and India to trap sediment during the wet season and create 'artificial' sand aquifers. An important advantage of sand dams over open water dams is that the water stored is enclosed within the permeable sediment, rather than open to evaporative loses and contamination. Cost-benefit results have been largely positive, with benefits to dry season drinking water access and agricultural production.

In India, groundwater recharge enhancement from check dams and other 'in-channel' structures has long formed part of government and NGO watershed programmes. Although not aimed at protecting drinking water supplies specifically, the best programmes have succeeded in preventing land degradation, lifting the productivity of the natural resource base, and (for some) increasing local water availability for domestic and productive uses. However, supply-side measures will not solve India's growing problem of groundwater overexploitation and the threat this poses to domestic supply.

In Bangladesh, over 20 million people living in coastal areas are already affected by saline drinking water – climate change impacts such as sea level rise and storm surges are set to exacerbate the problem. UNICEF has worked with the Government of Bangladesh and the University of Bangladesh to address problems of saline intrusion, dry season drinking water shortage and damage to conventional water supplies from floods in coastal areas. Innovative 'direct injection' techniques, a form of 'managed aquifer recharge', have been used to pump freshwater from a pond or roof into saline aquifers to create a freshwater bubble within the saline water. When pond water is used, sediment is first removed using sand filters to avoid clogging. By 2017, more than 100 such systems were operational.

Sources: World Bank, 2010; Tuinof et al, 2012; Lasage et al, 2015; UNICEF, 2017.

Key messages

In areas where rainfall is set to decrease or become more unpredictable, it is vital to make the most of natural or built water storage. Exploiting the natural storage of aquifers has many advantages and is likely to be more effective where there is good understanding of hydrogeological conditions. Contamination risks can be high, however, and require careful protection and management. Household-scale capture and storage of rainwater also has potential in some areas, although usually as a backup or supplementary source of supply.

4.4. Solar powered water systems: a climate smart solution

The sections above have looked at options for adapting to the impacts of climate change. We now turn briefly to an emerging technology: solar water pumping. This can also help with climate change mitigation by reducing the emission of greenhouse gases.

Solar powered water systems are receiving growing attention as a means of scaling up affordable, sustainable and 'climate smart' services. To date, the majority of systems have been installed in rural communities, schools and health care facilities, replacing handpumps and motorised systems. Their key advantages, in addition to their zero emissions in-use, include (after Bamford and Zadi, 2016):

- Long-term durability and low day-to-day running costs (unlike motorised systems); although the design and installation of systems can be technically demanding and expensive (costs are decreasing however).
- Suitability for multi-village piped schemes. Solar powered water systems could offer dispersed rural communities the opportunity to step up the water ladder to reach higher levels of service (Figure 1.2).
- Reduced pressure on boreholes, and therefore less likelihood of failure, because solar powered systems typically pump and move water over an extended period of time. In addition, the tank storage included in system design can provide an important supply buffer. Taken together, these attributes may increase the overall resilience of the service in drying conditions or droughts.

Recent reviews of their performance have been encouraging. Globally, 35 UNICEF country programmes are now using solar powered water systems, and their experience has been largely positive (Bamford and Zadi, 2016). Remaining challenges relate mainly to weak service chains (for parts and repair) and, as for any system, the successful collection and management of user fees by WASH committees.

The World Bank is also documenting experience with solar powered systems via its Solar Water Pumping Knowledge Base, with case studies (again largely positive) drawn from all regions where the Bank operates. The portal includes a comprehensive toolkit for implementing solar projects in developing countries (World Bank, 2010).

Table 4.4: Comparison of water pumping technologies

	Handpumps	Motorised pumps*	Solar pumps
Initial cost/user	US$10-20	US$20-50 (varies by context and system type/size)	US$10-90 (varies by context and system type/size)
Pumping depth	Typically up to 80m	Typically up to 600m	Typically up to 250m
Installation	Simple	Moderately complex	Moderately complex
User experience	Cheap to maintain but breakdown common; users need to collect water	Expensive to maintain and breakdown common; users need to collect water unless serves piped scheme	Cheap to maintain and breakdown infrequent; typically serves piped network – easier access
Operating costs	Low – simple maintenance and repair	High – cost of fuel and payment to operator	Low – unless system manually operated
Durability	Often poor - frequent breakdown	Often poor – frequent breakdown and outages	High – little maintenance required

	Handpumps	Motorised pumps*	Solar pumps
Pollution	No greenhouse gas emissions in-use	Significant greenhouse gas emissions in both construction and use	No greenhouse gas emissions in-use
Other factors	Shallow aquifers only	Deeper aquifers; noisy and needs reliable fuel supply	Requires consistent sun exposure throughout year. Reduced output when cloudy

*Note: *diesel or other fuel.*
Source: based on Bamford and Zadi (2016).

Key messages
Over recent years the cost of solar pumping technology has dropped significantly, making it cost-competitive with motorised systems. Coupled with its durability, modest running costs and zero emissions, solar pumping has many advantages. In rural areas in particular, solar pumping could support the development of multi-village piped schemes, providing higher levels of uninterrupted service.

5. Conclusions

In this Technical Brief we have looked at a wide range of technical, institutional and policy responses to the risks posed to WASH by climate variability and longer-term change. A key conclusion is that adaptation should start with measures that tackle existing threats, at least for WASH investments aimed at meeting short- to medium-term needs. A key argument is that many of these measures, such as risk-based approaches to the siting of latrines and water points, or the careful design and construction of WASH infrastructure, should already be familiar. If so, the key question becomes: are best practices for addressing known risks actually being implemented on the ground and, if not, why?

Following the logic of the Results Framework, the Brief goes onto to examine national, subnational and local/project-level measures for increasing the resilience of WASH services as attention shifts to meeting SDG ambitions. Those stakeholders seeking to strengthen and adapt national programming are urged to conduct a thorough screening process in which the best available evidence on the performance of services is compiled and analysed, avoiding the temptation to use climate change as an alibi for what may be complex problems: poor system functionality, unreliable water supplies and low sanitation uptake. Nonetheless, areas of critical climate risk are highlighted, focussing on maintaining reliable water supplies in difficult environments, and ensuring sanitation planning is informed by an understanding of climate risk. The overriding concern about the vulnerability of sanitation – both rural and urban – lies in its response to rising water levels and heavy rainfall and constructing resilient latrines.

This Brief takes an integrated approach by looking at the intersection of national and subnational programming. It also integrates WASH with wider water resources, picking out two often ignored elements of good WASH planning: water resources assessment and monitoring, and water resources management. A key argument here is that universal access to safe water and higher levels of service will not be achieved with a business-as-usual approach to service delivery that assumes quantity and quality needs can be met in isolation from other demands. WASH stakeholders will need to build alliances with unfamiliar constituencies – in agriculture, energy and industry – to ensure that domestic uses are prioritised and protected.

Finally, the Brief considers a mix of best practices and innovations that can be implemented at local/project level to build resilience, covering many different aspects of rural and urban WASH. Some of the biggest challenges are undoubtedly found in rapidly growing towns and cities, ill-equipped to deal with rising demand for water, and where most people – especially the urban poor – rely on on-site sanitation discharging directly to the environment. Strengthening FSM chains is an urgent priority, though government priorities frequently lie elsewhere.

For both water supply and sanitation, decentralised systems that can be added in stages to meet demand, and allow for greater design adaptation as climate risks and understanding evolve, offer huge potential, especially if the by-products of urban sanitation can be used to finance and fuel its expansion. Government oversight of decentralised systems will remain necessary, however, to ensure compliance with standards and a pro-poor bias.

In rural areas of the developing world, it is reasonable to assume continuing reliance on community-managed water systems and on-site sanitation for large numbers of people. Technologies and approaches can both be adapted. For example, boreholes can be made more drought- and flood-resistant; sanitation design and construction can be improved; additional water sources can be developed to spread risk; and groundwater storage can be better exploited. The options considered are by no means comprehensive, but do provide an indication of the potential envelope for adaptive design and management.

The Brief ends with a short summary of solar water pumping, an innovation receiving growing attention and investment. The attraction is obvious: capitalising on the sun's free energy to pump water to storage, where it can be conveyed to standposts or individual households. UNICEF's experience has been positive, and users' experience (compared with alternatives) is reportedly good. Wider scale-up seems certain, at least in those environments where supply chains are up and running, and the sun shines throughout the year.

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Appendix

A. Adaptation options: rural and urban WASH

Seasonal or drought-related reductions in water availability; longer-term declines in surface and/or groundwater availability

Key risks – water supply:

1. threats to water supply, especially rainwater storage, ephemeral streams and shallow wells
2. reductions in water quality because of less dilution at source (in combination with higher temperatures) and pressure changes in distribution systems – and the implications for health and treatment costs
3. increased demand for surface water storage and groundwater to bridge water deficits
4. growing competition for water between domestic and other uses

Key risks – sanitation:

1. less water available for flushing and cleaning of pit latrines and septic tanks
2. soil shrinkage and potential damage to infrastructure
3. pipe blockages from low or intermittent flows
4. more concentrated sewage at treatment plants or disposed in receiving bodies
5. less dilution of wastewater in receiving bodies – higher downstream pollution loads

Community/institutional water supply – protected wells, boreholes & springs			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Develop early warning and response plan for WASH	Can help identify vulnerable areas, sources and populations, and ensure timely response to drought	Data may be lacking on the vulnerability of resources, sources and exposure of populations Agencies collecting data for early warning often different to those tasked with response	Early warning: water point inventories, if available, can provide valuable information on type, location and functionality of water points Hydrogeological maps and monitoring can provide data on likely resilience of resources Response: e.g. target and step up maintenance/rehabilitation programmes; develop supplementary sources; provide help with water storage, transport and treatment; water tankering as a last resort.

Community/institutional water supply – protected wells, boreholes & springs			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Select most reliable/higher-yielding springs for development/ protection	Higher-yielding sources less likely to dry up seasonally and during drought	Possible trade-off between optimal hydrological siting and ease of access	Information on the reliability and quality of different springs can be gleaned from local people, especially women. Supplement with reported/recorded information on well discharge and quality variation.
Site wells or boreholes in most productive parts of aquifer	As above	As above, plus trade-off between groundwater investigation cost and benefits (success rate, well yield)	Context specific: investment in resource assessment and siting beneficial in more difficult hydrogeological environments, but may be unnecessary where groundwater widely available (e.g. major alluvial aquifers)
Ensure adequate construction standards and oversight for well and borehole completion	Can have a major impact on long-term performance of the source, including resilience to climate variability/change	Oversight of drilling contractors often weak where local-regional capacity is limited	Climate-relevant standards: well diameter, target yield, depth, well spacing, screen type/length, should all be detailed in contracts and tailored to hydro-climatic context Oversight: sign-off on completed wells and checks on standards and materials; plus periodic post-construction audits comparing contracts, work completed and work invoiced
Implement catchment protection measures to enhance long-term infiltration and groundwater recharge	Can enhance water storage and mitigate risks associated with flooding (damage to infrastructure; contamination of source)	Watershed protection often falls outside remit of water agencies, implying need for cross-sector collaboration Impacts on recharge are context specific	Measures include terracing, drainage, retention basins, re-vegetation. Need to monitor and maintain protection areas and wider catchment interventions to ensure impact. Impacts (positive or negative) on infiltration and recharge will vary according to prevailing climate and agro-ecology
Consider developing supplementary sources – e.g. collection and storage of surface water runoff, rainwater collection and storage, managed aquifer recharge, additional spring/well/ boreholes, self-supply	Can enhance drinking water availability and/or relieve pressure on existing sources for enhanced year-round supply	Extra cost and institutional burden of developing additional sources and storage Concerns over water quality if recharge schemes introduce contaminated water into aquifers	Options will be context specific

Community/institutional water supply – protected wells, boreholes & springs			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Raise awareness of need to prioritise domestic water over other uses at times of scarcity	Protection of basic needs over and above productive uses	Can be challenging where men control productive use and cash income in communities Risks of inappropriate water saving in the home	Should form part of a training package for water user groups Problem may be avoided if productive uses catered for separately – e.g. via MUS
Strengthen post-construction monitoring and support	Ensures continuous functioning of water point and early detection and remedy of problems	Local institutions tasked with backstopping may lack resources and capacity	Many elements related to sustaining and extending access, including support for maintenance or markets for hardware, systems for expanding/extending services and tracking uptake, professionalising community management, early warning and response plans for addressing droughts, floods, outbreaks of disease, etc. Weaknesses context specific, but typically lack of professional backstopping (local government) for major repairs and rehabilitation

Rural village/institutional piped schemes (RPS) and urban utility-managed piped supply (UPS)			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Develop early warning and response plan for times of extreme scarcity (mainly UPS)	Can protect residential/domestic use as highest priority	Monitoring data may be absent or scare May require ability to monitor and enforce compliance with demand management measures – strong oversight	Early warning: e.g. use of seasonal forecasting and hydrological monitoring to aid early warning and ensure public are prepared and receptive via media Response: e.g. public awareness campaigns in conjunction with rationing; temporary reductions in volumetric licenses for major users; mobilisation of water tankers; distribution of water purification tablets following contamination threat

Rural village/institutional piped schemes (RPS) and urban utility-managed piped supply (UPS)			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Investigate and develop supplementary sources of fresh water supply and storage, or modify existing ones (applies to RPS as well as UPS)	Can enhance drinking water availability and/or relieve pressure on existing sources	Cost of developing and connecting new sources and storage options New sources may have a competing prior use, leading to competition and conflict	Context specific: could include the development of new surface and groundwater sources (high cost) or modification to existing ones – e.g. adaptation to intake structures to accommodate low/ intermittent flows Urban growth will increasingly require development of new sources in urban hinterland at increasing distance and cost If supply becomes unreliable, households and businesses may develop their own (self-supply) sources, posing health risks
Investigate technical changes to design and layout to facilitate cross-supply (RPS and UPS)	If one water source develops problems, others can substitute	Cost and technical feasibility – may require re-engineering existing networks to allow cross-supply.	Experience in growing number of countries points to benefits of decentralised infrastructure (water supply and sewage) to prevent network-wide impacts – from floods and droughts.
Investigate potential for water reclamation and re-usereuse (mainly UPS)	Can reduce demand on freshwater sources for drinking water as part of wider efficiency plan	Recycling and reuse can pose health risks High cost – not widely practiced even in water-scarce, higher income countries	Likely to grow in importance as urbanisation accelerates but ‘formal’ engineered schemes remain a rarity – most widely cited (urban) examples are Singapore and Windhoek (Namibia) Likely to require long-term public education and outreach – from initial conception and planning, then throughout implementation
Raise awareness of need to conserve water to protect basic needs (mainly UPS).	Protection of basic needs over and above productive and/or discretionary uses.	May be little scope for reducing demand in circumstances where households already use very little.	Public awareness campaigns often work best in conjunction with regulatory and/or economic incentives to manage water demand (including Water Safety Planning) Efficiency/conservation measures could be extended to ‘upstream’ catchments – e.g. incentives for irrigators to conserve water in urban source catchments

Rural village/institutional piped schemes (RPS) and urban utility-managed piped supply (UPS)			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Implement pipe maintenance programme to reduce unaccounted for losses (RPS and UPS)	Can reduce demand on freshwater sources as part of wider efficiency plan	Can be expensive – e.g. where e.g. leaking pipes underlie densely populated areas.	For subsurface pipes, typically involves the monitoring of water pressure to aid leak detection Programmes can be targeted to increase water flows to poorer areas
Introduce regulatory controls to conserve water (mainly UPS)	Regulatory controls likely to be more effective and politically feasible than pricing for demand management.	Requires ability to monitor and enforce compliance – regulatory oversight.	Responsibility may fall with regulator or national authority rather than utility Options include building regulations (e.g. specifying use of water efficient appliances), stricter licensing (e.g. lower caps for water intensive industries) and rationing (between areas, users) at time of water stress
Address contamination threat from deterioration in raw water quality and/or ingress of contaminants into water distribution network (RPS and UPS).	Protects public health from problems associated with low flows (less dilution) and pressure changes in network.	Cost/feasibility: – e.g. with potential re-designredesign of treatment plants/ processes to cope with deteriorating raw water quality.	Measures should be included in WSP In poorly maintained networks, ingress of contaminants poses serious health risk – need to maintain pressure and control leaks Need to raise public awareness of possible contamination threat and need to treat/boil drinking water at times of system stress.
Implement catchment protection measures (RPS and UPS).	Can enhance water availability and quality, and also mitigate risks associated with flooding.	Upstream watershed protection falls outside remit of water agencies, implying need for cross-sector and upstream-—downstream collaboration.	Measures include terracing, drainage, retention basins, re-vegetation, plus (potentially) controls on upstream water use (e.g. irrigation) Need to monitor and maintain protection areas and wider catchment interventions to ensure impact Impacts on infiltration and recharge will vary according to prevailing climate and agro-ecology.

Sanitation – improved pit latrines and septic tanks			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Investigate lower water -use approaches for flushing &and cleaning.	Less water needed for flushing and cleaning; hygienic conditions maintained.	Availability and cost of appropriate materials.	May require changes in construction standards – e.g. slab type/construction, use of plastic rather than water seals in pour-flush latrines; use of low-flush toilets; more rodding eyes, plus awareness-raising of lower water-use latrine options If no water available, septic tanks not a viable option
Adapt construction standards to account for changes in soil moisture conditions.	Materials less likely to fracture, reducing risk of contamination to surrounding area/ groundwater.	Availability and cost of appropriate materials.	Ideally, monitor performance for blockages and breaks – e.g. regular septic tank inspection

Sanitation – sewers			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Develop early warning and response plan for times of extreme scarcity (mainly UPS) – part of overall water &and wastewater plan.	Can protect infrastructure and processes needed to maintain system performance.	Monitoring data on changes in wastewater quality and performance of systems may be lacking.	Early warning: e.g. use of seasonal forecasting and hydrological monitoring to aid early warning; monitoring of system performance – pressure, blockages, quality of receiving waters, etc. Response: e.g. public education on what should not be flushed down toilets and sinks.
Adapt inspection and maintenance programme to detect blockages and increase flushing.	Prevents pipe damage and potential spills of untreated sewage.	Need to plan for more operational expenditure.	Need to monitor sewer performance for blockages and link to priority repair/rehabilitation Raise public awareness around what is appropriate to flush down toilet in low flow periods to prevent blockages

Sanitation – sewers			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Investigate technical changes to sewer design, layout and construction to cope with low/intermittent flows.	Prevents blockages, damages and spills with less water	Cost and technical feasibility – especially in densely populated settlements.	May include: more inspection chambers and rodding eyes; steeper falls and increased pumping; development of decentralised systems that can be managed independently; installation of modified systems (simplified or small -bore) that require less water and/ or use interceptor chambers to remove solids at household or neighbourhood level.
Adapt treatment processes to cope with low/intermittent flows.	Improved treatment of sewage can safeguard quality of receiving waters.	Cost – especially if quality thresholds for conventional treatment breached.	Appropriate treatment processes may change – e.g. ponds or reed beds become viable in drying environments. Consider diluting flows before treatment. May need to adapt downstream water systems (supply and treatment) to cope with higher pollution loads from upstream urban areas.

Seasonal or flood-related increases in water levels/flows; longer-term increases in surface and/or groundwater levels/flows

Key risks – water supply:

1. physical damage to water supply infrastructure, including sources/storage, treatment and distribution systems
2. contamination of water sources and/or distribution systems from flood water and/or rising groundwater levels
3. inaccessibility of water sources due to flooding
4. power outages affect pumping and treatment processes

Key risks – sanitation:

1. physical damage to sanitation infrastructure, including sewerage and treatment systems
2. inundation and/or overloading of systems (including treatment) leading to widespread contamination of environment and water supply
3. inaccessibility of latrines due to flooding
4. power outages affect pumping and treatment processes
5. reverting back to bad sanitation and hygiene practices (e.g. open defecation)

Community/institutional water supply – protected wells, boreholes & springs			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Develop early warning and response plan.	Can identify vulnerable areas and populations and ensure timely response to floods.	Data may be lacking on flood risk. Agencies collecting data for early warning often different to those tasked with response.	Early warning: e.g. identify areas and populations at risk using local knowledge and remote sensing data; use forecasts, meteorological and hydrological data to predict problems; conduct regular sanitary inspections and water point mapping/audits to target maintenance and infrastructure upgrades. Response: e.g. target WASH rehabilitation efforts to affected areas; provide water supply alternatives if possible; provide support for water storage and transport; raise awareness of risks to water quality during and after flooding and need for water treatment; distribute water treatment kits; develop communication procedures to advise on when water is safe and carry out Water Safety Planning.
Site wells and boreholes away from flood-prone areas if possible.	Can reduce the risk of flood damage and the contamination of sources.	Siting options more restricted in densely populated areas; potential trade-off between ease of access and resilient siting.	Siting should be informed by local knowledge of flood risk and previous experience of flood-related problems. Ensure risk-based approaches to siting of both water sources and latrines are followed.
Implement catchment protection measures to reduce flood risk.	Can reduce the risk of flood damage and contamination of sources.	Watershed protection often falls outside remit of water agencies, implying need for cross-sector collaboration.	Includes use of terraces, bunds, drainage channels, etc. Wider benefits to dry season/ drought water availability through enhanced groundwater recharge. Can be labour-intensive and may involve area closures and negotiation with private land owners in source catchment.

Community/institutional water supply – protected wells, boreholes & springs			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Adapt design and construction of water point to reduce vulnerability.	Minimises the risk of flood damage and contamination of sources.	Ability of programmes to tailor designs to local environments may be weak. Cost – e.g. shallow wells replaced with deeper boreholes.	Springs: e.g. enclose both spring box and spring eye. Wells: e.g. improve well lining to prevent ingress of polluted water; extend lining above ground; extend radius of sanitary apron; upgrade unprotected wells to protected ones; consider replacing wells with deeper boreholes. Boreholes: e.g. ensure casing extends below shallower, more polluted aquifers and upper layers effectively sealed.

Rural village/institutional piped schemes (RPS) and urban utility-managed piped supply (UPS)			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Develop early warning and response plan (mainly UPS) – part of overall water and wastewater plan linked to WSP.	Can identify vulnerable areas and exposed populations. Protects infrastructure and processes needed to maintain system performance and mitigate health risk.	Monitoring data on flood risk and impact may be lacking.	Early warning: e.g. identify areas and populations at risk using local knowledge and remote sensing data; flood forecasting to predict problems; conduct regular inspections of infrastructure to target maintenance and infrastructure upgrades. Response: e.g. target infrastructure rehabilitation efforts to affected areas; provide water supply alternatives if possible; raise awareness of risks to water quality during and after flooding and need for water treatment; distribute water treatment kits if necessary; develop communication procedures to advise on when water is safe.

Rural village/institutional piped schemes (RPS) and urban utility-managed piped supply (UPS)			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Strengthen flood defences, upstream catchment management and drainage, land use planning.	Prevents damage to and inundation of water and sewerage system, including treatment works.	May not be sufficient to address risks associated with major floods, especially in low-lying, densely populated areas.	Surface water sources: e.g. design overflows for source reservoirs to prevent failure; strengthen/adapt river intakes to cope with fluctuating and more turbulent flows (e.g. floating booms; maintain spillways and channels). Groundwater sources: e.g. improve source protection zoning and inspection; ensure contaminated aquifer layers cased out; inspection/regulation of non-network sources (e.g. self-supply). All sources: step up water quality monitoring during and after flood; introduce/increase chlorination and filtration.
Step-up pipe inspection and maintenance programme to reduce leaks from sewers.	Can prevent pipe damage and potential for contamination of water supply.	Need to plan for more operational expenditure.	Need to monitor sewer performance and water quality in network. Major risks to water quality where self-supply from shallow (contaminated) groundwater and water-sewer pipes overlap/in close proximity.
Investigate technical changes to network design, layout and construction to cope with floods/rising water tables.	Can prevent pipe damage and potential for contamination of water supply across wide areas.	Cost and technical feasibility – especially in densely populated settlements.	Options include: adopt higher design standards for infrastructure to accommodate more frequent and severe floods (including stormwater drainage); separation of water and sewage pipes and relocation to less flood-prone areas; development of decentralised systems that can be managed independently to avoid cross-network impacts.

Rural village/institutional piped schemes (RPS) and urban utility-managed piped supply (UPS)			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Adapt treatment system to cope with flood events.	Protects from flood damage and can cope with higher suspended sediment loads.	Cost and technical feasibility.	Increased turbidity can increase coagulant demand, reduce the working period of multi-stage filters and increase chlorine demand. Responses: e.g. upstream catchment management to help capture and filter water; site treatment infrastructure away from flood-prone areas or build defences; consider smaller, more localised treatment options to spread risk.
Protect public standpipes from flood damage and contamination.	Maintains water quality and accessibility.	Need for regular sanitary inspection and water quality monitoring – especially after floods have receded.	Options: e.g. use of elevated platforms; robust construction; seal chambers; regular sanitary inspections; flushing/cleaning after flood events; raise awareness of risks and treatment needs. Standpipes may be concentrated in lower income, more flood-prone areas where water quality monitoring and sanitary inspection is weakest.

Sanitation – improved pit latrines and septic tanks			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Risk-informed siting of latrines in relation to flood hazards and water sources.	Minimises the risk of flooding, the spread of faecal matter and groundwater contamination.	Siting options more restricted in densely populated areas – e.g. peri-urban.	As discussed in Section 2 of this Brief: adopt risk-based approach to the siting of drinking water sources and latrines based on vertical and horizontal separation together with awareness-raising around contamination risks and the need for regular emptying.
Adaptations to design and construction in riskier areas – to prevent direct flood damage, inundation &and erosion.	Minimises the risk of flooding, the spread of faecal matter and groundwater contamination – maintaining open defecation free status.	Availability of materials in local markets, local construction skills and (potentially) cost.	Options include: design to allow regular emptying and post-flood rehabilitation to remove silt; installation of proper pit covers to prevent material flowing out; installing robust upper foundations, collar and footing to protect against erosion and flooding; building of bunds to divert water flow away from latrine; planting of shrubs around pit to reduce erosion; switch to composting or dry latrines; non-return valves on septic tanks.
Regular pumping or emptying of latrines to minimise sludge build-up.	Prevents systems over-flowing – as above.	Also need safe systems of transport, treatment and reuse/disposal – difficult in densely populated and/or inaccessible areas.	In urban areas, implies a focus on the complete FSM chain with strong regulatory oversight, looking firstly at the market for and/or safe disposal of end products. Consider smaller pits in urban areas to minimise quantity of faecal matter exposed to flooding. In rural areas, requires awareness-raising around need for regular maintenance as part of hygiene promotion/behaviour change campaign.
Monitoring and enforcement –– emptying and disposal.	Reduces intentional emptying of latrines during floods.	Absence of laws/ regulations to actually enforce; institutional capacity for monitoring and enforcement.	Assumes laws/regulations in place in the first place. Combine with public awareness-raising on risks to public health from unsafe disposal.

Sanitation - sewers			
Adaptation option	**Benefits**	**Constraints**	**Additional comments**
Develop early warning and response plan -— part of overall water &and wastewater plan linked to WSP.	See water supply above – a coordinated response can minimise immediate risks to health and address rehabilitation needs.	Monitoring data for flood forecasting and risk assessment may be lacking.	Early warning: e.g. identify areas and populations at risk using local knowledge and remote sensing data; flood forecasting to predict problems; conduct regular inspections of infrastructure to target maintenance and infrastructure upgrades. Response: e.g. target infrastructure rehabilitation efforts to affected areas; raise awareness of public health risks during and after flooding; invest in emergency response equipment (e.g. mobile pumps).
Strengthen flood defences and upstream catchment management.	Prevents inundation of sewerage system and treatment works.	May not be sufficient to address risks associated with major floods, especially in low-lying, densely populated areas.	Ideally as part of integrated flood defence and response strategy that extends beyond the urban area/jurisdiction of the utility and involves different sector stakeholders.
Step- up preventative maintenance to clear drains and sewers regularly.	Prevents overloading of infrastructure, including treatment works, and minimises downstream pollution.	May not be sufficient to address risks associated with major flood events.	Prioritise before the wet season. Based on ongoing monitoring of silt levels and flows/blockages. May need to prevent illegal connections to foul sewers to reduce risk of system damage.
Adapt or design new systems – e.g. decentralised systems to minimise impact of local flooding; sewage overflow routing or storage; separate sewage and stormwater systems.	Protects infrastructure and treatment processes, and to minimises cross-network risks.	Mitigates risks from localised flooding only.	Decentralised systems can 'diffuse' the risk of network-critical failures and enable more responsive local management. Cost can be reduced by using small-bore (simplified) designs located at shallower depths. Ideally, plan for separate sewage and stormwater removal, and gravity flow for sewers to reduce pumping costs and risk of failure. Sewage overflow routing or storage to protect treatment processes and equipment.

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