SECTOR ENVIRONMENTAL GUIDELINES

WATER SUPPLY AND SANITATION

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FRONT COVER: USAID is helping Tajikistan expand access to safe, potable water, now available to only about 40 percent of the population. Photo credit: USAID.

ABOUT THIS DOCUMENT AND THE *SECTOR ENVIRONMENTAL GUIDELINES*

This document presents guidelines for the water supply and sanitation sector, one of the sectors addressed in the *Sector Environmental Guidelines* prepared for USAID under the Agency's Global Environmental Management Support Project (GEMS). All sectors are accessible at www.usaidgems.org/bestPractice.htm.

Purpose. The purpose of this document and the *Sector Environmental Guidelines* overall is to support environmentally sound design and management (ESDM) of common USAID sectoral development activities by providing concise, plain-language information regarding:

- the typical, potential adverse impacts of activities in these sectors;
- how to prevent or otherwise mitigate these impacts, both in the form of general activity design guidance and specific design, construction, and operating measures;
- how to minimize vulnerability of activities to climate variability and change; and
- more detailed resources for further exploration of these issues.

Environmental Compliance Applications. USAID's mandatory life-of-project environmental procedures require that the potential adverse impacts of USAID-funded and managed activities be assessed prior to implementation, via the environmental impact assessment (EIA) process defined by 22 CFR 216 (Reg. 216). They also require that the environmental management/mitigation measures ("conditions") identified by this process be written into award documents, implemented over the life of a project, and monitored for compliance and sufficiency.

The procedures are USAID's principal mechanism to assure ESDM of USAID-funded activities – and thus to protect environmental resources, ecosystems, and the health and livelihoods of beneficiaries and other groups. They strengthen development outcomes and help safeguard the good name and reputation of USAID.

Climate risk management is required per USAID's Automated Directory Service (ADS) 201, Program Cycle Operational Policy. Climate risk management (CRM) is the process of assessing, addressing, and adaptively managing climate risks that may impact the ability of USAID programs to achieve objectives. For USAID's purposes, climate risks are potential negative consequences due to changing climatic conditions.

The *Sector Environmental Guidelines* directly support environmental compliance by providing information essential to the assessment of potential impacts of activities and to the identification and detailed design of appropriate mitigation and monitoring measures.

However, the Sector Environmental Guidelines *are **not** specific to USAID's environmental procedures. They are generally written and are intended to support ESDM of these activities by all actors, regardless of the specific environmental requirements, regulations, or processes that apply, if any.*

Region-Specific Guidelines Superseded. The *Sector Environmental Guidelines* replace the following region-specific guidance: (1) *Environmental Guidelines for Small-Scale Activities in Africa*; (2) *Environmental Guidelines for Development Activities in Latin America and the Caribbean*; and (3) Asia/Middle East: *Sectoral Environmental Guidelines.* With the exception of some more recent Africa sectors, all were developed over 1999–2004.

Development Process and Limitations. This document is the result of a technical update that retained limited content from predecessor guidelines, as appropriate.

The Guidelines are not a substitute for detailed sources of technical information or design manuals. Users are expected to refer to the accompanying list of references for additional information.

Comments and corrections. Each sector of these guidelines is a work in progress. Comments, corrections, and suggested additions are welcome. Email: gemscoreteam@cadmusgroup.com.

Advisory. *The Guidelines are advisory only. They are not official USAID regulatory guidance or policy. Following the practices and approaches outlined in the Guidelines does not necessarily assure compliance with USAID environmental procedures or host country environmental requirements.*

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ACRONYMS

AOR	Agreement Officer's Representative
COR	Contracting Officer's Representative
DEWATS	Decentralized Wastewater Treatment System
EIA	Environmental Impact Assessment
EMMP	Environmental Mitigation and Monitoring Plan
FSM	Fecal Sludge Management
IEE	Initial Environmental Examination
IP	Implementing Partner
IPCC	Intergovernmental Panel on Climate Change
IR	Intermediate Result
IWRM	Integrated Water Resources Management
MEO	Mission Environmental Officer
SDG	Sustainable Development Goal
SO	Strategic Objective
UN	United Nations
USAID	United States Agency for International Development
WSS	Water Supply and Sanitation
WQAP	Water Quality Assurance Plan

WATER SUPPLY AND SANITATION

1. PURPOSE AND BACKGROUND

According to WHO and UNICEF, 30 percent of the world's population (or 2.1 billion people) do not have access to safe drinking water; 60 sixty percent (4.5 billion people) lack safe sanitation (WHO/UNICEF, 2017). Of the 2.1 billion people without access to safe drinking water, 844 million do not have access to basic drinking water services. Conventional sanitation systems, whereby a flush toilet is connected to a centralized sewer collection system, are only available to a small percentage of the population in the developing world. Of the 4.5 billion people without access to safe sanitation, 2.3 billion use unsafe toilets or practice open defecation (WHO/UNICEF, 2017).

To address these critical issues, USAID implements activities to provide sustainable access to improved water supply and improved sanitation, in support of UN Sustainable Development Goal 6 to ensure availability and sustainable management of water and sanitation for all by 2030.

Water supply and sanitation (WSS) activities encompass two interrelated fields: (1) the provision of improved drinking water sources; and (2) the provision of improved sanitation facilities. This WSS Sector Environmental Guideline (SEG) provides a broad overview of the types of WSS activities typically funded by USAID, with a particular focus on potential environmental and social impacts, mitigation measures, and environmentally sound design and management (ESDM) for those activities.[1] This document is intended

[1] These projects typically involve small-scale, low-impact, or community-based water and sanitation projects. However, USAID works both directly with communities and with policymakers to address issues that affect broader geographic areas. As such, defining "small-scale" for USAID projects is challenging to do in any comprehensive and practical manner.

to help USAID Missions comply with Section 117 of the Foreign Assistance Act (FAA) and 22 CFR 216 (Regulation 216), which require that environmental impact assessments be conducted and appropriate mitigation measures implemented for all USAID projects. It will also help USAID staff and implementing partners (IPs) design WSS activities that are resilient to climate variability and change. USAID WSS activities are subject to specific legislation, regulation, and policies that provide a framework for project implementation. (See also Annex I: Governing Policy).

This document is organized in the following sections:

1. Overview of the WSS sector and its challenges;
2. Summary of potential adverse impacts from WSS activities;
3. Best management practices and mitigation measures for WSS activities;
4. Summary of climate risks associated with WSS activities; and,
5. Practical tools in support of WSS design, implementation, mitigation, and monitoring.

1.1 USAID WATER AND DEVELOPMENT STRATEGY

USAID interventions in the WSS sector are guided by USAID's Water and Development Strategy 2013-2018 within the broader framework of the United Nations (UN) Sustainable Development Goals (SDGs).

Issues surrounding WSS are relevant to nearly every aspect of USAID development programming. For that reason, USAID launched its Water and Development Strategy to "save lives and advance development through improvements in water supply, sanitation and hygiene programs, and through the sound management and use of water for food security" (USAID, 2013).

The Water for Health strategic objective (SO) of the Water and Development Strategy addresses key development challenges within the WSS sector, including ensuring sustainable access to safe drinking water and sanitation, alleviating poor health conditions associated with inadequate and unsafe drinking water and sanitation, and improving hygiene (see Annex I).

The Water and Development Strategy highlights the importance of using coordinated approaches for watershed and water resource management, such as integrated water resource management (IWRM), to ensure the sustainable and equitable provision of water and sanitation services. These approaches include considering and addressing issues related to gender inequality, water pollution, the impact of climate change on water resources, the significant energy requirements for treatment and distribution of water, and water as a potential source of conflict. The Water and Development Strategy also discusses how to ensure that WSS activities do not result in ecosystem degradation (USAID, 2013).

The definitions used by USAID for key terminology are summarized in Figure 1. Understanding USAID's use of these terms is critical to understanding the WSS activities conducted by USAID and the guidance provided in this SEG.

FIGURE 1: COMMON WATER SUPPLY AND SANITATION TERMINOLOGY

Environmental flows. The seasonally variable flows of water that sustain healthy river ecosystems and the goods and services that people derive from them. (USACE/TNC/ICPRB, 2013)

Effluent. General term for a liquid that leaves a technology. (Tilley, Ulrich, Luthi, Reymond, & Zurbrug, 2014)

Excreta. Urine and feces. (WHO, 2016)

Fecal sludge. Sludges of variable consistency collected from on-site sanitation systems, such as latrines, non-sewered public toilets, septic tanks, and aqua privies. Septage, the fecal sludge collected from septic tanks, is included in this term. (WHO, 2016)

Greywater. Water from the kitchen, bath, and/or laundry which, generally, does not contain significant concentrations of excreta. (WHO, 2016). Also known as sullage, grey wastewater, or light wastewater. Greywater accounts for approximately 65% of the wastewater produced in households with flush toilets. (Tilley, Ulrich, Luthi, Reymond, & Zurbrug, 2014)

Groundwater. Water located underground that is stored in and moves through aquifers (geologic formations of soil, sand, and rocks). Groundwater is "recharged" by rain and melted snow that seeps into the cracks beneath the earth's surface. (The Groundwater Foundation, 2017)

Hygiene. The ability to maintain hygienic conditions, through behaviors that lead to cleanliness and good health (i.e., handwashing and bathing). (Centers for Disease Control and Prevention, 2015)

Integrated water resource management (IWRM). Process that emphasizes a coordinated approach to water resource management to maximize socio-economic welfare without compromising key ecosystems. (Global Water Partnership, 2017)

River basin. Land that water moves across or under as it flows towards a river. A river basin drains the land surrounding a major river and can contain multiple watersheds. (NCDEQ, 2017)

Sanitation. The provision of improved sanitation facilities, i.e., facilities that hygienically separate human excreta from human contact with safe disposal of human waste. (Jones, 2011)

Stormwater. Rainfall runoff collected from roofs, roads, and other impervious surfaces. It is the portion of rainfall that does not infiltrate into the soil. (Tilley, Ulrich, Luthi, Reymond, & Zurbrug, 2014)

Surface water. Water on the earth's surface, such as a stream, river, lake, or reservoir. (USGS, 2016a)

Water security. A population's capacity to access sufficient quantities of water qualified to sustain livelihoods, protect human health, promote socio-economic development, ensure protection against water-borne diseases and disasters, and preserve ecosystems. There are many contributing factors to water security including infrastructural, biophysical, institutional, political, social, and financial. (UN Water, 2014)

Water supply. The provision of improved drinking water sources, i.e., adequately protected from outside contamination.

Watershed. An area of land where all surface water and precipitation drain to a common outlet (e.g., outflow of a reservoir, mouth of a bay, or point along a stream channel). Watersheds include both surface and ground water. Also referred to as a drainage basin or catchment. (USGS, 2016d)

Wastewater. Liquid waste from household uses (domestic) and industrial processes (industrial) and collected in piped systems and sewers. Domestic wastewater includes grey water and water flushed from toilets. Industrial wastewater is all water discharged from industrial facilities. Stormwater is sometimes combined with wastewater.

Water quality. The condition of the water including chemical, biological, and physical characteristics, usually with respect to its suitability for a particular purpose (i.e., drinking, swimming, or fishing) (NOAA, 2017). Water quality standards and criteria are established to protect human health and aquatic life (USEPA, 2016).

1.2 APPROACHES FOR MANAGING USAID WATER AND SANITATION PROJECTS

Planning and implementing effective and sustainable WSS programs in the developing world is complex. To help address these complexities and to minimize and prevent potential adverse impacts from WSS interventions, USAID should use approaches that have been developed and tested by regulatory agencies, research institutions, and non-governmental organizations (NGOs). Two potential approaches, integrated water resource management (IWRM) and the development of a water safety plan (WSP) or sanitation safety plan (SSP), are presented here.

The IWRM approach, key principles of which are listed in Figure 2, is most useful when planning a WSS activity at the national or regional level, or at the local level when the activity crosses political, governmental, and cultural boundaries. IWRM ensures that the competing demands for water across political and technical subdivisions are considered during planning and design of WSS activities, in order to provide sustainable and equitable allocation of these limited resources (USAID, 2014c).

FIGURE 2: IWRM – THE DUBLIN PRINCIPLES (ICWE, 1992)

1. Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.
2. Water development and management should be based on a participatory approach involving users, planners, and policy makers at all levels.
3. Women play a central part in the provision, management, and safeguarding of water.
4. Water has an economic value in all its competing uses and should be recognized as an economic good.

The International Conference on Water and Environment, January 1992, Dublin

The IWRM process includes three steps: initial assessment, implementation, and monitoring and evaluation. Water managers establish performance indicators to monitor project development and implementation. Major findings or changes to water resources in a specific area are reported to stakeholders such as local government, private sector, and NGOs. Additional information on the IWRM approach is presented in a series of case studies developed by the Global Water Partnership (Global Water Partnership, 2016a) (Global Water Partnership, 2016b).

While IWRM provides a comprehensive framework for sustainable management of water resources, other approaches focus more narrowly on the provision of drinking water or sanitation services. The WSP or SSP framework can be used to design and manage USAID projects with drinking water or sanitation components at a local level. WSP is a comprehensive risk assessment and risk management approach to ensure the safety of drinking water systems (WHO, 2005). WHO has developed WSPs that integrate climate risk considerations and supported implementation of resulting "climate-resilient WSPs", for example in Ethiopia (Ethiopia Ministry of Water, 2015). Like the WSP, the SSP framework can be used for the design and management of USAID wastewater disposal projects at the local level (WHO, 2016). Key similarities and differences between the WSP and SSP approaches are shown below in Table 1.

TABLE 1. COMPARISON OF WSP AND SSP FRAMEWORK (WHO, 2016)		
	SANITATION SAFETY PLANNING	WATER SAFETY PLANNING
SIMILARITIES	Derived from WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater	Derived from the WHO Guidelines for Drinking-Water Quality
	Uses risk management, HACCP, Stockholm Framework (see Note)	Uses risk management, HACCP, Stockholm Framework
	Core components: (1) system assessment; (2) monitoring; (3) management	Core components: (1) system assessment; (2) monitoring; (3) management
	Follows the sanitation chain	Follows the drinking water supply chain
DIFFERENCES	Considers multiple exposure groups for microbiological, physical and chemical hazards	Considers single exposure group (drinking water consumer) for microbiological, physical, chemical and radiation hazards
	Expands from waste generation to its uses and discharges into the environment	Contracts from catchments and converges to the drinking water delivery point
	Usually no clear regulatory framework – roles and responsibilities are shared over different sectors and levels	Usually operates in a clear regulatory framework
	Objectives – reduce negative health impacts of use of wastewater, excreta or greywater while maximizing the benefits of their use	Objectives – to consistently ensure the safety and acceptability of a drinking water supply and to reduce the risk of drinking water contamination
	Implementing agency – varies depending on objectives, skills and resources	Implementing agency – water utility or a community association for small supplies

The development and implementation of a WSP or SSP includes the following steps:

1. Assemble a team;
2. Document and describe the water or sanitation system;
3. Undertake a hazard assessment and risk characterization;
4. Assess the existing system with flow diagram;
5. Identify control measures;
6. Define operational limits and monitoring procedures;
7. Establish procedures to verify the WSP or SSP is working;
8. Develop supporting programs;
9. Prepare management procedures including corrective actions for normal and incident conditions; and,
10. Establish documentation and communication procedures.

This description of relevant approaches for WSS activity planning and implementation is not exhaustive, but rather illustrative of the variety of approaches that can be applied in developing and implementing effective, sustainable USAID WSS activities.

Each approach includes three core elements: data collection, analysis, and design; implementation; and monitoring. Additional approaches for planning and implementing water supply activities are described in Annex II. Similarly, approaches for planning and implementing sanitation interventions, including those for fecal sludge management and decentralized wastewater treatment systems (DEWATS), are included in Annex III.

1.3 ENVIRONMENTALLY SOUND DESIGN AND MANAGEMENT AND ENVIRONMENTAL IMPACT ASSESSMENT

ESDM is focused on impact avoidance and is characterized by the following three principles: (1) be prevention-oriented; (2) apply best management practice; and (3) be systematic. It is essential that the design/planning team considers prevention early in the process, when alternatives in technology, approach, or methodology can be considered based on identified impacts, and changes to initial project design made more quickly and at less expense. Best management practices relevant to the project context and goals should be employed to identify potential adverse impacts early, and to develop and prioritize more effective mitigation measures. Lastly, designers and implementers should systematically assess impacts and mitigation measures to ensure that significant concerns are addressed and solutions are found early.

The systematic approach of the environmental impact assessment (EIA) process is an important tool in achieving safe water supply and sanitation activities. The design/planning team should begin the EIA process as early in the project lifecycle as is practicable so it can integrate initial findings or outputs of the EIA process (such as a preliminary assessment) into project design and positively influence project or activity planning. Attempting to integrate the results of the EIA process after design and planning, during construction, or during implementation often costs significantly more and undermines project performance. It may also create tension between and among donors, government entities, and beneficiaries, as changes in WSS design or implementation can lead to unmet expectations or significantly increased costs.

2. OVERVIEW OF THE WATER SUPPLY AND SANITATION SECTOR

This section summarizes the challenges developing countries face in the provision of water and sanitation systems, the interventions that USAID funds to address these challenges, and ecosystem services that are preserved during implementation of these WSS interventions. The reader can use this section to better understand the extent of the challenges and the context of WSS interventions, as a starting point to identifying potential adverse impacts of the proposed activities.

2.1 CHALLENGES OF WATER SUPPLY AND SANITATION

Increased urbanization, rising population, watershed and environmental degradation, natural disasters, energy demands, climate change, conflict, and weak water management and governance are putting significant pressure on the world's water-related ecosystem services. This pressure has potential negative impacts on communities and water related ecosystems across the globe, especially in the developing world. Critical challenges facing practitioners in the water supply and sanitation sector include the following:

- Securing water for food production;
- Reducing health risks from inadequate and unsafe drinking water and sanitation;
- Ensuring equitable access to a clean and sustainable water supply;
- Sustaining healthy aquatic ecosystems and habitats;
- Balancing multiple uses of a water source (e.g., minimum stream flow, water supply, recreation); and,
- Adapting to climate change.

SECURING FOOD PRODUCTION

Water is crucial to food security. Crops and livestock need water to grow, and agriculture requires large amounts of water for irrigation and post-harvest production processes. Population growth and income growth result in greater demand for higher quantity and quality of food. To meet these needs, farmers will need to expand the use of irrigation. However, water availability will also be impacted by other stressors including climate change (see below) and competition for water from non-agriculture sectors. Currently, 70 percent of global water withdrawals are for agriculture. By 2050, 9 billion people will need food; meeting that need will likely require a 60 percent increase in agricultural production. See the USAID Sector Environmental Guideline on Agriculture for additional information on water for food security.

A USAID-funded irrigation program in Dowa District in central Malawi helps a farmer divert water from a main irrigation channel to a row of crops. Photo credit: USAID.

REDUCING HEALTH RISKS FROM INADEQUATE AND UNSAFE DRINKING WATER AND SANITATION

Approximately one half of the developing world's population is suffering from one or more of six major diseases caused by lack of access to water, contaminated water, or poor sanitation: diarrhea, ascaris, dracunculiasis, hookworm, schistosomiasis, and trachoma (USEPA, 2008). Water-related diseases can result from exposure to microorganisms and chemicals in drinking water. For example, part of the lifecycle of *Schistosoma* (the parasite that causes schistosomiasis) is in water, and malaria can be contracted through vectors that live in or near water (USEPA, 2008). Diarrhea, caused by unsafe water and hygiene conditions, is responsible for 1.4 million deaths annually worldwide (WHO, 2017). Infectious diarrhea can be caused by ingestion of bacteria such as *Campylobacter*, *Salmonella*, *Shigella*, *Giardia*, or *E. coli* which can be transmitted via water or food (Guerrant, et al., 2001). In addition, without sufficient quantities of water for hygiene, skin and eye infections (including trachoma) are easily transmitted through the fecal-oral route (WHO, 2000). Cancer and tooth/skeletal damage are prevalent among millions due to hazardous levels of arsenic and fluoride in water. Furthermore, the increased use of wastewater in agriculture poses significant threats, such as the survival of pathogens in the soil and on crops, which increases risk of disease transmission via produced foodstuff.

Children and mothers are disproportionately affected by water-related illnesses and water insecurity. Many children in developing countries suffer from diarrheal diseases and intestinal parasite infections. Consumption of fecally contaminated water and exposure to fecal material in water and soil in the children's play space and eating area are important routes of transmission of pathogens. Diarrheal and enteric diseases significantly hinder children from absorbing the nutrients they need, causing long-term negative effects on cognitive and physical development (World Bank, 2016). Without access to safe drinking water and basic sanitation, women face health risks in pregnancy, during childbirth and in the post-partum period.

ENSURING EQUITABLE ACCESS TO A CLEAN AND SUSTAINABLE WATER SUPPLY

As noted above, in 2015, 844 million people were living without access to basic drinking water service (WHO/UNICEF, 2017). Projections indicate that by 2025, 1.8 billion people will be living in conditions of "absolute" water scarcity (less than 500 m^3 per year per capita) and two-thirds of the world's population could be living under severe water stress (between 500 and 1,000 m^3 per year per capita) (FAO, 2012). Forty-five percent of people who lack access to improved source of drinking water live in rural areas and travel long distances carrying large amounts of water (WHO/UNICEF, 2017). In rural areas, barriers to water access may include a lack of roads, pipes, treatment plants, and/or wells.

Surface water and groundwater are both important sources for water supply. In locations where surface water is so polluted that ensuring access to a safe supply may require extensive treatment, groundwater may be a more practical water supply. Groundwater extracted via boreholes is generally protected from pathogenic bacteria, may be used without further treatment, and is often more reliable than surface waters (The Groundwater Foundation, 2017). However, groundwater from shallow wells can become contaminated from heavy metals, salts, agricultural inputs, and bacteria as a result of leaking septic systems, farming and irrigation, and other activities.

Insufficiently designed or operated wastewater treatment and sanitation systems may discharge effluent directly to the ground or into surface water, introducing contaminants to local aquatic ecosystems, or eventually into surficial groundwater aquifers. Excessive pumping (i.e., extraction) decreases the level of water in aquifers and can eventually reduce the ability of the well to supply water. Such issues illustrate why groundwater supplies and water treatment discharges require regular monitoring. Unfortunately, the associated monitoring costs often exceed local government budgets and are often not considered when evaluating alternative treatment and water supply options (UN Water, 2010).

Urban areas also face pressures from rapid population growth, changing life styles, poor waste management and sanitation, and competing demands, which increase competition for water and pose threats to water quality (India Water Week, 2015). In many areas, groundwater is extracted at high rates to keep up with rapid population growth, and human waste is increasing at a faster rate than the capacity of wastewater management systems, causing pollution of natural bodies of water and local depletion of aquifers (Moe & Gangarosa, 2009) (Fendorf & Benner, 2016).

SUSTAINING HEALTHY AQUATIC ECOSYSTEMS AND HABITATS

Biodiversity requires healthy ecosystems and in turn provides many ecosystem services. Changes in ecosystems and habitats that affect biodiversity will affect provision of these services and can have amplifying impacts on other species and aspects of ecosystems (UNEP, 2009).

Less than 70 of the world's longest 177 rivers are free from man-made obstructions, and over half of the world's wetlands have disappeared. This is particularly concerning, as wetlands can function as natural water treatment systems. Development, logging, pollution, agriculture, and poor management all contribute to the impairment of freshwater systems. (World Wildlife Fund, 2016)

Freshwater ecosystems account for less than 0.01 percent of the planet's total surface area, but they support more than 100,000 species, including fish, worms, mollusks, crayfish, frogs, newts, and insect larvae. Further, birds and mammals feed in wetland vegetation, and cave systems support blind fish and amphibians. Unfortunately, these freshwater systems are now some of the most highly endangered habitats in the world due to human development, climate change, and pollution.

ADAPTING TO CLIMATE CHANGE

The impacts of climate change on freshwater resources can be summarized as three main challenges: (1) too much water, (2) too little water, and (3) degraded water, according to the Intergovernmental Panel on Climate Change (IPCC) report on Climate Change and Water (IPCC, 2008). Approaches for managing climate change risks and impacts in USAID WSS projects are discussed in more detail in Section 5.

2.2 USAID WATER AND SANITATION ACTIVITIES

USAID activities address the challenges described above by designing and implementing appropriate sustainable water and sanitation activities and interventions, examples of which are shown in Figure 3. These activities address the spectrum of infrastructure needs for water supply, from the source through the distribution system to the user at each water point, and for sanitation, from the point of generation to the point of disposal. Addressing water and sanitation challenges in the developing world requires stakeholder-driven approaches that balance three critical components; (1) enabling environment (policies, social norms, institutions, and financing), (2) improved software (capacity building, technical assistance, behavior change), and (3) expanded access to hardware (or infrastructure) (USAID, 2016) (USAID, 2014b).

Sanitation: Sanitation interventions can be categorized as on-site sanitation systems (e.g., latrines) or off-site systems (e.g., flushing toilets, sewers, and wastewater treatment facilities). USAID interventions consider the entire system from toilet to disposal, across the sanitation service chain, as illustrated in Figure 4, for both sewerage (i.e., wastewater collection/treatment) and on-site systems (USAID, 2016).

In USAID priority countries, centralized wastewater collection and treatment systems are relatively rare. The most common sanitation systems include on-site facilities (e.g., pit latrines, septic tanks) in both rural and urban settings, and collection and treatment systems in urban areas. Stormwater collection systems (or surface water drainage systems) are often integrated into these centralized wastewater collection systems. Because conventional centralized wastewater collection and treatment systems (i.e., sewer systems) are not appropriate to many communities with limited financial and technical capacity, USAID interventions often support non-sewered, on-site sanitation systems, and fecal sludge management as viable alternatives to traditional sewered systems (USAID, 2016). Typical USAID sanitation interventions support sanitation and hygiene programs in rural areas, the construction of school latrines, the development of private sector sanitation markets, and the use of safely managed fecal sludge management services in urban and peri-urban areas. In exceptional cases, USAID has supported activities in large scale sanitation systems such as the construction or rehabilitation of conventional centralized wastewater collection and treatment systems, including stormwater collection systems.

FIGURE 3: REPRESENTATIVE WATER AND SANITATION ACTIVITIES/TECHNOLOGIES

Water sources

- Pond and spring improvements
- Hand-dug wells
- Small-diameter boreholes
- Wells with hand pumps
- Roof rainwater catchments
- Small dams and seasonal impoundments

Water distribution

- Simple spring-fed gravity feed water distribution systems
- Well or surface water source pump with storage tank and piped distribution to stand posts or individual yard taps or connections
- Extensions of existing urban water lines into unserved or under-served peri-urban zones

Water use points

- Stand posts/tap stands
- Cattle troughs
- Hand-washing taps
- Point-of-use treatment

Individual or community latrines

- Simple pits with or without covers
- Ventilated improved pits
- Ecological sanitation (e.g., urine-diverting toilets)
- Composting latrines
- Dehydrating latrines
- Pour-flush latrines

Wastewater collection/treatment

- Small-scale septic and leach field systems
- Settled and simplified sewers
- Water stabilization ponds
- Constructed wetlands
- Conventional wastewater collection system to primary/secondary treatment

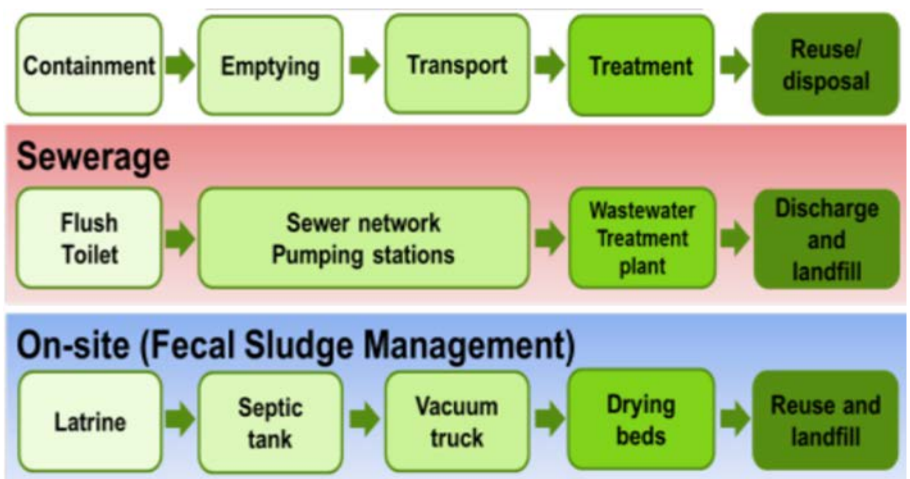
Water Supply: Water supply interventions in USAID priority countries focus on the provision of drinking water to vulnerable populations in rural, peri-urban and urban areas. USAID has leveraged its resources to address long term sustainability of water supply, and climate risk adaptation, by reinforcing activities including:

- Water efficiency and demand management;
- Redundant or combined/complementary storage systems (aquifers; ponds and tanks; wetlands; dams and reservoirs; soil moisture);

- Water utility reform, including improved financial viability, operations and maintenance cost recovery, commercialization, transparency; and,
- Water harvesting and conservation (rooftop; cisterns; contour bunds; check dams; gully plugs; dikes; surface ponds; fog harvesting).

Recent USAID water supply interventions include the construction and rehabilitation of water points, the development/support of low-cost drilling companies, the improved management of water utilities in urban and peri-urban areas (USAID, 2016b). In many regions, USAID has focused its interventions on household safe storage and point-of-use treatment of drinking water, in combination with hygiene promotion campaigns (USAID, 2010) (USAID, 2011). Other water supply interventions include the development of thousands of infiltration ponds to recharge groundwater aquifers for water utilities, and the establishment of water demand management and water conservation programs. Larger infrastructure interventions have included upgrading drinking water distribution systems by the construction and rehabilitation of pump stations, and the installation of new transmission/distribution pipelines. For example, in the Middle East, USAID completed the installation of 900 kilometers of water pipelines, the construction or renovation of 28 storage reservoirs, and the drilling or renovation of 29 wells and pump stations (USAID, 2016b).

FIGURE 4: SANITATION SERVICE CHAIN (USAID, 2016)



2.3 ECOSYSTEM SERVICES

Effective and sustainable management in the water sector involves balancing human demands for water supply and sanitation with the constraints of ecosystem health and services. Sometimes, ecosystem health has been degraded due to overexploitation, leading to compromised sustainability of water and sanitation infrastructure. A recent directive (i.e., the Ecosystem Directive) from the Office of the President of the United States (Donovan, Goldfuss, & Holdren, 2015) requires federal agencies to fully consider costs and benefits of ecosystem services as part of planning and decision making activities. In order to provide a broader framework and context for the implementation of WSS projects, this section describes the inherent services provided by a healthy ecosystem and the global challenges associated with maintaining these services in the context of development activities.

Ecosystem services[2] are typically divided into four categories: provisioning (products obtained from ecosystems); regulatory (benefits obtained from regulation of ecosystem processes); cultural (non-material benefits obtained through human enrichment and experience); and supporting (necessary for production of all other ecosystem services). Table 2 summarizes water-related ecosystem services that can be considered in WSS program design and implementation.

TABLE 2: WATER-RELATED ECOSYSTEM SERVICES (UNEP, 2009)
PROVISIONING SERVICES
• Fresh water (quantity and quality for domestic and agricultural and industrial use) • Water for non-consumptive use (for generating power and transport/navigation) • Aquatic organisms for food and medicines
REGULATORY SERVICES
• Maintenance of water quality (natural filtration and water treatment) • Buffering of flood and base flows, erosion control through water/land interactions and flood control infrastructure
CULTURAL SERVICES
• Tourism (river viewing) • Existence values (spiritual, religious, and aesthetic values, such as the aesthetic value of free-flowing rivers) • Recreation (river rafting, kayaking, hiking, and fishing as a sport)
SUPPORTING SERVICES
• Water's role in nutrient cycling (e.g., maintenance of floodplain fertility), primary production, groundwater recharge • Predator/prey relationships and ecosystem resilience

[2] As noted in the USAID Biodiversity Policy (USAID, 2014a), and consistent with the Millennium Ecosystem Assessment framework (World Resources Institute, 2005), short- and long-term benefits derived from natural ecosystems are often called "ecosystem services." Because ecosystem services are not fully captured in commercial markets or adequately quantified in terms comparable with economic services and manufactured capital, they are often given too little weight in policy decisions and project planning (Constanza, 1997).

3. POTENTIAL ADVERSE ENVIRONMENTAL, HUMAN HEALTH, AND SOCIAL IMPACTS

This section outlines potential direct, indirect, and cumulative impacts of WSS projects on human health and the environment, as well as their potential causes. The reader can use this section to better understand, evaluate, and articulate the potential impacts of WSS activities. These impacts are summarized in Table 3 for environmental impacts, Table 4 for human health impacts, and Table 5 for social impacts.

Water supply and sanitation projects are intended to improve environmental and public health (and provide numerous other benefits); however, when poorly designed or managed ineffectively, they may cause adverse impacts that can offset or eliminate the intended benefits. Such adverse human health and environmental impacts can be categorized as direct, indirect, and cumulative.

- **Direct Impacts.** Direct impacts are caused by the action (e.g., the project or activity) and occur at the same time and place as the action. An example of a direct impact is a decline in water quality resulting from discharge of contaminated effluent into a river.
- **Indirect Impacts.** Indirect impacts are caused by the action, but are realized later in time or at a removed distance, although they are still reasonably foreseeable. An example of an indirect impact is when a water supply project creates pools of stagnant water, whereby the water becomes a breeding ground for disease vectors, causing negative impacts on human health, such as increased incidence of malaria.
- **Cumulative Impacts.** Cumulative impacts are the total effect on a natural resource, ecosystem, or community resulting from the incremental impact of the action when added to other past, present, or reasonably foreseeable future actions, regardless of who undertakes those actions (USDOT FHA, 2017).

The conditions (e.g., environmental, economic, and demographic) underlying water and sanitation project implementation can shape the extent and scope of project impacts. As an example, climate stressors such as increased temperature, changing rainfall patterns, and increased frequency or severity of climate-related extreme events (e.g., droughts and floods) can exacerbate project impacts. In the case of human health, water scarcity and transmission of vector-borne diseases are sensitive to climate variability and change. The dynamic nature of such stressors highlights the importance of integrating climate variability and change into determination of baseline conditions and impact assessment.

3.1 ENVIRONMENTAL IMPACTS

WSS projects can degrade water-based ecosystems, decreasing biodiversity and influencing the provision of ecosystem services (UNEP, 2009). Aquatic ecosystems and habitats must be safeguarded for flora and fauna, including humans who depend on the healthy functioning of natural water systems for food and for the long-term provisioning of clean surface water and groundwater. The following examples highlight potential adverse impacts to biodiversity and ecosystems that can arise from inadequate design and implementation of WSS projects:

- **Water Supply.** Improperly designed water supply projects can over-extract fresh water, leading to reduced flows for downstream users as well as flows inadequate to maintain habitat, wetlands, and biodiversity.
- **Sanitation.** Poorly designed sanitation projects can contaminate receiving water with human

excreta, causing nutrient enrichment, depletion of dissolved oxygen, and other changes that disturb natural ecosystems and reduce the diversity of flora and fauna.

- **Construction.** Construction of water supply and sanitation infrastructure in or near sensitive areas like wetlands or estuaries can destroy flora, fauna, and/or their habitats, leading to losses in biodiversity and ecosystem functioning. It can also cause reductions in ecosystem services such as regulation of water flows and water quality, non-consumptive use (for generating power and transport/navigation, aesthetics, and recreational value). Soil erosion of exposed soils during construction can cause sedimentation into nearby water bodies, reducing the hydraulic capacity and water quality of surface water, and increasing risk of flooding and biodiversity loss.

TABLE 3: POTENTIAL ENVIRONMENTAL IMPACTS AND CAUSES

PROBLEMS	POSSIBLE IMPACTS	POSSIBLE CAUSES
WATER SUPPLY PROJECTS—WELLS, BOREHOLES, AND WATER SUPPLY SYSTEMS		
Depletion of fresh water resources (surface and groundwater) and habitat degradation	• Water scarcity for aquatic and terrestrial ecosystems • Potential loss of flora and fauna • Reduction in stream flow and changes in flow patterns • Changes to ecosystem function and structure, resulting in losses to biodiversity • Land subsidence	• Over-extraction of water supplies due to: o Inadequate planning and operation of water supplies (i.e., demand exceeds supply) o Inadequate consideration of climate change impacts • Inefficient use of water supplies due to: o Waste and leakage of potable water o Poor water pricing policies and practices, leading to excessive use, waste, and leakage • Siting of facilities within wetlands or other sensitive habitats, destroying habitat • Poor construction practices
SANITATION PROJECTS		
Degradation of stream, lake, estuarine, and marine water quality and habitat degradation	• Acute/chronic toxicity to aquatic life including shellfish and fish • Potential loss of flora and fauna • Changes to ecosystem function and structure, resulting in losses to biodiversity	• Disposal of wastewater indirectly to receiving water due to failure of sanitation facility (from improper operation and maintenance, overflow of latrines or failing septic tank system) • Disposal of excreta or wastewater directly into surface water and sensitive areas without adequate treatment
Degradation of groundwater quality	• Contamination of key freshwater aquifers, impacting the sustainability of freshwater	• Indirect disposal of wastewater into groundwater via sanitation facilities located and constructed in sensitive

TABLE 3: POTENTIAL ENVIRONMENTAL IMPACTS AND CAUSES		
PROBLEMS	POSSIBLE IMPACTS	POSSIBLE CAUSES
	supplies	groundwater recharge areas
CONSTRUCTION OF WATER SUPPLY AND SANITATION INFRASTRUCTURE		
Degradation of landscape/habitat	• Disturbance to existing landscape/habitat	• Clearing, grading, trenching, and other activities disturb landscape/habitat • Grading and leveling disrupt local drainage to nearby permanent or seasonal stream or waterbody
Degradation of surface waters, particularly at sites near a stream or waterbody.	• Sedimentation/fouling of surface waters	• Runoff containing sediments and contaminants from cleared ground or stockpiled material during construction
Increased greenhouse gas emissions	• Exacerbation of climate change	• Energy use for construction, maintenance, and operation of water extraction, supply, and distribution infrastructure • Energy use for construction, maintenance, and operation of sanitation and wastewater treatment infrastructure

3.2 HUMAN HEALTH IMPACTS

Poorly designed, constructed, and operated WSS projects may increase the incidence of water-borne, water-based, water-related, and water-washed human diseases, as described below:

- Infectious water-borne diseases (spread through fecal contamination of drinking water): typhoid, cholera, campylobacteriosis;
- Non-infectious water-borne diseases (chemical-mediated): arsenic poisoning, fluoride poisoning;
- Water-based diseases (causative organism lives in water during part of its lifecycle): schistosomiasis, dracunculiasis;
- Water-related diseases (vector requires access to water): malaria, onchocerciasis, trypanosomiasis; and
- Water-washed diseases (spread through communities that have insufficient water for proper hygiene): trachoma, scabies, shigella.

Water-related diseases can result from poor design, operation, and/or maintenance of water supply projects. Pools of stagnant water left near water taps, water pipes, or storage tanks can become breeding sites for disease vectors. Improper disposal of excreta and solid waste, including inadvertent disposal through poorly designed and maintained sanitation facilities, can lead to infectious disease outbreaks near the disposal site or can contaminate surface and groundwater supplies with infectious organisms.

Failure to adequately protect community water supplies and household water storage from accidental contamination can lead to the introduction of disease-causing microorganisms. Examples include contamination of household storage cisterns or rainwater harvesting systems by bird excreta when the birds shelter on the roofs of these systems.

Further, if untreated or improperly treated wastewater is used to grow food crops, infectious diseases can spread. Also, failing to test surface and groundwater prior to project implementation can lead to serious health problems if that water contains natural, industrial, or agricultural chemical contaminants, such as arsenic, mercury, fluoride, and nitrate.

The placement of water supply points within communities can also have indirect health impacts, including physical injuries resulting from traveling long distances carrying heavy containers, or the spread of diseases (whether derived from the water supply or from other sources) through communities along the routes that people take to collect water (Hunter, MacDonald, & Carter, 2010).

Two boys stand in a pool of water near their home in Uganda. Standing water and irrigation streams are home to the snails that carry schistosomiasis, also known as bilharzia, one of the seven diseases targeted by USAID's Neglected Tropical Disease Program. *Source: Andrea Peterson*

TABLE 4: POTENTIAL HEALTH IMPACTS AND CAUSES

PROBLEMS	POSSIBLE IMPACTS	POSSIBLE CAUSES
WATER SUPPLY PROJECTS—WELLS, BOREHOLES, AND WATER SUPPLY SYSTEMS		
Contamination of drinking water at water point	• Transmission of infectious disease (e.g., fecal contamination) • Chronic/acute toxicity from agricultural/industrial chemical contamination or natural geologic sources (e.g., arsenic and fluoride)	• Siting of water points near/downgradient of sanitation system (e.g., latrine) where latrine excreta or other wastewater could enter the water point resulting in fecal contamination • Storage of agricultural inputs (e.g., pesticides or fertilizers), or chemical/solid wastes (e.g., hazardous industrial wastes) near water points where inputs/wastes could enter the system resulting in chemical contamination • Inadequate protection of water supply points with proper seals, aprons, or drainage system to prevent entry of potentially contaminated water • Failure to test water quality at commissioning of infrastructure, resulting in undetected contamination

TABLE 4: POTENTIAL HEALTH IMPACTS AND CAUSES		
PROBLEMS	POSSIBLE IMPACTS	POSSIBLE CAUSES
		• Lack of ongoing water quality monitoring resulting in undetected contamination • Contaminated water hauling containers, mishandling of spigots/containers at water point
Degradation of source water (quality and/or quantity of surface or groundwater)	• Transmission of infectious disease and acute and chronic toxicity (from poor water quality) • Long-term scarcity of drinking water	• Depletion of surface and groundwater resources when withdrawals exceed watershed/aquifer replenishment • Inadequate protection of water source (e.g., reservoirs and wells) from erosion, animal encroachment, and other hazards. • Improper siting of intakes or supply wells near/downgradient of sanitation system, improperly stored agricultural inputs, or chemical/solid wastes.
Stagnant water at water points	• Transmission of vector-borne diseases • Transmission of infectious disease from standing water contaminated with fecal matter or other wastes (e.g., solid waste)	• Inadequately designed or operated drainage system at water point • Leakage from pipes/taps (inadequate operation and maintenance) • Creation of disease vector breeding sites • Contamination of fetched water • Foot infection of water point users
SANITATION PROJECTS		
Contamination of surface water, groundwater, soil, and food by excreta.	• Transmission of infectious disease associated with excreta (e.g., diarrheal, parasitic) • Acute/chronic health problems from consumption of or contact with contaminated water, soil or food • Acute/chronic toxicity and other health problems from consumption of shellfish, fish, or other foodstuffs harvested from contaminated water	• Improper siting of sanitation facility near water supplies, where latrine excreta or other wastewater could enter the water • Failure of sanitation facility due to improper operation and maintenance, where latrine excreta or other wastewater could enter the surface water, groundwater, soil, or food • Improper fecal sludge management, including improper handling/removal from latrines, transport, and operation and maintenance of sludge management facilities • Disposal of excreta or wastewater directly on land or into surface

TABLE 4: POTENTIAL HEALTH IMPACTS AND CAUSES		
PROBLEMS	POSSIBLE IMPACTS	POSSIBLE CAUSES
		water without adequate treatment
Creation of breeding areas for flies, mosquitoes, cockroaches and other disease vectors and nuisance insects.	• Transmission of insect-borne diseases by: o Culex mosquitoes, which can transmit filariasis, and breed extensively in septic tanks and flooded latrines o Flies and cockroaches, which thrive on excreta and have been implicated in some transmission of fecal-oral disease.	• Poor selection and design of sanitation facilities • Poor operation and maintenance of sanitation facilities

3.3 SOCIAL IMPACTS

As populations have grown rapidly, demand for water for food production and industrial growth has correspondingly increased. Rivers and streams all over the globe, from South America to Central Asia, have become severely degraded, resulting in flows insufficient for maintaining healthy ecosystems, (Bjorklund, et al., 2009) as well as the loss of ecosystem services, with significant social impacts. The degradation of water quantity and quality affects all those who depend on water resources for food or drinking resources (Bjorklund, et al., 2009). Ecological losses may also slow down economic production and services.

Over-drawing water sources leads to water scarcity and increased competition among users. For example, farmers and herders often share water sources, and conflicts between and amongst these groups often arise over water access. Such conflicts can be heightened during times of drought or severe or abnormal weather conditions, including those caused by climate change, and can result in anti-social behaviors such as livestock raiding or violence (Ember, Adem, Skoggard, & Jones, 2012). Government policies can add to the problem, as they often support settled agriculture over nomadic pastoralism. There is generally a lack of governance in pastoralist communities; therefore, these areas remain marginalized and more vulnerable to climate change and social conflict. For example, Mauritania, Mali, Burkina Faso, and Niger have passed laws that regulate the common use of rangelands by farming and herding communities; however, they are not always properly enforced.

Water distribution and access is often unequal, and the availability of clean water and sanitation can be strongly correlated with poverty. Poor residents of urban areas, particularly those living in slums, are less likely to have access to proper sanitation. While many people in impoverished areas still practice open defecation, it seldom occurs in wealthier communities. Many cities in developing countries do not have the necessary infrastructure for properly treating wastewater, and up to 90 percent of wastewater is discharged directly into bodies of water that other, often more impoverished people use as their water source (UN, 2010). With a rise in slum populations, access to water from water distribution infrastructure has been declining. Lack of clean water and residential supply is directly related to the portion of a population living in unplanned settlement areas (Dagdeviren & Robertson, 2012).

In many cases, subsidized clean water resources are allocated preferentially to the wealthy and the powerful. In contrast, underprivileged urban communities often pay high prices for water outside network infrastructure, which may or may not be unsafe for drinking (The Water Project, 2017). For example, in Haiti, residents spend 20 percent of their incomes, and in Nigeria, residents spend about 18 percent of their incomes on water (Jacobs, 2016).

Lack of access to water and sanitation facilities can also exacerbate the marginalization of women in the world's poorest countries. Women and girls often bear the responsibility of providing water for the entire family, which may require traveling great distances to collect the water and carry it home. The resulting time burden on women and girls can influence their ability to work outside the home or go to school. The burden of collecting the family's water can also put women and girls at greater risk of exposure to disease and violence, as traveling to water sources can be dangerous. Lack of private sanitation facilities can also lead to greater exposure to violence for women and girls, as they often must travel to the edge of villages to find a private and culturally acceptable place to relieve themselves (Clasen, 2009).

TABLE 5: POTENTIAL SOCIAL IMPACTS AND CAUSES (WORLD WATER ASSESSMENT PROGRAMME, 2009)

PROBLEMS	POSSIBLE IMPACTS	POSSIBLE CAUSES
WATER SUPPLY PROJECTS—WELLS, BOREHOLES, AND WATER SUPPLY SYSTEMS		
Water scarcity	• Reduced economic potential • Decrease in food production • Higher competition among users • Increased cost of water supply	• Degradation of water quality at source of drinking water (surface or groundwater) such that it does not meet standards for safe use, for human consumption or irrigation, resulting in need to find a new source • Depletion of fresh water resources (surface and groundwater) eliminates access to adequate quantities, resulting in need to find new source.
Conflict between farmer and herder communities	• Violence • Proliferation of ethnic militias • Inter-communal tension • Economic and security threats	• Inadequate planning of water distribution and delivery systems (e.g., location of water points) does not account for potential ethnic boundaries and cultural issues. • Poor governance of water allocation does not allocate resources appropriate to each community's needs.
Unequal distribution of water	• Increased illnesses • Higher mortality • Lack of livelihood	• Unfair prices (e.g., subsidized water supply directed to wealthy communities) • No infrastructure for water delivery in poor and/or unplanned urban developments

TABLE 5: POTENTIAL SOCIAL IMPACTS AND CAUSES (WORLD WATER ASSESSMENT PROGRAMME, 2009)		
PROBLEMS	POSSIBLE IMPACTS	POSSIBLE CAUSES
Disproportionate burden for water collection on women	• Lower school attendance due to water-carrying burden. • Lower economic productivity of women. • Greater risk of disease due to exposure during collection. • Higher risk of sexual harassment and assault while hauling water.	• Inadequate planning of water supply projects to reduce hauling distance for women and children. • Water scarcity or unequal access to water infrastructure.
SANITATION PROJECTS		
Gender inequality	• Higher risk of sexual harassment and assault while searching for privacy • Lower attendance at schools by girls. • Increased health care costs for women due to increased risk and transmission of disease	• Inadequate planning of sanitation projects to provide convenience and privacy for women and children (e.g., failure to provide separate sanitation facilities at schools). • Higher mortality rates/lower child survival results in demographic shift to higher fertility rates.
Degradation of groundwater quality in key aquifers	• Increased cost for consumers due to additional water treatment and/or aquifer remediation	
Creation of breeding areas for flies, mosquitoes, cockroaches and other disease vectors and nuisance insects.	• Disproportionate expenses on insect control (e.g., coils and nets)	

4. BEST MANAGEMENT PRACTICES AND MITIGATION MEASURES FOR WATER SUPPLY AND SANITATION

The potential adverse impacts – direct, indirect, and cumulative – of water supply and sanitation activities on human health and the environment can be avoided, mitigated, or offset through prevention-oriented design and the implementation of best management practices. The design team should consider mitigation measures or approaches as early in the project lifecycle as feasible, avoiding the most adverse potential impacts altogether, if possible. This section outlines best management practices for planning, design and implementation (Sections 4.1 through 4.6) and then describes mitigation measures (Sections 4.7 and 4.8). These best practices will assist the reader in designing activities to avoid or minimize potential adverse impacts. If the potential impacts cannot be designed around, then the description of mitigation measures will assist the reader in developing appropriate measures to implement after design.

4.1 GENERAL PRINCIPLES

Environmentally sound design and management (ESDM) is focused on impact avoidance, and is characterized by the following three principles: (1) be prevention-oriented; (2) apply best management practice; and (3) be systematic. It is essential that the design/planning team consider prevention early in the process, when alternatives in technology, approach, or methodology can be considered based on identified impacts, and changes to initial project design made more quickly and at less expense. Best management practices relevant to the project context and goals should be employed to identify potential adverse impacts early, and to develop and prioritize more effective mitigation measures. Lastly, designers and implementers should systematically assess impacts and mitigation measures to ensure that significant concerns are addressed and solutions are found early.

To minimize or prevent potential adverse impacts and to ensure long term sustainability, planning, design, and implementation for WSS activities should ideally include the following steps:

1. Defining baseline conditions;
2. Planning and design;
3. Implementation;
4. Operations and maintenance (O&M); and,
5. Monitoring.

4.2 DEFINING BASELINE CONDITIONS

The baseline or existing conditions of water use determine the starting point for sustainable WSS programming. Baseline data is critical to the design of any activity, and to appropriate evaluation and mitigation of potential adverse impacts in the environmental impact assessment (EIA) process. Without baseline data on the conditions of the biodiversity at a project site, for example, or the water quality of a groundwater source, one cannot determine the significance and scale of a potential impact during an EIA.

DEFINING EXISTING USES

Understanding existing uses is critical to designing a sustainable WSS project. Existing use information is needed to forecast demands on water resources. Existing water uses can be defined by (1) potable water demand (i.e., human consumption or ingestion), (2) wastewater discharge (i.e., discharge of human wastes), and (3) the characteristics of each (i.e., concentration of contaminants and flow rate). (Environmental flow is the complementary use, which is described further below.)

The baseline water use (i.e., the human context) and available water resources (i.e., the environmental context) determine the starting point for sustainable water resources management. Understanding these conditions helps to define the problem within a sustainable water management framework (Richter, Mathews, Harrison, & Wigington, 2003).

CALCULATING DEMAND

Water Supply: Potable water demand can be described using residential consumption rates, which are typically estimated using the number of expected consumers and a literature-based unit consumption rate (e.g., liters per day per capita). Future demand can be estimated based on variables including the level of service, population predictions, and standard design rates and formulas. Guidance for such estimates is typically provided by a design manual for a specific region or country, such as the *Rural Water Supply Design Manual for the Philippines* (World Bank, 2012).

Sanitation: Similarly, wastewater discharges or excreta volumes can be described using accumulation and/or waste production rates, based on the number of residents and a literature-based rate of waste production (e.g., pounds per day and gallons per day per capita). For example, for basic pit latrines, accumulation rates per capita can be used to estimate and design latrine capacity (Reed, 2014). Fecal loading rates for on-site sanitation (see example in Annex III) can be used for these estimates (Franceys, 1992). The characteristics of the flow rate for a given population would be described using existing data. The quality of the wastewater would depend on the dilution of the waste production within the given unit volume.

Minimum standards for water consumption and waste production rates for estimating demand for both water supply and sanitation interventions in emergency response to humanitarian disasters are available from the Sphere Project Handbook, Humanitarian Charter and Minimum Standards in Humanitarian Response (The Sphere Project, 2011).

Early identification of project impacts through the EIA process requires a strong understanding of baseline environmental conditions – the conditions that exist absent the planned WSS activity or intervention, and upon which the activity or intervention will depend for its success. Baseline environmental conditions may include:

- The availability and quality of ground or surface water resources.
- Community needs and the availability of or access to WSS technologies and/or construction materials.

Baseline data provide an accurate understanding of existing conditions, as well as the types and extent of environmental impacts that are likely to occur given the nature of the planned WSS activity. This information enables prevention-oriented project design and the selection of mitigation measures that are well matched to environmental risks.

Techniques used to gather baseline data include site visits and assessments, and review and synthesis of existing reports or analyses (e.g., hydrological or stream flow data, meteorological trends, climate change models, demographic statistics, land use patterns, or planning requirements). In addition to first-hand observations in the field, project planners can often access baseline data online, through government or private-sector counterparts or within their own organizations. The availability of extensive geospatial data has proven particularly valuable to project planners. Many of these types of data are available at no cost.

In the absence of site-specific existing baseline information that can be used for ESDM, WSS activity designers may choose to conduct targeted surveys, assessments, or data collection.

For example:

- Water Supply: Water source assessment a drinking water system includes three steps: (1) delineate the water source protection area; (2) conduct an inventory of potential sources of contamination, and (3) determine the vulnerability of the water supply to contamination. (An assessment of environmental flows can also be performed during this process.)
- Sanitation: A community survey to evaluate current infrastructure and assess needs could include a survey of seasonal and peak sanitation needs and an on-site assessment of the existing sanitation system facilities and operations to identify environmental and health risks.
- Water Supply and Sanitation: Willingness-to-pay surveys can be used to determine the economic feasibility or sustainability of a proposed WSS design or approach based on the principles of cost recovery and/or profitability.
- Water Supply and Sanitation: Cost-benefit analysis can be used to quantify alternate approaches to meeting WSS project objectives based on the estimated costs and gains of proposed interventions.
- Water Supply and Sanitation: Social impact assessment identifies and characterizes potential impacts and recommends mitigation measures specific to the social context.

In combination with traditional methods of baseline data collection (e.g., site visits, stakeholder interviews, document review, online research), such surveys and assessments allow WSS project planners to identify and avoid the most significant adverse environmental impacts early in the design phase.

RURAL OR URBAN SETTING

The setting of the WSS project, whether rural or urban, can define the characteristics of existing water use and sanitation (i.e., beneficiary control, population, and socioeconomic status), which all influence the design and operation of the proposed WSS project. Typically, in a rural setting, individuals served have more direct control and responsibility for managing WSS infrastructure. On the other hand, in an urban or peri-urban setting, the local population typically has no direct control. It is expected that urban systems would serve a larger and higher-density population than rural systems. Similarly, in locations where intensive agricultural production or commercial/industrial activities occur, greater concentrations of microbial and toxic contaminants would be expected in the water supply (due to industrial pollution) or potentially transmitted from sanitation systems to the environment.

Determining the appropriate scale and service area for a proposed intervention is critical to the long-term sustainability of the WSS project. The scale of the project determines the resources necessary to construct and maintain the system and the amount of project involvement and control on the part of beneficiaries. This can determine the type and effectiveness of the system's O&M after installation.

The scale and service area is typically determined by population of the community, its water and sanitation needs, and the financial and organizational resources available to the project.

ENVIRONMENTAL CONTEXT

The initial assessment of existing water resources (i.e., the environmental context) is critical to proper design and implementation of USAID WSS projects. This assessment will characterize the water resources not only for their potential as safe water sources and receptors of treated discharges, but also for measures to protect them from excessive withdrawals for water supply and from inadequately treated sanitation discharges.

The assessment of groundwater sources of water supply may include detailed studies of the hydrology and hydrogeology to determine baseline groundwater recharge rates. The hydrogeological study often includes a review of historical data, if available, from wells in the area to assess water quality, well yield, seasonal fluctuations, depth to the water table, and the local geology (via well drilling logs). At a minimum, a survey of nearby wells can be performed to determine typical yields and water quality, aquifer locations and depths, and prior drilling success rates (World Bank, 2012). Investigation of subsurface characteristics, soil type, and percolation rates will also assist in understanding the potential for the safe use of on-site sanitation systems. These data will also support the analysis of the vulnerability of groundwater sources to improper management of wastes, including wastewater. Resources for existing baseline data include local universities, government ministries, and NGOs.

The assessment of surface water as a source of water supply or as a potential receptor of treated wastewater discharges can be conducted using the environmental flow concept (i.e., maintaining sufficient flow in riverine systems – from headwaters to the coastal zone – to support ecosystems). The framework considers the environmental flow of rivers, streams, wetlands, floodplains, and the associated groundwater system. Note, however, that environmental flow is not focused solely on quantity. The maintenance of environmental flow is based on three characteristics: water quality, water quantity, and timing of the flow (i.e., seasonal flooding). In some cases, the quality of the water can influence the river ecosystem more than quantity or timing. For example, in small watersheds, poor water quality and disturbed stream habitat can be more important factors in the degradation of the macroinvertebrate community than stream flow (USACE/TNC/ICPRB, 2013).

More information on environmental flow assessment is available in "Environmental Flow Assessment: Recent Examples from Sri Lanka (Dissanayake, Weragala, & Smakhtin, 2010)" and in "Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity (Richter, Mathews, Harrison, & Wigington, 2003)."

To better ensure the sustainability of an intervention in the face of a changing climate, water vulnerability assessments should take into account climate variability and change to the extent possible. Analysis of historical hydrologic data can integrate general historical climate trends and seasonal patterns. Longer historical records provide increased ability to identify such trends and patterns. Beyond historical data, an improved assessment of water vulnerability would incorporate climate projections as well as other future trends (e.g., economic and demographic). Section 5 includes more detailed information and resources for using climate information to better assess and manage climate risks to water sources.

4.3 PLANNING AND DESIGN

Improved planning and design of water supply and sanitation activities should minimize or mitigate potential adverse impacts to the environment and public health. Using an integrated approach such as IWRM or WSP/SSP in project planning allows design of WSS projects that balance water and sanitation needs with available water resources, existing uses, and environmental flows. (Please see the Global Water documents for comprehensive guidelines on IWRM, with specific examples for WSS programs (Global Water Partnership, 2017).

Planning and design should include: (1) review and evaluation of potential solutions and technologies; (2) engagement with stakeholders, and (3) assessment of potential adverse impacts from the selected design.

The WSP/SSP approach includes steps to identify proposed actions (i.e., control measures) to manage priority risks and provide safe drinking water and sanitation systems. Examples of control measures in the WSP approach include source protection, water treatment, and repair of leaking pipelines. Similarly, examples of control measures in the SSP approach may include waste stabilization ponds (for biological treatment of wastewater), and personal protective equipment (for waste handlers) (WHO, 2016).

Additional guidance on the planning of water supply and sanitation activities can be found in "Water, Sanitation and Hygiene for Populations at Risk" (ACF, 2005), "Community-Led Urban Environmental Sanitation (CLUES): Complete Guidelines for Decision Makers with 30 Tools," (Luethi, Morel, Tilley, & Ulrich, 2011) and "Sanitation 21: A Planning Framework for Improving City-wide Sanitation Services" (Parkinson, Luthi, & Walther, 2014).

DESIGN CRITERIA

For WSS projects, developing the "basis of design" is often the next step in the process. The basis of design document, written by the project planners (i.e., IPs, USAID), summarizes the specific design criteria for the water or sanitation infrastructure that are required or recommended by host country regulations, international standards, and industry standards. Standards can be defined based on expected performance (for example, an expectation that drinking water will meet water quality standards or that wastewater discharges will meet effluent quality criteria), or by the expected level of treatment (for example, provision of disinfection or primary or secondary treatment) required by the host country or international organization. (For discussion of water quality standards, see Section 4.6 below.) In addition, applicable design criteria for the collection and treatment components within the water supply and sanitation systems are selected by the project planners and technical experts for inclusion in the basis of design.

Table 16 in Annex IV provides examples of design criteria for water system projects based on the Ten States Standards (GLUMRB, 2012). Similar example design criteria for wastewater collection and treatment systems are available from the Ten States Standards (GLUMRB, 2014). Additional design criteria for sanitation systems can be found in guidance manuals, including the Compendium of Sanitation Systems and Technologies (Tilley, Ulrich, Luthi, Reymond, & Zurbrug, 2014) and the "Decentralized Wastewater Treatment Systems (DEWATS) and Sanitation in Developing Countries: A Practical Guideline" (Ulrich, et al., 2010).

The completed basis of design is used to evaluate and select the appropriate combination of infrastructure and technology for a WSS project. Ideally, the needs of the community and other stakeholders, as well as the life-cycle costs, operational complexity, and cultural acceptance, will inform the infrastructure or technology selection process.

STAKEHOLDER ENGAGEMENT

Stakeholder consultation should occur throughout the entire activity development process, including after the preliminary design (i.e., selection of technology or infrastructure) is developed. It is critical that the local beneficiaries are engaged, especially if the O&M of the facility is to be transferred to a local water committee. Engagement of beneficiaries throughout planning, design, and implementation has been found to be critical to the long-term effectiveness of WSS programs. Guidance on stakeholder engagement during planning, in the context of the EIA process, has been summarized in the USAID factsheet on stakeholder consultation, and is available at: http://www.usaidgems.org/Documents/SocialImpacts/Stakeholder_Engagement_052016.pdf.

ENVIRONMENTAL IMPACT ASSESSMENT

Per Regulation 216 and host country requirements, the project planners should assess the potential adverse environmental and social impacts of the proposed WSS project once the preliminary design is developed, taking into account baseline environmental and social conditions as well as the results of stakeholder engagement. The environmental impact assessment will result in a set of mitigating actions and conditions, which are incorporated into the WSS program design, and are summarized in the environmental mitigation and monitoring plan (EMMP).

FINAL REVIEW AND DESIGN:

In the final step in the WSS design process, the planning/design team typically submits, for review and approval, the plans, specifications, and associated permitting documents to the regulatory authorities, local government, and other agencies that may be affected by the new WSS equipment or infrastructure. The planning/design team can then address all review comments and revise the design documents as suggested or required.

4.4 IMPLEMENTATION

Successful implementation of WSS programs over the long term, especially for small-scale activities in rural areas, will often depend on the capacity of project beneficiaries. Communities rely on WSS infrastructure but may lack the resources and expertise to continue to operate and maintain project infrastructure over time. Capacity building is central to achieving the full benefits of WSS activities and increasing access to improved water and sanitation services.

ASSIGNING STAKEHOLDER RESPONSIBILITY

Establishing community responsibility for all or part of project implementation can create a sense of ownership that encourages capacity building efforts. Such commitments can be agreed on in the planning phase and may encompass specific (and regular) duties or functions. These may include monitoring of water resource operations or performance; maintenance and repair of infrastructure, equipment, or other investments; and financial management.

Similarly, for the broader group of stakeholders, clear definition of each organization's roles and responsibilities during construction and then operation is critical. Table 6 provides examples of roles and responsibilities for different types of stakeholders.

TABLE 6: EXAMPLES OF ROLES AND RESPONSIBILITIES FOR PROJECT STAKEHOLDERS		
STAKEHOLDER	EXAMPLES OF ROLES	EXAMPLES OF SPECIFIC RESPONSIBILITIES
Community	Beneficiaries, operator	During the project planning phase, identify environmental issues and other potential impacts of the proposed facility. As operator, take responsibility for operation, maintenance, and financial sustainability (in some cases).
Public water/wastewater utility, or community water/sanitation committee	Owner, operator (once infrastructure has been transferred from the IP)	Comply with regulations; ensure that drinking water is safe for consumption; ensure that sanitation system is properly constructed; communicate with customers and stakeholders; establish and collect use fees; provide resources for staff training and O&M of water and sanitation system facilities.
USAID Mission	Program manager, until transfer of infrastructure.	Fund, design, monitor implementation of WSS program. Assess socio-economic issues with the beneficiaries and community.
Implementing partners	Owner, operator (until infrastructure has been transferred to local utility or government)	Assess socio-economic issues with the beneficiaries and community. Implement and monitor WSS program. Manage subcontractors (e.g., engineer and contractor) and engage community beneficiaries.
Engineer	Design, inspection during construction	Ensure that design meets regulatory requirements and industry standards, provides for ease of maintenance, and meets water and sanitation system needs and goals. Ensure that contractor builds the facilities in accordance with design documents.
Contractor	Project management	Ensure that contractor staff receive training and resources to complete the work in a safe manner per industry standards and regulations; build new facilities according to design requirements.
Host country regulatory agency	Regulatory oversight	Ensure that design meets regulatory requirements; provide guidance as requested by USAID and IPs.

CONSTRUCTION

The licensed engineering contractor typically leads the construction phase of the WSS activity with primary oversight by the design engineer. The WSS design engineer conducts periodic inspections of the construction work and communicates with the owner (i.e., IP and USAID) regarding issues of concern, including compliance with design specifications. The contractor notifies the engineer or owner when site conditions or other factors prevent construction of specific project components as designed.

COMMISSIONING

Before placing new equipment and infrastructure into service, it must be commissioned to ensure that it operates properly. For instance, in drinking water distribution systems, new water mains and service lines must be pressure-tested according to industry standards to ensure that no leaks are present and that the pipe and fittings have been properly installed. Any new or rehabilitated water system infrastructure (e.g., storage tank, water main) must be cleaned, disinfected, and tested for certain water quality parameters per the monitoring plan and project specifications to confirm that no contaminants are present. Monitoring and control systems must be tested to confirm that they are set up to operate as designed. Similarly, for sanitation systems, the equipment and treatment units must be checked by the contractor and specialty technician, if necessary, to assure that the treatment/disposal units are fully operational and that treatment objectives (e.g., effluent discharge limits) are being met. (See Section 4.6 for additional discussion of monitoring.)

4.5 OPERATIONS AND MAINTENANCE

The O&M of new WSS infrastructure may be conducted by community members, hired personnel (i.e., plumbers and mechanics), or in utility-owned systems, by utility staff. If appropriate, at the community level, a water/sanitation committee is often formed to assure that operations and maintenance tasks are designated and all responsible parties understand their roles and responsibilities.

O&M TASKS

O&M requirements, by their nature, evolve from and depend on the infrastructure design. The water/sanitation committee or equivalent manager, with the technical knowledge of, and training on, O&M support functions and safety regulations normally completes the following:

- Identifies all O&M tasks and prepares written procedures, checklists, and forms needed to accomplish each task.
- Identifies staff training needs (technical and worker safety) and required resources for implementing O&M tasks.
- Schedules preventive maintenance tasks on a routine basis (e.g., daily, weekly, monthly, and annually). Examples of preventive maintenance activities include security checks at remote equipment, monthly inspections of pumps and motors, and annual inspections of storage tanks and treatment units.
- Identifies and schedules water quality monitoring tasks (see Section 4.6 below).

In addition to routine and emergency operations and maintenance activities, experienced practitioners (i.e., trained plumbers or technicians) complete repairs identified during inspections, sanitary surveys, or leak detection programs.

FINANCIAL SUSTAINABILITY

The system manager (e.g., water/sanitation committee) typically identifies O&M expenses and develops a total budget. The USAID staff, the IP, and the water/sanitation committee can collaborate on this effort. Typical expenses may include labor, source water protection, water or wastewater treatment chemicals, vehicles, maintenance equipment, other materials and supplies, electricity, and fuel, as well as future independent sanitary surveys and health and safety audits. Financing should complement other interventions (e.g., training local contractors, and working with community committees) to ensure that financial credit is directed toward well-designed installations. Financing O&M should be included in the planning process to ensure that the new facilities are properly operated and maintained.

4.6 MONITORING

Monitoring requires the systematic observation of key environmental conditions and verification that mitigation measures are being implemented and are effective. Environmental monitoring should be a normal part of overall project monitoring and evaluation. Monitoring plans need to carefully consider and detail the required location, timing, and frequency of monitoring.

For example, for a surface water withdrawal for drinking water supply, water samples should be taken at the intake, as well as downstream, to understand the baseline conditions, and to track water quality during operation of the water supply system. Samples should also be taken at different locations at the same time, and during high- and low-flow periods (e.g., before, during, and after storm events), if possible. Similarly, for a wastewater discharge to a surface water (i.e., the effluent from a wastewater treatment system), ambient water quality samples should be taken to ensure the preservation of the water quality of the receiving surface waters.

Monitoring of WSS projects usually involves collecting and analyzing water samples at strategic points in the water supply or sanitation service chain to measure operational success (e.g., within a treatment process) or to verify compliance with water quality standards and safety (e.g., at point of delivery to consumer). The water quality monitoring program should include the following:

- Identification of appropriate water quality standards and effluent limits (i.e., host country and WHO standards);
- Selection or development of protocols for field measurement, sample collection, preservation, and transport; and
- Selection of laboratory for analysis of the parameters in accordance with standard methods.

The Water Quality Assurance Plan (WQAP) is the USAID mechanism to document the monitoring program for drinking water supply activities (please see the GEMS website at http://www.usaidgems.org/wqap.htm for additional information). Although a similar mechanism is not in place to document monitoring programs for USAID sanitation projects, the WQAP process, with some adjustments, would be the model to follow.

There are numerous tools and guidance documents available to assist USAID and its partners with water quality monitoring programs. For example, USAID has also developed the primary guidance document, *USAID Drinking Water Quality Monitoring, Protection, and Governance: An Interactive Toolkit for Activity Managers and Practitioners* (aka Drinking Water Quality Toolkit) that offers field-ready tools and references to define the actions USAID should take to provide drinking water of a defined quality along with adequate monitoring, protection, and governance.

IDENTIFICATION OF APPLICABLE STANDARDS

Based on research on the applicable guidance from USAID, the WHO, and host country regulations, the IP and USAID technical staff should identify appropriate water quality standards and effluent treatment standards. These will include the parameters to be analyzed, the frequency at which they should be measured, the allowable limits for each parameter, and the protocols by which they should be collected, measured, preserved, and analyzed.

Drinking Water Quality Standards

The selection of the water quality standards to be implemented for USAID drinking water activities projects depends on the host country regulatory framework, USAID recommended standards, and existing geologic and environmental conditions at the project location, as well as anthropomorphic and industrial activities in the vicinity of the project site. Host country standards usually follow international norms and standards, such as the WHO Guidelines for Drinking Water Quality (WHO, 2011). USAID recommends compliance with drinking water standards for arsenic, nitrite/nitrate, and coliform bacteria. Compliance with these standards is the minimum requirement for all USAID drinking water projects.

This requirement exists due to concerns raised in a cable sent by the U.S. Embassy in Sarajevo in the late 1990s, which shared reports of large rural populations in Bangladesh and India suffering from arsenicosis. (USAID, 1998) The Greater Ganges Delta was found to contain arsenic in the upper sediments. If the host country has established water quality standards, then its standards should also be incorporated into the water quality monitoring program for the project. For locations where the host country has not developed water quality standards, other international standards such the WHO *Guidelines for Drinking-Water Quality* or US Environmental Protection Agency (USEPA) standards can be used. Host country standards normally take precedence over other international standards; however, where host country and international standards conflict, USAID recommends that the more stringent standards apply.

Effluent Criteria and Ambient Water Quality Standards

Like the drinking water quality standards, effluent criteria and ambient water quality standards, if available, should be selected based on USAID guidance, international standards and host country regulations. Many priority countries in which USAID works do not have ambient quality standards or effluent criteria; however, international standards for effluent discharge are available in narrative form as guidance. For example, the International Finance Corporation (IFC) has issued Environmental, Health, and Safety Guidelines, which include narrative standards for wastewater and stormwater effluent, in addition to industry specific effluent standards (IFC, 2017). These standards typically require consideration of the ambient conditions (e.g., the existing water quality) and the finite assimilative capacity of the receiving waters, and promote pollution prevention, avoidance, or minimization of adverse impacts (i.e., treatment of effluents to preserve the environment). The WHO emphasizes wastewater reuse for agriculture, and incorporates the SSP process (WHO, 2016).

SAMPLE COLLECTION

The accuracy of water quality data depends on the proper collection and analysis of water samples; thus, it is critical that samples be collected and analyzed in accordance with internationally recognized protocols. Maintaining the integrity of the water sample means ensuring that the sample is not contaminated by other sources (e.g., bacteria from the hands) and is not altered by physical conditions (e.g., temperature or pH) during collection.

Proper sample collection requires trained staff, collection bottles and equipment, sample preservation appropriate to the parameter to be analyzed, as well as safe and timely transportation to a qualified laboratory. Identification of the methodology for collecting samples and for performing field measurements for the parameters is necessary. The methodology should specify the qualifications of trained staff; the equipment specifications; and the procedures and protocols for collection, measurement, sample preservation, and transport to laboratories.

LABORATORY ANALYSIS

An evaluation and identification of the resources available for analysis should be included in the monitoring plan (e.g., proximity to a qualified lab). The selected laboratory should have the resources or capacity to receive and store samples collected in the field, to perform the analysis according to standard protocols, to perform standard QA/QC, and to report the analytical results. The correct analytical procedure for the key parameters is normally defined in the water quality standard. Analytical procedures for water quality parameters are described in references such as the *Standard Methods for the Examination of Water and Wastewater* (APHA, 2012), or the ISO standard, ISO/TC 147, for water quality (ISO, 2016).

FIELD ANALYSIS

Field analysis can be conducted using portable test kits for selected parameters of concern, with approval from a USAID Environmental Officer. For example, field test kits exist for fecal coliform and arsenic. It is the responsibility of the IP to demonstrate to the appropriate USAID environmental officer that the use of the portable test kit produces accurate and replicable data. The IP should take the following steps:

- Describe the portable test kits available for testing the parameters of concern.
- Describe the process by which the accuracy of the test kits has been verified.
- Identify the field staff who have been trained in the use of the test kits.
- Include an inventory of supplies of the kits available in the field.
- Obtain approval of the selected test kits from the USAID Mission Environmental Officer, Regional Environmental Advisor, or Bureau Environmental Officer.

4.7 MITIGATION OF IMPACTS

By using the approaches described above in Sections 4.1 through 4.6, practitioners should be able to avoid adverse impacts. While the planning/design team may not always be able to design around or otherwise eliminate the risk of adverse impacts prior to implementation, all mitigation measures should be appropriate to the nature of the intervention, its location, and the dynamics of the community or beneficiaries being served.

WSS activities can take a range of forms, and can be undertaken in a variety of settings, from disaster relief and humanitarian response situations to schools, medical facilities, and municipal infrastructure. Each setting or context presents its own environmental and social conditions, which influence the types and extent of potential adverse impacts, and thus the mitigation measures necessary. Similar projects in different locations may require different approaches to mitigating potential adverse impacts.

Mitigation measures should be responsive to the site's natural and built environment, including its climate, topography, hydrology, population density, and land use. These attributes determine the types of impacts on human health and the environment that are most likely to emerge. Effective mitigation measures will account for the technical attributes of the specific water resource(s), including rainfall, slope, soil type, water table, and vegetation or ground cover, and whether the resources are in an urban, rural, or peri-urban setting. Quantitative hydrological and consumption data can help designers determine which mitigation measures will enhance sustainability and improve performance.

Mitigation measures must also account for the social and cultural mores of beneficiaries and community stakeholders. Interventions should be designed to accommodate local customs and practices that are not harmful, but that can still affect project outcomes. One such example may include provision of separate latrines that are secure and considered "safe" for use by women and girls. By addressing potential safety concerns within the community, the project can mitigate threats of physical violence against women and girls and improve their access to sanitation facilities. Similarly, traveling long distances to collect water may present concerns for the safety of women and girls and should be factored into mitigation design.

4.8 MITIGATION AND MONITORING MEASURES FOR WSS ACTIVITIES

Achieving ESDM requires that potential impacts be considered and, where significant, appropriate mitigation measures be adopted to reduce or eliminate those impacts. The results from reviewing potential impacts, developing appropriate mitigation measures, and identifying indicators to quantify implementation, can be summarized in a matrix such as Table 7. In contrast to Table 7, which presents these results for a set of broad categories, Table 8 presents potential impacts and mitigation measures for individual water and sanitation technologies. Note that in many cases, the mitigation measures are best practices. In general, USAID initial environmental examinations (IEEs) or sub-project review documents should note and assess the potential impacts listed here, and EMMPs should specify corresponding, appropriate mitigation measures.

TABLE 7: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR WSS ACTIVITIES				
PROBLEMS	POSSIBLE IMPACTS	MITIGATION MEASURE	MONITORING INDICATOR	CLIMATE STRESSOR[3]
HEALTH IMPACTS				
WATER SUPPLY PROJECTS—WELLS, BOREHOLES AND WATER SUPPLY SYSTEMS				
Contamination of drinking water at point of use	• Transmission of infectious disease (e.g., from fecal contamination) • Chronic/acute toxicity (agricultural/industrial chemical contamination) • Chronic/acute toxicity (natural geologic sources, e.g., arsenic and fluoride)	• Assess water quality upstream and downstream to determine if water is safe to drink and to establish a baseline so that any future degradation can be detected, prior to commissioning. • Assess quality of groundwater during investigation and confirm upon commissioning of system. • Develop and implement water quality assurance plan (WQAP). • Consider how the project will impact the water table level, particularly in the context of climate change. • Use fencing or equivalent to keep livestock from grazing upgradient of the water supply and drinking from the water source. • Ensure sanitation facilities are sited an appropriate distance away from source, at least 30 m. • Site wells a safe distance from any waste dumps or chemical or pesticide storage sites. • Periodically inspect area around the source for changes in land use that could introduce contamination.	• Frequency with which domesticated animals are found near the point of use • Perimeter at the point of use not enclosed within fencing or the equivalent, or radius of enclosed area (in meters) does not meet recommended minimum • Number of times fecal coliform bacteria are measured at the point of use at levels above the prescribed water quality standards • Sanitary survey conducted annually three years, reports generated	• Rainfall variability • Storms and storm surge • Flooding
Degradation of water quality at source of drinking water (groundwater)	• Transmission of infectious disease and chronic toxicity (from poor water quality) • Capital investment required to install new water treatment facilities			• Saltwater intrusion • Rainfall variability • Flooding increasing contamination of boreholes and unprotected wells

[3] For a discussion of indirect climate change impacts see Section 4.1.

TABLE 7: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR WSS ACTIVITIES				
PROBLEMS	POSSIBLE IMPACTS	MITIGATION MEASURE	MONITORING INDICATOR	CLIMATE STRESSOR[3]
		• Follow best practices for design and construction. • Monitor and repair leaks from cracked containment structures, broken pipes, faulty valves, etc. (i.e., conduct sanitary survey) to avoid creating new entry points for contamination. • Include focus on proper use and maintenance of the system as part of behavior change and education program. • Establish water committee to maintain and fund system.	• Number of community members trained on proper use and maintenance of the system • Number of water committees formed	
Degradation of water quality at source of drinking water (surface water)	• Transmission of infectious disease and chronic or acute toxicity (from poor water quality (e.g., from chemical contamination or harmful algal blooms)) • Capital investment required to install new water treatment facilities	• Use fencing or equivalent to keep livestock from grazing uphill of the water supply and drinking from the water source. • Assess water quality upstream and downstream to determine if water is safe to drink and to establish a baseline so that any future degradation can be detected, prior to commissioning. • Develop, implement, and periodically review WQAP. • Ensure sanitation facilities are sited an appropriate distance away from water supply, at least 30 m. • Site watering points a safe distance from any waste dumps or chemical or pesticide storage sites.	• Frequency with which domesticated animals are found near the point of use • Perimeter at the point of use not enclosed within fencing or the equivalent (in meters) • Number of times fecal coliform bacteria are measured • Exceedance of water quality standards	• Rainfall variability • Flooding • Storms • Increased algal blooms (from increasing temperatures) • Droughts resulting in stressed sanitation systems and increased pollutant concentrations

TABLE 7: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR WSS ACTIVITIES				
PROBLEMS	POSSIBLE IMPACTS	MITIGATION MEASURE	MONITORING INDICATOR	CLIMATE STRESSOR[3]
		• Periodically inspect area around the supply for changes in land use or water use that could introduce contamination. • Follow best practices for construction and source protection. • Monitor and repair leaks from cracked containment structures, broken pipes, faulty valves, etc. (i.e., conduct sanitary survey) to avoid creating new entry points for contamination. • Include focus on proper use and maintenance of the system as part of behavior change and education program. • Establish water committee to maintain and fund system.	• Number of community members trained on proper use and maintenance of the system • Sanitary survey conducted every three years, report generated • Number of water committees formed	
Reduction of available quantity at source or depression of water table below elevation of base of well.	• Long-term scarcity of drinking water • Capital investment required to install pump at a greater depth or to develop new sources.	• Calculate yield and extraction rates in relation to other area water uses and available supply. Monitor water levels to detect overdrawing. • Recalculate periodically. • Establish water committee to be responsible for water usage.	• Safe yield (% of total sustainable water extraction rate being withdrawn) • Water table elevation (change in meters in water table) • Pumping rate over time (cubic meters per second) • Water committee established	• Drought/shifting weather patterns could accentuate depression of water table • Increasing temperatures resulting in increased evaporative losses as well as increased water demand • Rainfall variability • Glacial melt resulting in changing

TABLE 7: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR WSS ACTIVITIES				
PROBLEMS	POSSIBLE IMPACTS	MITIGATION MEASURE	MONITORING INDICATOR	CLIMATE STRESSOR[3]
				and reduced seasonal water supply
Stagnant water at water points	• Transmission of vector-borne diseases • Transmission of infectious disease from standing water contaminated with fecal matter or other wastes (e.g., solid waste)	• Ensure that spilled water and rainwater drain to a soakaway or equivalent structure and do not accumulate as standing water. • Monitor and repair leaks from cracked containment structures, broken pipes, faulty valves, etc. • Include focus on proper use and maintenance of the system as part of behavior change and education program. • Establish water committee to oversee maintenance.	• Stagnant water visible at project site • Number of well-functioning systems with leaks • Number of community members trained on proper use and maintenance of the system • Operation and maintenance plan in place	• Flooding • Rainfall variability
SANITATION PROJECTS				
Contamination of surface water, groundwater, soil, and food by excreta	• Transmission of infectious disease associated with excreta (diarrheal, parasitic, etc.) • Acute/chronic toxicity and other health problems from consuming or contact with contaminated water (e.g., harmful algal blooms may cause acute or chronic toxic effects)	• Evaluate depth to water table, including seasonal fluctuations, groundwater hydrology, and any changes expected due to climate change. Pit latrines should not be installed where the water table is shallow or where the composition of the overlying deposits makes groundwater vulnerable to contamination. Replace pit latrine with a mounded latrine or other alternative. • Latrines should be sited a minimum of 30 m from water sources.	• Water quality reports • Number of latrines where water table level has been verified and documented • Number of latrines located less than 30 m from nearest water source • System in place for	• Flooding affecting sanitation systems and contaminating drinking water • Drought resulting in reduced efficiency of sanitation systems and reduced treatment performance

TABLE 7: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR WSS ACTIVITIES				
PROBLEMS	POSSIBLE IMPACTS	MITIGATION MEASURE	MONITORING INDICATOR	CLIMATE STRESSOR[3]
	• Acute/chronic toxicity and other health problems from consuming shellfish, fish, or other foodstuffs harvested from contaminated water	• Install hand wash stations near latrines (following mitigation measures described for water supplies above). • Ensure that a reliable system is used for safely emptying latrines, toilets, and septic tanks and transporting the collected material off-site for treatment. • Ensure that collected material is adequately treated to international standards and not directly applied to fields or otherwise disposed of improperly. • Properly decommission pit latrines. Do not leave pits open. Fill in unused capacity with rocks or soil. • Include focus on proper use and maintenance of the system as part of behavior change and education program. • Use the ventilated improved pit latrine design (as appropriate) that traps insect vectors. • Assess water quality upstream and downstream to establish a baseline so that any degradation can be detected. • Establish water committee to oversee maintenance and ensure drinking water is protected.	removing and treating effluent • Percentage of beneficiaries using proper hygiene and sanitation practices • Number of community members trained in maintenance and safe cleaning practices • Water committee established	
ENVIRONMENTAL IMPACTS				
WATER SUPPLY PROJECTS—WELLS, BOREHOLES, AND WATER SUPPLY SYSTEMS				
Depletion and	• Water scarcity for aquatic	• During project design, calculate yield and	• Water quality	• Drought

TABLE 7: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR WSS ACTIVITIES				
PROBLEMS	POSSIBLE IMPACTS	MITIGATION MEASURE	MONITORING INDICATOR	CLIMATE STRESSOR[3]
degradation of fresh water resources (surface and groundwater), environmental flows, and habitat	and terrestrial ecosystems • Reduction in stream flow and changes in flow patterns • Changes to ecosystem function and structure, resulting in losses to biodiversity and ecosystem services (such as water filtration by wetlands) • Land subsidence • Potential destruction of flora and fauna	extraction rates in relation to other area water uses and available supply. Monitor water levels to detect overdrawing. • Determine/evaluate how the project will impact water flows, particularly in the context of climate change. • Use fencing or equivalent to keep livestock from grazing uphill of the water supply and from drinking from the water source. • Survey for, and avoid, wetlands, estuaries, or other ecologically sensitive sites in the project area. Identify nearby areas that contain endangered species and get professional assessment of species' sensitivity to construction at site. • Follow Construction Guideline in this *Sector Environmental Guideline* series • Establish water committee to oversee usage and quality, educate committee members on ecosystem services.	reports • Presence of fence or equivalent • Water yield and extraction reports • Monitoring of water table • Monitoring of nearby wetlands • Gauge data from streams • Water committee established	• Rainfall and surface/groundwater flow variability • Increasing temperatures • Glacial melt • Saltwater intrusion
SANITATION PROJECTS				
Degradation of stream, lake, estuarine, and marine water quality and habitat	• Acute/chronic toxicity to aquatic life including shellfish and fish • Potential destruction of other flora and fauna • Changes to ecosystem function and structure, resulting in losses to	• Evaluate depth to water table, including seasonal fluctuations, groundwater hydrology and any changes expected due to climate change. Pit latrines should not be installed where the water table is shallow or where the composition of the overlying deposits makes groundwater vulnerable to contamination. • Latrines should be sited a minimum of	• Water quality reports • Number of latrines where water table level has been verified and documented • Number of latrines	• Algal blooms • Potential for increased dead zones due to increasing temperatures and changes in circulation and wind patterns

TABLE 7: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR WSS ACTIVITIES				
PROBLEMS	POSSIBLE IMPACTS	MITIGATION MEASURE	MONITORING INDICATOR	CLIMATE STRESSOR[3]
	biodiversity	30 m from water sources. • Ensure that a reliable system is used for safely emptying latrines, toilets, and septic tanks and transporting the collected material off-site for treatment. • Ensure that collected material is adequately treated and not directly applied to fields or otherwise disposed of improperly. • Properly decommission pit latrines. Do not leave pits open. Fill in unused capacity with rocks or soil. • Ensure adequate supply chain services are in place to sustain the sanitation improvements. • Ensuring adequate monitoring systems are functioning. • Assess water quality upstream and downstream to establish a baseline so that any degradation can be detected. • Train community members in cleaning and maintaining latrines.	located less than 30 m from nearest water source • System in place for removing and treating effluent • Number of community members trained in cleaning and maintenance	• Rainfall variability
Degradation of groundwater quality	• Contamination of key freshwater aquifers, impacting the sustainability of freshwater supplies • Increased cost of water treatment and/or aquifer remediation			• Drought • Flooding • Rainfall and surface/ groundwater flow variability
SOCIAL IMPACTS				
WATER SUPPLY PROJECTS—WELLS, BOREHOLES, AND WATER SUPPLY SYSTEMS				
Water scarcity	• Economic downturn • Decrease in food production • Higher competition among users • Increased cost of water	• Calculate yield and extraction rates in relation to other area water uses and available supply. Monitor water levels to detect overdrawing. • Consider how the project will impact water flows, particularly in the context	• Water yield and extraction reports • Number of water committees formed	• Drought • Rainfall variability • Glacial melt • Saltwater intrusion • Increasing

TABLE 7: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR WSS ACTIVITIES				
PROBLEMS	POSSIBLE IMPACTS	MITIGATION MEASURE	MONITORING INDICATOR	CLIMATE STRESSOR[3]
	supply	of climate change. • Ensure government involvement and trust between governments and communities via stakeholder engagement meetings during planning. • Establish water committee to oversee usage and consider pricing.		temperatures
Conflict between farmer and herder communities	• Violence • Proliferation of ethnic militias • Inter-communal tension • Economic and security threats	• Ensure all beneficiary viewpoints are included in project planning by conducting community forums and stakeholder engagement meetings.	• Number of stakeholders consulted and community meetings held • Specific plans established to ensure all viewpoints are included in project design	• Drought • Rainfall and surface/groundwater flow variability • Storms and flooding
Unequal distribution of benefits of WSS programming	• Increased illnesses • Higher mortality • Lack of livelihood	• Water use planning addresses equitable distribution among beneficiaries. • Community members of all beneficiary groups are represented in water use/management planning and operation.	• Water use planning incorporates equal distribution among beneficiaries • Community members represented in planning and management discussions	• Drought • Rainfall and surface/groundwater flow variability • Storms and flooding
Gender inequality	• Lower school attendance due to water-carrying	• Community meetings held with women and men separately to understand	• Meetings held with both women and	• Drought • Rainfall and

TABLE 7: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR WSS ACTIVITIES				
PROBLEMS	POSSIBLE IMPACTS	MITIGATION MEASURE	MONITORING INDICATOR	CLIMATE STRESSOR[3]
	burden. • Lower economic productivity of women • Women at greater risk of contracting diseases due to exposure while hauling water • Higher risk of sexual harassment and assault while hauling water	specific needs related to water access and use by each. • Ensure that women are not walking long distances to access water sources or latrines. • Ensure water and sanitation access benefits both genders equally and that women are not carrying the largest management burden.	men to identify specific needs • Average distance traveled to access water and sanitation	surface/groundwater flow variability • Storms and flooding
SANITATION PROJECTS				
Gender inequality	• Inadequate planning of sanitation projects regarding privacy and convenience for women and children (e.g., providing separate sanitation facilities at schools)	• Plan separate latrines for each gender. Seek input from women in the community on where to site facilities so they feel comfortable using them. • Devote adequate attention to identifying and addressing social barriers to using latrines.	• Number of separate sanitation latrine facilities constructed • Reduction in child mortality	• Storms and flooding (causing unhygienic conditions disproportionally affecting females)
Infrastructure/ system damage from poorly constructed system or extreme weather events	• Increased costs to replace/rehabilitate systems • Gap in water and sanitation provision while system is unusable, leading to increased illness, mortality, loss of livelihoods, etc.	• Follow construction guidelines. • Ensure that systems can withstand the projected impacts of climate change.	• Climate change impacts considered and addressed in design and planning • Mitigation measures from Construction Guideline followed where relevant	• Flooding • Sea level rise and storm surge • Strong winds/ storms • Drought • Increasing temperatures

TABLE 8: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR EXAMPLE WSS TECHNOLOGIES			
CATEGORY (ACTIVITY)	ISSUE (IMPACT)	MITIGATION MEASURE	MONITORING INDICATOR
Pit latrines (i.e., simple pit with or without cover, ventilated improved pit, pour-flush latrines, dehydrating latrines)	• Bacterial/microbial contamination of groundwater supply • Fecal sludge entering water supplies	• Bottom of the pit should be 2 m above groundwater level. • Minimum of 30 m distance between pit and water source. • Ensure that a reliable system for safely removing fecal sludge and transporting off-site for treatment is available. Ensure that collected fecal sludge is adequately treated and not directly applied to fields or otherwise improperly disposed of.	• Installation and completion reports, photos; water quality reports and photos; design drawings for treatment units • Operation and maintenance (O&M) plan • Approved fecal sludge management plan
Composting toilets (i.e., composting latrines	• Increase transmission of vector-borne diseases • Contaminate groundwater supply with pathogens • Cause disease transmission to O&M staff	• Maintain humidity of composting material above 60% and supplement excreta with generous quantities of carboniferous material (dry leaves, straw, etc.) to maintain aerobic, odor-free, and insect-free area. • Construct sealed vaults to hold composting material if using fixed-batch systems. If using movable-batch systems check removable containers for leaks before installing. • Test samples from active chamber and mature chamber after fallow period for Ascaris eggs and fecal coliforms. • Allow sufficient residence time in mature chamber. This may vary from 6 months in warm climates to 18 months in cooler climates. • Ensure that the systems will be properly	• Installation and completion reports, photos; water quality reports and photos; design drawings for treatment units • Operation and maintenance (O&M) plan

TABLE 8: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR EXAMPLE WSS TECHNOLOGIES			
CATEGORY (ACTIVITY)	ISSUE (IMPACT)	MITIGATION MEASURE	MONITORING INDICATOR
		operated and maintained so that the soil amendment taken out after the treatment period is truly sanitized.	
Septic tanks (i.e., small-scale septic & leach field systems)	• Bacterial/microbial contamination of groundwater supply • Contaminate surface water supply with nutrients, biological oxygen demand, suspended solids and pathogens • Contaminate water supplies, damage water quality and/or transmit disease at other locations if waste is not properly handled and treated during or after servicing	• Evaluate depth to the water table, including seasonal fluctuations. If water table is too high, line the tank with impermeable material to prevent leakage. • Avoid direct discharge of effluent to waterways. • Ensure that a reliable system for safely removing fecal sludge and transporting off-site for treatment is available. Ensure that collected fecal sludge is adequately treated and not directly applied to fields or otherwise improperly disposed of.	• Installation and completion reports, photos; water quality reports and photos; design drawings for treatment units • Operation and maintenance (O&M) plan • Approved fecal sludge management plan
Solids free and simplified sewers (settled and simplified sewers)	• Damage ecosystems and degrade surface water quality • Transmit diseases to field workers and consumers of agricultural products	• Ensure that collected sewage will be treated, in a wastewater stabilization pond, and not simply discharged to a river or stream or used directly in agriculture or aquaculture. This is especially important for simplified sewerage, since there is no interceptor or septic tank to remove solids. • Ensure that a reliable system for safely removing fecal sludge from interceptor	• Installation and completion reports, photos; water quality reports and photos; design drawings for treatment units • Operation and maintenance (O&M) plan • Approved fecal sludge management plan

TABLE 8: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR EXAMPLE WSS TECHNOLOGIES			
CATEGORY (ACTIVITY)	ISSUE (IMPACT)	MITIGATION MEASURE	MONITORING INDICATOR
		tanks and transporting off-site for treatment is available. Ensure that collected fecal sludge is adequately treated and not directly applied to fields or otherwise improperly disposed of.	
Wastewater stabilization ponds (anaerobic, facultative, aerobic).	• Damage ecosystems and degrade surface water quality • Transmit diseases to field workers and consumers of agricultural products	• Avoid discharging single (facultative) pond systems directly into receiving waters. If this is unavoidable, construct hydrography-controlled release lagoons that discharge effluent only when stream conditions are adequate. Install secondary treatment such as a constructed wetland, if possible. • Use two-, three- or five-pond systems if possible (anaerobic, facultative, maturation). • Allow only restricted uses for agriculture and aquaculture of effluent from all but five-pond systems.	• Installation and completion reports, photos; water quality reports and photos; design drawings for treatment units • Operation and maintenance (O&M) plan
Shallow wells (i.e., hand-dug wells, wells with hand pumps)	• Over-pumping • Contaminated by leaking septic tanks • Chemicals entering water supply from natural weathering, waste disposal, industry	• Perform an assessment of the watershed and aquifer to prevent over-pumping and contamination for long-term sustainability. • Take water samples and test water quality tests (physiochemical and bacteriological) in accordance with WQAP. • Install fencing around the shallow well.	• Approved WQAP • Installation and water quality reports, photos

TABLE 8: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR EXAMPLE WSS TECHNOLOGIES			
CATEGORY (ACTIVITY)	ISSUE (IMPACT)	MITIGATION MEASURE	MONITORING INDICATOR
		• Provide proper drainage of spilled water. • Undertake immediate repairs of any cracks on the well cap. • Provide a diversion trench for any stormwater to protect the well cap. • Provide hygiene and sanitation facilities a sufficient distance (e.g., 50 m) away from the borehole at an appropriate site. • Community education and outreach on proper handling of water after drawing	
Boreholes (i.e., small-diameter boreholes)	• Over-pumping • Chemicals entering water supply from natural weathering, waste disposal, industry	• Perform an assessment of the watershed and aquifer to prevent over-pumping and contamination for long-term sustainability. • Undertake water quality tests (physiochemical and bacteriological) in accordance with WQAP. • Maintenance of the borehole equipment and treatment unit • Provide hygiene and sanitation facilities a sufficient distance (e.g., 50 m) away from the borehole at an appropriate site. • Community education and outreach on proper handling of water after drawing it	• Installation and water quality reports, photos

TABLE 8: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR EXAMPLE WSS TECHNOLOGIES			
CATEGORY (ACTIVITY)	ISSUE (IMPACT)	MITIGATION MEASURE	MONITORING INDICATOR
Watershed/rock rainwater collection catchments	• Poor water quality • Disturbed stream habitat	• Remove any silt matter deposited in the catchments after and before the rainy season. • Replace the filter media placed in the catchments after some time to maintain proper filtration. • Undertake water quality tests (physiochemical and bacteriological) in accordance with WQAP. • Fence around the developed rock catchments. • Remove all waste matter from the rock catchments • Construct diversion trenches upstream of the rock catchments to prevent entrance of stormwater • Conduct water quality analysis of collected rainwater and provide appropriate treatment unit	• Installation and water quality reports, photos
Rainwater harvesting; tanks (i.e., roof rainwater catchments)	• Potential breeding sites for vector-borne diseases • Contamination from improper disposal methods of excreta and solid waste	• Empty and clean the tank using chlorine twice a year. • Ensure the roof catchment is free from any foreign matter at all times. • Provide a cover lid for the inspection chamber. • Provide an overflow pipe. • Provide a wash-out pipe at the bottom of the tank. • Construct a suitable water collection chamber and provide adequate drainage for spilled water. • Educate the users on the need to boil drinking water.	• Installation and water quality reports, photos

TABLE 8: IMPACTS, MITIGATION MEASURES, AND MONITORING INDICATORS FOR EXAMPLE WSS TECHNOLOGIES			
CATEGORY (ACTIVITY)	ISSUE (IMPACT)	MITIGATION MEASURE	MONITORING INDICATOR
		• Conduct water quality analysis.	
Small dams, seasonal impoundments, ponds and spring improvements	• Potential breeding sites for vector-borne diseases • Disturbed stream habitat • Inter-communal tension	• Perform an assessment of the watershed, including the stream, pond or spring to prevent unsustainable withdrawals and contamination • Evaluate and manage environmental flows, particularly in the context of climate change • Conduct water quality analysis • Ensure all beneficiary viewpoints are included in project planning by conducting community forums and stakeholder engagement meetings	• Installation and water quality reports, photos
Constructed wetlands	• Potential breeding sites for vector-borne diseases • Inter-communal tension	• Evaluate and manage environmental flows, particularly in the context of climate change • Ensure all beneficiary viewpoints are included in project planning by conducting community forums and stakeholder engagement meetings	• Installation and water quality reports, photos • Operation and maintenance (O&M) plan.

5. WATER SUPPLY AND SANITATION AND CLIMATE RISKS

This section includes a discussion of climate risks and tools for climate risk assessment. It will provide the reader with the tools to understand, evaluate, and articulate potential climate risks associated with WSS activities.

5.1 CLIMATE RISKS

Climate variability and change can place additional, significant stress on WSS services and infrastructure already challenged by population growth, pollution, poor infrastructure maintenance, and conflict. As noted in Section 2.1, climate impacts on water resources can be broadly categorized as too much water, too little water, or degraded water (IPCC, 2008). Changes in temperature, precipitation patterns and evaporation rates, increases in the intensity and/or frequency of extreme precipitation events, and rising sea levels can increase result in climate risks for water sector projects. Table 9 lists examples of these climate risks to WSS projects.

TABLE 9: CLIMATE RISKS TO WATER SUPPLY AND SANITATION PROJECTS (USAID CLIMATE RISK SCREENING AND MANAGEMENT TOOL 2017)

WATER QUANTITY	WATER QUALITY
• Increased evaporative water losses due to higher temperatures. • Increased demands for potable water and for other uses of water due to higher temperatures. • Decreased water availability in the dry season due to rapid runoff and reduced infiltration caused by heavy rainfall over sparsely vegetated watershed. • Reduced supply of freshwater due to inundation of coastal aquifers from sea level rise. • Eventual diminished seasonal water supply due to melting glaciers. • Increased conflicts over water in arid regions due to droughts. • Increased competition for water for rural and urban needs due to drought and water shortages. • Reduced surface water availability and groundwater recharge due to prolonged drought. • Increase in wells drying up, extending distances traveled to collect household water, due to declining precipitation. • Increased workload, time burden, and caloric expenditure for women and girls.	• Harmful algal blooms that produce toxins leading to human health impairment may be created by higher temperatures. • Reduced water quality due to increased pathogens and lower dissolved oxygen caused by higher temperatures. • Increased public health risks due to inundation and overflow of latrines and septic systems caused by increased precipitation and storm events. • Increased disease risks due to exposure of downstream residents to human and animal wastes caused by flooding of sanitation facilities. • Increased incidence of water-borne infectious diseases due to higher temperatures and flooding. • Contaminated groundwater through boreholes and unprotected wells due to flooding. • High levels of suspended sediments, potentially exceeding water treatment capacity, due to flood waters. • Higher pollutant concentrations in surface waters and reduced efficiency of sanitation systems due to prolonged drought. • Reduced ability of rivers to dilute and carry away contaminants due to low-flow periods. • Back up of discharge and spread of water-borne diseases due to flooded coastal outfalls caused by sea level rise and storm surge. • Accelerated salinization of coastal aquifers due to sea

TABLE 9: CLIMATE RISKS TO WATER SUPPLY AND SANITATION PROJECTS (USAID CLIMATE RISK SCREENING AND MANAGEMENT TOOL 2017)	
	level rise, storm surge, and/or reduced rainfall.
WATER & SANITATION INFRASTRUCTURE	BEHAVIORAL CHANGE AND ENABLING ENVIRONMENT
• Increased damage to water supply and sanitation systems, including collection, treatment, and distribution systems, due to flooding or increased intensity of precipitation. • Reduced efficiency of sanitation systems and treatment performance due to prolonged drought. • Damaged pumps due to sea level rise and saltwater intrusion. • Inundation of low-lying latrines and septic systems caused by sea level rise. • Damage to water and sanitation infrastructure due to heavy surface flows and floods from melting glaciers and glacial lake outburst floods. • Reduced access of marginalized populations to sanitation infrastructure due to flooding and extreme storm events. Disruption to supply chains for construction and maintenance of water and sanitation infrastructure due to flooding and/or severe events.	• Reduced number of stakeholders participating in risk-reducing practices as a result of infrastructure damage and community dislocation due to flooding or sea level rise. • Reduced resources available for community education as a result of resources required for emergency response. • Reduced participation in sanitation and hygiene training and awareness-raising due to community disruption and dislocation due to flooding, sea level rise, and extreme events. • Reduced resources for and enforcement of government policies and regulations related to water use and sanitation due to diversion of government staff and resources to address extreme events and other climate impacts.

The following measures could help ensure WSS investments are more resilient to climate risks:

1. Preparing for weather events that are more extreme than in historical experience, using climate data predictions and information as a guide;
2. Developing alternatives when traditional coping strategies are overwhelmed;
3. Establishing new norms and expectations for water service delivery or disaster relief;
4. Using capacity building and behavior change communication to decentralize and carry out climate-resilient planning; and,
5. Adjusting public funding to include allocations for climate resilience, especially for at-risk systems and populations (USAID Global Climate Change Office, 2012).

In seeking to systematically assess and address the risks from climate variability and change, USAID takes a climate risk management approach. USAID has developed guidance for applying this framework throughout the program cycle: “Mandatory Reference for ADS Chapter 201: Climate Change in USAID Country/Regional Strategies” (USAID, 2017a) and “Mandatory Reference for ADS Chapter 201: Climate Risk Management for USAID Projects and Activities” (USAID, 2017b). USAID requires nearly all strategies, projects, and activities to be screened for climate risks, and for climate risk management options to be developed. Examples of suggested climate risk management options for water supply and sanitation are shown below.

1. Invest in climate-related information collection and management systems:
    - Strengthen climate information systems, building on existing regional and national networks.
    - Build capacity of national governments to harmonize data across regions.
    - Build relevant national and/or regional research programs on the links between climate and water supply and sanitation (e.g., vulnerability index).

2. Strengthen WSS policies, planning, and systems:
    - Integrate climate information into WSS system planning.
    - Identify and prioritize technologies for water-related adaptation.
    - Improve design and construction of water supply and sanitation infrastructure to account for the potential for climate-related risks.
    - Improve water storage, conservation, and water demand management to account for climate-driven changes in supply and demand.
    - Foster integrated resource management with agriculture and energy sectors.

3. Consider rural vs urban needs:
    - Identify changes in demographics, urbanization, and land use that could dictate a shift in WSS investments, particularly in the face of the exacerbating influence of climate change.
    - Design urban WSS investments to "reach" more individuals potentially affected by climate change.
    - Consider water resource constraints when addressing the complexities of urban migration (family planning, economic opportunities, and integrated public services).

4. Develop multi-use systems to improve risk management for water systems:
    - Integrate WSS infrastructure for multiple uses at the household level to improve resilience to decreased rainfall from climate change and variability.
    - Implement rainwater harvesting and greywater reuse for agriculture, where appropriate.

5.2 TOOLS TO ASSESS CLIMATE RISKS FOR WSS PROJECTS

USAID maintains the Climatelinks website (www.climatelinks.org), which serves as a global knowledge portal for climate change and development practitioners. The website provides a central access point for climate-related resources, project information, and tools. This includes a suite of tools developed specifically to support climate risk screening and management in USAID strategy, project, and activity design. The tools provide guidance for completing the documentation (e.g., a climate risk screening table) required in the Mandatory References for ADS 201 mentioned in Section 5.1.

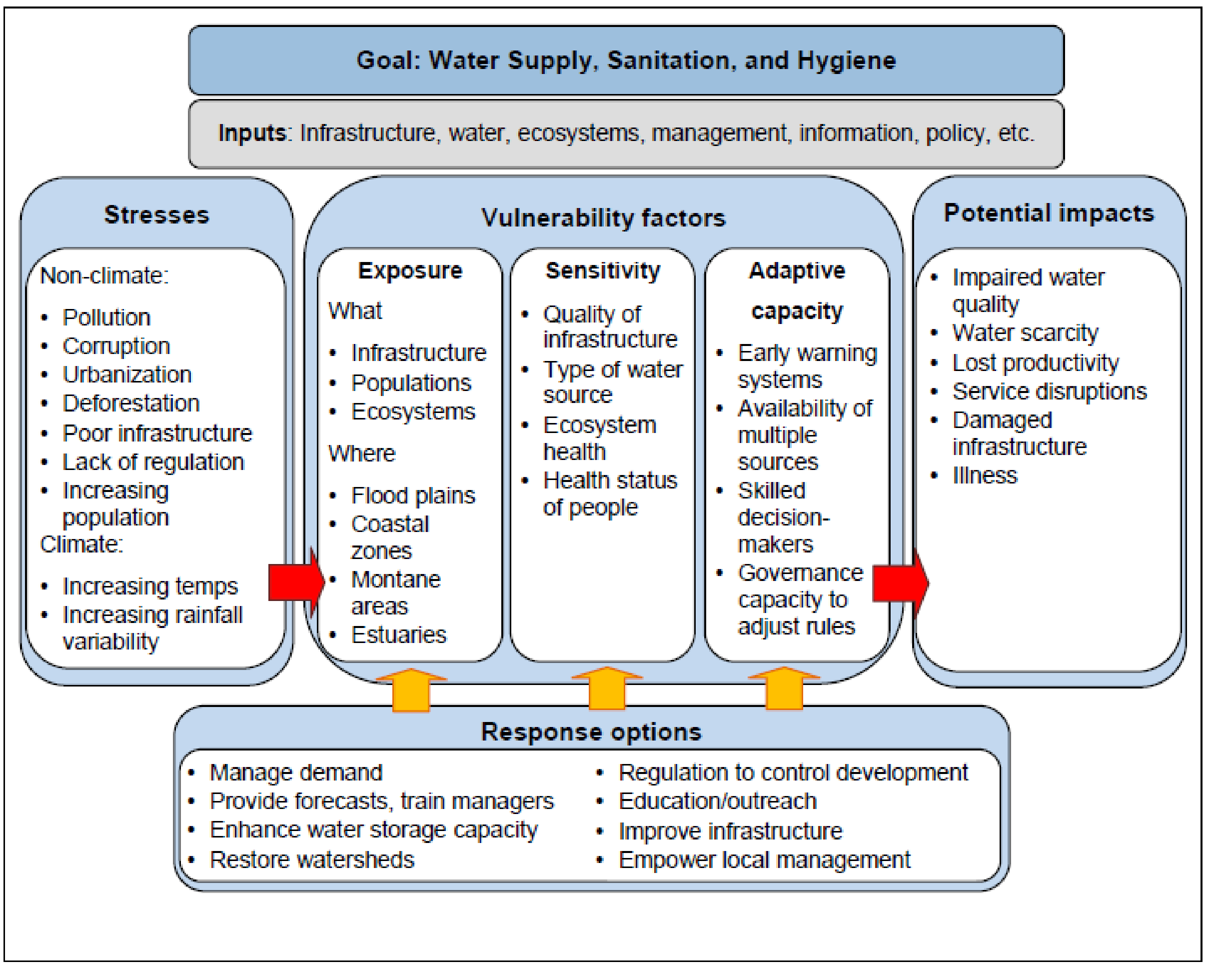
Several resources are available to assist with evaluating the potential impacts of climate change on WSS programs, including the following annexes to the USAID Climate Resilient Development Framework (2014):

- Climate Vulnerability Assessment Annex
- Climate Change and Water Annex
- Climate Change and Coastal Zones Annex

Another set of resources includes the following reports under the *Incorporating Climate Change Adaptation in Infrastructure Planning and Design* series: Sanitation; Flood Management; and Potable Water.

The assessment of WSS program vulnerability to climate change and other stresses can be summarized using the model framework shown in Figure 5 (see also the summary of USAID tools in Annex V.)

FIGURE 5: MODEL FRAMEWORK FOR CLIMATE VULNERABILITY ASSESSMENT (USAID GLOBAL CLIMATE CHANGE OFFICE, 2012)



6. PRACTICAL TOOLS

This section includes descriptions of practical tools for the design and implementation of water supply and sanitation activities. These tools include: (1) the drinking water quality toolkit, (2) the water quality assurance plan (WQAP), (3) sanitary survey guidance, and, (4) the WHO water safety plan (WSP) checklist.

6.1 USAID DRINKING WATER QUALITY MONITORING, PROTECTION, AND GOVERNANCE, AN INTERACTIVE TOOLKIT FOR ACTIVITY MANAGERS AND PRACTITIONERS

The toolkit is intended to help activity managers work toward USAID's goal of ensuring the availability of safe drinking water. The toolkit accomplishes this by defining the actions USAID should take to provide drinking water of a defined quality and adequate monitoring, protection, and governance. It provides tools for use in developing a project concept paper, a project appraisal document, or a statement of work for use in overseeing the performance of IPs. The toolkit is designed to act as a bridge between non-specialist activity managers and the specialist resources available within USAID. It does not replace the input of these specialists; rather it is meant to be a resource for activity managers so that they can take best advantage of the Agency's specialists.

This toolkit provides field-ready tools and references to assist activity managers in two ways:

1. Educating managers so Agency specialists can most efficiently provide specific technical input during planning and project development;
2. Proposing activities for USAID and IPs that support delivery of safe drinking water.

The toolkit supports the transition from the minimally acceptable level of "improved" drinking water supplies to USAID's goal of "safe" drinking water provision.

The toolkit, although in draft form at the date of publication of this guideline, will be posted on the GEMS website at this location: http://www.usaidgems.org/.

6.2 USAID WATER QUALITY ASSURANCE PLAN

The WQAP is one of the preferred methods for ensuring water quality in USAID projects involving the provision of drinking water. USAID recommends that new IEEs for drinking water provisioning activities require IPs to develop, implement, and report on a WQAP. The WQAP specifies how the IP will assure safe drinking water for the project and meet applicable host country water quality requirements given project implementation conditions.

The goal of the WQAP is to provide a framework by which the quality of the drinking water supply is sustainably ensured, by:

1. Identifying potential water quality issues;
2. Implementing, in advance, practical measures to prevent adverse impacts; and
3. Responding to these issues by implementing corrective measures in accordance with well-developed procedures.

Please see the GEMS website at http://www.usaidgems.org/wqap.htm for additional information.

6.3 SANITARY SURVEY GUIDANCE

Sanitary surveys are an important tool for ensuring water quality in potable water provisioning systems by identifying and remediating potential risks of contamination. They are often used in combination with water quality monitoring and other tools.

Sanitary surveys are often performed at the following critical times (WEDC, 2015):

- "when new water sources are being developed, to assess the water quality and any treatment needs;
- when comparing water sources for potential development;
- when contamination is suspected, to identify the likely cause;
- when there is an epidemic of a water-borne illness, to identify the likely cause;
- to interpret results from water quality analysis, to establish how the water became contaminated;
- as a routine exercise, to monitor sanitary conditions; or
- when there are significant changes (such as heavy rain or construction activity) which could affect water sources."

These surveys can be performed at three key locations within a water supply system; (1) at the source (e.g., borehole) or intake (e.g., river), (2) at the treatment system, and (3) at the distribution system (including at the water points).

The first task in the sanitary survey is for the inspector is to gather baseline information, which should include population data for the community and surrounding area, information on local water sources, summaries from past studies of data for water quality, identification of sources for which no water-quality data is available, summaries of health records on the incidence of illnesses associated with water quality and sanitary conditions, correlation between outbreaks of illnesses, and water source and quality, and any water-treatment methods being used (WEDC, 2015). This information will provide the inspector with a clearer understanding of the area prior to the site visit. Potential issues raised during the desk research phase will be noted as "sanitary risk factors."

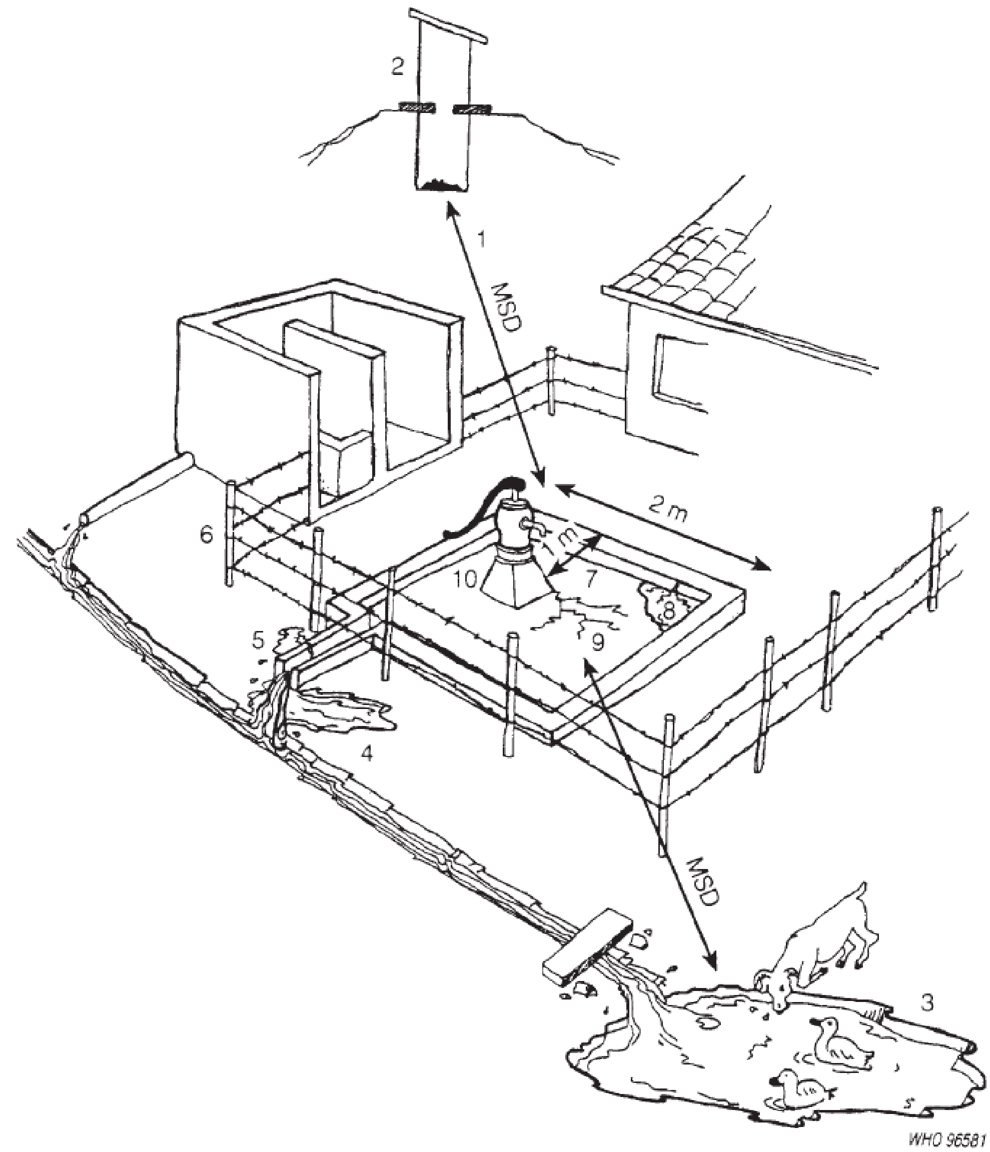
Following the collection of data, the inspector will undertake an in-person site-visit, which is an important step in the sanitary survey process. It will provide the inspector the ability to quickly observe any possible deficiencies. If there are problems, they will also be noted as sanitary risk factors.

At the conclusion of the site visit, the inspector will generate a sanitary survey report. The report should be a straightforward depiction of the water source and typically includes an illustration of the site (see Figure 6) as well as a checklist (see Table 10). The questions found on a sanitary survey checklist are formatted as yes/no questions to indicate whether a sanitary risk is possible, rather than attempting to determine the severity of the risk, which can be subjective. The sanitary risk factors highlighted in the final sanitary survey report are most likely to be eliminated if the report is shared with the appropriate parties to address the sanitary risk factors. Example forms for completing the report can be found at various sources including the WEDC sanitary survey guide (WEDC, 2015).

TABLE 10: SANITARY SURVEY CHECKLIST (UNICEF, 2013) (USAID, 2009)				
	QUESTION	YES	NO	REMARKS
1	Is there a latrine, waste dump or obviously contaminated surface water within 30 meters of the well?			
2	Is the latrine at higher elevation than the well?			
3	Is there any other source of pollution within 10 meters?			
4	Is there ponding/stagnating water around the well?			
5	Is the drainage channel broken/cracked or overflowing within 2 meters of the apron?			
6	Is there adequate fencing around the well (preventing animals from approaching the well)?			
7	Is the apron radius less than 1 meter around the well?			
8	Is there ponding/stagnating water at the apron?			
9	Are there any cracks in the well apron?			
10	Is the hand pump loose at the point of attachment?			
11	Is the well likely to be properly sealed (lined) within the first 3 meters below ground level? Is the above-ground well casing cracked or showing signs of fatigue?			
12	Is there is a cover on the well? Is it properly sealed so that no water can flow into the well?			
13	Is the hand pump broken?			
OTHER IMPORTANT ISSUES TO REVIEW:				
	Do nearby surface waters show evidence of being abnormally low for the season?			
	Are nearby surface waters overgrown with aquatic plants/algae?			
	Are children getting water-borne illnesses more frequently and/or more severely than in the past, and are these children drinking from a USAID-provided water source?			

TABLE 10: SANITARY SURVEY CHECKLIST (UNICEF, 2013) (USAID, 2009)				
	QUESTION	YES	NO	REMARKS
	Taste the water. Does it taste bad or salty? Are users complaining of a bad taste?			
	Look at and smell the water. Is it off-color? Is there sediment? Does it smell bad? Are users complaining of any these issues?			
	Are wells going dry (seasonally) at the inspection site or in the surrounding area that did not in the past?			
	Is water leaking from tanks/pipes/supply points?			

FIGURE 6: MAP OF POTENTIAL SOURCES OF CONTAMINATION (UNICEF, 2013)



Please see also the USAID Water Supply Visual Guide (December 2009) at
http://www.usaidgems.org/Documents/VisualFieldGuides/ENCAPVslFldGuide--WaterSupply_1Dec09.pdf

Sanitary Surveys for Large Water Supply Systems

In the United States, sanitary surveys are required under federal drinking water regulations every three to five years. As defined in the Code of Federal Regulations: "Sanitary survey means an onsite review of the water source, facilities, operation and maintenance of a public water system for the purpose of planning or evaluating the adequacy of such source, facilities, equipment, and operation and maintenance for producing and distributing safe drinking water." There are eight key water system areas that are evaluated by regulators during a sanitary survey, as listed in Table 11 (USEPA, 1999).

TABLE 11: EIGHT AREAS OF A SANITARY SURVEY

AREA	DESCRIPTION
SOURCE	Reviews a raw water source's features for the purpose of preventing potential contamination or water quality degradation.
TREATMENT	Identifies existing or potential sanitary risks by evaluating the design, operation, maintenance, and management of water treatment plants.
DISTRIBUTION SYSTEM	Reviews the design, operation, maintenance, and management of distribution systems to prevent contamination of the drinking water as it is delivered to customers.
FINISHED WATER STORAGE	Reviews the design and major components of finished water storage facilities in order to prevent water quality problems from arising during storage.
PUMPS	Reviews the design and use of water supply pumping facilities in order to determine overall reliability and identify potential sanitary risks.
MONITORING & REPORTING	Determines water system conformance with regulatory requirements through the review of water quality monitoring plans and system records; verifies data reported to the regulatory agency are consistent with system records.
MANAGEMENT & OPERATION	Evaluates water system performance in terms of management and operation, including its long-term viability in meeting water quality goals.
OPERATOR COMPLIANCE	Ensures water systems have qualified professionals that meet all applicable operator certification requirements.

6.4 WHO WATER SAFETY PLAN CHECKLIST

The WSP is designed to ensure the safety of drinking water by preventing contamination of source waters; treating the water to reduce or remove contamination to the extent possible; and preventing recontamination during storage, distribution, and handling of drinking water (WHO, 2005). Adoption of a water safety plan helps to provide a systematic assessment and prioritization of hazards, minimize the chance of failure due to lapse of management, and provides contingency plans to respond to system failures or unforeseeable hazardous events. The development and implementation of a WSP includes three main components: system assessment and design; operational monitoring; and management plans, documentation, and communication. Each component has series of steps, which are shown in Table 12.

TABLE 12: STEPS IN THE DEVELOPMENT OF A WATER SAFETY PLAN

COMPONENT	STEPS	DESCRIPTION
	Assemble team	For large supplies, assemble a multi-disciplinary team including managers, engineers, water quality controllers, and technical staff.
System Assessment	Document water supply	Fully describe the water supply from the source to the point of supply.
	Conduct hazard analysis	Identify all potential hazards, their sources, possible hazardous events and an assessment of the risk presented by each.
	Identify control measures (barriers)	Identify the hazardous events that can cause contamination of water, and define control measures, the activities that can mitigate the risks from those events, both at the point of contamination and downstream.
Operational Monitoring	Define operational limits	For each control measure define operational limit and criteria that indicate whether the control measure is functioning well or exceeds the operational limit and needs a corrective action.
	Establish monitoring	Monitor, conduct series of observations or measurements of operational limits, to assess whether the system operates properly.
Management & Communication	Establish corrective actions and incident response	Define corrective actions, the action to be taken when monitoring indicates a deviation from the operational limit.
	Establish emergency management	For unforeseen events, establish an emergency response plan that includes a protocol for situation assessment and the description of situations that require activation of the emergency response plan.
	Establish record keeping	Keep all records and documents from water safety plan set-up, implementation process, monitoring, corrective actions taken, etc., to demonstrate adherence to the plan and to improve preparedness and planning for future events.
	Validation and verification	Obtain evidence that the elements of the water safety plan are working as expected.

7. RESOURCES

SANITATION

- ARGOSS. (2001). *Guidelines for Assessing the Risk to Groundwater from On-Site Sanitation.* London: NRC, British Geological Survey Commissioned Report, CR/01/142. doi:http://www.susana.org/en/resources/library/details/1926

  The manual helps those planning water supply and sanitation schemes to select design options that minimize the risk of contamination of the water supply. It assesses the risk of microbiological contamination of groundwater supplies via aquifer pathways. The document emphasizes the importance of follow-up monitoring as an integral part of the design for water supply and sanitation scheme.

- Clasen, T. F. (2009). Scaling Up Household Water Treatment Among Low-Income Populations. *Public Health and Environment.*

  This document discusses effective household water treatment and safe storage (HWTS) techniques. It reviews the development and evolution of leading household water treatment technologies, identifies their main constraints, and recommends solutions to overcome those constraints.

- Franceys, R. J. (1992). *A Guide to the Development of On-Site Sanitation.* Retrieved from the World Health Organization (WHO).

  This document provides technical guidance about the design, construction, operation, and maintenance of major types of on-site sanitation facilities including pit latrines, aqua privies, and septic tanks. The document also describes the planning and development processes and the financial and institutional factors that need to be considered.

- Moe, C., & Gangarosa, E. J. (2009). Improving water and sanitation access in developing countries: progress and challenges. *Achieving Water and Sanitation Services for Health in Developing Countries.*

  Approximately 17 percent of the world's population, are without improved water, and approximately 41 percent lives without improved sanitation. Millennium Development Goal Number Seven, outlined by the United Nations, helps to reduce the proportion of those without improved water and sanitation. This document discusses the needs for evaluation, accountability, sustainability and capacity of water and sanitation projects in developing countries. It emphasizes on the importance of monitoring and evaluation of the project from inception through implementation, and technical, financial, and environmental sustainability of the project.

- Strande, L., Ronteltap, M. & Brdjanovic, D. (Eds). (2014). Fecal sludge management: Systems approach for implementation and operation. London, UK: IWA Publishing. Retrieved from www.sandec.ch/fsm_book

This on-line book provides detailed guidance on fecal sludge management. It promotes an integrated systems approach to fecal sludge management by incorporating technology, management and planning. The book addresses the planning and organization of the entire fecal sludge management service chain, from the collection and transport of sludge and treatment options to the final end use or disposal of treated sludge.

- Reed, B. (2014). *Latrine Pit Design.* Retrieved from Water, Engineering and Development Centre (WEDC): http://wedc.lboro.ac.uk/resources/booklets/G023-Latrine-pit-design-on-line.pdf

  This guide examines some of the factors that need to be considered when planning and designing a latrine pit (twin pits), including the location of a latrine, its shape, volume, liquid capacity, and life.

- UNHCR WASH Manual, Wiki site, http://www.ben-harvey.org/UNHCR/WASH-Manual/Wiki/index.php/Chapter_5#ANNEX:_List_of_key_excreta_management_references

  This chapter on excreta management from the draft UNHCR WASH manual provides guidance on the selection and design of many excreta disposal technologies. Its annexes include a comprehensive list of key references (Annex 1), and UNHCR tools for rapid assessment of toilet infrastructure (Annex 2), for comprehensive assessment of excreta management (Annex 3) and for interviews and focus groups (Annex 4).

- USAID. (2016). *Sanitation Implementation Brief – July 2016.* Retrieved from USAID Water and Development Strategy: https://www.usaid.gov/sites/default/files/documents/1865/Sanitation_Implementation_Brief_72516.pdf

- Warner, D. B., & Abate, C. G. (2005). Guidelines for the Development of Small-Scale Rural Water Supply and Sanitation in East Africa: A Policy and Planning Framework for Activities Funded under the Title II FFP Program. Retrieved 2016, from CRS tools and research: http://www.crs.org/sites/default/files/tools-research/guidelines-small-scale-rural-water-sanitation-east-africa.pdf

  These guidelines are the result of the combined efforts of many individuals, both within Catholic Relief Services (CRS) and other organizations. This document contains general guidelines for the planning and implementation of small-scale water supply and sanitation activities in rural East Africa, which include both projects funded under the USAID Title II (Food for Peace) Program and projects funded by other donors. It is intended to help CRS and its partners in improving the effectiveness, and long-term sustainability of water and sanitation activities in the rural, and often food-insecure, areas of East Africa, as well as in improving environmental protection.

- World Bank. (2016). What's so hard about improving access to water and sanitation?

  This Evidence to Policy note describes the importance of water and sanitation programs. While development groups and governments know that clean water matters, they do not know how to ensure everyone has it. A World Bank research team analyzed more than 130 water, sanitation, and hygiene evaluations to understand what in needed for successful programs and what still needs to be learned. The researchers found that improving sanitation and handwashing reduces diarrhea. However, more needs to be done to understand how to expand services to large populations and how to change behaviors, such as getting people to add chlorine to drinking water or to wash their hands.

WATER SUPPLY

- Alley, W. M., Reilly, T. E., & Franke, O. L. (1999). *Sustainability of Ground-Water Resources.* U.S. Geological Survey. Retrieved from https://pubs.usgs.gov/circ/circ1186/

  This document illustrates the hydrologic, geologic, and ecological concepts that must be considered to assure the wise and sustainable use of precious ground-water resources. It describes groundwater development, sustainability, and water budgets. The document also explains effects of groundwater development on groundwater flow to and from surface water bodies, and on groundwater storage. The sustainability of groundwater resources is a function of many factors, including decreases in groundwater storage, reductions in streamflow and lake levels, loss of wetland and riparian ecosystems, land subsidence, saltwater intrusion, and changes in groundwater quality. Each groundwater system is unique and its sustainability should be evaluated based on the nature of water issues faced, including social, economic, and legal constraints.

- Carter, R., Chilton, J., Danert, K., & Olschewski, A. (2014). *Siting of Drilled Water Wells – A Guide for Project Managers.* Retrieved from Rural Water Supply Network: http://www.rural-water-supply.net/en/sustainable-groundwater-management/code-of-practice

  This document provides a step-by-step guide on the siting of drilled water wells and explains the items to be considered when selecting a suitable site for drilling.

- Hunter, P. R., MacDonald, A. M., & Carter, R. C. (2010). Water Supply and Health. *PLoS Med*.

  This article describes the importance of a safe, reliable, affordable, and easily accessible water supply, and presents the challenges and constraints involved in accessing adequate water supply. Slow progress toward full water supply coverage at a national level can be related to national GDP, government effectiveness, or shortages of water, and among them a low GDP is a major challenge in efforts to improve water supplies.

- Ponce, V. M. (2006, March). *Groundwater Utilization and Sustainability.* (V. M. Ponce, Ed.) Retrieved September 2016, from San Diego State University (SDSU): http://groundwater.sdsu.edu/

  The sustainability of groundwater utilization must be assessed from an interdisciplinary perspective, where hydrology, ecology, geomorphology, and climatology play an important role, and to assure sustainability, the impact of groundwater utilization on these aspects should be kept minimal. This document describes groundwater systems, groundwater utilization and depletion, and the importance of sustainable groundwater use. To assure groundwater sustainability, the authors suggest the use of deep percolation water as the primary source of groundwater, and shallow percolation water as the secondary source.

- USAID. (2014b). *Water and Development Strategy Implementation Field Guide.* Retrieved from https://www.usaid.gov/sites/default/files/documents/1865/Strategy_Implementation_Guide_web.pdf

- WHO (2005). *Water Safety Plans. Managing drinking-water quality from catchment.* Geneva: Water, Sanitation and Health Protection and the Human Environment World Health Organization. Retrieved from http://www.who.int/water_sanitation_health/dwq/wsp170805.pdf

  A water safety plan consists of system assessment and design, operational monitoring, and management plans (including documentation and communication). This document describes the steps required to set up and implement a water safety plan, depending on the size of the system or its location.

- Zekster, I. S., & Everett, L. G. (2004). Groundwater Resources of the World and Their Use. *UNESCO IHP-VI, Series on Groundwater No. 6*.

  This book explains the crucial role played by groundwater to the ecosystem. Chapters are dedicated to specific regions of the world as well as groundwater's role as a public water supply, modern concepts of ground water resources, scientific principles of regional assessment, and mineral and thermal power.

WATER DISTRIBUTION

- AWWA. (2014). *AWWA Free Water Audit Software.* Retrieved from American Water Works Association: http://www.awwa.org/home/awwa-news-details/articleid/2641/awwa-free-water-audit-software-version-5-0-now-available.aspx

  This new AWWA software is a free spreadsheet-based audit tool designed to quantify and track water losses associated with water distribution systems and to identify areas for improved efficiency and cost recovery.

- Dighade, R., Kadu, M., & Pande, A. (2014, June). Challenges in Water Loss Management of Water Distribution Systems in Developing Countries. *International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 6,* Retrieved from http://www.ijirset.com/upload/2014/june/85_Challenges.pdf

  One of the major issues affecting water utilities in the developing world is the considerable difference between the amount of water put into the distribution system and the amount of water billed to consumers. This paper describes the challenges in water loss management of water distribution systems in developing countries and provides solutions for the reduction and control of water loss.

- Mutikanga, H. E., Sharma, S., & Vairavamoorthy, K. (2009, December). Water Loss Management in Developing Countries: Challenges and Prospects. *Journal – American Water Works Association, 101, Number 12*, 57-68. Retrieved from Journal – American Water Works Association: http://www.awwa.org/publications/journal-awwa/abstract/articleid/22458.aspx

  The AWWA/IWA water audit/water balance tool is the most widely used method for measuring water loss from distribution systems. The water district in Kampala, Uganda, is provided as an example where it is possible to assess water loss and develop appropriate strategies and tools to manage water losses in developing countries.

WATER QUALITY MONITORING

- APHA. (2012, September 10). *Standard Methods for the Examination of Water and Wastewater* (22nd Edition ed.). (R. B. E.W. Rice, Ed.) American Public Health Association. American Water Works Association, Water Environment Federation. Retrieved from Standard Methods for the Examination of Water and Wastewater: https://www.standardmethods.org/

  This comprehensive reference describes the detailed protocols for water and wastewater analysis techniques. Standard Methods is a joint publication of the American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF).

- ISO. (2016, September 10). *ISO/TC 147 – Water quality*. Retrieved September 10, 2016, from ISO Standards Catalogue: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_tc_browse.htm?commid=52834

  This reference catalogues the water quality standards issued by the International Organization for Standards (ISO) (ISO/TC 147), including the definition of terms, sampling of waters, measurement, and reporting of water characteristics.

- UNICEF. (2008). *UNICEF Handbook on Water Quality*. New York, NY: United Nations Children's Fund (UNICEF).

  This handbook is a comprehensive tool that introduces all aspects of water quality, focusing on those that are relevant to professionals working in developing countries. It covers the effects of poor water quality, quality monitoring, the protection of water supplies, methods for improving water quality, and building awareness and capacity related to water quality. It also provides an extensive set of links to key water quality references and resources.

- USEPA. (2009). *National Primary Drinking Water Regulations.* Retrieved from USEPA: https://www.epa.gov/sites/production/files/2016-06/documents/npwdr_complete_table.pdf

  This document provides the US national primary and secondary drinking water regulations that apply to public water systems.

- USEPA. (2016). *Aquatic Life Ambient Water Quality Criteria*. Retrieved from Basic Information on Water Quality Criteria: https://www.epa.gov/wqc/aquatic-life-ambient-water-quality-criteria

  This link provides an example of ambient water quality guidelines, including criteria and methods, developed by the US EPA. The EPA bases these aquatic life criteria on how much of a chemical can be present in surface water before it is likely to harm plant and animal life. The EPA designs aquatic life criteria to protect both freshwater and saltwater organisms from short-term and long-term exposure.

INTEGRATED WATER RESOURCE MANAGEMENT

- The United Nations World Water Assessment Programme. (2009). *Introduction to the Integrated Water Resource Management (IWRM) Guidelines at the River Basin Level.* Retrieved from UNESCO: http://unesdoc.unesco.org/images/0018/001850/185074e.pdf

This document provides the necessary information for practitioners to implement IWRM. It describes the fundamental concepts of IWRM as well as insights into the perspectives of various stakeholders on water issues, keys to overcoming problems, and good examples where such keys for success were applied.

- Global Water Partnership. (2016a). Case study: Cameroon: Challenges in Kumbo community to improve water supply management (#364). Retrieved from Global Water Partnership: http://www.gwp.org/en/learn/KNOWLEDGE_RESOURCES/Case_Studies/Africa/Cameroon-Challenges-in-Kumbo-community-to-improve-water-supply-management-364/

    This case study describes an example of applying IWRM, in Kumbo, Cameroon, to improve water supply management. Ownership of the Kumbo water supply had been contested over many years. Management of the supply was transferred to the Kumbo Urban Council, which resulted in the establishment of an inclusive water governance structure. This case study shows how take-over of management of the water system by local communities can improve deteriorating drinking water service delivery. It also shows the importance of involving management in resolving water catchment conflicts and in improving efficiency of delivery.

- Global Water Partnership. (2016b). *Case study: Jamaica: Implementing environmental management systems for sustainable tourism (#153)*. Retrieved from Global Water Partnership: http://www.gwp.org/en/learn/KNOWLEDGE_RESOURCES/Case_Studies/Americas--Caribbean/Jamaica-Implementing-environmental-management-systems-for-sustainable-tourism-153/

    This case study, applying IWRM in Jamaica, describes implementation of environmental management systems for sustainable tourism. Tourism has placed great pressure on the natural environment of Jamaica. Through a USAID funded project, action was taken to increase water use efficiency and improve environmental management. The case study shows how environmental management can help to reduce demand for potable water, promote water recycling and greywater reuse, and improve proper handling and treatment of wastewater.

ECOSYSTEM SERVICES

- Dissanayake, P., Weragala, N., & Smakhtin, V. (2010). Environmental Flow Assessment: Recent Examples from Sri Lanka. In A. Evans, & K. Jinapala (Ed.), *Proceedings of the National Conference on Water, Food Security and Climate Change in Sri Lanka*, *Vol. 2*. Colombo, Sri Lanka. Retrieved from International Water Management Institute: http://publications.iwmi.org/pdf/H042856.pdf

    This document describes the importance of environmental flow (EF) assessment for the protection of aquatic ecosystems. It provides two recent studies which focus on EF assessment (EFA) and valuation of EF benefits in the Walawe and Menik Ganga river basins located in a semi-arid zone of southern Sri Lanka.

- Donovan, S., Goldfuss, C., & Holdren, J. (2015). Memorandum for Executive Departments and Agencies. Incorporating Ecosystem Services into Federal Decision Making. *M-16-01*. Executive Office of the President of the United States.

    The memorandum (aka the Ecosystem Directive) directs agencies to develop and institutionalize policies to promote consideration of ecosystem services.

- Dyson, M. B. (2003). *Flow. The Essentials of Environmental Flows.* Gland, Switzerland and Cambridge, UK: IUCN.

  This document provides practical guidance for the implementation of the environmental flows in the river basins of the world. It explains how to assess flow requirements, change the legal and financial framework, and involve stakeholders in negotiations to reduce poverty, maintain ecosystems, and share water equitably.

- Poff, N. L., & Zimmerman, J. K. (2010). Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows. *Freshwater Biology, 55*, 194-205.

  In this study, 165 published papers on aquatic or riparian responses to flow regime alteration were reviewed to develop quantitative relationships between various examples of flow alteration and ecological responses.

- Richter, B. D., Mathews, R., Harrison, D. L., & Wigington, R. (2003). Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity. *Ecological Applications, 13(1)*, 206–224. Retrieved 2016, from conservationgateway.org: https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/Documents/ED_freshwater_ESWM_Eco_Applications.pdf

  This paper presents a framework for developing an ecologically sustainable water management program, which includes: (1) developing initial numerical estimates of key aspects of river flow necessary to sustain native species and natural ecosystem functions; (2) accounting for human uses of water; (3) assessing incompatibilities between human and ecosystem needs; (4) collaboratively searching for solutions to resolve incompatibilities; (5) conducting water management experiments; and (6) designing and implementing an adaptive management program.

- UNEP. (2009). *Water Security and Ecosystem Services: The Critical Connection.* United Nations Environmental Program, Ecosystem Management Program. Nairobi: UNEP.

  This report describes the direct link between sustainable development and ecosystem services. It provides several case studies from the Aral Sea (Central Asia), Chilika Lake (India), Lake Hornborgasjön (Sweden), Delavan Lake (USA), and the Lower Danube River and Danube Delta (Southeast Europe) to present lessons learned on habitat rehabilitation, watershed management, pollution control, and environmental flows.

- USACE/TNC/ICPRB. (2013). *Middle Potomac River Watershed Assessment: Potomac River Sustainable Flow and Water Resources Analysis. Final Report.* Baltimore: U.S. Army Corps of Engineers (USACE), The Nature Conservancy (TNC), Interstate Commission on the Potomac River Basin (ICPRB).

  This article describes the USACE, TNC, and ICPRB project to quantify environmentally sustainable flows for the Potomac watershed that sustain healthy river ecosystems while humans derive services from them. The goal of the assessment was to identify key ecological needs related to stream flow, and the impacts of current and future human activities and potential effects of climate change on the Potomac watershed's hydrology. The article provides practical tools for completing such an assessment.

- World Resources Institute. (2005). *Ecosystems and Human Well-being: Synthesis*. Retrieved September 11, 2016, from Millennium Ecosystem Assessment: http://www.millenniumassessment.org/documents/document.356.aspx.pdf

  This assessment focuses on the linkages between ecosystems and human well-being. It examines how changes in ecosystem services influence human well-being. The assessment synthesizes information from the scientific literature and relevant peer-reviewed datasets and models. It incorporates knowledge held by the private sector, practitioners, local communities, and indigenous peoples.

CLIMATE CHANGE

- IPCC. (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, 210.

  This technical paper describes the impact of climate change on freshwater resources. Seawater level rise would impact freshwater in coastal areas and beyond. Climate, freshwater, and socio-economic systems are interconnected, and it is important to understand the relationship between climate change and freshwater resources.

- USAID Global Climate Change Office. (2012). *Guidance Brief: Integrating Climate Resilience into Water, Sanitation, and Hygiene (WASH) Programs.*

  This document describes the importance of considering climate variability and change on the design of WASH initiatives.

- USAID. (2014c). Climate Change and Water: An Annex to the USAID Climate-Resilient Development Framework. USAID.

  This annex provides a comprehensive summary of climate variability and change and the challenges it poses for freshwater resources. It discusses actions that can be adopted to reduce water resources vulnerability and increase system resilience.

- USAID. (2017a). *Climate Change in USAID Country/Regional Strategies: A Mandatory Reference for ADS Chapter 201*. Retrieved from https://www.usaid.gov/sites/default/files/documents/1876/201mat.pdf

  Effective October 1, 2015, climate risk management is required as part of the development of all new country/regional USAID strategies. This document describes the process through which climate change risks should be assessed and addressed as well as considerations for climate change mitigation in USAID mission/regional strategies. This is a companion document to USAID (2017b).

- USAID. (2017b). *Climate Risk Management for USAID Projects and Activities: A Mandatory Reference for ADS Chapter 201*. Retrieved from https://www.usaid.gov/sites/default/files/documents/1868/201mal_042817.pdf

  This document provides guidance for climate risk management on USAID projects and activities. USAID design teams are required to identify relevant climate risks and then qualitatively assess

them as low, moderate, or high, unless the project or activity falls under a development objective or intermediate result.

OTHER RESOURCES

- Pacific Institute. (2012, March 15). *Multiple-Use Water Services (MUS): Recommendations for a Robust and Sustainable Approach*. (M. P.-S. Veena Srinivasan, Editor) Retrieved August 2016, from Pacific Institute: http://pacinst.org/app/uploads/2013/02/mus-full-report.pdf

  This report describes the Multiple Use Water Services (MUS) concept. MUS is an approach to develop multiple community sources to meet rural and peri-urban water needs for a variety of purposes, ranging from drinking and sanitation to growing food and other productive activities.

- VIRGINIA SWRP – DRAFT, Virginia DEQ *(2015)*. Retrieved from Assessing the Long Term Sustainability of Water – Chapter 5: http://www.deq.virginia.gov/Portals/0/DEQ/Water/SWRP/Ch%205%20Assessing%20the%20Long%20Term%20Sustainability%20of%20Water%20Resources.pdf

  This document the expected cumulative impacts of future water demands on stream flows and long-term sustainability of water resources from Virginia (Eastern USA). Four flow indicators were selected in this study to describe risk to critical conditions that reflect impacts on infrastructure, downstream uses, aquatic life, and assimilative capacity due to increased water use. Cumulative impact modeling was conducted to predict the approximate location, direction, and magnitude of impacts to the water system from increasing water demand and water supply system management actions.

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11. ANNEXES

ANNEX I: GOVERNING POLICY

SENATOR PAUL SIMON WATER FOR THE WORLD ACT OF 2014

This act establishes requirements to ensure that water, sanitation, and hygiene projects carried out under the Foreign Assistance Act of 1961 and the Senator Paul Simon Water for the Poor Act of 2005 achieve their full impact. It states that the initial USAID Water and Development Strategy is a significant accomplishment that improves USAID's capacity to provide sustainable and effective water, sanitation, and hygiene assistance, and that the Secretary of State, through the Special Advisor for Water Resources, should develop and oversee the Global Water Resources Strategy relating to U.S. foreign policy water objectives. It amends the Foreign Assistance Act of 1961 to include the provision of safe hygiene among the goals of the program. It directs the Administrator of USAID to serve concurrently as the USAID Global Water Coordinator and to oversee WSS (also called WASH) programs, lead implementation and revision of USAID's portion of the Global Water and Development Strategy, and expand USAID's program capacity in high priority countries (H.R. 2901, 2014).

USAID'S CLIMATE CHANGE AND DEVELOPMENT STRATEGY (2012-2016)

USAID'S 2012-2016 Climate Change and Development Strategy sought to equip developing countries for the transition to climate-resilient, low-emission economic growth. The Plan can be summarized as three objectives: (1) accelerate the transition to low-emission development through investments in clean energy and sustainable landscapes; (2) increase resilience of people, places, and livelihoods through investments in adaptation; and 3) strengthen development outcomes by integrating climate change in Agency programming, learning, policy dialogues, and operations.

USAID has become more conscientious of how human activities affect greenhouse gas emissions and the climate change impacts that occur as a result. The strategy prioritized development planning and programming for sustainable economic growth that is not only resilient to climate change, but also reduces contributions to greenhouse gas emissions. Implementing practical adaptation responses to threats that occur as a result of climate change is an important element of risk mitigation, both to ensure the livelihoods and health of USAID's beneficiaries and the sustainability of past, current, and future USAID development investments. Risk mitigation is crucial to WSS efforts, as effective planning of water and sanitation requires assessing and responding to the potential impacts of climate change on water flows and rainfall in addition to other factors such as population growth, pollution, and conflict. Situations that should be assessed for WSS projects include risks from extreme weather events, saltwater intrusion into drinking supplies, and a decrease in water supplies that draw from melting or climate-sensitive storage systems (USAID, 2012).

USAID WATER AND DEVELOPMENT STRATEGY (2013-2018) AND USAID WATER AND DEVELOPMENT STRATEGY AND IMPLEMENTATION FIELD GUIDE (2013-2018)

This strategy and field guide responds to USAID's need to focus their investments and priority on the effects of water and watershed management on energy, climate change, biodiversity, ecosystems, and economic growth. It supports the approaches of IWRM as well as the use of relevant technologies to achieve said objectives. The strategy emphasizes the importance of proper sanitation for human health and the environment. It also raises important issues like the impact of climate change on water resources and water as a potential source of conflict.

The operational principles of the strategy define how water issues will be incorporated into USAID programming, which is crucial to improving health and food security. These include supporting host country ownership, integrating sustainability from the first stages of project design, applying integrated approaches to development, leveraging science and technology, promoting gender equality, evaluating impacts to achieve best practices, and attaining resilience (USAID, 2013).

The overarching goal of the strategy is achieved through two strategic objectives, SO1, and SO2:

> **SO1 – Improve health outcomes through the provision of sustainable safe water, sanitation, and hygiene (WASH)**
>
> The main objectives of WASH are to increase first-time and improved access to sustainable water supply as well as sustainable sanitation, and increase utilization of preferred hygiene practices. SO1's target is to provide a minimum of 10 million people with sustainable access to improved water supply and 6 million people with sustainable access to improved sanitation over the five-year span of the strategy.
>
> **SO2 – Manage water in agriculture sustainably and more productively to enhance food security**
>
> The main objective of Water for Food Security is to manage water for agriculture more sustainably by improving the efficiency of food production in rainfed and irrigated agricultural systems. Success of SO2 can be measured by analyzing the number of water resources sustainability assessments undertaken, hectares under new or improved irrigation or drainage services as a result of USG assistance, and the number of farmers who have applied improved technologies or management practices as a result of USG assistance (USAID, 2014b).

To achieve these objectives, the strategy stipulates investments in longer-term monitoring and evaluation of its water activities, emphasizes integrated water resource management in the development field, and increases attention to sanitation in WSS programs.

OCTOBER 7, 2015, MEMORANDUM ON "INCORPORATING ECOSYSTEM SERVICES INTO FEDERAL DECISION MAKING" (DRAFT POLICY)

The Obama Administration released a new memorandum in 2015 which urges federal agencies to consider the value of ecosystem services and natural infrastructure when making federal decisions in planning, investment, and regulatory contexts. The memorandum also institutes a process for the federal government to create more concrete guidance on incorporating ecosystem service assessments into projects to ensure the sustainable use of resources, maintain the value of the country's landscapes, and reduce the chance of unprecedented consequences (Zaidi, Dickinson, & Male, 2015).The law strives to implement practices such as moderating the quantity of and ensuring the quality of water, enhancing climate resilience, and providing wildlife habitat for fisheries.

EXECUTIVE ORDER ON CLIMATE-RESILIENT INTERNATIONAL DEVELOPMENT

The Executive Order for Climate-Resilient International Development strives to ensure security and economic growth as well as the sustainability of U.S. development work in less-developed countries. It calls for (1) the reduction of greenhouse gas emissions to prevent the consequences of climate change;

(2) incorporation of climate resilience into international development decision making; (3) proliferation of data, tools, and information on climate-resilient international development; (4) establishment of a working group on climate-resilient international development; (5) reporting of progress; (6) proliferation of climate change mitigation programs.

The order requires agencies engaged in international development to collaborate with other countries to identify and evaluate climate change-related risks when planning projects and investments, adapting their strategies based on evaluation results, and monitoring progress. These agencies should also incorporate climate risks into all planning, investments, and projects like WSS and track their progress in relation to climate-conscious efforts (The White House, 2014).

ANNEX II: SUSTAINABLE MANAGEMENT OF WATER SUPPLY ACTIVITIES

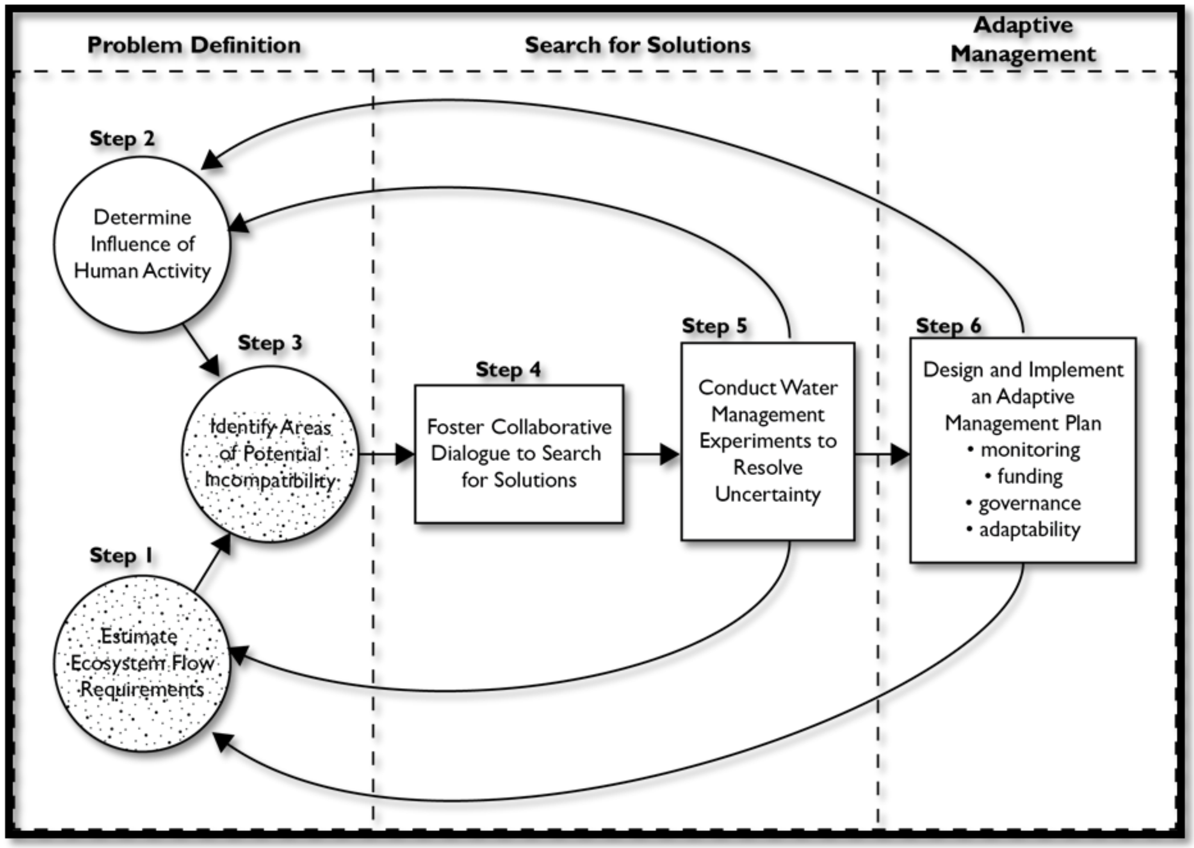
The management of water supply interventions for long term sustainability is described in this annex, and includes brief introductions to:

1) Ecologically sustainable water management (ESWM) approach,
2) Sustainable groundwater and surface water withdrawal assessment,
3) Monitoring of water withdrawals, and
4) Water conservation in water distribution systems.

ECOLOGICALLY SUSTAINABLE WATER MANAGEMENT

The ESWM framework draws upon the principles of IWRM and similarly seeks to balance water needs with available water resources, existing uses, and environmental flows (Richter, Mathews, Harrison, & Wigington, 2003). As shown in Figure 7, once existing uses (e.g., ecosystem and human uses) are defined (Steps 1 and 2), the ESWM process requires stakeholders to work together to define and face potential conflicts immediately (Step 3). Stakeholders then work collaboratively to define tradeoffs and search for solutions to potential conflicts (Step 4). The ESWM approach provides the flexibility to return to Steps 1 and 2 to collect more information on the existing conditions during the piloting of appropriate water management strategies (Step 5), and during the design of an adaptive management strategy (Step 6).

FIGURE 7: SUSTAINABLE WATER RESOURCES MANAGEMENT FRAMEWORK (RICHTER, MATHEWS, HARRISON, & WIGINGTON, 2003)



WATER SUPPLY – WITHDRAWAL

Sustainable water withdrawals can be defined as water withdrawals for which the volume withdrawn is based on the available water supply and environmental flow requirements (Giordano, 2015). This definition implies two phases in determining sustainable withdrawal: (1) initial assessment of the withdrawal; and (2) measurement to confirm that the withdrawal, is in fact, sustainable.

The sustainable yield may be balanced with expected demand from the community. In some cases, a preliminary rough estimate of demand and yield can be made using guidance illustrated in Table 13 (Carter, Chilton, Danert, & Olschewski, 2014).

TABLE 13: WATER SUPPLY AND DEMAND			
WATER USE	SCALE	APPROXIMATE DEMAND [M^3/DAY]	AVERAGE PUMP RATE [L/SEC]*
Rural water supply	Single well for 100-300 persons	2-6	0.1-0.3
Small town water supply	Single well for 2,000-10,000 persons	500-2,000	2-10
Irrigation scheme	100 hectares	5,000	140
Assumptions for consumption: Rural water supply – 20 liters/person/day Small town water supply – 40 liters/person/day Irrigation scheme – 50 m^3/hectare *Assumes that water is pumped for 10 hours/day			

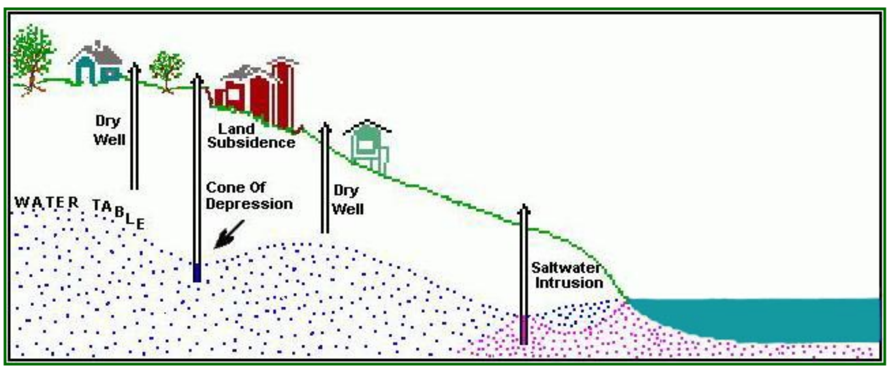
ASSESSMENT OF SUSTAINABLE GROUNDWATER WITHDRAWAL

Factors that influence the sustainability of groundwater withdrawals include the sources' vulnerability to pollution from the land surface, its susceptibility to permanent degradation from excessive exploitation, and its ability to renew storage reserves when factoring in forecasted climate change impacts (Bjorklund, et al., 2009) (Zekster & Everett, 2004).

Unsustainable groundwater withdrawal can have significant impacts on surface waters and aquatic, riparian, and terrestrial ecosystems. Groundwater depletion can result in several impacts to the ecosystem, including the following:

- Loss of base flow in nearby surface water (e.g., streams or lakes) and subsequent loss of wetland and riparian vegetation, loss of wildlife habitat and reduction in biodiversity (Ponce, 2006);
- Increased vulnerability to droughts;
- Drying up of wells;
- Saltwater intrusion in coastal areas; and
- Land subsidence (Figure 8).

FIGURE 8: IMPACTS FROM GROUNDWATER DEPLETION (ALLEY, REILLY, & FRANKE, 1999)



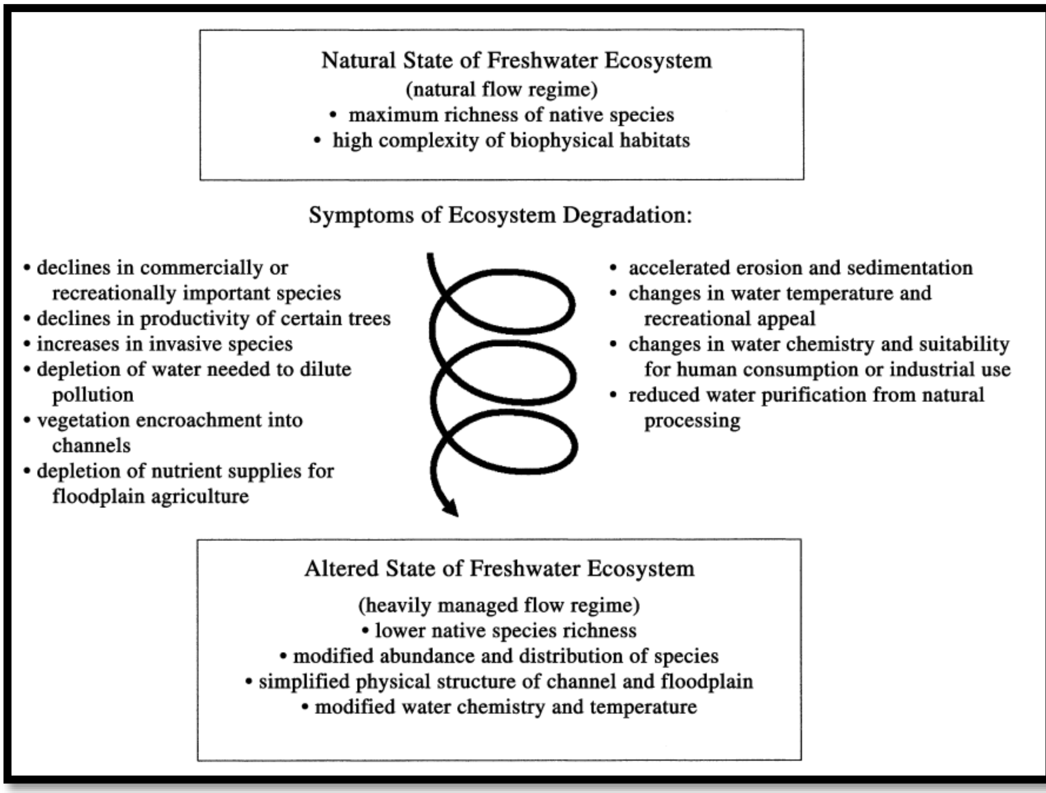
To ensure the sustainability of groundwater withdrawal, detailed studies of the hydrology and hydrogeology may be performed to determine baseline groundwater recharge rates. The hydrogeological study would include a review of historical data from wells in the area to assess water quality, well yield, seasonal fluctuations, depth to the water table, and the local geology (via well drilling logs). At a minimum, a survey of nearby wells may be performed to determine typical yields and water quality, depths and which aquifer to tap, and prior drilling success rates (World Bank, 2012).

For shallow groundwater wells, baseline studies of nearby surface water may be performed to confirm that minimal impacts to base flow are occurring. For deep borehole wells, a reference estimate of sustainable yields can be produced based on calculation of recharge from global percolation rates, if local baseline studies are not available (Ponce, 2006). Sustainable yield can also be calculated based on the results of multiple pumping tests at several drilled wells. Baseline and long-term studies of hydrology and hydro-ecology are necessary to monitor the impacts of groundwater withdrawals on local freshwater, ecosystems, and geomorphology (Ponce, 2006).

ASSESSMENT OF SUSTAINABLE SURFACE WATER WITHDRAWAL

Unsustainable withdrawal from rivers or other surface waters can modify the natural flow regime to such an extent that it triggers a series of reactions degrading the river ecosystem over time (or adversely impacting downstream users). As illustrated in Figure 9, unsustainable withdrawal could adversely impact humans, native species, and ecosystem services (Richter, Mathews, Harrison, & Wigington, 2003).

FIGURE 9: IMPACTS FROM OVEREXPLOITATION OF SURFACE WATER (RICHTER, MATHEWS, HARRISON, & WIGINGTON, 2003)



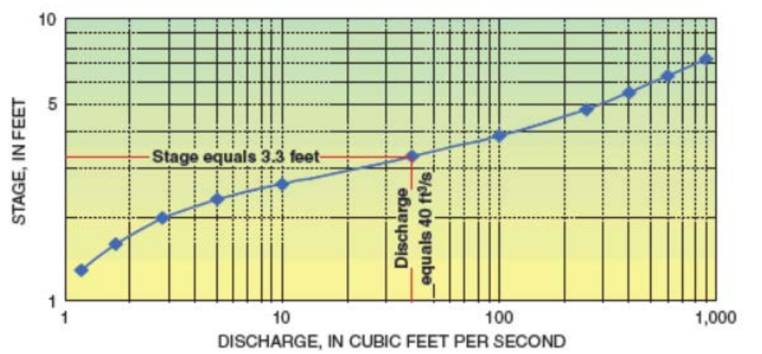
Rivers and streams require a variable flow regime to maintain ecosystem health, including both base flow (i.e., the water between rain storms) and storm flow (i.e., the water from rainfall during the storm). Both base flow and storm flow provide habitat and other services to aquatic life and must be protected to ensure ecosystem health (Srivastava, 2010).

Planning water supply projects requires development of the baseline flow budget, based on a hydrologic model; defining human and ecosystem requirements for flow; and determining the condition at which these competing demands potentially conflict (i.e., during drought conditions). From this information, an operation plan can be developed.

The “baseline flow budget” is estimated by building a model of the volume and timing of flows across the surface water (i.e., river) system, before including withdrawals, discharge, and storage in lakes and reservoirs. This allows estimation of total capacity and stress on the system due to water supply withdrawals. The baseline budget provides for an accounting of how the existing or future uses alter the quantity, quality, and timing of water flow. Hydrologic models are used to simulate the hydrology (i.e., rainfall, runoff, percolation, and stream flow) in order to estimate the baseline flow budget (Virginia DEQ, 2015).

Decisions on water withdrawal rates and duration are usually based on stream flow data from historical measurement data, flood forecasting systems, or from a rating curve (developed at a defined flow gauge location). If historic stream flow data or flood forecasting tools are not available, determining the sustainable withdrawal will depend on data collected at the flow intake structure and the flow gauge. An example rating curve or stage-discharge curve developed for a river in the United States is shown in Figure 10 (USGS, 2016b).

FIGURE 10: EXAMPLE STAGE-DISCHARGE CURVE (USGS, 2016B)



Example of a typical stage-discharge relation; here, the discharge of the river is 40 cubic feet per second (ft^3/s) when the stage is 3.30 feet (ft). The dots on the curve represent concurrent measurement of stage and discharge.

Water withdrawals for drinking water need to be evaluated along with other uses of the source of supply. One approach is to evaluate these multiple uses on a seasonal basis (Table 14). The "X" shows that uses are vulnerable to corresponding seasonal flow conditions (Virginia DEQ, 2015).

TABLE 14: WATER WITHDRAWAL AND OTHER USES UNDER CRITICAL CONDITIONS

SEASON/FLOW	DIRECT WITHDRAWALS	RESERVOIR STORAGE	AQUATIC LIFE	WASTE ASSIMILATION	REGULATION OF ALGAL BLOOMS
Winter High					
Winter Low		X			
Spring High			X		
Spring Low		X	X		
Summer High			X		X

TABLE 14: WATER WITHDRAWAL AND OTHER USES UNDER CRITICAL CONDITIONS					
SEASON/FLOW	DIRECT WITHDRAWALS	RESERVOIR STORAGE	AQUATIC LIFE	WASTE ASSIMILATION	REGULATION OF ALGAL BLOOMS
Summer Low	X	X	X	X	
Fall High			X		X
Fall Low	X	X	X	X	

MONITORING OF WATER WITHDRAWAL

It is often difficult to understand the seasonal and long-term availability of a water resource. Daily monitoring of withdrawal rates and water levels (as well as other parameters including water quality and temperature) will help to ensure that water is not over-extracted, and that sufficient flow is maintained to support the ecosystem (i.e., environmental flow). Monitoring data and information can be shared with stakeholders to improve decision making.

In many countries, government agencies do not have the capacity or resources to adequately conduct the research, monitoring, and tracking of water resources necessary to monitor water withdrawals. Unfortunately, inadequate monitoring of water resources is more likely in poor, rural areas more than urban areas. Improvements to water resource monitoring are necessary to reduce the inequalities for disadvantaged communities, especially in rural areas (UN Water & WHO, 2014).

WATER SUPPLY – DISTRIBUTION

Ensuring sustainable water management includes assuring that water, once withdrawn from the source, is delivered efficiently to the consumer and is not wasted via leakage.

Leakage control requires an understanding of where leaks in the distribution system occur, calculating the amount of water being lost, and implementing a program to repair the leaking pipes or other damaged infrastructure. Water audits are usually performed to provide an understanding of the location and magnitude of leakage. These audits use a water balance approach to determine where losses occur. Water supplied to the distribution system, (i.e., the system input volume), is balanced with the water consumed by local residents, authorized consumption, and water losses, as illustrated in Figure 11, which shows the typical water balance for water distribution systems in the United States.

In rural, less densely populated locations, the “real losses,” including leakage from distribution mains and overflows from storage tanks, are expected to be the major source of leakage. In urban or peri-urban, more densely populated areas, where water is provided by municipal distribution systems, “apparent losses” will exist (Dighade, Kadu, & Pande, 2014). For example, in Kampala, Uganda, water loss has been exacerbated by illegal connections, meter tampering, and metering inaccuracies. The overall non-revenue water (NRW), including unbilled authorized consumption, apparent losses, and real losses, for the Kampala distribution system is approximately 40 percent of the input volume, as illustrated in Figure 12, (Mutikanga, Sharma, & Vairavamoorthy, 2009).

FIGURE 11: ANNUAL WATER BALANCE (AWWA, 2016)

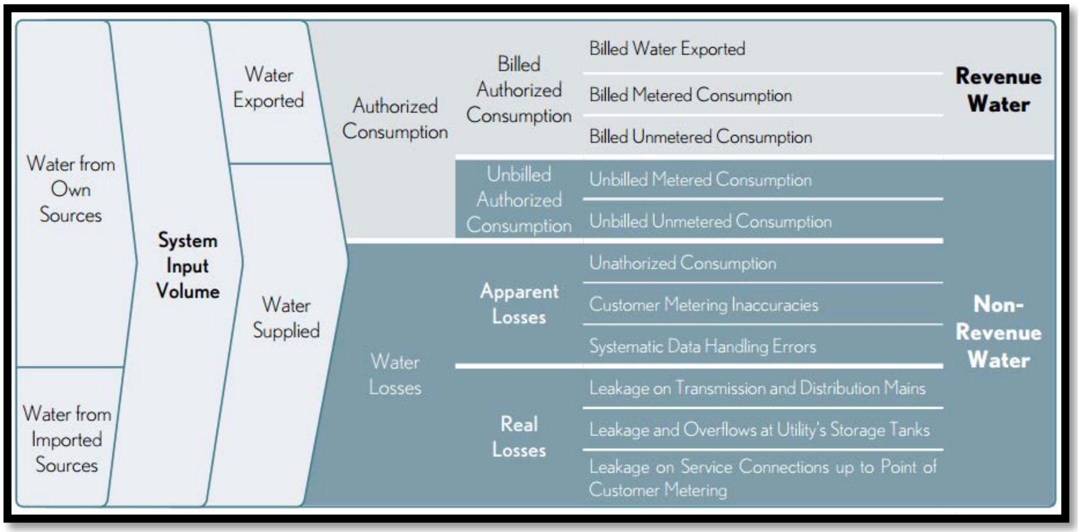
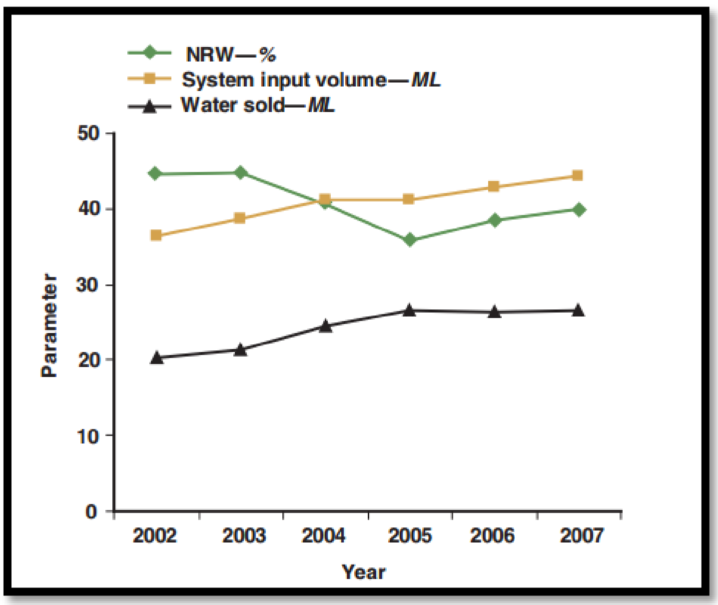


FIGURE 12: WATER LOSS: KAMPALA DISTRIBUTION SYSTEM (MILLION LITERS = ML) (MUTIKANGA, SHARMA, & VAIRAVAMOORTHY, 2009)



Spreadsheet-based water audit tools are available to help quantify water losses associated with water distribution systems and identify areas for improved efficiency and cost recovery (AWWA, 2014). Typically, staff input standard water supply information such as the volume of water supplied, customer consumption, distribution system attributes, and quantities of losses. The tool can be used to estimate water loss metrics of the distribution system based upon miles of pipe, number of connections, operating pressure, and other inputs.

Implementing repair programs, based on the results of a water audit, requires prioritization of investments based on available financing and the magnitude of water losses from each node. Long-term monitoring via meters allows the operators of the distribution system to make continuous improvements to the system based on periodic audits and inspections.

ANNEX III: SUSTAINABLE MANAGEMENT OF SANITATION ACTIVITIES

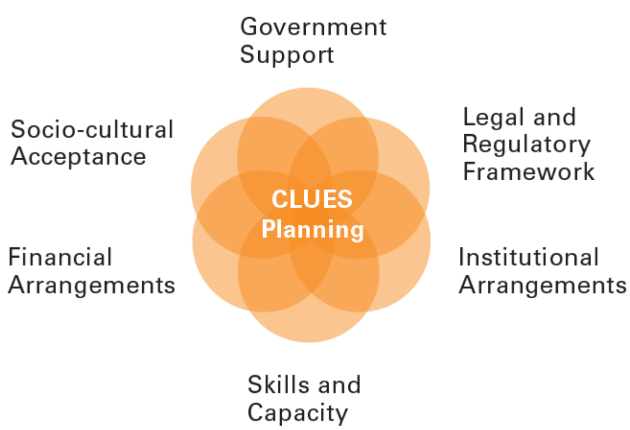
The management of sanitation interventions for long term sustainability is described in this annex and includes brief introductions to:

1. The community-led urban environmental sanitation (CLUES) approach,
2. The USAID local systems framework,
3. The assessment of the sustainability of sanitation activities,
4. The decentralized wastewater treatment system (DEWATS) principles, and
5. Fecal sludge management (FSM) tools.

THE COMMUNITY-LED URBAN ENVIRONMENTAL SANITATION (CLUES) APPROACH

This CLUES approach process emphasizes stakeholder participation and an enabling environment to ensure sustainability of sanitation activities (Luethi, Morel, Tilley, & Ulrich, 2011). The six key elements to support an enabling environment for a sustainable project are shown in Figure 13.

FIGURE 13: SIX KEY ELEMENTS OF ENABLING ENVIRONMENT



The CLUES process includes seven planning steps;

1. Process Ignition and Demand Creation
2. Launch of the Planning Process
3. Detailed Assessment of the Current Situation
4. Prioritization of Community Problems and Validation
5. Identification of Service Options
6. Development of an Action Plan
7. Implementation of the Action Plan

Along with these seven steps, the CLUES approach describes three cross-cutting tasks that should be applied throughout the planning process: (1) awareness-raising and communication; (2) capacity development; and (3), process monitoring and evaluation.

The CLUES guidance and a toolkit containing 30 separate tools can be accessed here:

http://www.eawag.ch/en/department/sandec/projects/sesp/clues/

Example tools from the CLUES guidance include:

1. The Compendium of Sanitation Systems and Technologies, T15
2. Procedure for the Pre-Selection of the Sanitation Systems, T17
3. The Greywater Management Manual, T18
4. The Surface Water Drainage Manual, T19
5. The Sanitation Costing Tool, T20

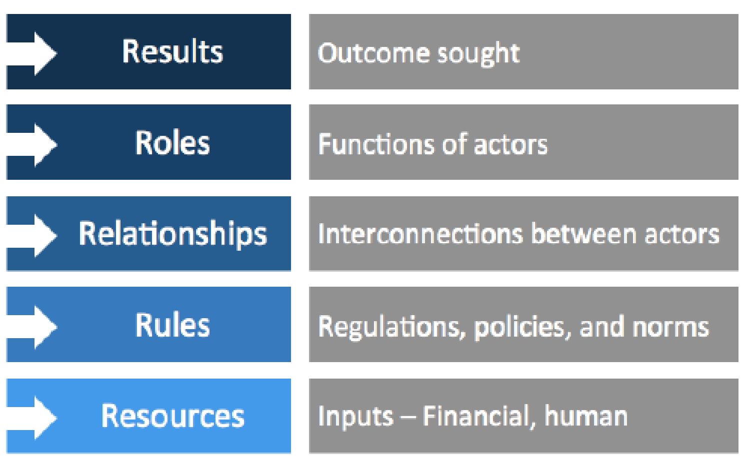
THE USAID LOCAL SYSTEMS FRAMEWORK: APPLIED TO SANITATION SYSTEMS

USAID defines the local system as "the interconnected sets of actors – governments, civil society, the private sector, universities, individual citizens and others – that jointly produce a particular development outcome." (USAID, 2014)The local systems framework applies ten overarching principles to engage local partners in development activities;

1. Recognize there is always a system.
2. Engage local systems everywhere.
3. Capitalize on our convening authority.
4. Tap into local knowledge.
5. Map local systems.
6. Design holistically.
7. Ensure accountability.
8. Embed flexibility.
9. Embrace facilitation.
10. Monitor and evaluate for sustainability.

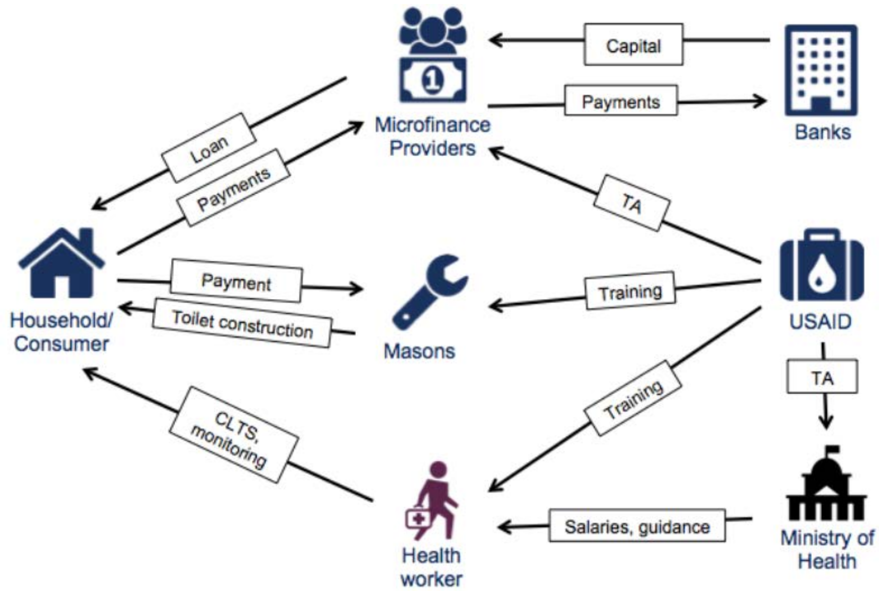
The local systems framework can be applied by defining the Five R's: resources, roles, relationships, rules and results, as summarized in Figure 14 below (USAID, 2016).

FIGURE 14: FIVE R'S OF LOCAL SYSTEMS FRAMEWORK



Applying the "Five Rs" allows review and identification of the strengths and weaknesses of the existing local system so that appropriate interventions can be designed to strengthen the weaknesses (or fill the gaps). In the case of sanitation interventions, this framework can be used to develop a model of a generic rural sanitation activity as shown in Figure 15 below.

FIGURE 15: MODEL OF GENERIC RURAL SANITATION ACTIVITY



ASSESSMENT OF SUSTAINABILITY FOR SANITATION AND WASTEWATER MANAGEMENT PROJECTS

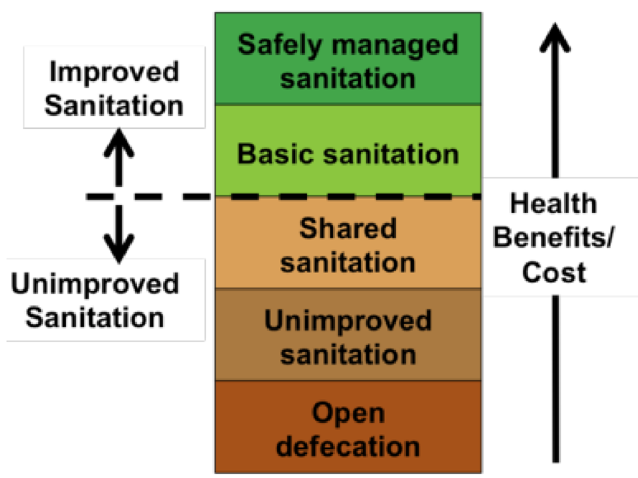
Like water supply projects, sanitation and wastewater management projects require an assessment of the sustainability of the associated water resources. Sanitation addresses the infrastructure to manage human outflow while water supply addresses infrastructure to manage the inflow. Rivers or streams can provide the assimilative capacity for sanitation projects, specifically by receiving appropriately treated wastewater discharges and stormwater runoff from developed areas; however, an assessment of the quantity and treatment level of wastewater versus the flow regime in the body of water receiving the wastewater is important to understanding the sustainability of the wastewater management project.

Within this human use framework, outflow (or wastewater flow) can be predicted using accumulation and/or waste production rates, based on the number of residents and a literature-based rate of waste production (e.g., pounds per day and gallons per day per capita). For example, for basic pit latrines, accumulation rates per capita can be used to estimate and design latrine capacity (Reed, 2014). Example fecal loading rates for on-site sanitation as shown in Table 15 below can be used for these estimates (Franceys, 1992). The characteristics of the flow rate for a given set of the population can be described using existing data. The quality of outflow depends on the dilution of the waste production within the given unit volume.

TABLE 15: QUANTITY OF WET FECES, ADULTS (GRAMS PER PERSON PER DAY)		
PLACE	QUANTITY	REFERENCES
China (men)	209	Scott (1952)
India	255	Macdonald (1952)
India	311	Tandon & Tandon (1975)
Peru (rural Indians)	325	Crofts (1975)
Uganda (villagers)	470	Burkitt et al. (1974)
Malaysia (rural)	477	Balasegaram & Burkitt (1976)
Kenya	520	Cranston & Burkitt (1975)

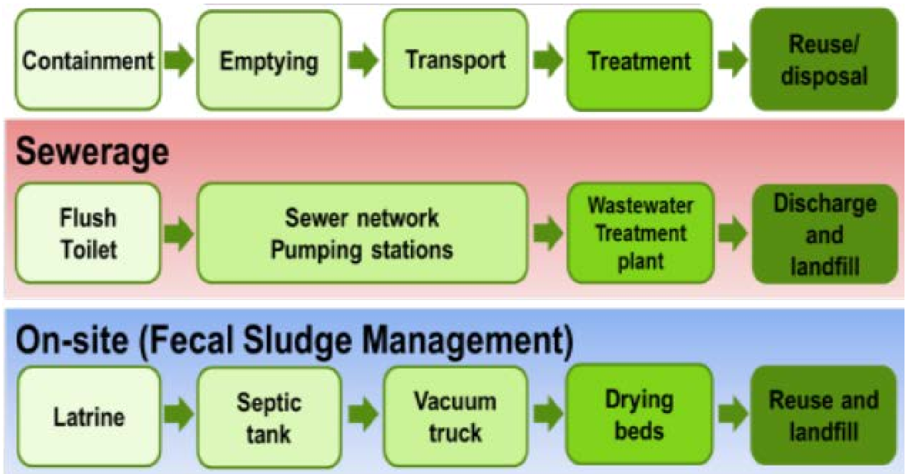
SANITATION—LEVELS OF SERVICE AND THE SERVICE CHAIN: Sanitation projects can be defined by levels of service, and their associated benefits and costs, as illustrated by the "Sanitation Service Ladder," Figure 16. As a household moves from open defecation to basic sanitation (defined as any latrine on a raised, cleanable platform that hygienically prevents human contact with waste), the services' health benefits rise and its costs increase (USAID, 2016). As shown in Figure 16, significant health benefits can be attained in a community by moving up the ladder from open defecation to improved sanitation (USAID, 2016).

FIGURE 16: SANITATION SERVICE LADDER (USAID, 2016)



Sanitation projects include on-site sanitation systems (e.g., latrines) or off-site systems (e.g., flushing toilets, sewers, and wastewater treatment facilities). In many developing countries, centralized wastewater collection and treatment systems are relatively rare. The most common sanitation systems include on-site facilities (pit latrines, septic tanks) in both rural and urban settings, and collection and treatment systems in urban areas. The entire system from toilet to disposal can be summarized in a service chain as illustrated in Figure 17 for both sewerage (i.e., wastewater collection/treatment) and on-site systems (USAID, 2016).

FIGURE 17: SANITATION SERVICE CHAIN (USAID, 2016)



ALTERNATIVES TO CONVENTIONAL WASTEWATER SYSTEMS; DECENTRALIZED WASTEWATER TREATMENT SYSTEMS AND FECAL SLUDGE MANAGEMENT

Because centralized wastewater collection and treatment systems are expensive to construct and difficult to operate and maintain, the most common sanitation systems in both rural and urban areas in USAID priority countries are on-site facilities (pit latrines, septic tanks) in both rural and urban settings. Two alternatives to centralized wastewater systems considered here are decentralized wastewater treatment systems (DEWATS), and fecal sludge management (FSM) systems.

Decentralized wastewater treatment systems (DEWATS): The DEWATS approach was developed in the 1990s by a group of NGOs and international agencies to address the challenges of sanitation and wastewater management in developing countries (Ulrich, et al., 2010). Some of the key features of the DEWATS approach include:

1. The technology packages can provide primary, secondary and tertiary treatment for industrial and domestic wastewaters;
2. The technologies are designed for reliability, longevity, flexibility to handle changes in inflow, cost efficiency and, low operation and maintenance requirements;
3. DEWATS usually function without technical energy inputs. Independence from outside energy sources and sophisticated technical equipment provides more reliable operation and, thereby, fewer fluctuations in effluent quality;
4. DEWATS are based on a modular, technical configuration concept. The appropriate combination of treatment modules can be selected, depending on the required treatment efficiency, costs, and land availability;
5. The DEWATS approach includes the community-based sanitation process to ensure stakeholder involvement throughout planning and implementation of the sanitation activity.

The individual chapters from the guidance manual, "Decentralized Wastewater Treatment Systems and Sanitation in Developing Countries (DEWATS): A Practical Guide," can be accessed here: https://wedc-knowledge.lboro.ac.uk/details.html?id=10409

Fecal Sludge Management (FSM): Because on-site systems are often the primary sanitation systems in urban and peri-urban areas in developing countries, international institutions and NGOs have focused on ensuring that fecal wastes from these systems are managed to protect public health and the environment. For example, the World Bank Water Sanitation Program has funded the research, "Fecal Sludge Management: Diagnostics for Service Delivery in Urban Areas," from which tools and guidelines have been developed to manage fecal sludge from these on-site systems (Blackett & Hawkins, 2016). Three key diagnostic tools were developed during the research including:

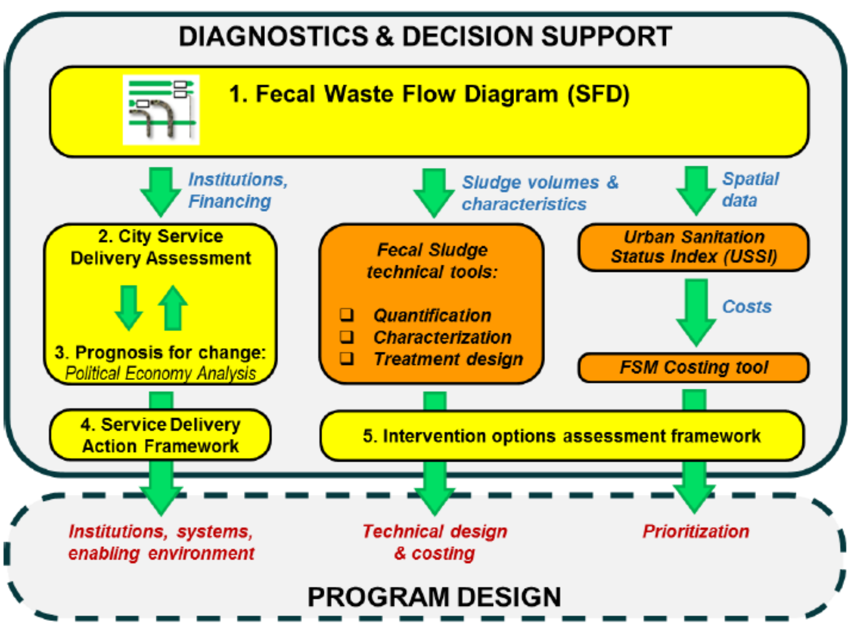
1. The fecal waste flow diagram (SFD);
2. The city service delivery assessment; and,
3. The prognosis for change.

The research resulted in two decision-support tools, including:

1. The service delivery action framework and,
2. The intervention options assessment.

Figure 18 shows how the tools are integrated in developing FSM programs (Blackett & Hawkins, 2016). (Note that the yellow highlighted boxes show the newly developed tools, while the orange boxes show the existing tools.)

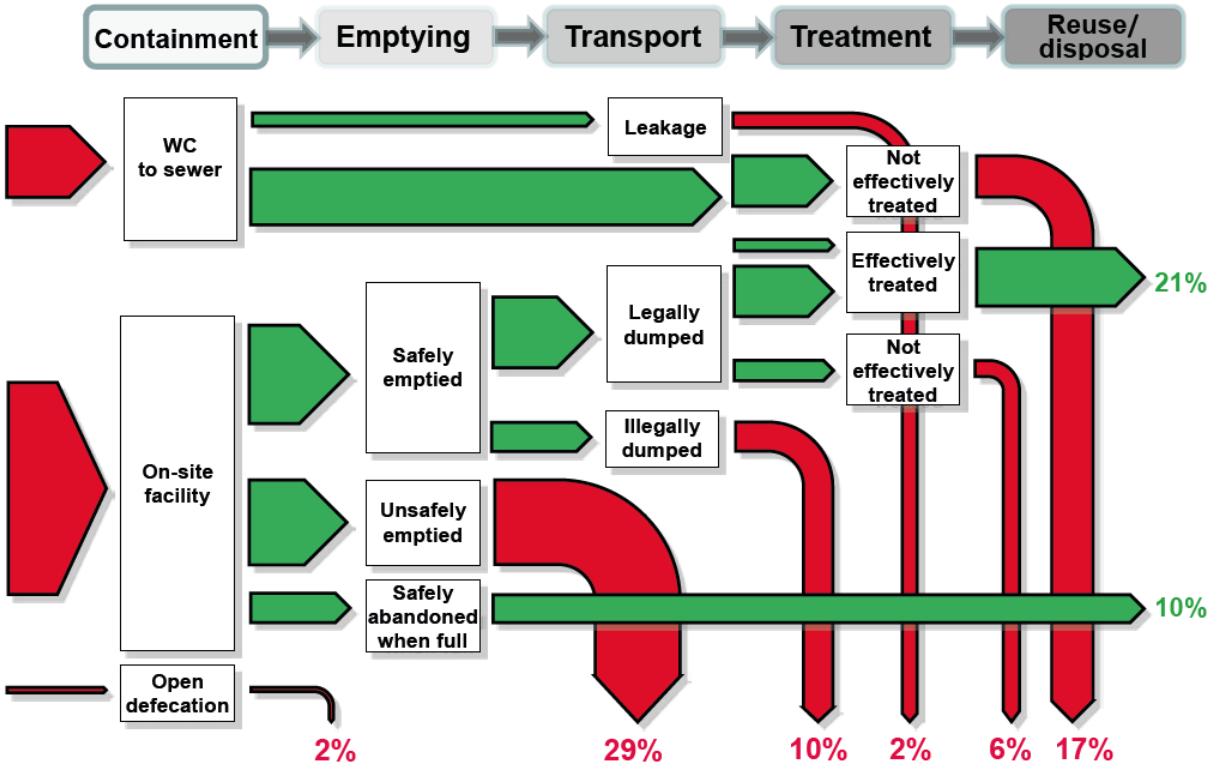
FIGURE 18: FSM DIAGNOSTIC AND DECISION TOOLS



Case studies were used to test the new as well as existing tools, in real world settings in Lima, Peru; Dhaka, Bangladesh; Balikpapan, Indonesia; Santa Cruz, Bolivia; and Hawassa, Ethiopia.

An example SFD, developed for Dakar, Senegal, during a separate study, is illustrated below in Figure 19.

FIGURE 19: FECAL WASTE FLOWS IN DAKAR, SENEGAL (WORLD BANK, 2014)



ANNEX IV: EXAMPLE DESIGN CRITERIA FOR WATER DISTRIBUTION SYSTEMS

TABLE 16: EXAMPLE DESIGN CRITERIA FOR DRINKING WATER SUPPLY PROJECTS (GLUMRB, 2012)	
TYPE OF PROJECT	DESIGN CRITERIA
SOURCE OF SUPPLY	
New well	Available yield or flow rate meets the maximum projected demand for the service area (*the village or community*).
	Water quality meets "potable" water standards *(as defined by host country regulations and USAID guidance*).
New surface water supply	The design of the intake structure shall allow withdrawal of water from multiple depths if water quality varies with depth.
	The determination of available yield shall consider requirements for downstream flow and shall be based on conditions for the extreme drought of record.
WATER TREATMENT (TREATMENT PROCESSES ARE OFTEN APPLICABLE ONLY TO LARGE WATER SUPPLY SYSTEMS)	
Coagulation	Mixing – The detention period should be instantaneous, but not longer than 30 seconds with mixing equipment capable of imparting a minimum velocity gradient (G) of at least 750 fps/ft. The design engineer should determine the appropriate G value and detention time through jar testing.
Flocculation	Detention – The detention time for floc formation should be at least 30 minutes with consideration to using tapered (i.e., diminishing velocity gradient) flocculation. The flow-through velocity should be not less than 0.5 nor greater than 1.5 feet per minute.
Sedimentation	A minimum of four hours of settling time shall be provided.
Rapid rate gravity filters	The rate of filtration shall be determined through consideration of such factors as raw water quality, degree of pre-treatment provided, filter media, water quality control parameters, competency of operating personnel, and other factors as required by the reviewing authority. Typical filtration rates are from 2 to 4 gallons per minute per square foot.
Disinfection	The chlorinator capacity shall be such that a free chlorine residual of at least 2 mg/L can be maintained in the water once all demands are met after an effective contact time of at least 30 minutes, when maximum flow rate coincides with

TABLE 16: EXAMPLE DESIGN CRITERIA FOR DRINKING WATER SUPPLY PROJECTS (GLUMRB, 2012)	
TYPE OF PROJECT	DESIGN CRITERIA
	anticipated maximum chlorine demand. Solution-feed gas chlorinators or hypochlorite feeders of the positive displacement type must be provided.
WATER DISTRIBUTION	
Pumping station	Pump capacity shall be able to meet maximum day demand with one pump out of service.
	In general, piping shall be designed so that the friction losses will be minimized; not be subject to contamination; have watertight joints; be protected against surge or water hammer and provided with suitable restraints where necessary; and be designed such that each pump has an individual suction line or that the lines shall be so manifolded that they will insure similar hydraulic and operating conditions.
Finished water storage	Storage facilities should have sufficient capacity, as determined from engineering studies, to meet domestic demands. The minimum storage capacity (or equivalent capacity) for systems not providing fire protection shall be equal to the average daily consumption. This requirement may be reduced when the source and treatment facilities have sufficient capacity (with standby power) to supplement peak demands of the system. Excessive storage capacity should be avoided to prevent potential water quality deterioration problems.
Distribution mains	Sizing based on a hydraulic analysis of flow demands and pressure requirements. Minimum size of mains should be 3-inch diameter. A minimum pressure of 20 psi should be maintained at ground level at all points in the system under all flow conditions.

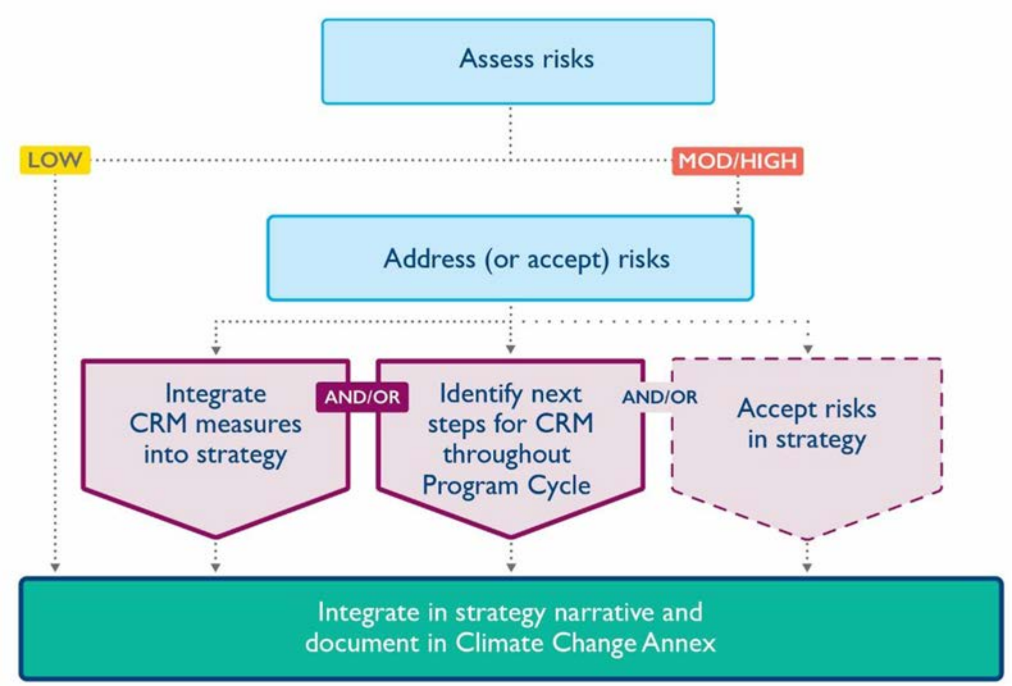
ANNEX V: CLIMATE RISK MANAGEMENT RESOURCES AND TOOLS

USAID has developed a suite of tools to support climate risk screening and management. (See Figure 20 for the risk management process.) The tools are designed to help USAID strategy planners, project planners, and activity planners to assess and address climate-related risks to USAID programming. The tools guide the users through eight steps, listed below:

1. Set up tool and scope;
2. Identify climate risks;
3. Assess adaptive capacity;
4. Assign risk rating;
5. Identify opportunities;
6. Identify and select risk management options;
7. Identify next steps; and,
8. Accept risks.

The first five steps are designed to assess climate risks and should be used early in the strategy design process, and the last three steps are designed to address identified climate risks. The different societal roles, needs, constraints, and opportunities of individuals and groups based on their identities are considered in the tools analysis. The tools also provide guidance for completing the documentation (e.g., a climate risk screening table) as required by the Mandatory References for ADS Chapter 201. Additional information on climate change implications for water supply and sanitation are provided in an annex on the tools website. Please see https://www.climatelinks.org/resources/climate-risk-screening-management-tool for additional information.

FIGURE 20: CLIMATE RISK SCREENING AND MANAGEMENT IN STRATEGY DESIGN



USAID has also developed climate risk profiles to support climate risk management. The profiles summarize existing climate variability and change data and information for a country or region. They provide historical and projected climate trends, climate impacts and risks by sector, relevant climate policies, and existing climate programs in the country or region. The risk profiles can be found on Climatelinks: https://www.climatelinks.org/integration/climate-risk-management/resources.